

**HETEROSIS AND COMBINING
ABILITY STUDIES OF RATOONING
IN RICE (*Oryza sativa* L.)**

HARI RAM KUMAR BANDI
M.Sc. (Ag.)

**DOCTOR OF PHILOSOPHY IN AGRICULTURE
(GENETICS & PLANT BREEDING)**



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**HETEROSIS AND COMBINING ABILITY
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RICE (*Oryza sativa* L.)**

By
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*Place: **Bapatla***

Date:

(HARI RAM KUMAR BANDI)

DECLARATION

I, **Mr. HARI RAM KUMAR BANDI** hereby declare that the thesis entitled “**HETEROSIS AND COMBINING ABILITY STUDIES OF RATOONING IN RICE (*Oryza sativa* L.)**” submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** in the major field of **Genetics and Plant Breeding** is the result of the original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Bapatla
Date:

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CERTIFICATE

This is to certify that thesis entitled “**HETEROSIS AND COMBINING ABILITY STUDIES OF RATOONING IN RICE (*Oryza sativa* L.)**” submitted in partial fulfillment of the requirements for the degree of ‘**DOCTOR OF PHILOSOPHY IN AGRICULTURE**’ of the Acharya N. G. Ranga Agricultural University, Lam, Guntur is a record of the bonafide original research work carried out by **Mr. HARI RAM KUMAR BANDI** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Mr. HARI RAM KUMAR BANDI has satisfactorily prosecuted the course of research and that the thesis entitled “**HETEROSIS AND COMBINING ABILITY STUDIES OF RATOONING IN RICE (*Oryza sativa* L.)**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

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LIST OF SYMBOLS AND ABBREVIATIONS

A.M	:	Before noon
A.P	:	Andhra Pradesh
APRRI	:	Andhra Pradesh Rice Research Institute
ANOVA	:	Analysis of variance
CD	:	Critical difference
cm	:	Centimeter
CV	:	Coefficient of variation
df	:	Degrees of freedom
F ₁	:	First filial generation of a cross
Fig	:	Figure
g	:	Grams
GA	:	Genetic advance
GAM	:	Genetic advance as per cent of mean
GCV	:	Genotypic coefficient of variation
<i>gca</i>	:	General combining ability
GT	:	Gelatinization temperature
ha	:	Hectare
h ² (b)	:	heritability in broad sense
k	:	Selection differential
kg	:	Kilogram
kg ha ⁻¹	:	Kilogram per hectare
L/B	:	Length/ Breadth
MSS	:	Mean sum of squares
mha	:	milllion hectare
Max	:	Maximum
Min	:	Minimum
mm	:	millli meter
m ²	:	Square meter
ml	:	millli litre
mt	:	million tones
No.of	:	Number of
NS	:	Non-significant

PCV	:	Phenotypic Co-efficient of Variation
<i>Per se</i>	:	As such with mean
RARS	:	Regional Agricultural Research Station
RCBD	:	Randomized complete block design
S	:	Significant
<i>sca</i>	:	Specific Combining ability
SEm	:	Standard error of mean
t/ha	:	Tones per hectare
%	:	per cent
<i>viz.,</i>	:	Namely
<i>vs.</i>	:	Against
/	:	Per
%	:	Per cent
⁰ C	:	Degree centigrade
<i>et al.,</i>	:	and coworkers
g	:	Grams
Kg/ha	:	Kilogram per hectare
$\overline{X}$	:	Grand mean

ABSTRACT

Name of the Author : **HARI RAM KUMAR BANDI**

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The present investigation was carried out at APRRI and RARS, Maruteru with the prime objective of testing eight selected parents, based on the ratoonability performance in *rabi*, 2014-15, to elicit information for their combining ability and to know the gene actions involved in the inheritance of different traits related to ratoonability in rice. Apart from combining ability studies other parameters like mean, variability, heritability, expected genetic advance, heterosis, character association and path coefficient analysis were also studied for twenty four characters (yield attributing and quality traits) of both F₁ main crop and its ratoon crop during *rabi*, 2015-16 and summer, 2016 respectively. Further, in ratoon crop along with number of tillers per plant, number of ear bearing tillers per plant, additionally another 3 characters viz., number of ratoon tillers as percentage of main crop tiller, number of vegetative buds after the harvest of main crop, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers are considered as traits related to ratoonability.

Analysis of variance studies in both main crop and ratoon crop revealed high degree of variability in the material. The genotypic coefficients of variation for all the characters studied were lesser than the phenotypic coefficients of variation indicating the influence of environment on expression of these traits. Wider variability was observed for gel consistency and alkali spreading value both in F₁ and its ratoon crop and moderate variability was observed for traits viz., total number of tillers per plant, number of grains per panicle, LAI at maximum tillering stage, volume expansion ratio, water uptake, amylose content and grain yield per plant in F₁ main crop; and number ratoon tillers as percentage of main crop tillers, total number of ear bearing tillers per plant, number of ratoon ear bearing tillers as percentage of ear bearing tillers per plant, number of grains per panicle, water uptake and amylose content in F₁ ratoon crop. High heritability and high genetic advance as per cent of means were observed for total number of tillers per plant, number of grains per panicle, leaf area index at maximum tillering stage, water uptake, gel consistency, alkali spreading value, amylose content

and grain yield per plant both in F₁ main crop and its ratoon crop, revealed the role of additive gene action. This in turn suggests the feasibility of simple selection procedures for improving these traits.

Further the analysis of variance for combining ability for both F₁ main crop and its ratoon crop revealed that parental, crosses and parents vs crosses effects had significant amount of variability with in each of them for majority of the traits studied. Out of the eight parents tested for their combining ability the genotype MTU 1001 found to be good combiner in main crop and as well as ratoon crop for the traits, days to 50% flowering, days to maturity, plant height (cm), test weight (g), leaf area index at maximum tillering stage, head rice recovery (%), kernel length (mm), kernel linear elongation ratio, alkali spreading value (mm) and grain yield per plant (g), while the general combining ability for ratoonability related traits revealed that the parent MTU 1121 and MTU 1061 recorded as a best general combiner for total number of tillers per plant; MTU 1121, MTU 1140 and MTU 1064 for number of ear bearing tillers per plant and MTU 1140 for number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers. Whereas MTU 1001, MTU 1121 and BPT 3291 as good general combiners for number of vegetative buds and total number of tillers as percentage of main crop tillers. Therefore these lines can be utilized in improvement of the respective traits in any breeding programme where hybridization is involved.

Among the 28 cross combinations, the crosses, MTU 1001 × MTU 1061, MTU 1001 × MTU 1140, MCM 100 × MTU 1064 and MCM 100 × MTU 1140 in F₁ main crop; and MTU 1001 × MTU 1140, MCM 100 × MTU 1140 and MTU 1140 × MTU 7029 in F₁ ratoon crop expressed high *sca* effects with high *per se* performance for grain yield per plant. These crosses did not express high *sca* effects for all the yield attributing traits, revealing that there is no relationship between *per se* performance of hybrids and *gca* effects of parents. The *gca* effects of parents and *sca* effects of their hybrid combinations indicated that the crosses with high *sca* effects were resulted due to all possible parental *gca* combinations i.e., high × high, high × low, low × high and low × low. Therefore, one can afford to include some low general combiners also along with good combiners in breeding programmes where hybridization is involved.

Studies on specific combining ability effects for the ratoonability related traits disclose that, crosses MTU 1001 × MTU 1140, BPT 3291 × MTU 1061 and MCM 100 × MTU 7029 exhibited high *sca* effects for total number of tillers per plant; and MTU 1140 × MTU 7029, MCM 100 × MTU 7029 and MTU 1001 × MTU 1140 for total number of tillers as percentage of main crop tillers; the crosses MTU 1001 × MTU 1140, BPT 3291 × MTU 1121 for the trait total number of vegetative buds after the harvest of main crop; and the trait, total number of ear bearing tillers per plant showed high *sca* effects for BPT 3291 × MTU 1061; MTU 1001 × MTU 1140, BPT 3291 × MTU 1061. The crosses MTU 1140 × MTU 7029 and MTU 1140 × MTU 7029 showed high *sca* for number of ear bearing tillers as percentage of main crop ear bearing tillers.

Gene action studies for the ratoonability related traits revealed the preponderance of both additive and non-additive gene action in the inheritance of total number of tillers per plant, total number of ear bearing tillers per plant, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers, which can be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations, while the other two traits, number of ratoon tillers as percentage of main crop tillers and number of vegetative buds after the harvest of F₁

main crop) were controlled by non-additive gene action and hence these traits can be improved either by heterosis breeding and recombination breeding with postponement of selection at later generations..

Perusal of relative heterosis, heterobeltiosis, *sca* effects and *per se* performance, the cross MTU 1001 × MTU 1140 was identified as a promising hybrid by registering significant relative heterosis, heterobeltiosis, *sca* effects and better *per se* performance for the traits total number of tillers per plant, leaf area index at maximum tillering stage, milling per cent, head rice recovery, L/B ratio, gel consistency and grain yield per plant in F₁ main crop; and number of tillers per plant, number of vegetative buds after the harvest of main crop, number of ear bearing tillers per plant, milling per cent, head rice recovery, and grain yield in F₁ ratoon crop.

Genotypic correlations in general are higher than phenotypic correlations studies both in F₁ main crop and its ratoon crop indicating that the apparent associations are largely due to genetic reasons. Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that improvement of grain yield per plant with good quality trait is possible through simultaneous manifestation of days to 50% flowering, days to maturity, total number of tillers per plant, total number of ear bearing tillers per plant, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, milling percentage, head rice recovery, and gel consistency.

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L., $2n=24$) is the most important food crop in the world (Asia, Latin America, parts of Africa and the Middle East), which accounts for more than 21% of the calorific needs of the world's population and up to 76% of the calorific intake of the population of South East Asia (Melissa *et al.*, 2009). About 90% of the world's rice is grown and consumed in Asia. According to the projections made by the Population Foundation of India, the country's population will be 1546 million by the end of 2030 and 1824 million by the end of 2050. It is estimated that the demand for rice will be 121.2 million tonnes by the year 2030 and 137.3 million tonnes by the year 2050. (CRRI -VISION 2050).

India has the largest area of 43.86 million hectares under rice cultivation and ranks second with an average production of 104.32 million tonnes and productivity of 2404 kg ha⁻¹; (Ministry of Agriculture, Directorate of Economics and Statistics, 2014-15). In Andhra Pradesh, rice is cultivated in an area of 2.39 million hectares, with a production of 3.36 million tonnes and productivity of 3532 kg ha⁻¹ (Annual Report-ANGRAU, Guntur, 2014-15). Due to various socio-economic constraints, a chance of bringing more area under rice cultivation is very remote. In view of the current situation of food insecurity, a number of limiting factors such as population growth in most of the Asian countries except China continues to be around 2% per year, agricultural land and water resources, ever increasing biotic, and abiotic stress and low economic activity in agricultural sector have led to decrease in crop productivity. Hence to achieve the target of increased rice production, it requires raising the production per unit area.

Emphasis is being diverted towards the maximum utilization of land by producing more rice yield per unit area per unit time for which there is a need to improve different traits related to grain yield. Hence, ratooning, the ability of the rice plant to regenerate new panicle-bearing tillers after harvest, could be a practical approach to increase rice production per unit area and per unit time. Because, ratoon rice has shorter growth duration than a newly planted crop, it can increase productivity where cropping intensity is limited by inadequate irrigation in cropping season. The ratoon crop may fit well in rainfed areas on residual moisture left after wet season and considered as an alternative for double rice cropping. It is also a practical tool in

exploiting the ability of the plants to regenerate after harvest. Agronomic practices such as harvesting main crop at correct stage and at optimum cutting height were found to influence ratoon crop performance (Chauhan *et al.* 1985). In India, of the 40 m ha under rice, there is scope of utilizing approximately 18.9 m ha of area for rice ratooning under low land situations (<https://www.dawn.com/news/241368>).

Rice ratoon cropping systems on a commercial scale have not been developed chiefly because of lack of cultivars specially suited to ratoon cropping with built-in resistance to insect pests & diseases and lack of appropriate agronomic practices. Varietal differences also exist with respect to emergence of ratoon tillers from different nodes of the stubbles. Ratooning ability is a potentially important but complicated varietal character. Considerable progress has been made in the field of genetics of quantitative and qualitative traits in this crop, but not much had been accomplished with regard to inheritance of ratooning ability. Moreover, the economic traits of the rice are under the control of polygenic system. It is imperative, that enhanced ratoon rice crop yield is totally dependent upon the ratooning ability. An understanding of the nature of gene action governing the economic traits is of primary importance because the type of breeding procedure to be adopted for genetic improvement in a crop mainly depends on the relative magnitude of the additive, dominance and epistatic gene effects. It is also of significance to know the inheritances of such traits. The major factors affecting ratooning ability, besides the inherent ratooning ability of the cultivars, are light, temperature, soil moisture, and fertility and management. Therefore, superior ratooning cultivars with other desirable attributes are to be identified. The adaption of hybrids /varieties towards the improvement of the ratooning trait can contribute to increase production and productivity (Mishra, 2001).

The success of a hybrid towards the ratoonability and the magnitude of heterosis depend up on genetic distance existing between the parents involved in the combination. Selection of parents on the basis of phenotypic performance alone is not a sound procedure, since phenotypically superior lines may yield inferior hybrids or/and poor recombinants in segregating generations. It is, there for essential that parents should be chosen on basis of their combining ability.

The idea of combining ability analysis (Sprague and Tatum, 1942) is one of the effective approaches available to assess the nicking ability of the parental lines using several mating designs like diallel (Griffing, 1956). This, in turn, helps in selecting the

advantageous parental lines for mission-oriented recombination breeding programme in rice for estimating the combining ability effects that help in selecting desirable parents and crosses for the exploitation of heterosis towards the ratooning ability in rice. Knowledge on the ratooning ability of cultivars in hybrid combination is of paramount importance, since the combining ability of parents and hybrids does not always depend on the *per se* performance. It is therefore, necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities which are due to additive and non-additive gene action, respectively. In this direction, the Griffings Diallel method II (F_1 + Parents), (1956) had proved as a very useful tool to work out the combining ability of parents. In order to identify potential cross combinations in rice, it is very important to screen out the parent materials for their genetic diversity and combining ability (Satyanarayana *et al.*, 2000).

The estimates of correlation coefficients mostly indicated the interrelationships of the character and path analysis permits the understanding of the cause and effect of related characters (Wright, 1921). Path analysis helps in partitioning the total correlations into direct and indirect contribution, thereby suggesting the degree of importance of each of the character towards yield.

Hence, keeping this in view, the present study was undertaken to determine the combining ability effects of 28 F_1 s, main crop and its ratoon crop, which are developed by crossing 8 parents (selected based on the ratoonability performance and grain yield) in Griffing's diallel model II, method 2 for ratooning ability related traits, grain yield and grain quality traits with the following objectives.

1. To assess the ratooning ability of elite rice varieties.
2. To study heterosis and combining ability of ratoonability in main crop.
3. To evaluate grain quality of main and ratoon crop.
4. To ascertain the extant of character association between yield and yield component characters.
5. To assess the magnitude of direct and indirect effects of component characters on grain yield.

Chapter II

REVIEW OF LITERATURE

Rice is considered to be the worlds' most diverse cereal crop and originated from South East Africa, grown extensively in the humid tropical and subtropical regions of the world. Rice is the most popular staple food crop of world nearly half of the world population taking rice as their daily diet.

The present investigation in rice was undertaken to study assess the ratooning ability of elite rice varieties, study heterosis and to estimate GCA, SCA effects (diallel mating) through combining ability studies of ratoonability in main crop, evaluate grain quality of main and ratoon crop, ascertain the extant of character association between yield and yield component characters and to assess the magnitude of direct and indirect effects of component characters on grain yield.

The literature available on the main objectives of the present study has been comprehensively reviewed under the following headings.

ASSESSMENT OF RATOONABILITY/RATOONING RATE (RR) IN RICE

To measure varietal differences in ratooning ability/ratooning rate (RR) under field conditions or within cultivars, Samson (1980) suggested the ratooning rating (RR) by the following formulae:

$$RR = (1.0 - 0.1 \text{ ratooning vigor rating}) \times \left(1.0 - \frac{\text{Missing hills/plot}}{\text{Total hills/plot}} \right) \times \left(\frac{\text{Total tillers/hill}}{16} \right)$$

A high ratoon rating indicates less than 5% missing hills, at least 16 tillers per hill, and excellent vigour. Where rating scale for ratoon vigour was given as:

Ratoon extra vigorous (count basal + nodal ratoons):	1
Ratoon normal or intermediate (count only basal ratoons):	5
Ratoon very weak and few (no counting):	9

Basal ratoons-tillers that grow from the nodes of the stubble from the base up to 1cm above the ground. Upper nodal ratoons- tillers that grow from the nodes of the stubble more than 1cm above the ground. Dead hills- no ratoons.

Another formulae for ratoon rating (RR) was proposed by Ichii and Sumi, 1983 was

$$RR = (\text{Average number ratoon tillers per hill}) \times \{1 - (0.01 \text{ ratoon vigor})\}$$

Chauhan *et al.*, (1989) ratooning ability (RA) was calculated as the ratio between the ratoon crop productive tillers to the main crop productive tillers.

$$\text{Ratooning ability (RA)} = \frac{\text{Ratoon crop productive tillers}}{\text{Main crop productive tillers}}$$

2.1. REVIEW OF LITERATURE ON RATOONING IN RICE

Alberto Baeta *et al.* (2002), study was to determine the effects of drainage and irrigation periods, before and after, respectively, main crop harvest on the performance of flooded rice main and ratoon crop. Treatments consisted of the combination of four drainage periods (0, 10, 20, and 30 days) before the main crop harvest with the introduction of irrigation at 0, 10, 20, and 30 days after the main crop harvest. The experimental design was a randomized complete block in a 4x4 factorial scheme, with four replication. Retardation in flooding decreased grain yield and grain quality, when air temperatures unsuitable to ratoon crop development. Under suitable air temperatures conditions, starting flooding at nine days after the main crop harvest was the best treatment to the performance of ratoon crop, which represented 14% of saved irrigation water.

Ambili *et al.* (2002), character association in 24 ratoon genotypes of rice (*Oryza sativa* L.) studies revealed that the characters viz. number of productive tillers plant per plant, straw yield, total number of tillers during flowering, and LAI (flowering) were found to be the major contributing characters towards ratoon yield.

Arumugachamy *et al.* (1995) studies on reciprocal difference in 6 x 6 diallel (Griffing's method I, model I) for ratoon traits in rice with six rice genotypes (Bhavani, MDU 3, IET 6262, IET 6709, IET 7552 and IET 9239), in randomised

block design, with three replications, each entry in 2m long at 20 × 10 cm spacing, at maturity, the crop was harvested at 20 cm above the ground level revealed that significant positive and negative reciprocal effects for regenerated tillers in six and five crosses respectively indicated the presence of considerable genetic divergence between the parents. In general, higher regenerated tillers were obtained, when IET 6709 and IET 7552 were used as ovule parents. The crosses Bhavani/IET 6263, MDU3/LET 9239, IET 6262/IET 7552 and IET 7552/IET 9239 revealed significant and positive reciprocal effects for both ratoon yield and regenerated tillers. For ratoon yield also, the means were higher when IET 7552 was used as female parent and also indicated that the profound influence of maternal effects for ratoon traits. It would be beneficial to use IET 7552 as ovule parent in hybridisation programme for improving ratoon yield.

Chauhan *et al.* (1985) studies on number of seedlings per hill and ratooning ability of rice (*Oryza sativa* L.) with 20 days old seedlings of IR 44 were transplanted at the rate of 1, 2, 4, 6 and 8 per hill at 25 × 20 cm spacing in RBD with four replications, fertilizer was applied at 90 kg N, 13 kg P and 25 kg K/ha. Two third of N and full dose of P and K was incorporated into the soil at final puddling. The remaining N was top dressed at 30 days after transplanting. At maturity, plant stalks were cut at a height of 15 cm. Nitrogen was broadcast at 40 kg/ha immediately after cutting, observed that ratoon tillers regeneration generally increased with increased with number of seedlings per hill in the main crop. Eight seedlings per hill in the main crop resulted in the highest regeneration, which however was not significantly different from the percentages resulting from 4 and 6 seedlings per hill. The number of seedlings per hill in the main crop did not affect the number of tillers per hill at 0, 7, 14 and 21 days after first harvest nor at ratoon harvest. However, at ratoon harvest, tiller number per square meter was significantly larger with 4-8 seedlings per hill than with 1 and 2 seedlings per hill. The number of tillers and panicles was highest with 8 seedlings per hill, mainly because more hills were missing from treatment with 1 and 2 seedlings per hill. Ratoon grain yield was significantly lower with one seedling per hill than with 2-8 seedlings per hill. Four seedling per hill gave the highest ratoon yields, which, however, were not statistically different from those of 2, 6 or 8 seedlings per hill. The highest ratoon and main-crop grain yields were obtained when 4 seedlings per hill were used in the main crop. The yield components, when expressed on per hill basis, did not differ significantly. The number of seedlings per hill in the main crop affects mainly the number of missing hills in the ratoon crop.

Chauhan *et al.* (1989) genetic analysis of generation means of F_1 , F_2 , F_3 , F_4 and the parental populations of the cross IR10154-233-3A/IR15795-232-3-3-2 for ratooning ability was conducted and observed that good ratooning ability is a recessive trait. The parents differed by at least two pairs of major genes for ratooning ability. A large proportion of transgressive segregants in F_2 suggested that the expression of ratooning ability is influenced not only by major genes but also by modifiers. Broad-sense heritability estimates computed by different methods ranged from 0.66 to 0.88. Narrow-sense heritability by the F_4 - F_3 regression method was 0.39. The heritability estimates were 0.42 and 0.33 by the variance component method. The prevalence of additive x additive type of gene effects along with prominent additive effects imply some scope for selection in the segregating generations. However, non-additive type of gene action also affects the expression of ratooning ability.

Chauhan *et al.* (1991) parental, F_2 , F_3 and F_4 generations of a rice cross (IR 19657-34-2-2-3-3 A x IR 56) were evaluated for inheritance of ratooning ability and revealed that additive and dominant gene effects were significant. The dominance of genes for lower parental value predominantly controlled the inheritance of ratooning ability in this cross. Broad-sense heritability estimate was moderate, whereas narrow sense heritability values were low in F_2 and F_3 indicated that the contribution of non-additive gene action to the expression of rationing ability character. Selection schemes utilizing additive and non-additive gene actions should, therefore, be adopted for the improvement of rice ratooning ability.

Dustin *et al.* (2009) studies were to evaluate the effect of main-crop stubble height on ratoon grain yield, agronomics, and cumulative/weekly panicle growth parameters (density, point of origin, and weight). Main-crop 'Cocodrie' and 'Trenasse' rice cultivars were harvested to leave either a 40- or 20-cm stubble height revealed that when the initial stubble height is reduced from 40 to 20 cm the growth of the ratoon crop is altered by shifting panicle point of origin during the early growth period and delaying maturity.

Golam *et al.* (2004) an attempt was made to know the inheritance pattern of cooked kernel elongation in Mahsuri Mutant crosses. In all the three Mahsuri Mutant crosses, the frequency distribution of kernel elongation ratio of segregating populations always formed a bimodal curve. However, in crosses of Mahsuri Mutant

and Mahsuri (even in the reciprocal cross) the bimodal curve progressed towards lower kernel elongation. So it can be assumed that this character may be governed from 1 or 2 loci. But in cross of Mahsuri Mutant and 9192 a very smaller peak compared to the other was noted, which denotes the predominance of one major gene along with few modifier genes.

Golam Faruq *et al.* (2014) studies rice ratoon crop: a sustainable rice production system for tropical hill with 22 rice entries transplanted in completely randomized design with five replications to assess agronomic performance of main crop and ratoon crop where entry 13 demonstrated highest grain yield per plant (42.06 ± 1.2 gm) as main crop, as well as ratoon crop (3.37 ± 0.28 gm); entry 19 produced lowest grain yield per plant (5.01 ± 0.31 gm) as main crop and entry 31 as ratoon crop (0.47 ± 0.03 gm) and the grain yield per plant of both the main and ratoon crop demonstrated significant positive correlation with number of tiller per plant (0.64 ** and 0.52); number of fertile tiller per plant (0.66 ** and 0.63 **); grain per panicle (0.72 ** and 0.53); fertile grain per panicle (0.80 *** and 0.63) and thousand-grain weight (0.66 ** and 0.54). The Duncan Multiple Range test and Analysis of Variance also confirmed the different grouping and significant differences of productivity and agronomic performances of the entries.

Hassan Akhgari *et al.* (2013) evaluated the effects of planting methods on yield and yield components of ratoon and main plant of rice (*Oryza sativa* L) was conducted in Rasht, north of Iran in a split-plot on base of randomized complete block design with three replications, main-plots were variety with four levels (Hashemi, Khazar, Hassani and Ali-Kazemi) and the sub-plots were planting methods with four levels (broadcast direct seeding, linear direct seeding, hill direct seeding and transplanting), observed that effect of variety on main plant and ratoon yield of rice were significant ($p < 0.01$) that maximum average of main plant and ratoon yield were in treatments of Hashemi and Hassani with means of 364.05 and 146.92 g/m², respectively. Also, there was a significant difference ($p < 0.05$) between treatments of planting methods regarding ratoon yield that maximum average of ratoon yield ($M = 139.08$ g/m²) was in transplanted rice.

Ichii and Sumi (1983) studies on effect of food reserves on the ratoon growth of rice plant revealed that in order to regulate artificially the amount of food reserves of rice plants, they were grown for 2 weeks before cutting under 3 different

environments, which were full sunlight, shaded to about 50% sunlight and shaded to about 25% sunlight. Percentage of ratoon tillers, ratoon height and ratoon weight were highest for full sunlight; second for the 50% sunlight and lowest for the 25% sunlight and there was a significant difference among the 3 different environments. The time required to reach the maximum value was about 15 days for the percentage of ratoon tillers, and was from 20 to 30 days for ratoon height. Weight and TAC amount in the stem base of the mother plant decreased significantly and linearly with the intensity of shading. It was assumed from these that ratoon traits might be correlative to stem base traits and is highly significant.

Jane Ringera *et al.* (2014) studies on ratooning ability and its effect on grain yield of upland Nerica rice varieties in Central Kenya where four upland NERICA (NERICA 1, 4, 10 and 11) along with one local *Oryza sativa* (Duorado precoce) rice varieties were planted in randomized complete block design with three replicates. The main crop was harvested at maturity after which the tillers were hand cut to stubble of about 15cm tall. The stubbles were left to grow without application of any further input until the ratooned plants were ready for harvest and observed that correlation between grain yield and agronomic traits revealed that total number of tillers ($r=0.601^{***}$) and productive tillers ($r=0.586^{***}$) from the main crop significantly and positively correlated to grain yield. Similarly, the two agronomic traits (tiller number and productive tillers) from the ratoon crop were significantly and positively correlated (0.487^{***} and 0.528^{***} respectively) with grain yield.

Jane Ringera *et al.* (2014) conducted studies on rice ratooning ability and its effect on grain yield of four upland New Rice for Africa and one local *Oryza sativa* (Duorado precoce) rice varieties which revealed that ratooning ability among the NERICAs ranged from 26% (NERICA 1) to 39% (NERICA 4) while Duorado precoce recorded the lowest (19%). Total grain yield (main crop plus ratoon) differed significantly ($p<0.05$) among the rice varieties with NERICA 4 attaining the highest total yield (6206 kg ha^{-1}) while the local variety Duorado precoce attained the lowest (3376 kg ha^{-1}). NERICA 4 and NERICA 10 recorded remarkable yield increase of more than 1500 kg ha^{-1} (the average yield of upland rice in Sub-sahara Africa) with no additional input.

Kailou Liu *et al.* (2012) observed the effects of different different cultivations (DS: direct-seeding, ST: seedling-throwing, TP: transplanting) and planting periods of the main crop on physiological traits and rice yields, as well as to find the source of

the nutrients in the ratoon crop by studying the stubble dry matter and nitrogen translocation of pre-anthesis and its efficiency in the ratoon crop revealed that the yields of the main crop were different significantly. The yield of TP was significantly higher than ST and DS as well as the yield of D3 was more than the yields of other periods. In the ratoon crop, the yield of D1 was more than that in other periods. The ratooning ability was different significantly among different cultivations. The cultivations affected the tillering ability in the ratoon crop and the translocation of the stubble dry matter and nitrogen uptaking in which TP was better than others. From March to April, sowing or transplanting date did not affect the stubble dry matter and N translocation of pre-anthesis and its efficiency and suggested that TP treatment could get the highest yield among the three cultivations. The crops could get higher grain yield when the ratoon rice were planted during the period of late March to April in southeastern China.

Kai-lou Liu *et al.* (2015) observed that the growth of ratoon rice (*Oryza sativa* L.) is affected by growth of main rice, so it could be evaluated by determining growing condition of main rice, through regression model for predicting ratoon rice growth rhythm through establishing the quantitative relationship between growth rhythm in ratoon rice and normalized difference vegetation index (NDVI) after heading of main rice. NDVI at key growth stages of main rice was measured using active spectrometry for 12 varieties in 2008 and for 23 varieties in 2009, and compared the physiological indexes of main and ratoon rice. There was an exponential correlation ($P < 0.05$) between the NDVI after heading of the main rice and biomass, N concentration of green leaves and stems or leaf area index (LAI) after heading of the ratoon rice for all the 12 varieties in 2008. The regression models from the rice variety experiment in 2008 were used to calculate predicted values with NDVI after heading of main rice in 2009. The results showed that the predicted values of biomass, N uptake, and LAI in ratoon rice were significantly different to measured values. However, there were exponential and significantly positive correlation ($p < 0.05$) between biomass and N uptake and LAI in ratoon rice and NDVI after heading of main rice in 2009. Therefore, it suggested that regression models were not perfect, and need to be improved adding more parameters about spectral characteristic of main and ratoon rice.

Kouakou Olivier *et al.* (2014) studies on growth, yields and ratooning performance of lowland rice NERICA L14 as affected by different fertilizers in a complete randomized block design with 3 replications at 100 N kg ha⁻¹, 55 P₂O₅ kg ha⁻¹, 150 kg K ha⁻¹, 33 kg Ca ha⁻¹, 15 kg Mg ha⁻¹ and 10 Zn kg ha⁻¹ including no fertilized plot as control after the harvest of main crop of rice variety NERICA L14 previously fertilized with 200 kg ha⁻¹ of NPK (10-18-18) in all the plots revealed that there was a significant ($p < 0.05$) effect of sequential cropping on the numbers of tiller and panicle every year likewise for the physiological and life cycles of rice. Highest numbers of tiller (406-555 m⁻²) and panicle (397- 349 m⁻²) were accounted for ratoon crop characterized by shortest life cycle (54-60 days). Positive impacts of N, K, and Zn fertilizers were also recorded for these parameters across years showing contrast between years for Zn-fertilizer in relation with presuming water availability in the field. Rice grain yields were ranging from 0.70 to 1.30 t.ha⁻¹ for ratoon against 4.22 t ha⁻¹ recorded for the main crop. Although no significant difference was observed for the total grain yield according to fertilizer treatments, yield increasing ratio was high (20% – 50%) for treatment Zn. Applying N, K and Zn fertilizer is recommended for improving rice rationing and its production in a rainfed lowland subjected to fluctuation of water availability in the humid forest zone of Cote d'Ivoire.

Manjappa and Prabhakar (2002) Studies on effect of cultural practices on ratooning ability of hybrid rice revealed that the grain and straw yields of ratoon crop were 2385 and 4644 kg ha⁻¹, respectively (means over two years) with 33 per cent higher population of main crop and was significantly higher than that obtained with normal population of main crop. Harvesting of main crop at physiological maturity resulted in higher grain yield (2427 kg ha⁻¹) compared to harvest maturity (2180 kg ha⁻¹). Between cutting heights, 20 cm cuttings height recorded significantly higher grain yield than 10 cm. Planking soon after harvest of main crop gave significantly higher grain yield when compared to no planking.

Masahiko (1983) studied the effect of water management on ratoon ability of rice plants by two experiments with 1/2000 Wagner pots to determine the effect of water management systems on the ratoon ability. Rice plants were cut on the 10th day following heading. Cutting heights in experiment I were at the ground level or 5 cm above the ground, while in experiment II they were 20 cm above the ground

respectively. where the percentages of ratoon tillers and ratoon heights were noted for 40 days after cutting and revealed that most of the hills did not produce ratoons when the main crop was cut at ground level and the water depth was maintained at 5 cm above the ground, water depth did not affect the percentage of ratoon tillers and ratoon heights when the main crop was cut 5 cm above the ground and also no significant effects of water management on the percentage of ratoon tillers and ratoon heights were observed, when the main crop was cut at 20 cm above the ground, no special attention to the water management during the period before and after cutting.

Mohamad *et al.* (2012) studies on the effects of harvest time and harvest height on grain yield and yield components of rice (Taroem Hasemi variety), in split plot design within randomized complete block design with three replications. Where, harvest height was considered as sub-factor (H₁: Level ground, H₂: 10 cm, H₃: 20 cm, H₄: 30 cm and H₅: 40 cm). Harvesting height had significant influence on the number of tillers, the number of fertile tillers, the number of panicles per m² and the number of filled spikelets. The results of the survey concluded that the harvesting at 40 cm height and harvesting on 29 August had the potential to produce higher yields.

Mruthunjaya *et al.* (1996) investigated 18 F₁ hybrids in *Oryza sativa* L. were studied for their ratooning ability and revealed the presence of epistasis by scaling tests. Partial dominance was prevailed in majority of the crosses. Inbreeding depression was low. Moderate to fairly high degree of heritability (50.2% to 81.2%) and genetic advance (9.30% to 29.8%) were observed. Most of the crosses showed additive (d) and additive × additive (i) types of gene effects. Thus, ratooning ability was governed by additive gene action.

Mruthunjaya *et al.* (2002), studied on additive and non additive gene effects for ratooning ability in eighteen crosses of rice (*Oryza sativa* L.). The results revealed that dominance gene effect was predominant for ratooning ability, though additive gene effects were also important. Inter-mating of selects followed by visual selection in early segregating generations would bring important in the trait. The results suggested the complex nature of inheritance of ratooning ability in rice.

Muhammad *et al.* (2008) response of different fertilizer doses was studied on the ratoon crop as well as main crop. The different fertilizer doses under the study were F₁ (N=90, P₂O₅ = 45, K₂O=50, S=13, Zn = 4: in kg ha⁻¹), F₂ (N=105, P₂O₅ = 55,

K₂O=60, S=13, Zn = 4: in kg ha⁻¹), F₃ (N=120, P₂O₅ = 65, K₂O=70, S=13, Zn = 4: in kg ha⁻¹), F₄(N =135, P₂O₅ =75, K₂O=80, S=13, Zn=4: in kg ha⁻¹) and F₅ (N=150, P₂O₅ = 85, K₂O = 90, S=13, Zn = 4: in kg ha⁻¹). In the main crop, the highest grain and biological yields were produced by F₃ dose. The highest straw yield was produced by F₄ dose. The lowest grain yield and the lowest biological yield were produced by F₁ dose and the lowest straw yield was produced by F₂ dose. The highest crop duration was found using F₁ dose and the shortest crop duration was found using F₃ doses. In the ratoon crop, the highest grain yield, straw yield and biological yield was produced by F₅ dose whereas the lowest grain yield, straw yield and biological yield was achieved with F₁ dose. The longest crop duration was observed using F₂ dose and the shortest crop duration was recorded using F₅ dose.

Oad *et al.* (2002), studies on correlation and path analysis of thirty rice ratoon varieties and advanced lines of rice revealed that grain yield showed positive correlation with plant height, ratoon rating, 1000 grain weight, number of panicles, panicle length, seed length, and tillers at harvest. Path analysis indicated ratoon crop parameters had low positive direct effects and suggests that selecting varieties may base higher ratoon rice grain yields or advanced lines, which has higher tillers, more panicles per plant, lengthy panicles, and high ratoon rating.

Veerasha *et al.* (2013b) studied combining ability in rice (*Oryza sativa* L.) involving four CGMS lines, 11 testers and resulting 44 rice hybrids, revealed IR 68897A was a good general combiner for days to 50% flowering, plant height and grain yield per plant, CGMS line IR 68888A was a good general combiner for the number of panicles per plant and panicle weight. Eight cross combinations exhibited high SCA effects for grain yield per plant. These crosses were found to involve at least one parent with high GCA effect and other parents having either high or low GCA effect indicating the involvement of additive as well as non-additive gene action operating in these crosses.

Waghmode *et al.* (2011) studied combining ability analysis involving 125 crosses for grain yield, its components in Line × Tester design. The magnitudes of SCA variances were higher than the GCA variances for all the characters except for productive tillers plant⁻¹. Among females, RTN3B and RTN-2B and among males IR-63879-195-195-2-2-3-2, NVSR-20, BL-184AR, GR-7 and IR-8866 were observed to be good general combiner for yield and most of the yield contributing characters.

Yih-Chuan Kuo, *et al.* (1997), studies on Griffing and Hayman diallel analysis of variance for eating and processing quality parameters of milled rice, in a six-parents diallel cross revealed that reciprocal differences in both Griffing's and Hayman's diallel analysis were not significant and gene action in the parents studied was mainly additive for all evaluated endosperm characteristics.

2.2 VARIABILITY

For the formulation of successful breeding programme, knowledge on the nature and magnitude of the genotypic and phenotypic variability present in any crop species plays a vital role. The phenotypic expression of a character is the result of the interaction between genotype and environment. Hence the total variation needs to be partitioned into variance due to genotype (heritable) and variance due to environment (non-heritable) for assessing the true breeding behavior of the phenotype. The efficiency of selection in plant breeding largely depends upon the amount of heritable variation present in the material. Available literature on variability in rice is reviewed and presented in table 2.1.

Table 2.2. Review of literature on phenotypic coefficient of variance and genotypic coefficient of variance in rice (*Oryza sativa* L.)

S. No.	Character	Variability	Reference
1	Days to 50 % flowering	Low PCV, GCV	Allam <i>et al.</i> (2015), Navin Kumar <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Arpita <i>et al.</i> (2014), Gokulakrishnan <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Osekita <i>et al.</i> (2014), Sandhya <i>et al.</i> (2014), Swati Sharma <i>et al.</i> (2014), Thirumala Rao <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Awaneet Kumar and Senapati (2013), Gangashetty <i>et al.</i> (2013), Gulzar <i>et al.</i> (2013), Paikhomba <i>et al.</i> (2013), Sathya and Jebaraj (2013), Shiva Prasad <i>et al.</i> (2013), Mulugeta <i>et al.</i> (2012), Neha and Gabriel (2012), Ravindra Babu <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011), Dinesh <i>et al.</i> (2011), Sangam Kumar Singh <i>et al.</i> (2011), Shiva Prasad <i>et al.</i> (2011), Siva Parvathi <i>et al.</i> (2011), Ullah <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011)
2	Days to maturity	Low PCV, GCV	Allam <i>et al.</i> (2015), Tuhina-Khatun <i>et al.</i> (2015), Navin Kumar <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Arpita <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Osekita <i>et al.</i> (2014), Sandhya <i>et al.</i> (2014), Swati Sharma <i>et al.</i> (2014), Ashok Kumar Tuwar <i>et al.</i> (2013), Atif and Khalid (2013), Awaneet Kumar and Senapati (2013), Gulzar <i>et al.</i> (2013), Toshimenla and Sapu (2013), Mulugeta <i>et al.</i> (2012), Neha and Gabriel (2012), Akinwale <i>et al.</i> (2011), Akhtar <i>et al.</i> (2011), Sangam Kumar Singh <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011)
3	Plant height	Low PCV, GCV	Navin Kumar <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Thirumala Rao <i>et al.</i> , (2014), Paikhomba <i>et al.</i> (2013), Sathya and Jebaraj (2013), Mulugeta <i>et al.</i> (2012), Akhtar <i>et al.</i> (2011),, Akinwale <i>et al.</i> (2011), Dinesh <i>et al.</i> (2011), Ullah <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Khatun <i>et al.</i> (2010)
4	Total number of tillers per plant	Moderate PCV, GCV	Vijay Kumar <i>et al.</i> (2015), Sandhya <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Sathya and Jebaraj (2013), Yadav <i>et al.</i> (2010))
		High PCV, Moderate GCV	Nitiprasad and Lotan Kumar (2014), Osekita <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Vange (2009)
		Moderate PCV, Low GCV	Gokulakrishnan <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Paikhomba <i>et al.</i> (2013), Akinwale <i>et al.</i> (2011)

Table 2.2 (Cont.)

5	Number of ear bearing tillers plant per plant	High GCV, PCV	Allam <i>et al.</i> (2015), Tuhina-Khatun <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Arpita <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Osekita <i>et al.</i> (2014), Swati Sharma <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Ashok Kumar Tuwar <i>et al.</i> (2013), Awaneet Kumar and Senapati (2013), Gangashetty <i>et al.</i> (2013), , Sathya and Jebaraj (2013), Shiva Prasad <i>et al.</i> (2013), Ukaoma <i>et al.</i> (2013), Neha and Gabriel (2012), Seyoum <i>et al.</i> (2012), Babu <i>et al.</i> (2011), Mohan Lal and Chauhan (2011) , Selvaraj <i>et al.</i> (2011), Singh <i>et al.</i> (2011), Shiva Prasad <i>et al.</i> (2011), Sangam Kumar Singh <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011), Venkata Subbaiah <i>et al.</i> (2011), Verma <i>et al.</i> (2011), Jayasudha and Deepak (2010)
		High PCV, Moderate GCV	Perera <i>et al.</i> (2014), Sandhya <i>et al.</i> (2014), Toshimenla and Sapu (2013), Saidaiiah <i>et al.</i> (2010b), Satish Chandra <i>et al.</i> (2009) , Vange (2009), Vijayalakshmi <i>et al.</i> (2008) , Rita Binse <i>et al.</i> (2006) , Singh <i>et al.</i> (2006), Sobita Devi <i>et al.</i> (2006)
		Moderate PCV, GCV	Keya <i>et al.</i> (2015), Navin Kumar <i>et al.</i> (2015), Gokulakrishnan <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Ravindra Babu <i>et al.</i> (2012), Pankaj Garg <i>et al.</i> (2010), Shiva Prasad <i>et al.</i> (2011), Siva Parvathi <i>et al.</i> (2011) , Ullah <i>et al.</i> (2011)
6	Panicle length	Low PCV, GCV	Navin Kumar <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Gokulakrishnan <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Perera <i>et al.</i> (2014), Rahman <i>et al.</i> (2014), Sandhya <i>et al.</i> (2014), Osekita <i>et al.</i> (2014), Thirumala Rao <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Atif and Khalid (2013), Awaneet Kumar and Senapati (2013), Paikhomba <i>et al.</i> (2013), Sathya and Jebaraj (2013), Mulugeta <i>et al.</i> (2012), Ravindra Babu <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011), Sangam Kumar Singh <i>et al.</i> (2011), Ullah <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Yadav <i>et al.</i> (2010)
7	Number grains panicle per plant	Moderate PCV, GCV	Keya <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Gokulakrishnan <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Paikhomba <i>et al.</i> (2013), Sathya and Jebaraj (2013), Yadav <i>et al.</i> (2010)
8	Test weight	Moderate PCV, GCV	Allam <i>et al.</i> (2015), Keya <i>et al.</i> (2015), Tuhina-Khatun <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Arpita <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Gokulakrishnan <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Sandhya <i>et al.</i> (2014), Atif and Khalid (2013), Awaneet Kumar and Senapati (2013), , Gulzar <i>et al.</i> (2013), Shiva Prasad <i>et al.</i> (2013), Neha and Gabriel (2012), Mohan Lal and Chauhan (2011), Sangam Kumar Singh <i>et al.</i> (2011), Shiva Prasad <i>et al.</i> (2011), Ullah <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Khatun <i>et al.</i> (2010), Saidaiiah <i>et al.</i> (2010b) , Yadav <i>et al.</i> (2010)

Table 2.2 (Cont.)

		Low PCV, GCV	Navin Kumar <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Osekita <i>et al.</i> (2014), Rahman <i>et al.</i> (2014) Paikhomba <i>et al.</i> (2013), Mulugeta <i>et al.</i> (2012), Akhtar <i>et al.</i> (2011), Satish (2000)
9	Leaf area index	High PCV, GCV	Zulqarnain <i>et al.</i> (2012), Surender Raju (2002), Shivani and SriramaReddy (2000), Niranjan Murthi <i>et al.</i> (1999), Chauhan <i>et al.</i> (1994), Prasanthi (1993), Srivastava and Saxena (1982)
		Moderate PCV, GCV	Ullah <i>et al.</i> (2011)
10	Grain yield plant per plant	High PCV, GCV	Allam <i>et al.</i> (2015), Keya <i>et al.</i> (2015), Tuhina-Khatun <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Sandhya <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Swati Sharma <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Ashok Kumar Tuwar <i>et al.</i> (2013), Awaneet Kumar and Senapati (2013) Gangashetty <i>et al.</i> (2013), , Gulzar <i>et al.</i> (2013), Shiva Prasad <i>et al.</i> (2013), Toshimenla and Sapu (2013), Ukaoma <i>et al.</i> (2013), Neha and Gabriel (2012), Zulqarnain <i>et al.</i> (2012), Akhtar <i>et al.</i> (2011), Dinesh <i>et al.</i> (2011), Mohan Lal and Chauhan (2011), Sangam Kumar Singh <i>et al.</i> (2011)
		Moderate PCV, GCV	Navin Kumar <i>et al.</i> (2015), Sameera <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Gokulakrishnan <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Thirumala Rao <i>et al.</i> (2014), Paikhomba <i>et al.</i> (2013), Ullah <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Saidaiah <i>et al.</i> (2010b) , Yadav <i>et al.</i> (2010), Satish Chandra <i>et al.</i> (2009) , Zia-Ul-Qamar <i>et al.</i> (2005), Kumar <i>et al.</i> (2006) , Bhavana (2003), Satish (2000)
11	Hulling per cent	Low PCV, GCV	Venkanna <i>et al.</i> (2014), Siva Parvathi <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Umadevi <i>et al.</i> (2010b) , Satish Chandra <i>et al.</i> (2009), Vanaja and Luckins (2006), Mishra and Pravin (2004), Nagajyothi (2001)
12	Milling per cent	Low PCV, GCV	Ravindra Babu <i>et al.</i> (2012), Siva Parvathi <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Rajeswari <i>et al.</i> (2010) , Satish Chandra <i>et al.</i> (2009), Krishna Naik (2004) , Chaudhry and Motiramani (2003) , Nagajyothi (2001)
13	Head rice recovery per cent	Low PCV, GCV	Ravindra Babu <i>et al.</i> (2012), Venkata Subbaiah <i>et al.</i> (2011), Sivaparvathi <i>et al.</i> (2011) , Rajeswari <i>et al.</i> (2010) , Satish Chandra <i>et al.</i> (2009) , Krishna Naik (2004), Patil <i>et al.</i> (2003b)
14	Kernel Length (mm)	Low PCV, GCV	Tuhina-Khatun <i>et al.</i> (2015), Gokulakrishnan <i>et al.</i> (2014), Osekita <i>et al.</i> (2014), Venkanna <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Awaneet Kumar and Senapati (2013), , Ravindra Babu <i>et al.</i> (2012), Venkata Subbaiah <i>et al.</i> (2011), Rita Bisne <i>et al.</i> (2009), Vanaja and Luckins (2006)

Table 2.2 (Cont.)

15	Kernel Breadth (mm)	Low PCV, GCV	Allam <i>et al.</i> (2015), Venkanna <i>et al.</i> (2014), Aditya Kumar <i>et al.</i> (2013), Awaneet Kumar and Senapati (2013), Ravindra Babu <i>et al.</i> (2012), Venkata Subbaiah <i>et al.</i> (2011), Rita Bisne <i>et al.</i> (2009)
16	L/B ratio	Low PCV, GCV	Venkanna <i>et al.</i> (2014), Venkata Subbaiah <i>et al.</i> (2011)
17	Kernel length after cooking	Moderate PCV, GCV	Allam <i>et al.</i> (2015)
		Low PCV, GCV	Venkata Subbaiah <i>et al.</i> (2011)
18	Kernel breadth after cooking	Low PCV, GCV	Venkata Subbaiah <i>et al.</i> (2011)
19	Kernel elongation ratio	Low PCV,GCV	Allam <i>et al.</i> (2015), Venkata Subbaiah <i>et al.</i> (2011), Sunayana <i>et al.</i> (2010), Vanaja and Luckins (2006) , Krishna Naik (2004) , Mishra and Pravin (2004)
20	Volume expansion ratio	Moderate PCV, PCV	Ravindra Babu <i>et al.</i> (2012), Vanaja and Luckins (2006)
		Low PCV,GCV	Venkata Subbaiah <i>et al.</i> (2011)
21	Water Uptake	Moderate GCV, PCV	Siva Parvathi <i>et al.</i> (2011), Venkata Subbaiah <i>et al.</i> (2011), Umadevi <i>et al.</i> (2010b), Vanaja and Luckins (2006)
22	Gel consistency	High PCV, GCV	Siva Parvathi <i>et al.</i> (2011), Umadevi <i>et al.</i> (2010b), Asish Binodh <i>et al.</i> (2007)
		Moderate PCV, GCV	Ravindra Babu <i>et al.</i> (2012), Venkata Subbaiah <i>et al.</i> (2011)
23	Alkali spreading value	High PCV, GCV	Allam <i>et al.</i> (2015), Siva Parvathi <i>et al.</i> (2011) , Venkata Subbaiah <i>et al.</i> (2011), Rajeswari <i>et al.</i> (2010), Sunayana <i>et al.</i> (2010), Umadevi <i>et al.</i> (2010b), Asish Binodh <i>et al.</i> (2007), Vanaja and Luckins (2006) , Krishna Naik (2004), Patil <i>et al.</i> (2003b), Nagajyothi (2001)
24	Amylose content	Moderate PCV, GCV	Sunayana <i>et al.</i> (2010), Asish Binodh <i>et al.</i> (2007), Vanaja and Luckins (2006), Patil <i>et al.</i> (2003b)
		Low PCV,GCV	Allam <i>et al.</i> (2015), Aditya Kumar <i>et al.</i> (2013), Ravindra Babu <i>et al.</i> (2012), Siva Parvathi <i>et al.</i> (2011) , Rajeswari <i>et al.</i> (2010), Kumar <i>et al.</i> (2006), Krishna Naik (2004), Satish (2000)

2.3 HERITABILITY AND GENETIC ADVANCE

Hanson *et al.* (1956) defined heritability in broad sense as the ratio of genotypic variance to the total variance in the non segregating populations. Phenotype is the expression of a genotype in a given environment, sometimes when the environmental influence is less; the true heritability becomes much higher. Heritability (h^2) measures the relative amount of the heritable portion of variability, while the genetic advance (GA) helps to measure the amount of progress that could be expected with selection in a character. So, only heritability will not give a true picture of inherited variance and high heritability is not always an indication of true genetic gain. Hence there is need to estimate genetic advance, which is a relative measure and reliable indication of true genetic gain.

Literature available in rice on heritability and genetic advance was reviewed and presented in table 2.3.

Table 2.3. Review of literature on heritability and genetic advance as per cent of mean in rice (*Oryza sativa* L.)

S.No.	Character	Heritability	Genetic advance as per cent of mean	Reference
1.	Days to 50% flowering	High	Moderate	Keya <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Arpita <i>et al.</i> (2014) Gokulakrishnan <i>et al.</i> (2014) Sandhya <i>et al.</i> (2014) Swati Sharma <i>et al.</i> (2014) Aditya Kumar <i>et al.</i> (2013) Atif and Khalid (2013) Awaneet Kumar and Senapati (2013) Gangashetty <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2013) Toshimenla and Sapu (2013) Ravindra Babu <i>et al.</i> (2012) Sangam Kumar Singh <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011) Siva Parvathi <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Jayasudha and Deepak (2010) Saidaiah <i>et al.</i> (2010b) Yadav <i>et al.</i> (2010)
		High	Low	Navin Kumar <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Lingaiah <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014) Mulugeta <i>et al.</i> (2012) Seyoum <i>et al.</i> (2012) Akinwale <i>et al.</i> (2011) Dinesh <i>et al.</i> (2011) Ullah <i>et al.</i> (2011) Zia-Ul-Qamar <i>et al.</i> (2005)
2.	Days to maturity	High	Moderate	Allam <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Arpita <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Ashok Kumar Tuwar <i>et al.</i> (2013) Atif and Khalid (2013) Toshimenla and Sapu (2013) Sangam Kumar Singh <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011) Venkata Subbaiah <i>et al.</i> (2011) Vange (2009)

Table 2.3 (Cont.)

3.	Plant height	High	Moderate	Keya <i>et al.</i> (2015) Navin Kumar <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Paikhomba <i>et al.</i> (2013) Sathya and Jebaraj (2013) Toshimenla and Sapu (2013) Mulugeta <i>et al.</i> (2012) Ravindra Babu <i>et al.</i> (2012) Akinwale <i>et al.</i> (2011) Dinesh <i>et al.</i> (2011) Mamta Singh <i>et al.</i> (2007) Vaithiyalingan and Nadarajan (2006) Zia-Ul-Qamar <i>et al.</i> (2005)
4.	Number of tillers per plant	High	High	Sameera <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Arpita <i>et al.</i> (2014) Perera <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Sandhya <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Swati Sharma <i>et al.</i> (2014) Ashok Kumar Tuwar <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Gulzar <i>et al.</i> (2013) Sathya and Jebaraj (2013) Ukaoma <i>et al.</i> (2013) Priyanka Yadav <i>et al.</i> (2010)
		High	Moderate	Atif and Khalid (2013)
		Moderate	Moderate	Navin Kumar <i>et al.</i> (2015) Gokulakrishnan <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014) Paikhomba <i>et al.</i> (2013) Ravindra Babu <i>et al.</i> (2012)
5.	No. of ear bearing tillers per plant	High	High	Allam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Arpita <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Perera <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Swati Sharma <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014)

Table 2.3 (Cont.)

				Aditya Kumar <i>et al.</i> (2013) Ashok Kumar Tuwar <i>et al.</i> (2013) Sandhya <i>et al.</i> (2014) Gangashetty <i>et al.</i> (2013) Sathya and Jebaraj (2013) Ukaoma <i>et al.</i> (2013) Dinesh <i>et al.</i> (2011) Mohan Lal and Chauhan (2011) Seyed Mustafa Sadeghi (2011) Siva Parvathi <i>et al.</i> (2011) Singh <i>et al.</i> (2011) Verma <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Jayasudha and Deepak (2010) Khatun <i>et al.</i> (2010) Saidaiah <i>et al.</i> (2010b) Sreeparvathy <i>et al.</i> (2010)
		Moderate	Moderate	Navin Kumar <i>et al.</i> (2015) Gokulakrishnan <i>et al.</i> (2014) Pankaj Garg <i>et al.</i> (2010) Vange (2009) Bharadwaj <i>et al.</i> (2007) Karim <i>et al.</i> (2007) Monalisa Manna <i>et al.</i> (2006)
6.	Panicle length	High	Moderate	Sameera <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014) Sandhya <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014) Ashok Kumar Tuwar <i>et al.</i> (2013) Venkata Subbaiah <i>et al.</i> (2011) Saidaiah <i>et al.</i> (2010b)
		Moderate	Low	Navin Kumar <i>et al.</i> (2015) Perera <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Aditya Kumar <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2013) Sathya and Jebaraj (2013) Ullah <i>et al.</i> (2011) Bhavana (2003)
7.	Number of filled grains panicle per panicle	High	High	Allam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015)

Table 2.3 (Cont.)

				Alam <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Gokulakrishnan <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Perera <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Aditya Kumar <i>et al.</i> (2013) Ashok Kumar Tuwar <i>et al.</i> (2013) Awaneet Kumar and Senapati (2013) Gulzar <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2013) Sathya and Jebaraj (2013) Ukaoma <i>et al.</i> (2013) Ravindra Babu <i>et al.</i> (2012) Zulqarnain <i>et al.</i> (2012) Dinesh <i>et al.</i> (2011) Sangam Kumar Singh <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011) Siva Parvathi <i>et al.</i> (2011) Ullah <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011)
		High	Moderate	Keya <i>et al.</i> (2015) Atif and Khalid (2013) Monalisa Manna <i>et al.</i> (2006)
8.	Test weight	High	High	Allam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Arpita <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Rahman <i>et al.</i> (2014) Sandhya <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Swati Sharma <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014) Ashok Kumar Tuwar <i>et al.</i> (2013) Awaneet Kumar and Senapati (2013) Gangashetty <i>et al.</i> (2013) Gulzar <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2013) Toshimenla and Sapu (2013) Ukaoma <i>et al.</i> (2013) Bhadru <i>et al.</i> (2012) Dinesh <i>et al.</i> (2011)

Table 2.3 (Cont.)

				Mohan Lal and Chauhan (2011) Shiva Prasad <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Khatun <i>et al.</i> (2010) Saidaiah <i>et al.</i> (2010b) Yadav <i>et al.</i> (2010)
		High	Moderate	Navin Kumar <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Gokulakrishnan <i>et al.</i> (2014) Mulugeta <i>et al.</i> (2012) Ravindra Babu <i>et al.</i> (2012) Seyed Mustafa Sadeghi (2011) Satish (2000)
9.	Leaf area Index at maximum tillering stage	High	High	Zulqarnain <i>et al.</i> (2012) Surender Raju (2002) Shivani and SriramaReddy (2000) Niranjana Murthy <i>et al.</i> (1999) Pradyumma Rao <i>et al.</i> (1996) Chauhan <i>et al.</i> (1994)
		Moderate	Moderate	Satish <i>et al.</i> (2004) Prasanthi (1993)
		Moderate	Low	Ullah <i>et al.</i> (2011)
10.	Grain yield per plant	High	High	Allam <i>et al.</i> (2015) Tuhina-Khatun <i>et al.</i> (2015) Navin Kumar <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Gokulakrishnan <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Sandhya <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Swati Sharma <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014) Aditya Kumar <i>et al.</i> (2013) Awaneet Kumar and Senapati (2013) Gangashetty <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2013) Toshimenla and Sapu (2013) Ukaoma <i>et al.</i> (2013) Bhadru <i>et al.</i> (2012) Akinwale <i>et al.</i> (2011) Dinesh <i>et al.</i> (2011) Pankaj Garg <i>et al.</i> (2010) Yadav <i>et al.</i> (2010) Siva Parvathi <i>et al.</i> (2011) Singh <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Anjaneyulu <i>et al.</i> (2010)

Table 2.3 (Cont.)

				Khatun <i>et al.</i> (2010) Sreeparvathy <i>et al.</i> (2010) Uma Devi <i>et al.</i> (2010)
		Moderate	Moderate	Vijay Kumar <i>et al.</i> (2015) Mulugeta <i>et al.</i> (2012)
11.	Hulling per cent	High	Low	Venkata Subbaiah <i>et al.</i> (2011) Satish Chandra <i>et al.</i> (2009) Vanaja and Luckins (2006)
		Moderate	Low	Siva Parvathi <i>et al.</i> (2011)
		Low	Low	Venkanna <i>et al.</i> (2014) Nagajyothi (2001)
12.	Milling per cent	High	Low	Venkata Subbaiah <i>et al.</i> (2011) Rajeswari <i>et al.</i> (2010) Satish Chandra <i>et al.</i> (2009) Krishna Naik (2004)
		Moderate	Low	Ravindra Babu <i>et al.</i> (2012) Nagajyothi (2001)
13.	Head rice recovery per cent	High	Moderate	Siva Parvathi <i>et al.</i> (2011) Krishna Naik (2004) Patil <i>et al.</i> (2003)
		High	Low	Venkata Subbaiah <i>et al.</i> (2011) Rajeswari <i>et al.</i> (2010) Madhavalatha <i>et al.</i> (2005)
14.	Kernel Length	High	Low	Sayed Mustafa Sadeghi (2011) Prasad <i>et al.</i> (2009)
		High	Moderate	Tuhina-Khatun <i>et al.</i> (2015) Gokulakrishnan <i>et al.</i> (2014) Awaneet Kumar and Senapati (2013) Ravindra Babu <i>et al.</i> (2012) Venkata Subbaiah <i>et al.</i> (2011) Rita Bisne <i>et al.</i> (2009) Bharadwaj <i>et al.</i> (2007) Vanaja and Luckins (2006) Rita Binse <i>et al.</i> (2006)
15.	Kernel breadth	High	Moderate	Allam <i>et al.</i> (2015) Nitiprasad and Lotan Kumar (2014) Singh <i>et al.</i> (2014) Awaneet Kumar and Senapati (2013) Rita Bisne <i>et al.</i> (2009)
		High	Low	Ravindra Babu <i>et al.</i> (2012) Sayed Mustafa Sadeghi (2011) Venkata Subbaiah <i>et al.</i> (2011) Prasad <i>et al.</i> (2009)
16.	L /B Ratio	High	Low	Mohan Lal and Chauhan (2011) Singh <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Verma <i>et al.</i> (2011)

Table 2.3 (Cont.)

17.	Kernel length after cooking	High	Low	Venkata Subbaiah <i>et al.</i> (2011) Sarkar <i>et al.</i> (2007) Krishna Naik (2004)
18.	Kernel Breadth after cooking	High	Moderate	Venkata Subbaiah <i>et al.</i> (2011)
19.	Water uptake	High	High	Siva Parvathi <i>et al.</i> (2011) Chakraborty <i>et al.</i> (2010) Umadevi <i>et al.</i> (2010b) Vanaja and Luckins (2006) Yadav <i>et al.</i> (2002)
		High	Moderate	Ravindra Babu <i>et al.</i> (2012) Venkata Subbaiah <i>et al.</i> (2011)
20.	Volume expansion ratio	High	High	Ravindra Babu <i>et al.</i> (2012) Umadevi <i>et al.</i> (2010b) Vanaja and Luckins (2006)
21.	Kernal elongation ratio	High	Low	Sunayana <i>et al.</i> (2010) Madhavalatha <i>et al.</i> (2005)
		High	Moderate	Vanaja and Luckins (2006)
22.	Gel consistency	High	High	Ravindra Babu <i>et al.</i> (2012) Siva Parvathi <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Manonmani <i>et al.</i> (2010) Umadevi <i>et al.</i> (2010b) Asish Binodh <i>et al.</i> (2007) Singh and Singh (2005) Yadav <i>et al.</i> (2002) Nagajyothi (2001)
23.	Alkali spreading value	High	High	Allam <i>et al.</i> (2015) Ravindra Babu <i>et al.</i> (2012) Siva Parvathi <i>et al.</i> (2011) Venkata Subbaiah <i>et al.</i> (2011) Chakraborty <i>et al.</i> (2010) Rajeswari <i>et al.</i> (2010) Sunayana <i>et al.</i> (2010) Umadevi <i>et al.</i> (2010b) Asish Binodh <i>et al.</i> (2007) Vanaja and Luckins (2006) Singh and Singh (2005) Chaudhary <i>et al.</i> (2004) Chaudhry and Motiramani (2003) Patil <i>et al.</i> (2003b)
24.	Amylose content	High	High	Venkata Subbaiah <i>et al.</i> (2011) Rajeswari <i>et al.</i> (2010) Sunayana <i>et al.</i> (2010) Umadevi <i>et al.</i> (2010b) Asish Binodh <i>et al.</i> (2007) Krishnaveni <i>et al.</i> (2006) Vanaja and Luckins (2006)

Table 2.3 (Cont.)

				Patil <i>et al.</i> (2003b)
		High	Moderate	Allam <i>et al.</i> (2015) Ravindra Babu <i>et al.</i> (2012) Siva Parvathi <i>et al.</i> (2011) Chakraborty <i>et al.</i> (2010) Krishna Naik (2004) Nagajyothi (2001)
		High	Low	Aditya Kumar <i>et al.</i> (2013) Kumar <i>et al.</i> (2006) Satish (2000)

2.4 CHARACTER ASSOCIATION

Correlation coefficient is a measure of the degree of closeness and the linear relationship between two variables. The study of correlations between different characters may not help the plant breeder to know how the improvement of one character will bring simultaneous changes in other characters. The yield of a plant is polygenically inherited and highly influenced by environment. Its expression depends upon a number of component traits. Hence direct selection for yield may not be effective. Further the component characters may be simply inherited and also less subjected to environmental variations. To effect selection of these component characters, it is essential to have the knowledge of genetic correlations among the factors contributing to the yield that leads to most effective method of selection by the use of favorable contributions of characters and to minimize the retarding effect of antagonistic correlations (Singh and Bains, 1967).

Correlation studies indicate the magnitude of association between pairs of characters and are useful for selecting genotypes with desirable contributions of characters thereby aiding the plant breeder in crop improvement.

The available literature on character association studies in rice is summarized below for ready reference (Table 2.4 & 2.5).

Table 2.4. Review of literature on association of component characters with grain yield

S. No.	Characters	Association	S/NS	P/G	References
1	Days to 50% flowering	Positive	S	P,G P,G P P,G P,G P,G ---- P,G P P,G P,G G P,G G P,G P	Islam <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Nagaraju <i>et al.</i> (2013) Tushara <i>et al.</i> (2013) Krishna veni <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012) Ruth Elizabeth Ekka <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011)
		Negative	S	P,G P G G P,G ---- G P,G P,G	Bornare <i>et al.</i> (2014) Imad <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013) Gangashetty (2013) Ukaoma <i>et al.</i> (2013) Ravindra Babu <i>et al.</i> (2012) Hasan <i>et al.</i> (2011) Dey <i>et al.</i> (2010)
2	Days to maturity	Positive	S	G P,G P,G P,G P,G P,G P,G ---- P,G P,G P P,G P P,G	Golam Sarwar <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Kundu Sritama <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Mohammad and Kayvan Agahi (2014) Rashid <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Venkata Lakshmi <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Bhabendra <i>et al.</i> (2012) Seyed Mustafa Sadeghi (2011) Khatun <i>et al.</i> (2010)
		Negative	S	P,G P P,G P,G	Alam <i>et al.</i> (2014) Imad <i>et al.</i> (2014) Gulzar <i>et al.</i> (2013) Akhtar <i>et al.</i> (2011)
3	Plant height (cm)	Positive	S	P P,G P,G	Anis <i>et al.</i> (2016) Islam <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015)

Table 2.4 (Cont.)

				P P,G ---- P,G ---- P,G P,G P,G P,G ---- P,G G P,G P P,G P P G P,G P,G P,G P,G P,G P P,G	Singh <i>et al.</i> (2015) Kundu Sritama <i>et al.</i> (2015) Marzieh Moosavi <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Dilruba <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Norain <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014) Singh <i>et al.</i> (2015) Venkata Lakshmi <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Ali <i>et al.</i> (2013) Atif and Khalid (2013) Idris and Mohamed (2013) Awaneet Kumar and Senapathi (2013) Bekele <i>et al.</i> (2013) Sudharani <i>et al.</i> (2013) Shet <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Ruth Elizabeth Ekka <i>et al.</i> (2011) Sayed Mustafa Sadeghi (2011) Khatun <i>et al.</i> (2010)
			NS	P,G P P P P,G P,G P G P P,G P,G P,G P,G P,G P,G	Golam Sarwar <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Pradhan <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Bornare <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013) Awaneet Kumar and Senapathi (2013) Gulzar <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Rangare <i>et al.</i> (2012) Hasan <i>et al.</i> (2011) Ullah <i>et al.</i> (2011)
4	Total number of tillers per plant	Positive	S	P,G P,G P,G ---- P,G P,G P,G --- P,G P P,G	Golam Sarwar <i>et al.</i> (2015) Kundu sritama <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Mohammad and Kayvan Agahi (2014) Patel <i>et al.</i> (2014) Norain <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Idris and Mohamed (2013) Gulzar <i>et al.</i> (2013)

Table 2.4 (Cont.)

				P	Akinwale <i>et al.</i> (2011)
5	Number of ear bearing tillers per plant	Positive	S	P,G P,G ---- ---- P,G P P P,G P,G P P,G P,G P,G P,G P,G P,G P,G ---- P,G ---- P G P,G G P P,G ---- P, G ---- P G P,G G P P,G P,G ---- P	Golam Sarwar <i>et al.</i> (2015) Keya <i>et al.</i> (2015) Kundu Sritama <i>et al.</i> (2015) Marzieh Moosavi <i>et al.</i> (2015) Sandhyarani Das (2015) Sathisha <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Dilruba <i>et al.</i> (2014) Imad <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Norain <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014) Thirumula Rao <i>et al.</i> (2014) Venkata Lakshmi <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013) Atif and Khalid (2013) Awaneet Kumar and Senapathi (2013) Dahui Huang <i>et al.</i> (2013) Idris and Mohamed (2013) Nagaraju <i>et al.</i> (2013) Ukaoma <i>et al.</i> (2013) Krishna veni <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012) Ravindra Babu <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Hasan <i>et al.</i> (2011) Hashem and Peyman (2011) Seyed Mustafa Sadeghi (2011)
6	Panicle length per plant (cm)	Positive	S	G ---- P,G P ---- P,G P,G P,G ---- G P P P,G P	Kundu Sritama <i>et al.</i> (2015) Marzieh Moosavi <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Patel <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Nitiprasad and Lotan Kumar (2014) Norain <i>et al.</i> (2014) Thirumula Rao <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Arulmozhi and Muthuswamy (2013) Ashim and Ghosh (2013) Gangashetty <i>et al.</i> (2013)

Table 2.4 (Cont.)

				P,G G P P,G P,G G P,G P,G ---- P,G P P,G P P,G	Gulzar <i>et al.</i> (2013) Krishna veni <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Sudharani <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012) Rangare <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Hashem and Peyman (2011) Ruth Elizabeth Ekka <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011) Ullah <i>et al.</i> (2011) Rani and Reddy (2010) Yadav <i>et al.</i> (2010)
7	Number of Grains per panicle	Positive	S	P,G P,G P,G P,G P,G ---- P,G P,G P,G P,G P,G P,G ---- P,G ---- P,G P,G G P G G P,G ---- P ---- P,G P,G P,G G P P,G P P,G P,G P,G	Islam <i>et al.</i> (2015) Kundu Sritama <i>et al.</i> (2015) Sandhyarani Das (2015) Sarafraz <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Alam <i>et al.</i> (2014) Dhurai <i>et al.</i> (2014) Imad <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Mohammad and kayvan Agahi (2014) Nitiprasad and Lotan Kumar (2014) Norain <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Thirumula Rao <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Arulmozhi and Muthuswamy (2013) Awaneet Kumar and Senapathi (2013) Gulzar <i>et al.</i> (2013) Dahui Huang <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Ukaoma <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Mulugeta Seyoum <i>et al.</i> (2012) Zulqarnian <i>et al.</i> (2012) Akhtar <i>et al.</i> (2011) Akinwale <i>et al.</i> (2011) Ruth Elizabeth Ekka <i>et al.</i> (2011) Seyed Mustafa Sadeghi (2011) Ullah <i>et al.</i> (2011) Praveen <i>et al.</i> (2010) Yadav <i>et al.</i> (2010)
			NS	P	Anis <i>et al.</i> (2016)

Table 2.4 (Cont.)

				P,G P,G P P P,G P,G P,G P,G G P,G P P P G G P ----	Golam Sarwar <i>et al.</i> (2015) Keya <i>et al.</i> (2015) Pradhan <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Shajedur Hossain <i>et al.</i> (2015) Vijay Kumar <i>et al.</i> (2015) Bornare <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Venkata Lakshmi <i>et al.</i> (2014) Atif and Khalid (2013) Idris and Mohamed (2013) Awaneet Kumar and Senapathi (2013) Nagaraju <i>et al.</i> (2013) Bhadru <i>et al.</i> (2012) Akhtar <i>et al.</i> (2011) Hashem and Peyman (2011)
8	Test weight (gm)	Positive	S	P,G P,G P,G P P,G P,G P P,G ---- P,G ---- P,G G P,G ---- P,G ---- P,G P,G ---- P,G P,G P,G P,G G P,G ---- P,G	Kundu Sritama <i>et al.</i> (2015) Sarafraz <i>et al.</i> (2015) Sathisha <i>et al.</i> (2015) Singh <i>et al.</i> (2015) Dilruba <i>et al.</i> (2014) Imad <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Mohammad and Kayvan Agahi (2014) Norain <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014) Thirumula Rao <i>et al.</i> (2014) Ali <i>et al.</i> (2013) Dahui Huang <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Gopikannan and Ganesh (2013) Nagaraju <i>et al.</i> (2013) Sudharani <i>et al.</i> (2013) Ukaoma <i>et al.</i> (2013) Bhabendra <i>et al.</i> (2012) Seyoum <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Zulqarnian <i>et al.</i> (2012) Akhtar <i>et al.</i> (2011) Hasan <i>et al.</i> (2011) Hashem and Peyman (2011) Ruth Elizabeth Ekka <i>et al.</i> (2011)
9	Leaf area index at maximum tillering stage	Positive	S	P,G ---- ---- P,G	Keya <i>et al.</i> (2015) Ganghua <i>et al.</i> (2014) Hashem and Peyman (2011) Ullah <i>et al.</i> (2011)
		Negative	NS	P,G	Bhabendra <i>et al.</i> (2012)

Table 2.4 (Cont.)

10	Hulling per cent (%)	Positive	S	---- P,G	Tushara <i>et al.</i> (2013) Prem Kumar <i>et al.</i> (2010)
		Negative	NS	P	Nagajyothi (2001)
11	Milling per cent (%)	Positive	S	P P,G P,G	Nagaraju <i>et al.</i> (2013) Ruth Elizabeth Ekka <i>et al.</i> (2011) Prem Kumar <i>et al.</i> (2010)
		Negative	NS	G P,G	Manonmani <i>et al.</i> (2010) Nagajyothi (2001)
12	Head Rice Recovery per cent (%)	Positive	S	G P,G	Krishna veni <i>et al.</i> (2013) Prem Kumar <i>et al.</i> (2010)
			NS	P,G P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011) Praveen <i>et al.</i> (2010)
13	Kernel length (mm)	Positive	S	P,G P,G ---- P P,G P	Sathisha <i>et al.</i> (2015) Nitiprasad and Lotan Kumar (2014) Norain <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Venkata Lakshmi <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013)
			NS	P,G G P,G P,G P,G P,G	Dhurai <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Awaneet Kumar and Senapathi (2013) Ruth Elizabeth Ekka <i>et al.</i> (2011) Praveen <i>et al.</i> (2010) Prem Kumar <i>et al.</i> (2010)
		Negative	NS	P,G P,G P,G P	Islam <i>et al.</i> (2015) Singh <i>et al.</i> (2014) Gulzar <i>et al.</i> (2013) Seyed Mustafa Sadeghi (2011)
14	Kernel Breadth (mm)	Positive	NS	P,G P,G ---- P,G P,G G P,G P,G P,G	Islam <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014) Norain <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Krishna veni <i>et al.</i> (2013) Ruth Elizabeth Ekka <i>et al.</i> (2011) Praveen <i>et al.</i> (2010) Siva Parvathi (2011)
		Negative	NS	P,G P P,G	Nitiprasad and Lotan Kumar (2014) Aditya and Anuradha Bhartiya (2013) Awaneet Kumar and Senapathi (2013)
15	Kernel length (L)/Breadth (B) Ratio	Positive	NS	P,G P,G P,G G P,G G G P,G P,G G	Sathisha <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Venkata Lakshmi <i>et al.</i> (2014) Awaneet Kumar and Senapathi (2013) Nagaraju <i>et al.</i> (2013) Malini <i>et al.</i> (2011) Parvathi <i>et al.</i> (2011) Khatun <i>et al.</i> (2010) Manonmani <i>et al.</i> (2010)

Table 2.4 (Cont.)

		Negative	NS	G P,G	Krishna veni <i>et al.</i> (2013) Pankaj Garg <i>et al.</i> (2010)
16	Kernel length after cooking (mm)	Positive	NS	P,G P,G	Dhurai <i>et al.</i> (2014) Prem Kumar <i>et al.</i> (2010)
17	Kernel breadth after cooking (mm)	Positive	S	P,G	Prem Kumar <i>et al.</i> (2010)
			NS	G	Arulmozhi and Muthuswamy (2013)
18	Kernel elongation ratio	Positive	NS	P,G P,G	Dhurai <i>et al.</i> (2014) Chaudhary and Motiramani (2003)
		Negative	NS	G G G	Krishna veni <i>et al.</i> (2013) Malini <i>et al.</i> (2011) Manonmani <i>et al.</i> (2010)
19	Volume expansion ratio	Positive	S	G G P,G	Arulmozhi and Muthuswamy (2013) Krishna veni <i>et al.</i> (2013) Praveen <i>et al.</i> (2010)
			NS	G P,G	Manonmani <i>et al.</i> (2010) Satyavathi <i>et al.</i> (2001)
		Negative	NS	G	Malini <i>et al.</i> (2011)
20	Water uptake (ml)	Positive	NS	G G	Krishna veni <i>et al.</i> (2013) Malini <i>et al.</i> (2011)
21	Gel Consistency (mm)	Positive	NS	G P,G	Malini <i>et al.</i> (2011) Nagajyothi (2001)
22	Alkali spreading value (mm)	Positive	S	----	Tushara <i>et al.</i> (2013)
		Negative	NS	G	Manonmani <i>et al.</i> (2010)
23	Amylose content	Positive	S	G P	Arulmozhi and Muthuswamy (2013) Nagajyothi (2001)
			NS	G G P	Malini <i>et al.</i> (2011) Manonmani <i>et al.</i> (2010) Pankaj Garg <i>et al.</i> (2010)
		Negative	NS	P,G G G P,G	Patel <i>et al.</i> (2014) Krishna veni <i>et al.</i> (2013) Pankaj Garg <i>et al.</i> (2010) Siva Parvathi (2011)

Table 2.5: Review of literature on association among different components in rice (*Oryza sativa* L.)

S.No	Characters	Association	S/NS	P/G	References
I	Days to 50% flowering				
1	Days to maturity	Positive	S	P,G	Islam <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Singh <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Bhabendra <i>et al.</i> (2012), Mulugeta Seyoum <i>et al.</i> (2012), Hasan <i>et al.</i> (2011)
				P	Ferdinard <i>et al.</i> (2015), Patel <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Nagaraju <i>et al.</i> (2013), Akinwale <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010)
2	Plant height	Positive	S	P,G	Islam <i>et al.</i> (2015), Keya <i>et al.</i> (2015), Sandhyarani Das (2015), Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012), Ravindra Babu <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011)
				P	Ferdinard <i>et al.</i> (2015), Krishna Veni <i>et al.</i> (2013), Aditya and Anuradha Bhartiya (2013), Ukaoma <i>et al.</i> (2013)
			NS	P,G	Golam Sarwar <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Singh <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Satish Kumar Rai <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Bhabendra <i>et al.</i> (2012), Yadav <i>et al.</i> (2010)
				P	Atif and Khalid (2013)
				P,G	Tirumala Rao <i>et al.</i> (2014), Arulmozhi and Muthuswamy (2013), Bhadraru <i>et al.</i> (2012)
3	Total number of tillers per plant	Positive	S	P,G ----	Sathisha <i>et al.</i> (2015), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014) Rashid <i>et al.</i> (2014)
			NS	P,G	Golam Sarwar <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Gulzar <i>et al.</i> (2013), Bhabendra <i>et al.</i> (2012), Mulugeta Seyoum <i>et al.</i> (2012)
				P	Ferdinard <i>et al.</i> (2015), Atif and Khalid (2013), Ukaoma <i>et al.</i> (2013)
		Negative	S	G	Satish Kumar Rai <i>et al.</i> (2014), Arulmozhi and Muthuswamy (2013)
4	Number of ear bearing tillers per	Positive	S	P,G	Golam Sarwar <i>et al.</i> (2015), Keya <i>et al.</i> (2015), Venkata Lakshmi <i>et al.</i> (2014), Rashid <i>et al.</i> (2014)
				P	Lingaiah <i>et al.</i> (2014)
				G	Tirumala Rao <i>et al.</i> (2014), Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

	plant	Negative	S	P,G G	Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Sravan <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011), Hasan <i>et al.</i> (2011) Satish Kumar Rai <i>et al.</i> (2014), Ravindra Babu <i>et al.</i> (2012), Yadav <i>et al.</i> (2010)
5	Panicle length per plant	Positive	S	P,G P	Keya <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Ravindra Babu <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011) Sandhyarani Das (2015), Aditya and Anuradha Bhartiya (2013) Bhabendra <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	P,G P G	Sathisha <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Nagaraju <i>et al.</i> (2013) Singh <i>et al.</i> (2015), Seyed Mustafa Sadeghi (2011) Sandhyarani Das (2015), Bhadru <i>et al.</i> (2012)
		Negative	S	P,G P G	Rashid <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Sravan <i>et al.</i> (2012) Atif and Khalid (2013), Awaneet Kumar and Senapathi (2013), Nandan <i>et al.</i> (2010) Arulmozhi and Muthuswamy (2013)
6	Number of grains per panicle	Positive	S	P,G P G	Islam <i>et al.</i> (2015), Sandhyarani Das (2015), Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Bhabendra <i>et al.</i> (2012), Bhadru <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011), Nandan <i>et al.</i> (2010) Singh <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Ravindra Babu <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011) Aditya and Anuradha Bhartiya (2013), Nagaraju <i>et al.</i> (2013)
			NS	P,G P G	Keya <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Yadav <i>et al.</i> (2010) Awaneet Kumar and Senapathi (2013) Nitiprasad and Lotan Kumar (2014), Tirumala Rao <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013)
7	Test weight	Positive	NS	P,G P	Shajedur Hossain <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Rashid <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Mulugeta Seyoum <i>et al.</i> (2012), Ravindra Babu <i>et al.</i> (2012), Sravan <i>et al.</i> (2012) Singh <i>et al.</i> (2015), Lingaiah <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Atif and Khalid (2013), Akinwale <i>et al.</i> (2011)

Table 2.5(Cont.)

		Negative	S	P,G P G	Singh <i>et al.</i> (2014), Yadav <i>et al.</i> (2010) Islam <i>et al.</i> (2015), Nagaraju <i>et al.</i> (2013), Ukaoma <i>et al.</i> (2013), Seyed Mustafa Sadeghi (2011) Bhadru <i>et al.</i> (2012)
8	Leaf area index at maximum tillering stage	Positive	S	P,G P	Keya <i>et al.</i> (2015) Ullah <i>et al.</i> (2011)
			NS	---- G	Ganghua <i>et al.</i> (2014) Ullah <i>et al.</i> (2011)
9	Hulling per cent	Positive	NS	P	Nandan <i>et al.</i> (2010)
10	Milling per cent	Positive	S	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	P,G	Nagaraju <i>et al.</i> (2013)
11	Head rice recovery	Positive	S	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	G	Krishna Veni <i>et al.</i> (2013)
12	Kernel length	Negative	S	P,G G	Islam <i>et al.</i> (2015), Singh <i>et al.</i> (2014) Krishna Veni <i>et al.</i> (2013)
			NS	P,G	Dhurai <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Awaneet Kumar and Senapathi (2013)
13	Kernel breadth	Negative	S	P,G P	Nitiprasad and Lotan Kumar (2014) Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010)
14	Kernel length/breadth ratio	Positive	S	P,G	Gulzar <i>et al.</i> (2013)
			NS	P,G	Dhurai <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014)
		Negative	NS	P,G P G	Nagaraju <i>et al.</i> (2013) Aditya and Anuradha Bhartiya (2013), Nandan <i>et al.</i> (2010) Arulmozhi and Muthuswamy (2013)
15	Kernel length after cooking	Positive	S	P,G	Afzal <i>et al.</i> (2006)
		Negative	NS	G P	Krishna Veni <i>et al.</i> (2013) Nandan <i>et al.</i> (2010)

Table 2.5(Cont.)

16	Kernel breadth after cooking	Negative	S	P	Nandan <i>et al.</i> (2010)
17	Kernel elongation ratio	Positive	NS	P,G G	Dhurai <i>et al.</i> (2014) Krishna Veni <i>et al.</i> (2013)
18	Volume expansion ratio	Positive	NS	G	Krishna Veni <i>et al.</i> (2013)
		Negative	S	G	Arulmozhi and Muthuswamy (2013)
19	Water uptake	Positive	NS	G	Krishna Veni <i>et al.</i> (2013)
		Negative	S	P	Nandan <i>et al.</i> (2010)
20	Amylose content	Positive	S	P,G	Patel <i>et al.</i> (2014)
			NS	G	Krishna Veni <i>et al.</i> (2013)
II	Days to maturity				
1	Plant height	Positive	S	P,G	Islam <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Patel <i>et al.</i> (2014) Satish Kumar Rai <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012)
				P	Ferdinard <i>et al.</i> (2015), Singh <i>et al.</i> (2015), Imad <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Seyed Mustafa Sadeghi (2011)
				G	Akhtar <i>et al.</i> (2011)
			NS	P,G	Sathisha <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Awaneet Kumar and Senapathi (2013), Bhabendra <i>et al.</i> (2012), Khatun <i>et al.</i> (2010)
				G	Imad <i>et al.</i> (2014)
				P	Singh <i>et al.</i> (2015), Nandan <i>et al.</i> (2010)
2	Total number of tillers per plant	Positive	S	P,G	Sathisha <i>et al.</i> (2015), Patel <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Singh <i>et al.</i> (2014)
				G	Akhtar <i>et al.</i> (2011)
			NS	P,G	Golam Sarwar <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Gulzar <i>et al.</i> (2013), Bhabendra <i>et al.</i> (2012), Kayan Agahi <i>et al.</i> (2007)
				P	Ferdinard <i>et al.</i> (2015), Atif and Khalid (2013), Mulugeta Seyoum <i>et al.</i> (2012)

Table 2.5(Cont.)

		Negative	S	P,G	Satish Kumar Rai <i>et al.</i> (2014)
3	Number of ear bearing tillers per plant	Positive	S	P,G	Mohammad and Kalyan Agahi (2014), Rashid <i>et al.</i> (2014), Bhabendra <i>et al.</i> (2012)
				G	Dilruba <i>et al.</i> (2014), Khatun <i>et al.</i> (2010)
		Negative	S	P,G	Bornare <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014)
			NS	P,G	Alam <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Imad <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012), Hasan <i>et al.</i> (2011), Zia-Ul-Qamar <i>et al.</i> (2005)
				P	Aditya and Anuradha Bhartiya (2013), Akinwale <i>et al.</i> (2011),
				G	Awaneet Kumar and Senapathi (2013),
4	Panicle length per plant	Positive	S	P,G	Bornare <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013)
				G	Dilruba <i>et al.</i> (2014), Imad <i>et al.</i> (2014),
				P	Singh <i>et al.</i> (2015), Aditya and Anuradha Bhartiya (2013), Akinwale <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011)
		Negative	S	P,G	Mohammad and Kalyan Agahi (2014), Rashid <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014)
				P	Atif and Khalid (2013), Awaneet Kumar and Senapathi (2013), Nandan <i>et al.</i> (2010)
5	Number of grains per panicle	Positive	S	P,G	Islam <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Bhabendra <i>et al.</i> (2012)
				P	Singh <i>et al.</i> (2015), Aditya and Anuradha Bhartiya (2013), Atif and Khalid (2013), Nagaraju <i>et al.</i> (2013), Akinwale <i>et al.</i> (2011), Kayan Agahi <i>et al.</i> (2007)
				G	Imad <i>et al.</i> (2014), Mohammad and Kalyan Agahi (2014),
		Negative	NS	P,G	Golam Sarwar <i>et al.</i> (2015), Keya <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013)
				P G	Singh <i>et al.</i> (2015), Imad <i>et al.</i> (2014), Mohammad and Kalyan Agahi (2014), Nandan <i>et al.</i> (2010) Nagaraju <i>et al.</i> (2013), Kayan Agahi <i>et al.</i> (2007)
6	Test weight	Positive	NS	P,G	Golam Sarwar <i>et al.</i> (2015), Rashid <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Bhabendra <i>et al.</i> (2012), Khatun <i>et al.</i> (2010)
				P G	Singh <i>et al.</i> (2015), Aditya and Anuradha Bhartiya (2013), Akinwale <i>et al.</i> (2011) Dilruba <i>et al.</i> (2014)
		Negative	S	P,G	Islam <i>et al.</i> (2015), Singh <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Zia-Ul-Qamar <i>et al.</i> (2005)

Table 2.5(Cont.)

				P	Atif and Khalid (2013), Nagaraju <i>et al.</i> (2013), Nandan <i>et al.</i> (2010)
7	Leaf area index at maximum tillering stage	Positive	S	P,G	Keya <i>et al.</i> (2015)
			NS	----	Ganghua <i>et al.</i> (2014)
8	Milling per cent	Positive	S	P	Nagaraju <i>et al.</i> (2013)
			NS	G	Nagaraju <i>et al.</i> (2013)
		Negative	NS	P	Nandan <i>et al.</i> (2010)
9	Kernel length	Negative	S	P,G P	Islam <i>et al.</i> (2015), Nandan <i>et al.</i> (2010), Kayan Agahi <i>et al.</i> (2007) Gulzar <i>et al.</i> (2013)
			NS	P,G P	Dhurai <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013) Sayed Mustafa Sadeghi (2011)
10	Kernel breadth	Negative	S	P,G G	Mohammad and Kalyan Agahi (2014), Gulzar <i>et al.</i> (2013) Nandan <i>et al.</i> (2010)
			NS	P,G P	Dhurai <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013), Seyed Mustafa Sadeghi (2011)
11	Kernel length/breadth ratio	Positive	S	P,G	Khatun <i>et al.</i> (2010)
			NS	P,G P	Dhurai <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Nagaraju <i>et al.</i> (2013) Aditya and Anuradha Bhartiya (2013)
12	Kernel length after cooking	Negative	NS	P,G P	Dhurai <i>et al.</i> (2014) Nandan <i>et al.</i> (2010)
13	Kernel breadth after cooking	Negative	S	P	Nandan <i>et al.</i> (2010)
14	Kernel elongation ratio	Positive	S	P	Nandan <i>et al.</i> (2010)
			NS	P,G	Dhurai <i>et al.</i> (2014)
15	Water uptake	Negative	S	P	Nandan <i>et al.</i> (2010)

Table 2.5(Cont.)

16	Amylose content	Positive	S	P,G	Patel <i>et al.</i> (2014)
III	Plant Height				
1	Total number of tillers per plant	Positive	S	P,G P G	Norain <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Singh <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014), Arulmozhi and Muthuswamy (2013)
			NS	P,G P G	Vijay Kumar <i>et al.</i> (2015) Ali <i>et al.</i> (2013) Mamunur <i>et al.</i> (2014)
2	Number of ear bearing tillers per plant	Positive	S	P,G P G	Anis <i>et al.</i> (2016), Norain <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Khatun <i>et al.</i> (2010) Nibedita Mohanty <i>et al.</i> (2015), Singh <i>et al.</i> (2015) Rahman <i>et al.</i> (2014), Sravan <i>et al.</i> (2012), Hasan <i>et al.</i> (2011)
			NS	P,G P G	Keya <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Mamunur <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Rashid <i>et al.</i> (2014), Ali <i>et al.</i> (2013), Awaneet Kumar and Senapathi (2013), Ghaffar and Ghorbanali (2012), Mulugeta Seyoum <i>et al.</i> (2012), Yadav <i>et al.</i> (2010) Singh <i>et al.</i> (2015), Sravan <i>et al.</i> (2012), Hasan <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011) Nibedita Mohanty <i>et al.</i> (2015), Dilruba <i>et al.</i> (2014)
3	Panicle length per plant	Positive	S	P,G P G	Golam Sarwar <i>et al.</i> (2015), Marzieh Moosavi <i>et al.</i> (2015), Sandhyarani Das (2015), Sathisha <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Imad <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Mohammad and Kalyan Agahi (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Ali <i>et al.</i> (2013), Bhadru <i>et al.</i> (2012), Ravindra Babu <i>et al.</i> (2012), Sravan <i>et al.</i> (2012), Hasan <i>et al.</i> (2011), Ruth Elizabeth Ekka <i>et al.</i> (2011), Jayasudha and Deepak (2010), Yadav <i>et al.</i> (2010), Kayan Agahi <i>et al.</i> (2007), Rahim <i>et al.</i> (2007), Nayak <i>et al.</i> (2001) Nibedita Mohanty <i>et al.</i> (2015), Pradhan <i>et al.</i> (2015), Lingaiah <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Seyed Mustafa Sadeghi (2011) Nitiprasad and Lotan Kumar (2014), Tirumala Rao <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Krishna Veni <i>et al.</i> (2013)
4	Number of grains per	Positive	S	P,G	Islam <i>et al.</i> (2015), Sandhyarani Das (2015), Sathisha <i>et al.</i> (2015), Norain <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Ghaffar and Ghorbanali (2012),

Table 2.5(Cont.)

	panicle			P	Ravindra Babu <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011), Rahim <i>et al.</i> (2007), Nayak <i>et al.</i> (2001) Pradhan <i>et al.</i> (2015), Mamunur <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Awaneet Kumar and Senapathi (2013), Ukaoma <i>et al.</i> (2013), Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010)
				G	Golam Sarwar <i>et al.</i> (2015), Imad <i>et al.</i> (2014), Rahman <i>et al.</i> (2014)
			NS	P,G	Vijay Kumar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Bornare <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Dahuri Huang <i>et al.</i> (2013), Ullah <i>et al.</i> (2011), Yadav <i>et al.</i> (2010), Kayan Agahi <i>et al.</i> (2007), Afzal <i>et al.</i> (2006)
				P	Anis <i>et al.</i> (2016), Golam Sarwar <i>et al.</i> (2015), Imad <i>et al.</i> (2014), Rafii <i>et al.</i> (2014), Atif and Khalid (2013)
				G	Mamunur <i>et al.</i> (2014), Tirumala Rao <i>et al.</i> (2014), Arulmozhi and Muthuswamy (2013), Awaneet Kumar and Senapathi (2013)
5	Test weight	Positive	S	P,G	Bornare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Norain <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Sravan <i>et al.</i> (2012), Akhtar <i>et al.</i> (2011), Ullah <i>et al.</i> (2011), Khatun <i>et al.</i> (2010)
				P	Nibedita Mohanty <i>et al.</i> (2015), Ali <i>et al.</i> (2013), Nagaraju <i>et al.</i> (2013), Afzal <i>et al.</i> (2006)
				G	Hasan <i>et al.</i> (2011)
		Negative	NS	P,G	Keya <i>et al.</i> (2015), Marzieh Moosavi <i>et al.</i> (2015), Sarafranz <i>et al.</i> (2015), Khare <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Ghaffar and Ghorbanali (2012), Mulugeta Seyoum <i>et al.</i> (2012), Yadav <i>et al.</i> (2010), Kayan Agahi <i>et al.</i> (2007), Rahim <i>et al.</i> (2007), Zia-Ul-Qamar <i>et al.</i> (2005), Nayak <i>et al.</i> (2001)
				P	Pradhan <i>et al.</i> (2015), Ukaoma <i>et al.</i> (2013), Akinwale <i>et al.</i> (2011)
				G	Imad <i>et al.</i> (2014), Krishna Veni <i>et al.</i> (2013), Ravindra Babu <i>et al.</i> (2012)
6	Leaf area index at maximum tillering stage	Positive	S	P,G	Keya <i>et al.</i> (2015), Ganghua <i>et al.</i> (2014)
			NS	P,G	Bhabendra <i>et al.</i> (2012)
7	Hulling %	Negative	S	P	Nandan <i>et al.</i> (2010)
8	Milling per cent	Negative	S	P	Nagaraju <i>et al.</i> (2013)
			NS	G	Nagaraju <i>et al.</i> (2013)

Table 2.5(Cont.)

				P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
9	Head rice recovery	Positive	NS	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
10	Kernel length	Positive	NS	P,G P	Islam <i>et al.</i> (2015), Nibedita Mohanty <i>et al.</i> (2015), Venkata Lakshmi <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013)
11	Kernel breadth	Positive	NS	P,G P G	Islam <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Norain <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Ghaffar and Ghorbanali (2012) Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010) Nibedita Mohanty <i>et al.</i> (2015)
		Negative	NS	P,G P	Nitiprasad and Lotan Kumar (2014), Patel <i>et al.</i> (2014), Singh <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013)
12	Kernel length/breadth ratio	Positive	S	P,G	Patel <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Kayan Agahi <i>et al.</i> (2007)
			NS	P,G	Venkata Lakshmi <i>et al.</i> (2014), Ruth Elizabeth Ekka <i>et al.</i> (2011), Khatun <i>et al.</i> (2010)
		Negative	NS	P,G P G	Dhurai <i>et al.</i> (2014) Aditya and Anuradha Bhartiya (2013) Nibedita Mohanty <i>et al.</i> (2015), Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013), Nagaraju <i>et al.</i> (2013)
13	Kernel length after cooking	Negative	S	G	Krishna Veni <i>et al.</i> (2013)
				P	Nandan <i>et al.</i> (2010)
			NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014)
14	Kernel breadth after cooking	Positive	NS	P	Nibedita Mohanty <i>et al.</i> (2015)
				G	Nandan <i>et al.</i> (2010)
15	Kernel elongation ratio	Positive	S	P	Nandan <i>et al.</i> (2010)
		Negative	NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014)
				G	Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)
16	Volume expansion ratio	Positive	NS	G	Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

17	Water uptake	Positive	NS	G	Krishna Veni <i>et al.</i> (2013)
				P	Nandan <i>et al.</i> (2010)
18	Gel consistency	Positive	S	P	Rafii <i>et al.</i> (2014)
19	Amylose content	Positive	NS	P	Rafii <i>et al.</i> (2014)
		Negative	NS	P,G	Patel <i>et al.</i> (2014)
				G	Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)
IV	Total number of tillers per plant				
1	Number of ear bearing tillers per plant	Positive	S	P,G	Golam Sarwar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Ali <i>et al.</i> (2013) Mulugeta Seyoum <i>et al.</i> (2012), Jayasudha and Deepak (2010), Yadav <i>et al.</i> (2010), Kayan Agahi <i>et al.</i> (2007), Rahim <i>et al.</i> (2007)
				P	Aditya and Anuradha Bhartiya (2013), Ukaoma <i>et al.</i> (2013)
			NS	P	Akinwale <i>et al.</i> (2011)
2	Panicle length per plant	Positive	S	P,G	Kayan Agahi <i>et al.</i> (2007)
				G	Arulmozhi and Muthuswamy (2013), Rahim <i>et al.</i> (2007)
				----	Norain <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Singh <i>et al.</i> (2014)
			NS	P,G	Vijay Kumar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Ali <i>et al.</i> (2013), Jayasudha and Deepak (2010)
				P	Akinwale <i>et al.</i> (2011), Rahim <i>et al.</i> (2007)
3	Number of grains per panicle	Positive	S	----	Norain <i>et al.</i> (2014)
				P,G	Singh <i>et al.</i> (2014), Kayan Agahi <i>et al.</i> (2007)
				G	Arulmozhi and Muthuswamy (2013)
4	Test weight	Positive	S	G	Gulzar <i>et al.</i> (2013), Akhtar <i>et al.</i> (2011)
				P	Ukaoma <i>et al.</i> (2013)
				P,G	Afzal <i>et al.</i> (2006)
			NS	----	Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014), Rashid <i>et al.</i> (2014)
				P,G	Satish Kumar Rai <i>et al.</i> (2014), Rahim <i>et al.</i> (2007)
				P	Aditya and Anuradha Bhartiya (2013), Gulzar <i>et al.</i> (2013)

Table 2.5(Cont.)

		Negative	S	P,G	Golam Sarwar <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Singh <i>et al.</i> (2014), Ali <i>et al.</i> (2013), Afzal <i>et al.</i> (2006)
				P	Mamunur <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012), Kayan Agahi <i>et al.</i> (2007)
				G	Yadav <i>et al.</i> (2010)
			NS	P,G	Golam Sarwar <i>et al.</i> (2015), Sarafraz <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014)
				G	Dilruba <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012), Kayan Agahi <i>et al.</i> (2007)
				P	Atif and Khalid (2013, Yadav <i>et al.</i> (2010)
5	Leaf area index at maximum tillering stage	Positive	S	----	Ganghua <i>et al.</i> (2014)
			NS	P,G	Bhabendra <i>et al.</i> (2012)
6	Kernel length	Positive	NS	----	Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014)
				P	Aditya and Anuradha Bhartiya (2013)
				P,G	Kayan Agahi <i>et al.</i> (2007)
7	Kernel breadth	Positive	S	P,G	Kayan Agahi <i>et al.</i> (2007)
			NS	P,G	Nitiprasad and Lotan Kumar (2014)
		Negative	S	P,G	Singh <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013)
			NS	----	Norain <i>et al.</i> (2014)
				P	Aditya and Anuradha Bhartiya (2013)
8	Kernel length/breadth ratio	Positive	NS	P,G	Sathisha <i>et al.</i> (2015), Gulzar <i>et al.</i> (2013)
				G	Aditya and Anuradha Bhartiya (2013)
				P	Arulmozhi and Muthuswamy (2013)
9	Kernel length after cooking	Positive	S	P	Kayan Agahi <i>et al.</i> (2007)
			NS	G	Kayan Agahi <i>et al.</i> (2007)
		Negative	NS	P,G	Afzal <i>et al.</i> (2006)
10	Kernel breadth after	Negative	S	G	Arulmozhi and Muthuswamy (2013)

Table 2.5(Cont.)

	cooking				
11	Kernel elongation ratio	Positive	NS	G	Arulmozhi and Muthuswamy (2013)
12	Amylose content	Negative	NS	G	Arulmozhi and Muthuswamy (2013)
V	Number of ear bearing tillers per plant				
1	Panicle length per plant	Positive	S	P,G P G	Keya <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Norain <i>et al.</i> (2014), Hashem and Peyman (2011) Singh <i>et al.</i> (2015), Aditya and Anuradha Bhartiya (2013), Nagaraju <i>et al.</i> (2013), Kayan Agahi <i>et al.</i> (2007) Krishna Veni <i>et al.</i> (2013), Sravan <i>et al.</i> (2012), Rahim <i>et al.</i> (2007)
			NS	P,G P G	Nibedita Mohanty <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014), Rashid <i>et al.</i> (2014), Ghaffar and Ghorbanali (2012), Mamunur <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Ali <i>et al.</i> (2013), Jayasudha and Deepak (2010), Nayak <i>et al.</i> (2001) Sravan <i>et al.</i> (2012), Rahim <i>et al.</i> (2007) Nagaraju <i>et al.</i> (2013), Hasan <i>et al.</i> (2011), Kayan Agahi <i>et al.</i> (2007)
2	Number of grains per panicle	Positive	S	P,G P G ----	Keya <i>et al.</i> (2015), Alam <i>et al.</i> (2014) Bornare <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013), Seyed Mustafa Sadeghi (2011) Rahim <i>et al.</i> (2007) Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014)
				NS	Nitiprasad and Lotan Kumar (2014), Satish Kumar Rai <i>et al.</i> (2014), Mulugeta Seyoum <i>et al.</i> (2012)
			NS	P	Anis <i>et al.</i> (2016), Singh <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Rafii <i>et al.</i> (2014), Ukaoma <i>et al.</i> (2013), Ravindra Babu <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011), Rahim <i>et al.</i> (2007)
				G	Nagaraju <i>et al.</i> (2013), Praveen <i>et al.</i> (2010)
3	Test weight	Positive	S	P,G P	Hasan <i>et al.</i> (2011), Khatun <i>et al.</i> (2010) Nibedita Mohanty <i>et al.</i> (2015), Ukaoma <i>et al.</i> (2013)

Table 2.5(Cont.)

			G		Bhadru <i>et al.</i> (2012), Sravan <i>et al.</i> (2012)
			NS	P,G	Keya <i>et al.</i> (2015), Nibedita Mohanty <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Satish Kumar Rai <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013), Ghaffar and Ghorbanali (2012), Hashem and Peyman (2011), Rahim <i>et al.</i> (2007), Zia-Ul-Qamar <i>et al.</i> (2005)
				P	Anis <i>et al.</i> (2016), Singh <i>et al.</i> (2015), Aditya and Anuradha Bhartiya (2013), Ravindra Babu <i>et al.</i> (2012), Sravan <i>et al.</i> (2012), Akinwale <i>et al.</i> (2011)
				G	Lingaiah <i>et al.</i> (2014)
4	Leaf area index at maximum tillering stage	Positive	S	P,G	Bhabendra <i>et al.</i> (2012)
			NS	P,G	Keya <i>et al.</i> (2015)
				----	Hashem and Peyman (2011)
5	Hulling per cent	Positive	NS	P,G	Praveen <i>et al.</i> (2010)
6	Milling per cent	Positive	S	P	Nagaraju <i>et al.</i> (2013)
			NS	G	Nagaraju <i>et al.</i> (2013)
				P,G	Praveen <i>et al.</i> (2010)
		Negative	NS	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
7	Head rice recovery	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
8	Kernel length	Positive	S	P	Nibedita Mohanty <i>et al.</i> (2015)
			NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Norain <i>et al.</i> (2014), Ghaffar and Ghorbanali (2012), Kayan Agahi <i>et al.</i> (2007)
				P	Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013)
				G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
9	Kernel breadth	Positive	S	P	Sayed Mustafa Sadeghi (2011)
				P,G	Kayan Agahi <i>et al.</i> (2007)
			NS	P	Nibedita Mohanty <i>et al.</i> (2015)
				P,G	Dhurai <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014)
		Negative	S	G	Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

			NS	P,G P G ----	Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011), Praveen <i>et al.</i> (2010) Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013) Nibedita Mohanty <i>et al.</i> (2015) Norain <i>et al.</i> (2014)
10	Kernel length/breadth ratio	Positive	NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Kayan Agahi <i>et al.</i> (2007), Nayak <i>et al.</i> (2001)
				G	Nagaraju <i>et al.</i> (2013)
				P	Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013)
		Negative	NS	G	Krishna Veni <i>et al.</i> (2013)
				P,G	Praveen <i>et al.</i> (2010)
11	Kernel length after cooking	Positive	S	P,G	Dhurai <i>et al.</i> (2014)
		Negative	NS	G	Krishna Veni <i>et al.</i> (2013)
12	Kernel elongation ratio	Positive	NS	P,G	Dhurai <i>et al.</i> (2014)
				G	Krishna Veni <i>et al.</i> (2013)
		Negative	S	P	Nibedita Mohanty <i>et al.</i> (2015)
			NS	G	Nibedita Mohanty <i>et al.</i> (2015)
13	Volume expansion ratio	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	P,G	Praveen <i>et al.</i> (2010)
14	Water uptake	Positive	NS	G	Krishna Veni <i>et al.</i> (2013)
15	Gel consistency	Negative	NS	P	Rafii <i>et al.</i> (2014)
16	Alkali spreading value	Negative	NS	P	Rafii <i>et al.</i> (2014)
17	Amylose content	Negative	NS	G	Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

VI	Panicle length per plant				
1	Number of grains per panicle	Positive	S	P,G	Golam Sarwar <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Imad <i>et al.</i> (2014) Khare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Norain <i>et al.</i> (2014), Aditya and, Anuradha Bhartiya (2013), Awaneet Kumar and Senapathi (2013), Gulzar <i>et al.</i> (2013),, Ravindra Babu <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011), Nayak <i>et al.</i> (2001)
				P	Sandhyarani Das (2015), Bornare <i>et al.</i> (2014), Atif and Khalid (2013), Seyed Mustafa Sadeghi (2011)
				G	Arulmozhi and Muthuswamy (2013), Bhadru <i>et al.</i> (2012), Rahim <i>et al.</i> (2007)
			NS	P,G	Keya <i>et al.</i> (2015), Vijay Kumar <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Dhurai <i>et al.</i> (2014) Mamunur <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013), Ghaffar and, Ghorbanali (2012), Mulugeta Seyoum <i>et al.</i> (2012)
2	Test weight	Positive	S	P	Pradhan <i>et al.</i> (2015), Singh <i>et al.</i> (2015), Rafii <i>et al.</i> (2014), Akinwale <i>et al.</i> (2011), Yadav <i>et al.</i> (2010), Rahim <i>et al.</i> (2007)
				G	Sandhyarani Das (2015), Tirumala Rao <i>et al.</i> (2014)
			NS	P,G	Keya <i>et al.</i> (2015), Bornare <i>et al.</i> (2014), Nitiprasad and Lotan Kumar (2014), Satish Kumar Rai <i>et al.</i> (2014), Ravindra Babu <i>et al.</i> (2012), Hasan <i>et al.</i> (2011), Norain <i>et al.</i> (2014) Nibedita Mohanty <i>et al.</i> (2015), Lingaiah <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013), Nandan <i>et al.</i> (2010) Golam Sarwar <i>et al.</i> (2015), Tirumala Rao <i>et al.</i> (2014)
				P	
				G	
		Negative	NS	P,G	Sathisha <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Ali <i>et al.</i> (2013), Awaneet Kumar and Senapathi (2013), Mulugeta Seyoum <i>et al.</i> (2012), Ruth Elizabeth Ekka <i>et al.</i> (2011)
				P	Golam Sarwar <i>et al.</i> (2015), Pradhan <i>et al.</i> (2015) Singh <i>et al.</i> (2015), Akinwale <i>et al.</i> (2011), Seyed Mustafa Sadeghi (2011)
				G	Nibedita Mohanty <i>et al.</i> (2015), Dilruba <i>et al.</i> (2014), Lingaiah <i>et al.</i> (2014), Nagaraju <i>et al.</i> (2013)
				----	Marzieh Moosavi <i>et al.</i> (2015)
		Negative	NS	P,G	Sandhyarani Das (2015), Dhurai <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Yadav <i>et al.</i> (2010), Rahim <i>et al.</i> (2007), Nayak <i>et al.</i> (2001)
				P	Aditya and Anuradha Bhartiya (2013), Atif and Khalid (2013)

Table 2.5(Cont.)

				G ----	Imad <i>et al.</i> (2014), Krishna Veni <i>et al.</i> (2013), Bhadrn <i>et al.</i> (2012) Ghaffar and Ghorbanali (2012)
3	Leaf area index at maximum tillering stage	Positive	S	P,G	Bhabendra <i>et al.</i> (2012)
			NS	P,G ----	Keya <i>et al.</i> (2015) Hashem and Peyman (2011)
4	Hulling per cent	Positive	S	P	Nandan <i>et al.</i> (2010)
5	Milling per cent	Positive	NS	P,G	Nagaraju <i>et al.</i> (2013)
		Negative	NS	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
6	Head rice recovery	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
7	Kernel length	Positive	S	P,G	Mohammad and Kalyan Agahi (2014), Nitiprasad and Lotan Kumar (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011) Kayan Agahi <i>et al.</i> (2007)
				P ----	Nibedita Mohanty <i>et al.</i> (2015), Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010) Norain <i>et al.</i> (2014)
		Negative	NS	P,G	Sathisha <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Nayak <i>et al.</i> (2001)
				P ----	Aditya and Anuradha Bhartiya (2013), Seyed Mustafa Sadeghi (2011) Ghaffar and Ghorbanali (2012)
8	Kernel breadth	Positive	S	P ----	Nibedita Mohanty <i>et al.</i> (2015) Norain <i>et al.</i> (2014)
			NS	P,G P G	Dhurai <i>et al.</i> (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014) Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Nandan <i>et al.</i> (2010) Nibedita Mohanty <i>et al.</i> (2015)
		Negative	S	P,G ----	Kayan Agahi <i>et al.</i> (2007) Ghaffar and Ghorbanali (2012)
			NS	P,G ----	Nitiprasad and Lotan Kumar (2014), Awaneet Kumar and Senapathi (2013), Krishna Veni <i>et al.</i> (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011) Gulzar <i>et al.</i> (2013)

Table 2.5(Cont.)

9	Kernel length/breadth ratio	Positive	S	P,G P	Nayak <i>et al.</i> (2001) Awaneet Kumar and Senapathi (2013), Nandan <i>et al.</i> (2010)
		Negative	NS	P,G P G	Nibedita Mohanty <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014) Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013) Nagaraju <i>et al.</i> (2013)
10	Kernel length after cooking	Positive	S	P	Nandan <i>et al.</i> (2010)
		Negative	NS	P,G G	Dhurai <i>et al.</i> (2014) Krishna Veni <i>et al.</i> (2013)
11	Kernel breadth after cooking	Positive	S	P	Nandan <i>et al.</i> (2010)
12	Kernel elongation ratio	Positive	NS	P,G G	Dhurai <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)
		Negative	S	P	Nandan <i>et al.</i> (2010)
			NS	P,G	Nibedita Mohanty <i>et al.</i> (2015)
13	Volume expansion ratio	Positive	NS	G	Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)
14	Water uptake	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
		Negative	NS	P	Nandan <i>et al.</i> (2010)
15	Gel consistency	Positive	NS	P	Rafii <i>et al.</i> (2014)
16	Amylose content	Positive	S	G	Arulmozhi and Muthuswamy (2013)
			NS	P	Rafii <i>et al.</i> (2014)
		Negative	S	G	Krishna Veni <i>et al.</i> (2013)
VII	Number of grains per panicle				
1	Test weight	Positive	S	P,G P G	Sarafraz <i>et al.</i> (2015), Shajedur Hossain <i>et al.</i> (2015), Zulqarnian <i>et al.</i> (2012), Afzal <i>et al.</i> (2006), Nayak <i>et al.</i> (2001) Kayan Agahi <i>et al.</i> (2007) Imad <i>et al.</i> (2014)

Table 2.5(Cont.)

				----	Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014), Rashid <i>et al.</i> (2014)
		Negative	S	P,G	Islam <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Alam <i>et al.</i> (2014), Khare <i>et al.</i> (2014), Mamunur <i>et al.</i> (2014), Mohammad and Kalyan Agahi (2014), Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013), Yadav <i>et al.</i> (2010)
				P	Pradhan <i>et al.</i> (2015), Seyed Mustafa Sadeghi (2011), Nandan <i>et al.</i> (2010)
				G	Dilruba <i>et al.</i> (2014), Tirumala Rao <i>et al.</i> (2014), Bhadru <i>et al.</i> (2012)
				----	Hashem and Peyman (2011)
2	Leaf area index at maximum tillering stage	Positive	S	P,G	Keya <i>et al.</i> (2015), Bhabendra <i>et al.</i> (2012)
			NS	P	Saumya and Lal (2014)
				----	Zulqarnain <i>et al.</i> (2012)
		Negative	S	----	Ganghua <i>et al.</i> (2014)
			NS	----	Hashem and Peyman (2011)
3	Hulling per cent	Positive	NS	P	Nandan <i>et al.</i> (2010)
				P,G	Praveen <i>et al.</i> (2010)
4	Milling per cent	Positive	S	P	Nagaraju <i>et al.</i> (2013)
				P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	G	Nagaraju <i>et al.</i> (2013)
				P,G	Praveen <i>et al.</i> (2010)
5	Head rice recovery	Positive	S	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	P,G	Praveen <i>et al.</i> (2010)
6	Kernel length	Positive	NS	P,G	Dhurai <i>et al.</i> (2014), Ruth Elizabeth Ekka <i>et al.</i> (2011), Praveen <i>et al.</i> (2010), Afzal <i>et al.</i> (2006)
				P	Perera <i>et al.</i> (2014)
		Negative	S	P,G	Islam <i>et al.</i> (2015), Singh <i>et al.</i> (2014), Kayan Agahi <i>et al.</i> (2007), Nayak <i>et al.</i> (2001)
				P	Seyed Mustafa Sadeghi (2011)
			NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Gulzar <i>et al.</i> (2013)
				P	Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Nandan <i>et al.</i> (2010), Afzal <i>et al.</i> (2006)
7	Kernel breadth	Positive	NS	P,G	Venkata Lakshmi <i>et al.</i> (2014), Gulzar <i>et al.</i> (2013)
				P	Praveen <i>et al.</i> (2010)
		Negative	S	P,G	Nitiprasad and Lotan Kumar (2014), Singh <i>et al.</i> (2014)

Table 2.5(Cont.)

			NS	P,G P	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011) Rafii <i>et al.</i> (2014)
8	Kernel length/breadth ratio	Positive	NS	P,G P G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013) Rafii <i>et al.</i> (2014), Praveen <i>et al.</i> (2010) Nagaraju <i>et al.</i> (2013)
		Negative	S	P,G P	Kayan Agahi <i>et al.</i> (2007), Nayak <i>et al.</i> (2001) Nandan <i>et al.</i> (2010)
9	Kernel length after cooking	Positive	S	G	Afzal <i>et al.</i> (2006)
			NS	P	Afzal <i>et al.</i> (2006)
		Negative	NS	P,G P	Dhurai <i>et al.</i> (2014) Nandan <i>et al.</i> (2010)
10	Kernel breadth after cooking	Negative	NS	P	Nandan <i>et al.</i> (2010)
11	Kernel elongation ratio	Positive	S	P	Nandan <i>et al.</i> (2010)
		Negative	NS	P,G G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013)
12	Volume expansion ratio	Positive	S	G	Arulmozhi and Muthuswamy (2013), Praveen <i>et al.</i> (2010)
			NS	P	Praveen <i>et al.</i> (2010)
13	Water uptake	Negative	S	P	Nandan <i>et al.</i> (2010)
14	Gel consistency	Positive	NS	P	Rafii <i>et al.</i> (2014)
15	Amylose content	Positive	NS	P G	Rafii <i>et al.</i> (2014) Arulmozhi and Muthuswamy (2013)
VIII	Test weight				
1	Leaf area index at maximum	Positive	NS	P,G	Keya <i>et al.</i> (2015)
		Negative	NS	P,G ----	Zulqarnain <i>et al.</i> (2012) Hashem and Peyman (2011)

Table 2.5(Cont.)

	tillering stage				
2	Hulling per cent	Positive	S	P P,G	Nandan <i>et al.</i> (2010) Praveen <i>et al.</i> (2010)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015)
3	Milling per cent	Positive	S	P,G	Praveen <i>et al.</i> (2010)
			NS	P	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	G P,G	Nirmaladevi <i>et al.</i> (2015) Nagaraju <i>et al.</i> (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011)
4	Head rice recovery	Positive	S	P,G	Praveen <i>et al.</i> (2010)
			NS	P	Nirmaladevi <i>et al.</i> (2015)
		Negative	S	P,G	Ruth Elizabeth Ekka <i>et al.</i> (2011)
			NS	G	Nirmaladevi <i>et al.</i> (2015), Krishna Veni <i>et al.</i> (2013)
5	Kernel length	Positive	S	P,G P G ----	Nibedita Mohanty <i>et al.</i> (2015), Sathisha <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Mohammad and Kalyan Agahi (2014), Singh <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Gulzar <i>et al.</i> (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011), Afzal <i>et al.</i> (2006), Nayak <i>et al.</i> (2001) Aditya and Anuradha Bhartiya (2013), Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013) Norain <i>et al.</i> (2014), Perera <i>et al.</i> (2014)
			NS	P,G P G ----	Islam <i>et al.</i> (2015), Nitiprasad and Lotan Kumar (2014), Venkata Lakshmi <i>et al.</i> (2014), Praveen <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015) Nibedita Mohanty <i>et al.</i> (2015) Ghaffar and Ghorbanali (2012)
6	Kernel breadth	Positive	S	P,G P	Mohammad and Kalyan Agahi (2014), Singh <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014) Awaneet Kumar and Senapathi (2013), Ruth Elizabeth Ekka <i>et al.</i> (2011), Kayan Agahi <i>et al.</i> (2007) Nibedita Mohanty <i>et al.</i> (2015), Gulzar <i>et al.</i> (2013), Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

				G ----	Norain <i>et al.</i> (2014), Ghaffar and Ghorbanali (2012)
			NS	P,G P G	Nirmaladevi <i>et al.</i> (2015), Nitiprasad and Lotan Kumar (2014) Aditya and Anuradha Bhartiya (2013) Nibedita Mohanty <i>et al.</i> (2015), Gulzar <i>et al.</i> (2013)
7	Kernel length/breadth ratio	Negative	S	P, G P	Venkata Lakshmi <i>et al.</i> (2014), Kayan Agahi <i>et al.</i> (2007) Nibedita Mohanty <i>et al.</i> (2015)
			NS	P,G G	Awaneet Kumar and Senapathi (2013) Nibedita Mohanty <i>et al.</i> (2015), Nirmaladevi <i>et al.</i> (2015), Krishna Veni <i>et al.</i> (2013)
8	Kernel length after cooking	Positive	S	P,G P G	Afzal <i>et al.</i> (2006) Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014)
9	Kernel breadth after cooking	Positive	S	P	Nandan <i>et al.</i> (2010)
10	Kernel elongation ratio	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015)
		Negative	S	P	Nibedita Mohanty <i>et al.</i> (2015), Nandan <i>et al.</i> (2010)
			NS	P,G P G	Dhurai <i>et al.</i> (2014) Nibedita Mohanty <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013)
11	Volume expansion ratio	Positive	S	G	Praveen <i>et al.</i> (2010)
			NS	P,G P	Nirmaladevi <i>et al.</i> (2015) Praveen <i>et al.</i> (2010)
		Negative	NS	G	Krishna Veni <i>et al.</i> (2013)
12	Water uptake	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013)
		Negative	NS	P	Nandan <i>et al.</i> (2010)
13	Gel	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015)

Table 2.5(Cont.)

	consistency				
14	Alkali spreading value	Positive	NS	P	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015)
15	Amylose content	Positive	S	P,G G	Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013)
IX	Hulling per cent				
1	Milling per cent	Positive	S	P,G P G ----	Praveen <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010) Subudhi <i>et al.</i> (2011) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Subudhi <i>et al.</i> (2011)
2	Head rice recovery	Positive	S	P,G G	Praveen <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011)
3	Kernel length	Positive	S	P G	Nandan <i>et al.</i> (2010) Praveen <i>et al.</i> (2010)
			NS	P,G P	Subudhi <i>et al.</i> (2011), Prem Kumar <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015)
4	Kernel breadth	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011) Nandan <i>et al.</i> (2010)
		Negative	S	G	Premiladevi <i>et al.</i> (2012)
5	Kernel length/breadth ratio	Positive	S	P	Nandan <i>et al.</i> (2010)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011) Krishna Veni <i>et al.</i> (2013), Manonmani <i>et al.</i> (2010)
6	Kernel length after cooking	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011), Prem Kumar <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013)

Table 2.5(Cont.)

		Negative	NS	----	Mahmuda Khatun <i>et al.</i> (2003)
7	Kernel breadth after cooking	Positive	NS	P	Prem Kumar <i>et al.</i> (2010), Nandan <i>et al.</i> (2010)
8	Kernel elongation ratio	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	P,G P G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	NS	G ----	Nirmaladevi <i>et al.</i> (2015), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
9	Volume expansion ratio	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Praveen <i>et al.</i> (2010) Manonmani <i>et al.</i> (2010)
		Negative	NS	G	Subudhi <i>et al.</i> (2011)
10	Water uptake	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011) Krishna Veni <i>et al.</i> (2013)
		Negative	NS	P,G P G ----	Prem Kumar <i>et al.</i> (2010) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Nandan <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
11	Gel consistency	Positive	S	G ---	Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015)
12	Alkali spreading value	Positive	S	P	Subudhi <i>et al.</i> (2011)
			NS	P G ----	Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015), Manonmani <i>et al.</i> (2010)
13	Amylose content	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)

Table 2.5(Cont.)

			NS	P,G G	Subudhi <i>et al.</i> (2011) Krishna Veni <i>et al.</i> (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
X	Milling per cent				
1	Head rice recovery	Positive	S	P,G P G	Ruth Elizabeth Ekka <i>et al.</i> (2011), Praveen <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010), Mahmuda Khatun <i>et al.</i> (2003) Subudhi <i>et al.</i> (2011) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Subudhi <i>et al.</i> (2011)
2	Kernel length	Positive	S	G	Praveen <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010)
			NS	P,G P G ----	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015), Praveen <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010) Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	P,G G	Ruth Elizabeth Ekka <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012)
3	Kernel breadth	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015), Ruth Elizabeth Ekka <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011), Praveen <i>et al.</i> (2010)
		Negative	NS	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
4	Kernel length/breadth ratio	Positive	S	P	Nagaraju <i>et al.</i> (2013)
			NS	P,G P G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015) Nagaraju <i>et al.</i> (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	S	G ----	Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
5	Kernel length after cooking	Positive	S	P,G	Prem Kumar <i>et al.</i> (2010)
			NS	P,G	Subudhi <i>et al.</i> (2011)

Table 2.5(Cont.)

6	Kernel breadth after cooking	Positive	NS	P,G P	Nirmaladevi <i>et al.</i> (2015) Prem Kumar <i>et al.</i> (2010)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015)
7	Kernel elongation ratio	Positive	NS	G	Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011)
8	Volume expansion ratio	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Praveen <i>et al.</i> (2010) Manonmani <i>et al.</i> (2010)
		Negative	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011)
			----	----	Mahmuda Khatun <i>et al.</i> (2003)
9	Water uptake	Positive	NS	P	Subudhi <i>et al.</i> (2011)
			S	G	Prem Kumar <i>et al.</i> (2010)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
10	Gel consistency	Positive	S	G	Manonmani <i>et al.</i> (2010)
			NS	G	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	P	Nirmaladevi <i>et al.</i> (2015)
11	Alkali spreading value	Positive	NS	P,G G ----	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	P G	Nirmaladevi <i>et al.</i> (2015) Manonmani <i>et al.</i> (2010)
12	Amylose content	Positive	NS	G	Nirmaladevi <i>et al.</i> (2015), Manonmani <i>et al.</i> (2010)
		Negative	NS	P,G P G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)

Table 2.5(Cont.)

				----	Mahmuda Khatun <i>et al.</i> (2003)
XI	Head rice recovery				
1	Kernel length	Positive	NS	P,G P	Ruth Elizabeth Ekka <i>et al.</i> (2011), Prem Kumar <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015)
		Negative	S	P ----	Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G G	Praveen <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011)
2	Kernel breadth	Positive	NS	P,G	Praveen <i>et al.</i> (2010)
3	Kernel length/breadth ratio	Negative	S	G ----	Nirmaladevi <i>et al.</i> (2015), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
4	Kernel length after cooking	Positive	S	P,G	Prem Kumar <i>et al.</i> (2010)
			NS	P P,G	Nirmaladevi <i>et al.</i> (2015) Subudhi <i>et al.</i> (2011)
5	Kernel breadth after cooking	Positive	NS	P,G	Prem Kumar <i>et al.</i> (2010)
6	Kernel elongation ratio	Positive	S	P	Subudhi <i>et al.</i> (2011)
			NS	P G	Nirmaladevi <i>et al.</i> (2015) Subudhi <i>et al.</i> (2011)
7	Volume expansion ratio	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P G	Subudhi <i>et al.</i> (2011), Praveen <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015) Manonmani <i>et al.</i> (2010)
		Negative	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)

Table 2.5(Cont.)

			NS	G	Nirmaladevi <i>et al.</i> (2015)
8	Water uptake	Positive	S	P	Subudhi <i>et al.</i> (2011)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Prem Kumar <i>et al.</i> (2010) Subudhi <i>et al.</i> (2011)
		Negative	NS	G ----	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
9	Gel consistency	Positive	S	G ----	Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015)
10	Alkali spreading value	Positive	S	P	Subudhi <i>et al.</i> (2011)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)

11	Amylose content	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015)
		Negative	S	G P ----	Mehdi Mirarab <i>et al.</i> (2011) Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Premiladevi <i>et al.</i> (2012), Subudhi <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
XII	Kernel length				
1	Kernel breadth	Positive	S	P,G P ----	Gulzar <i>et al.</i> (2013) Aditya and Anuradha Bhartiya (2013) Norain <i>et al.</i> (2014)
2	Kernel length/breadth ratio	Positive	S	P,G P G	Sathisha <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Venkata Lakshmi <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Kayan Agahi <i>et al.</i> (2007), Nayak <i>et al.</i> (2001) Nibedita Mohanty <i>et al.</i> (2015), Rafii <i>et al.</i> (2014), Aditya and Anuradha Bhartiya (2013), Subudhi <i>et al.</i> (2011), Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Praveen <i>et al.</i> (2010)

Table 2.5(Cont.)

				----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P G	Nirmaladevi <i>et al.</i> (2015) Praveen <i>et al.</i> (2010) Nibedita Mohanty <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011)
3	Kernel length after cooking	Positive	S	P,G P G ----	Dhurai <i>et al.</i> (2014), Prem Kumar <i>et al.</i> (2010), Afzal <i>et al.</i> (2006) Subudhi <i>et al.</i> (2011), Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013) Mahmuda Khatun <i>et al.</i> (2003)
4	Kernel breadth after cooking	Positive	NS	P	Nandan <i>et al.</i> (2010), Prem Kumar <i>et al.</i> (2010)
		Negative	NS	G	Prem Kumar <i>et al.</i> (2010)
5	Kernel elongation ratio	Negative	S	P G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014), Subudhi <i>et al.</i> (2011), Nandan <i>et al.</i> (2010) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
6	Volume expansion ratio	Positive	S	G	Mehdi Mirarab <i>et al.</i> (2011)
			NS	P,G P G	Praveen <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012)
		Negative	S	P	Subudhi <i>et al.</i> (2011)
			NS	G ----	Nirmaladevi <i>et al.</i> (2015), Krishna Veni <i>et al.</i> (2013), Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
7	Water uptake	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Prem Kumar <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	NS	P,G P ----	Subudhi <i>et al.</i> (2011) Nandan <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
8	Gel consistency	Positive	S	---	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	P	Nirmaladevi <i>et al.</i> (2015)

Table 2.5(Cont.)

9	Alkali spreading value	Positive	NS	P,G G ----	Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	P,G	Subudhi <i>et al.</i> (2011)
10	Amylose content	Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G P	Nirmaladevi <i>et al.</i> (2015) Rafii <i>et al.</i> (2014)
XIII	Kernel breadth				
1	Kernel length/breadth ratio	Negative	S	P,G P G ----	Dhurai <i>et al.</i> (2014), Awaneet Kumar and Senapathi (2013), Gulzar <i>et al.</i> (2013), Kayan Agahi <i>et al.</i> (2007) Nibedita Mohanty <i>et al.</i> (2015), Rafii <i>et al.</i> (2014), Subudhi <i>et al.</i> (2011), Nandan <i>et al.</i> (2010) Krishna Veni <i>et al.</i> (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
2	Kernel length after cooking	Positive	NS	P P,G	Nirmaladevi <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014)
		Negative	NS	P,G P G	Subudhi <i>et al.</i> (2011) Nandan <i>et al.</i> (2010) Nirmaladevi <i>et al.</i> (2015)
3	Kernel breadth after cooking	Positive	S	P	Nandan <i>et al.</i> (2010)
4	Kernel elongation ratio	Negative	NS	P,G G ----	Nibedita Mohanty <i>et al.</i> (2015) Nirmaladevi <i>et al.</i> (2015) Mahmuda Khatun <i>et al.</i> (2003)
5	Volume expansion ratio	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Praveen <i>et al.</i> (2010) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	S	G ----	Krishna Veni <i>et al.</i> (2013) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P	Subudhi <i>et al.</i> (2011) Nandan <i>et al.</i> (2010)

Table 2.5(Cont.)

				G	Krishna Veni <i>et al.</i> (2013)
6	Water uptake	Positive	NS	P,G	Subudhi <i>et al.</i> (2011)
				P	Nirmaladevi <i>et al.</i> (2015)
				G	Krishna Veni <i>et al.</i> (2013)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
NS	P		Nirmaladevi <i>et al.</i> (2015)		
			G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)	
7	Gel consistency	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015)
				P	Rafii <i>et al.</i> (2014)
		Negative	NS	----	Mahmuda Khatun <i>et al.</i> (2003)
8	Alkali spreading value	Positive	NS	P,G	Subudhi <i>et al.</i> (2011)
				P	Nirmaladevi <i>et al.</i> (2015)
				----	Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
9	Amylose content	Positive	NS	P,G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011)
				P	Rafii <i>et al.</i> (2014)
				G	Premiladevi <i>et al.</i> (2012)
XIV	Kernel length/breadth ratio				
1	Kernel length after cooking	Positive	S	G	Krishna Veni <i>et al.</i> (2013)
				----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014)
2	Kernel elongation ratio	Positive	NS	P	Nirmaladevi <i>et al.</i> (2015)
				G	Arulmozhi and Muthuswamy (2013), Krishna Veni <i>et al.</i> (2013)
		Negative	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
			NS	P,G	Nibedita Mohanty <i>et al.</i> (2015), Dhurai <i>et al.</i> (2014)
				P	Nirmaladevi <i>et al.</i> (2015), Malini <i>et al.</i> (2011) , Manonmani <i>et al.</i> (2010), Nandan <i>et al.</i> (2010)
	----	Mahmuda Khatun <i>et al.</i> (2003)			
3	Volume expansion ratio	Positive	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
			NS	P,G	Praveen <i>et al.</i> (2010)
				P	Nirmaladevi <i>et al.</i> (2015)

Table 2.5(Cont.)

				G ----	Krishna Veni <i>et al.</i> (2013), Malini <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	S	G	Arulmozhi and Muthuswamy (2013), Manonmani <i>et al.</i> (2010)
			NS	G	Nirmaladevi <i>et al.</i> (2015)
4	Water uptake	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P G	Nirmaladevi <i>et al.</i> (2015) Nandan <i>et al.</i> (2010) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	NS	G	Krishna Veni <i>et al.</i> (2013), Malini <i>et al.</i> (2011)
5	Gel consistency	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
		Negative	S	P G	Rafii <i>et al.</i> (2014) Manonmani <i>et al.</i> (2010)
			NS	G	Malini <i>et al.</i> (2011)
6	Alkali spreading value	Positive	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
			NS	P,G ----	Nirmaladevi <i>et al.</i> (2015) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	G	Malini <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
7	Amylose content	Positive	NS	P ----	Nirmaladevi <i>et al.</i> (2015), Rafii <i>et al.</i> (2014) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	G	Nirmaladevi <i>et al.</i> (2015), Arulmozhi and Muthuswamy (2013), Premiladevi <i>et al.</i> (2012), Malini <i>et al.</i> (2011), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
XV	Kernel length after cooking				
1	Kernel breadth after cooking	Positive	NS	P	Nandan <i>et al.</i> (2010)
		Negative	S	G	Prem Kumar <i>et al.</i> (2010)
			NS	P	Prem Kumar <i>et al.</i> (2010)
2	Kernel elongation ratio	Positive	S	P,G G	Dhurai <i>et al.</i> (2014) Krishna Veni <i>et al.</i> (2013)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015)

Table 2.5(Cont.)

				P	Subudhi <i>et al.</i> (2011)
		Negative	S	P	Nandan <i>et al.</i> (2010)
			NS	G	Subudhi <i>et al.</i> (2011)
3	Volume expansion ratio	Positive	NS	P,G G ----	Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	P,G	Subudhi <i>et al.</i> (2011)
4	Water uptake	Positive	NS	P,G G ----	Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	P,G P	Subudhi <i>et al.</i> (2011), Prem Kumar <i>et al.</i> (2010) Nandan <i>et al.</i> (2010)
5	Gel consistency	Positive	NS	P ----	Nirmaladevi <i>et al.</i> (2015) Mahmuda Khatun <i>et al.</i> (2003)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015)
6	Alkali spreading value	Positive	NS	P,G ----	Nirmaladevi <i>et al.</i> (2015) Mahmuda Khatun <i>et al.</i> (2003)
7	Amylose content	Positive	NS	P,G G	Subudhi <i>et al.</i> (2011), Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013)
		Negative	NS	G ----	Nirmaladevi <i>et al.</i> (2015) Mahmuda Khatun <i>et al.</i> (2003)
XVI	Kernel breadth after cooking				
1	Kernel elongation ratio	Negative	NS	P	Nandan <i>et al.</i> (2010)
2	Water uptake	Positive	S NS	P P	Nandan <i>et al.</i> (2010) Prem Kumar <i>et al.</i> (2010)
		Negative	NS	G	Prem Kumar <i>et al.</i> (2010)

Table 2.5(Cont.)

XVII	Kernel elongation ratio				
1	Volume expansion ratio	Positive	S	G P ----	Krishna Veni <i>et al.</i> (2013) Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Manonmani <i>et al.</i> (2010)
		Negative	S	G	Arulmozhi and Muthuswamy (2013), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
			NS	G	Malini <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011)
2	Water uptake	Positive	S	G ----	Krishna Veni <i>et al.</i> (2013), Malini <i>et al.</i> (2011), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G P	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015)
		Negative	S	G	Premiladevi <i>et al.</i> (2012)
			NS	G P	Nirmaladevi <i>et al.</i> (2015) Nandan <i>et al.</i> (2010)
3	Gel consistency	Positive	NS	P G	Nirmaladevi <i>et al.</i> (2015) Malini <i>et al.</i> (2011)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Nirmaladevi <i>et al.</i> (2015), Manonmani <i>et al.</i> (2010)
4	Alkali spreading value	Positive	S	P	Subudhi <i>et al.</i> (2011)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Malini <i>et al.</i> (2011), Subudhi <i>et al.</i> (2011)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
5	Amylose content	Positive	S	G ----	Arulmozhi and Muthuswamy (2013), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P G	Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Malini <i>et al.</i> (2011), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	S	P	Subudhi <i>et al.</i> (2011)
			NS	P	Nirmaladevi <i>et al.</i> (2015)

Table 2.5(Cont.)

				G	Krishna Veni <i>et al.</i> (2013), Subudhi <i>et al.</i> (2011)
XVIII	Volume expansion ratio				
1	Water uptake	Positive	S	G ----	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G G	Subudhi <i>et al.</i> (2011), Nirmaladevi <i>et al.</i> (2015) Krishna Veni <i>et al.</i> (2013)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015), Malini <i>et al.</i> (2011), Mehdi Mirarab <i>et al.</i> (2011)
2	Gel consistency	Positive	S	G	Manonmani <i>et al.</i> (2010)
			NS	P	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	G ----	Nirmaladevi <i>et al.</i> (2015), Malini <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
3	Alkali spreading value	Positive	NS	P G	Nirmaladevi <i>et al.</i> (2015) Manonmani <i>et al.</i> (2010)
		Negative	S	G ----	Malini <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015), Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
4	Amylose content	Positive	S	G ----	Arulmozhi and Muthuswamy (2013), Malini <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010) Mahmuda Khatun <i>et al.</i> (2003)
			NS	P G	Nirmaladevi <i>et al.</i> (2015) Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
		Negative	S	G	Krishna Veni <i>et al.</i> (2013)
			NS	P,G G	Subudhi <i>et al.</i> (2011) Nirmaladevi <i>et al.</i> (2015)
XIX	Water uptake				
1	Gel consistency	Positive	S	G	Malini <i>et al.</i> (2011)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	----	Mahmuda Khatun <i>et al.</i> (2003)
2	Alkali	Positive	S	G	Malini <i>et al.</i> (2011)

Table 2.5(Cont.)

	spreading value			P	Subudhi <i>et al.</i> (2011)
			NS	P,G G	Nirmaladevi <i>et al.</i> (2015) Subudhi <i>et al.</i> (2011)
		Negative	S	G ----	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
3	Amylose content	Positive	NS	P,G G	Nirmaladevi <i>et al.</i> (2015), Subudhi <i>et al.</i> (2011) Krishna Veni <i>et al.</i> (2013), Malini <i>et al.</i> (2011)
		Negative	S	G	Premiladevi <i>et al.</i> (2012), Mehdi Mirarab <i>et al.</i> (2011)
			NS	G ----	Subudhi <i>et al.</i> (2011) Mahmuda Khatun <i>et al.</i> (2003)
XX	Gel consistency				
1	Alkali spreading value	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	G	Malini <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)
		Negative	NS	G	Nirmaladevi <i>et al.</i> (2015)
2	Amylose content	Positive	S	G	Malini <i>et al.</i> (2011)
			NS	P,G P G	Nirmaladevi <i>et al.</i> (2015) Rafii <i>et al.</i> (2014) Manonmani <i>et al.</i> (2010)
		Negative	S	----	Mahmuda Khatun <i>et al.</i> (2003)
XXI	Alkali spreading value				
1	Amylose content	Positive	S	----	Mahmuda Khatun <i>et al.</i> (2003)
			NS	P,G	Nirmaladevi <i>et al.</i> (2015)
		Negative	NS	P,G G	Subudhi <i>et al.</i> (2011) Premiladevi <i>et al.</i> (2012), Malini <i>et al.</i> (2011), Mehdi Mirarab <i>et al.</i> (2011), Manonmani <i>et al.</i> (2010)

2.5 PATH COEFFICIENT ANALYSIS

Path coefficient analysis as devised by Wright (1921) is standardized partial regression coefficient, which helps in partitioning the correlation coefficient into direct and indirect effects of independent variables on the dependent variable. The path coefficient analysis further helps to elucidate the intrinsic nature of the observed associations and imparts a degree of confidence in the selection scheme adopted for a given situation. It may also help to minimize the number of attributes for which simultaneous selection must be exercised (Dewey and Lu, 1959).

The literature on direct and indirect effects of yield components on grain yield is reviewed and presented in Tables 2.6 and 2.7, respectively.

Table. 2.6. Review of literature on direct effects of component characters with grain yield.

S. No.	Character	Direction of effect	Generation studied	P/ G	Reference
1	Days to 50% flowering	Positive	20 advanced lines	----	Islam <i>et al.</i> (2015)
			20 genotypes	----	Keya <i>et al.</i> (2015)
			35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			60 upland germplasm	P	Khare <i>et al.</i> (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			40 genotypes	P,G	Satish Kumar <i>et al.</i> (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			12 rice hybrids	G	Seesang <i>et al.</i> (2013)
			100 rice genotypes	P	Basavaraja <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			21 gall midge resistance genotypes	G	Bhadru <i>et al.</i> (2012)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			40 rice germplasm lines	P,G	Rangare <i>et al.</i> (2012)
			14 rice genotypes	G	Seyoum <i>et al.</i> (2012)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			124 land races	P	Pal <i>et al.</i> (2011)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			47 genotypes	G	Jayasudha and Deepak (2010)

Table 2.6 (Cont.)

		Negative	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			30 genotypes	G	Pradhan <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			20 genotypes	G	Imad <i>et al.</i> (2014)
			60 upland germplasm	G	Khare <i>et al.</i> (2014)
			64 elite mid early genotypes	P	Lingaiah <i>et al.</i> (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			64 rice genotypes	P	Bekele <i>et al.</i> (2013)
			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			21 rice hybrids	P	Babu <i>et al.</i> (2012)
			64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
			21 hybrids	P,G	Ravindra Babu <i>et al.</i> (2012)
			32 genotypes	P,G	Sravan <i>et al.</i> (2012)
			48 rice genotypes	P,G	Garg <i>et al.</i> (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
2	Days to maturity	Positive	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			20 advanced lines	----	Islam <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)
			32 genotypes	P,G	Dhurai <i>et al.</i> (2014)

Table 2.6 (Cont.)

			20 genotypes	G	Imad <i>et al.</i> (2014)
			60 upland germplasm	P,G	Khare <i>et al.</i> (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	P	Gulzar <i>et al.</i> (2013)
			64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			10 genotypes	----	Akhtar <i>et al.</i> (2011)
			40 genotypes	G	Khatu <i>et al.</i> (2010)
		Negative	130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			40 genotypes	P,G	Satish Kumar <i>et al.</i> (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			14 diverse cold tolerant local red ecotypes	G	Gulzar <i>et al.</i> (2013)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			22 genotypes	----	Nandan <i>et al.</i> (2010)
3	Plant height	Positive	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			20 advanced lines	----	Islam <i>et al.</i> (2015)
			30 genotypes	G	Pradhan <i>et al.</i> (2015)
			24 accessions	----	Sarfraz <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)

Table 2.6 (Cont.)

		35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
		15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
		41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)
		32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
		60 upland germplasm	P,G	Khare <i>et al.</i> (2014)
		64 elite mid early genotypes	P	Lingaiah <i>et al.</i> (2014)
		21 varieties	G	Mamunur <i>et al.</i> (2014)
		22 upland genotypes	G	Nitiprasad and Lotan (2014)
		7 advanced fine rice lines of 10 th generation	G	Rahman <i>et al.</i> (2014)
		40 genotypes	P,G	Satish Kumar <i>et al.</i> (2014)
		18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
		21 genotypes	P,G	Ali <i>et al.</i> (2013)
		64 rice genotypes	P	Bekele <i>et al.</i> (2013)
		64 genotypes	P	Berhanu <i>et al.</i> (2013)
		14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
		6 Pure lines	P	Nagaraju <i>et al.</i> (2013)
		15 F ₁ hybrids	P,G	Nagaraju <i>et al.</i> (2013)
		100 rice genotypes	P	Basavaraja <i>et al.</i> (2012)
		64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
		28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
		44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
		14 genotypes	G	Mulugeta <i>et al.</i> (2012)
		40 rice germplasm lines	P,G	Rangare <i>et al.</i> (2012)
		21 hybrids	G	Ravindra Babu <i>et al.</i> (2012)
		14 rice genotypes	G	Seyoum <i>et al.</i> (2012)

Table 2.6 (Cont.)

			24 hybrids	----	Hasan <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
			47 genotypes	G	Jayasudha and Deepak (2010)
			40 genotypes	G	Khatu <i>et al.</i> (2010)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
		Negative	20 genotypes	----	Keya <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			20 genotypes	G	Imad <i>et al.</i> (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			34 genotypes	G	Krishnamurthy <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			21 rice hybrids	P	Babu <i>et al.</i> (2012)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			21 hybrids	P	Ravindra Babu <i>et al.</i> (2012)
			36 genotypes	P,G	Sravan <i>et al.</i> (2012)
			10 genotypes	----	Akhtar <i>et al.</i> (2011)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			10 rice hybrids	G	Rani and Reddy (2010)
4	Number of tillers per Plant	Positive	42 aman rice genotypes	----	Golam <i>et al.</i> (2015)
			49 genotypes	P,G	Mohammad and Kayvan (2014)

Table 2.6 (Cont.)

			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			40 genotypes	G	Satish Kumar <i>et al.</i> (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			21 genotypes	P,G	Ali <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	P	Gulzar <i>et al.</i> (2013)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
		Negative	24 Asian accessions	----	Sarfraz <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			21 varieties	G	Mamunur <i>et al.</i> (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			40 genotypes	P	Satish Kumar <i>et al.</i> (2014)
			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	G	Gulzar <i>et al.</i> (2013)
			34 genotypes	G	Krishnamurthy <i>et al.</i> (2013)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			10 genotypes	----	Akhtar <i>et al.</i> (2011)
			47 genotypes	G	Jayasudha and Deepak (2010)
5	Number of productive tillers	Positive	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			30 breeding lines of rice	----	Marzieh <i>et al.</i> (2015)
			30 genotypes	G	Pradhan <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)

Table 2.6 (Cont.)

			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)
			32 genotypes	P	Dhurai <i>et al.</i> (2014)
			20 genotypes	G	Imad <i>et al.</i> (2014)
			60 upland germplasm	P,G	Khare <i>et al.</i> (2014)
			64 elite mid early genotypes	P	Lingaiah <i>et al.</i> (2014)
			21 varieties	G	Mamunur <i>et al.</i> (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			7 advanced fine rice lines of 10 th generation	G	Rahman <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			65 genotypes of scented rice	P,G	Kumar <i>et al.</i> (2013)
			15 F ₁ hybrids	P,G	Nagaraju <i>et al.</i> (2013)
			64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			44 selected lines from F ₂ population	G	Ghaffar <i>et al.</i> (2012)
			21 hybrids	P,G	Ravindra Babu <i>et al.</i> (2012)
			36 genotypes	P	Sravan <i>et al.</i> (2012)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			47 genotypes	G	Jayasudha and Deepak (2010)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
			40 genotypes	G	Khatu <i>et al.</i> (2010)

Table 2.6 (Cont.)

			22 genotypes	---	Praveen <i>et al.</i> (2010)
			10 rice hybrids	G	Rani and Reddy (2010)
		Negative	20 genotypes	----	Keya <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			32 genotypes	G	Dhurai <i>et al.</i> (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			40 genotypes	P,G	Satish Kumar <i>et al.</i> (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			21 genotypes	P,G	Ali <i>et al.</i> (2013)
			34 genotypes	G	Krishnamurthy <i>et al.</i> (2013)
			36 genotypes	G	Sravan <i>et al.</i> (2012)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			22 genotypes	----	Nandan <i>et al.</i> (2010)
			10 rice varieties	G	Rani and Reddy (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
6	Panicle length	Positive	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			30 breeding lines of rice	P	Marzieh <i>et al.</i> (2015)
			30 genotypes	G	Pradhan <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			76 genotypes	P	Alam <i>et al.</i> (2014)
			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			32 genotypes	G	Dhurai <i>et al.</i> (2014)
			64 elite mid early genotypes	P	Lingaiah <i>et al.</i> (2014)
			7 advanced fine rice lines of 10 th generation	G	Rahman <i>et al.</i> (2014)

Table 2.6 (Cont.)

			40 genotypes	G	Satish Kumar <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			21 genotypes	G	Ali <i>et al.</i> (2013)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			34 genotypes	G	Krishnamurthy <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			21 rice hybrids	P	Babu <i>et al.</i> (2012)
			100 rice genotypes	P	Basavaraja <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			40 rice germplasm lines	P,G	Rangare <i>et al.</i> (2012)
			21 hybrids	P,G	Ravindra Babu <i>et al.</i> (2012)
			14 rice genotypes	G	Seyoum <i>et al.</i> (2012)
			36 genotypes	P,G	Sravan <i>et al.</i> (2012)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			10 rice hybrids	G	Rani and Reddy (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
		Negative	20 genotypes	----	Keya <i>et al.</i> (2015)
			35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
			76 genotypes	G	Alam <i>et al.</i> (2014)
			41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)

Table 2.6 (Cont.)

			32 genotypes	P	Dhurai <i>et al.</i> (2014)
			20 genotypes	G	Imad <i>et al.</i> (2014)
			60 upland germplasm	P,G	Khare <i>et al.</i> (2014)
			21 varieties	G	Mamunur <i>et al.</i> (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			40 genotypes	P	Satish Kumar <i>et al.</i> (2014)
			21 genotypes	P	Ali <i>et al.</i> (2013)
			15 F1 hybrids	P,G	Nagaraju <i>et al.</i> (2013)
			12 rice hybrids	G	Seesang <i>et al.</i> (2013)
			28 rice hybrids	G	Sudharani <i>et al.</i> (2013)
			64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
			44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
			10 rice genotypes	G	Gopikannan and Ganesh (2012)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			47 genotypes	G	Jayasudha and Deepak (2010)
			48 rice genotypes	G	Garg <i>et al.</i> (2010)
			10 rice varieties	G	Rani and Reddy (2010)
7	Number of total grains per panicle	Positive	20 advanced lines	----	Islam <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)
			32 genotypes	P	Dhurai <i>et al.</i> (2014)

Table 2.6 (Cont.)

			20 genotypes	G	Imad <i>et al.</i> (2014)
			21 varieties	G	Mamunur <i>et al.</i> (2014)
			49 genotypes	P,G	Mohammad and Kayvan (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			7 advanced fine rice lines of 10 th generation	G	Rahman <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			15 F ₁ hybrids	P,G	Nagaraju <i>et al.</i> (2013)
			64 exotic genotypes	G	Bineeta <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			36 genotypes	P,G	Sravan <i>et al.</i> (2012)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			10 rice hybrids	G	Rani and Reddy (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
		Negative	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			20 genotypes	----	Keya <i>et al.</i> (2015)
			30 elite low land rice	G	Pradhan <i>et al.</i> (2015)
			32 genotypes	G	Dhurai <i>et al.</i> (2014)

Table 2.6 (Cont.)

			60 upland germplasm	P,G	Khare <i>et al.</i> (2014)
			40 genotypes	P, G	Satish Kumar <i>et al.</i> (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			64 exotic genotypes	P	Bineeta <i>et al.</i> (2012)
			21 hybrids	P,G	Ravindra Babu <i>et al.</i> (2012)
			20 genotypes	G	Zulqarnain <i>et al.</i> (2012)
			10 genotypes	----	Akhtar <i>et al.</i> (2011)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			10 rice varieties	G	Rani and Reddy (2010)
8	Test weight	Positive	42 Aman rice genotypes	----	Golam <i>et al.</i> (2015)
			20 genotypes	----	Keya <i>et al.</i> (2015)
			30 elite low land rice	G	Pradhan <i>et al.</i> (2015)
			130 traditional land races	P	Sathisha <i>et al.</i> (2015)
			24 Asian accessions	----	Sarfaraz <i>et al.</i> (2015)
			100 F ₂ and F ₃ progenies	----	Singh <i>et al.</i> (2015)
			76 genotypes	P,G	Alam <i>et al.</i> (2014)
			15 CMS x 10 restores	P	Bornare <i>et al.</i> (2014)
			41 aromatic rice germplasm	G	Dilruba <i>et al.</i> (2014)
			21 varieties	G	Mamunur <i>et al.</i> (2014)
			49 genotypes	P,G	Mohammad and Kayvan (2014)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			7 advanced fine rice lines of 10 th generation	G	Rahman <i>et al.</i> (2014)
			40 genotypes	P	Satish Kumar <i>et al.</i> (2014)
			49 entries	G	Thirumala Rao (2014)

Table 2.6 (Cont.)

			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			40 rice genotypes	P,G	Gangashetty <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			65 genotypes of scented rice	P, G	Kumar <i>et al.</i> (2013)
			64 exotic genotypes	P,G	Bineeta <i>et al.</i> (2012)
			28 indigenous, 1 modern, 1 exotic cultivars	G	Bhabendra <i>et al.</i> (2012)
			44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
			36 genotypes	P,G	Sravan <i>et al.</i> (2012)
			14 rice genotypes	G	Seyoum <i>et al.</i> (2012)
			40 rice germplasm lines	P,G	Rangare <i>et al.</i> (2012)
			20 genotypes	----	Zulqarnain <i>et al.</i> (2012)
			10 genotypes	----	Akhtar <i>et al.</i> (2011)
			24 genotypes	----	Hasan <i>et al.</i> (2011)
			60 rice germ plasm lines	P	Pal <i>et al.</i> (2011)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			49 Iranian land races	P	Seyed (2011)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
			40 genotypes	G	Khatu <i>et al.</i> (2010)
			10 rice varieties	G	Rani and Reddy (2010)
			40 genotypes	G	Yadav <i>et al.</i> (2010)
		Negative	20 advanced lines	----	Islam <i>et al.</i> (2015)
			35 genotypes	P,G	Shajedur <i>et al.</i> (2015)
			32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			20 genotypes	G	Imad <i>et al.</i> (2014)
			60 upland germplasm	P,G	Khare <i>et al.</i> (2014)

Table 2.6 (Cont.)

			64 elite mid early genotypes	P	Lingaiah <i>et al.</i> (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			40 genotypes	G	Satish Kumar <i>et al.</i> (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			14 genotypes	G	Mulugeta <i>et al.</i> (2012)
			21 hybrids	P,G	Ravindra Babu <i>et al.</i> (2012)
			48 rice genotypes	G	Garg <i>et al.</i> (2010)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			10 rice hybrids	G	Rani and Reddy (2010)
9	Hulling percentage	Positive	76 rice genotypes	P,G	Madhusoodanan (2013)
			JGL 384 × Rasi cross combination and parents	P, G	Mahalingam <i>et al.</i> (2013)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			30 crosses	G	Prem Kumar <i>et al.</i> (2010)
10	Milling percentage	Positive	76 rice genotypes	P,G	Madhusoodanan (2013)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			30 crosses	G	Prem Kumar <i>et al.</i> (2010)
			23 rice genotypes	G	Nagajyothi (2001)
		Negative	15 F ₁ hybrids	P,G	Nagaraju <i>et al.</i> (2013)
			23 rice genotypes	P	Nagajyothi (2001)
11	Head rice recovery	Positive	70 genotypes	G	Krishna veni <i>et al.</i> (2013)

Table 2.6 (Cont.)

			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
		Negative	22 genotypes	----	Praveen <i>et al.</i> (2010)
12	Kernel Length	Positive	20 advanced lines	----	Islam <i>et al.</i> (2015)
			32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			49 genotypes	P,G	Mohammad and Kayvan (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
			49 Iranian land races	P	Seyed (2011)
			14 Basmati genotypes	----	Afzal <i>et al.</i> (2006)
			200 scented + 1 non scented (Check)	G	Nayak <i>et al.</i> (2001)
		Negative	130 traditional land races	----	Sathisha <i>et al.</i> (2015)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			30 crosses	G	Prem Kumar <i>et al.</i> (2010)
			200 scented + 1 non scented (Check)	P	Nayak <i>et al.</i> (2001)
13	Kernel breadth	Positive	32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			49 genotypes	P,G	Mohammad and Kayvan (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)

Table 2.6 (Cont.)

			64 genotypes	P	Berhanu <i>et al.</i> (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			44 selected lines from F ₂ population	----	Ghaffar <i>et al.</i> (2012)
			49 Iranian land races	P	Seyed (2011)
		Negative	20 advanced lines	----	Islam <i>et al.</i> (2015)
			22 upland genotypes	G	Nitiprasad and Lotan (2014)
			44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			96 accessions + 6 cultivars	G	Ruth <i>et al.</i> (2011)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
14	L/B ratio	Positive	130 traditional land races	----	Shathisha <i>et al.</i> (2015)
			32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			18 rainfed upland genotypes	P	Aditya and Anuradha (2013)
			14 diverse cold tolerant local red ecotypes	P,G	Gulzar <i>et al.</i> (2013)
			70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			65 genotypes of scented rice	P, G	Kumar <i>et al.</i> (2013)
			76 rice genotypes	P,G	Madhusoodanan <i>et al.</i> (2013)
			6 Pure lines	P	Nagraju <i>et al.</i> (2013)
			15 F ₁ hybrids	P,G	Nagaraju <i>et al.</i> (2013)
			60 rice germplasm lines	P	Pal <i>et al.</i> (2011)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
			200 scented + 1 non scented (Check)	P,G	Nayak <i>et al.</i> (2001)
		Negative	44 diverse genotypes	G	Patel <i>et al.</i> (2014)

Table 2.6 (Cont.)

			33 lines of F ₅ progenies	G	Awaneet and Senapati (2013)
			48 rice genotypes	P,G	Garg <i>et al.</i> (2010)
			40 genotypes	G	Khatu <i>et al.</i> (2010)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
15	Kernel length after cooking	Positive	70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			30 crosses	G	Prem Kumar <i>et al.</i> (2010)
		Negative	32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			14 Basmati genotypes	----	Afzal <i>et al.</i> (2006)
16	Kernel breadth after cooking	Positive	33 genotypes	----	Nandan <i>et al.</i> (2010)
		Negative	30 crosses	G	Prem Kumar <i>et al.</i> (2010)
17	Water uptake	Positive	70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			84 rice genotypes	P	Parvathi <i>et al.</i> (2010)
			30 crosses	G	Prem Kumar <i>et al.</i> (2010)
		Negative	33 genotypes	----	Nandan <i>et al.</i> (2010)
			84 rice genotypes	G	Parvathi <i>et al.</i> (2010)
18	Kernel elongation ratio	Positive	32 genotypes	P,G	Dhurai <i>et al.</i> (2014)
			76 rice genotypes	P,G	Madhusoodanan (2013)
			JGL 384 × Rasi cross combinations and parents	P,G	Mahalingam <i>et al.</i> (2013)
			33 genotypes	----	Nandan <i>et al.</i> (2010)
			84 rice genotypes	P, G	Parvathi (2010)
		Negative	70 genotypes	G	Krishna veni <i>et al.</i> (2013)
19	Volume expansion ratio	Positive	70 genotypes	G	Krishna veni <i>et al.</i> (2013)
			22 genotypes	----	Praveen <i>et al.</i> (2010)
20	Amylose content	Positive	70 genotypes	G	Krishna veni <i>et al.</i> (2013)

Table 2.6 (Cont.)

			100 rice genotypes	P	Basavaraja <i>et al.</i> (2012)
			48 rice genotypes	G	Garg <i>et al.</i> (2010)
			23 rice genotypes	P	Bhattacharyya <i>et al.</i> (2007)
		Negative	44 diverse genotypes	G	Patel <i>et al.</i> (2014)
			48 rice genotypes	P	Garg <i>et al.</i> (2010)
			23 rice genotypes	P, G	Nagajyothi (2001)
21	Leaf area index	Negative	20 genotypes	----	Zulqarnain <i>et al.</i> (2012)
			10 local biron rice	----	Ullah <i>et al.</i> (2011)

Table. 2.7. Review of literature on indirect effects among component characters with grain yield.

S. No	Character showing indirect effect on yield	Direction of effect	Characters through which effect is expressed	P/G	Reference
1	Days to 50% flowering	Positive	Days to maturity, plant height, total number of tillers per plant, effective tillers per plant, panicle length.	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, plant height, filled grains per plant, test weight.	----	Islam <i>et al.</i> (2015)
			Effective tillers per plant, number grains per plant	G	Pradhan <i>et al.</i> (2015)
			Days to 50% flowering, plant height, number of grains per panicle, test weight.	P,G	Shajedur <i>et al.</i> (2015)
			Days to 50% flowering, number of tillers per plant, panicle length, test weight.	G	Alam <i>et al.</i> (2014)
			Plant height, productive tillers, grain length, grain breadth.	G	Nitiprasad and Lotan (2014)
			Days to maturity, number of tillers per plant, grain length, grain breadth, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, number of tillers per plant, effective tillers per plant, kernel width.	P	Aditya and Anuradha(2013)
			Days to 50% flowering, plant height, number of tillers per plant, effective tillers per plant, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to 50% flowering, days to maturity, effective tillers per plant, grain length.	P	Berhanu <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length, grain length, L/B ratio.	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, number of tillers, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, ear bearing tillers, panicle length, head rice recovery, kernel length, kernel breadth, water uptake, volume expansion ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Day to 50% flowering, number of productive tillers, panicle length, number of spiklets, days to maturity, test weight.	P,G	Bineeta <i>et al.</i> (2012)
			Days to 50% flowering, days to maturity, plant height, panicle length, test weight.	G	Bhabendra <i>et al.</i> (2012)
			Days to 50% flowering, plant height, effective tillers , panicle length, number of grains per panicle.	G	Bhadru <i>et al.</i> (2012)
			Days to flowering, days to maturity, plant height, grain length, number of productive tillers per plant, number of grains per panicle	P	Seyed (2011)
			Days to 50 % flowering, plant height, panicle length, kernel breadth, milling percent, head rice recovery,	G	Ruth <i>et al.</i> (2011)
			Plant height, tillers per plant, panicle length, amylose content	P	Garg <i>et al.</i> (2010)
			Plant height, tillers per plant, test weight, protein content	G	Garg <i>et al.</i> (2010)
			Days to 50% flowering, tillers per plant, productive tillers per plant, panicle length	G	Jayasudha andd Deepak (2010)
			Days to 50% flowering, days to maturity,, grains per panicle, hulling per cent, elongation ratio	----	Nandan <i>et al.</i> (2010)

Table 2.7 (Cont.)

		Negative	Number of tillers per plant, number of panicles per plant, panicle length, , test weight	G	Yadav <i>et al.</i> (2010)
			Days to maturity, number of effective tillers per plant, plant height, number of grains per panicle,	G	Alam <i>et al.</i> (2014)
			Plant height, panicle length, days to maturity, number of tillers per plant, number of effective tillers per plant, number of grains per panicle,	P	Alam <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Total number of tillers, panicle length, number of grains per panicle, test weight	G	Nitiprasad and Lotan (2014)
			Plant height, productive tillers, panicle length, total number of grains per panicle, test weight, L/B ratio	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of ear bearing tillers, number of grains per panicle, grain length	P	Sathisha <i>et al.</i> (2015)
			Days to maturity, plant height, panicle length, number of grains per panicle, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to maturity, panicle length, number of grains per panicle, test weight, grain length, grain width	G	Awaneet and Senapati (2013)
			Plant height, number of tillers per plant, test weight, grain width.	P	Berhanu <i>et al.</i> (2013)
			Days to maturity, number of grains, panicle length, test weight, grain width	P	Gulzar <i>et al.</i> (2013)
			Number of tillers, number of grains, test weight, grain width,	G	Gulzar <i>et al.</i> (2013)
			Test weight/b ratio, kernel length after cooking, kernel elongation ratio,	G	Krishna veni <i>et al.</i> (2013)
			Number of tillers, number of effective tillers, number of spikelets per plant,	G	Bhabendra <i>et al.</i> (2012)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of tillers per plant, number of productive tillers per plant, number of grains per panicle, test weight	G	Mulugeta <i>et al.</i> (2012)
			Effective tillers per plant, filled grains per panicle, test weight, kernel length,	G	Ruth <i>et al.</i> (2011)
			Effective tillers, plant height, panicle length ,test weight, kernel length, kernel length after cooking, kernel breadth, L/B ratio, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Days to 50% flowering, plant height, number of spikelets per plant	G	Yadav <i>et al.</i> (2010)
2	Days to maturity	Positive	Days to 50% flowering, days to maturity, total number of tillers per plant, effective tillers per plant, panicle length, number of filled grains per plant, test weight	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of ear bearing tillers, number of grains per panicle, grain length	P	Sathisha <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, Plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Days to maturity, number of effective tillers per plant, panicle length, number of grains per panicle, L/B ratio, kernel length after cooking, kernel elongation ratio test weight	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of grains per panicle, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)

Table 2.7 (Cont.)

			Days to 50% flowering, number of tillers per plant, effective tillers per plant, number of grains per panicle, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to 50% flowering, days to maturity, plant height, number of tillers per plant, test weight, grain width.	P	Berhanu <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length, grain length, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, number of tillers, panicle length, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Day to 50% flowering, plant height, number of productive tillers, number of spikelets, days to maturity, test weight	P,G	Bineeta <i>et al.</i> (2012)
			Days to maturity, plant height, number of tillers, number of effective tillers, panicle length, number of spikelets per plant, test weight	G	Bhabendra <i>et al.</i> (2012)
			Days to 50% flowering, days to maturity, plant height, number of productive tillers per plant, test weight	P	Bhabendra <i>et al.</i> (2012)
			Number of grains per panicle, number of tillers per plant, days to maturity	----	Akhtar <i>et al.</i> (2011)
			Number of effective tillers per plant, days to 50% flowering, panicle length, days to maturity,	----	Hasan <i>et al.</i> (2011)
			Days to maturity, plant height, grain width, number of productive tillers per plant, test weight	P	Sayed (2011)
			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, kernel breadth, L/B ratio, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
		Negative	Days to maturity, plant height, number of tillers per plant, number of effective tillers per plant, panicle length	P	Alam <i>et al.</i> (2014)
			Plant height, panicle length, number of grains per panicle	G	Dilruba <i>et al.</i> (2014)
			Days to 50% flowering, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth,	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, Days to maturity, plant height, productive tillers, panicle length	G	Imad <i>et al.</i> (2014)
			Days to maturity, productive tillers, panicle length, total number of grains per panicle	P,G	Khare <i>et al.</i> (2014)
			Days to 50% flowering, plant height, panicle length, , productive tillers, total number of grains per panicle, test weight, L/B ratio, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of grains per panicle, test weight	G	Satish Kumar <i>et al.</i> (2014)
			Number of tillers per plant, effective tillers per plant, kernel width	P	Aditya and Anuradha (2013)
			Days to maturity, plant height, panicle length, test weight, grain length, grain width	G	Awaneet and Senapati (2013)
			Number of tillers, number of grains, test weight, grain width	G	Gulzar <i>et al.</i> (2013)
			Days to maturity, number of grains, test weight, grain width	P	Gulzar <i>et al.</i> (2013)
			Panicle length, number of tillers per plant, number of grains per panicle	G	Mulugeta <i>et al.</i> (2012)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation ratio	----	Nandan <i>et al.</i> (2010)

Table 2.7 (Cont.)

			Plant height, panicles per plant, days to maturity	----	Umakanta <i>et al.</i> (2001)
3	Plant height	Positive	Days to 50% flowering, plant height, number of filled grains per plant, test weight	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, Days to maturity, plant height, filled grains per plant, test weight		Islam <i>et al.</i> (2015)
			Days to 50% flowering, plant height, total number of tillers, panicle length, grain breadth	G	Nitiprasad and Lotan (2014)
			Days to 50% flowering, days to maturity, Plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Days to 50% flowering, plant height, kernel breadth, kernel length after cooking	P,G	Dhurai <i>et al.</i> (2014)
			Plant height, number of effective tillers, number of effective spikelets per plant	G	Mamunur <i>et al.</i> (2014)
			Days to maturity, number of tillers per plant, , total number of grains per panicle, grain length, grain breadth,	G	Patel <i>et al.</i> (2014)
			Plant height, productive tillers, panicle length, total number of grains per panicle, test weight	G	Rahman <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of grains per panicle, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Plant height, total number of tillers per plant, productive tillers per plant, panicle length, test weight	P,G	Ali <i>et al.</i> (2013)
			Plant height, number of tillers per plant, panicle length, grain length,	G	Awaneet and Senapati (2013)
			Days to 50% flowering, plant height, number of tillers per plant, test weight, grain width.	P	Berhanu <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, number of tillers, panicle length, test weight, grain length, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, panicle length, test weight, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Plant height, ear bearing tillers, test weight, head rice recovery, kernel length, L/B ratio, kernel length after cooking, kernel elongation ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Plant height, number of productive tillers, panicle length, days to maturity, test weight	P,G	Bineeta <i>et al.</i> (2012)
			Days to 50 % flowering, plant height, panicle length, test weight, kernel length head rice recovery	G	Ruth <i>et al.</i> (2011)
			Days to flowering, days to maturity, plant height, grain width, number of productive tillers per plant, number of grains per panicle, test weight	P	Sayed (2011)
			Tillers per plant, filled grains per panicle, test weight, protein content, amylose content	G	Garg <i>et al.</i> (2010)
			Tillers per plant, panicle length, filled grains per panicle, protein content	P	Garg <i>et al.</i> (2010)
			Effective tillers, days to maturity, plant height, grains per panicle, elongation ratio, kernel breadth, kernel breadth, water uptake	-----	Nandan <i>et al.</i> (2010)
			Days to 50% flowering, plant height, number of tillers per plant, number of panicles per plant, panicle length, number of spikelets per plant,	G	Yadav <i>et al.</i> (2010)
		Negative	Grain length, grain width		Islam <i>et al.</i> (2015)
			Days to maturity, total number of tillers per plant, effective tillers per plant, panicle length.	----	Golam <i>et al.</i> (2015)

Table 2.7 (Cont.)

			Number of ear bearing tillers, grain length, L/B ratio	P	Sathisha <i>et al.</i> (2015)
			Plant height, number of grains per panicle, test weight.	----	Sarfraz <i>et al.</i> (2015)
			Days to maturity, plant height, productive tillers per plant, test weight.	----	Singh <i>et al.</i> (2015)
			Panicle length, number of grains per panicle, test weight.	P,G	Shajedur <i>et al.</i> (2015)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle,	P,G	Alam <i>et al.</i> (2014)
			Days to maturity, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, L/B ratio, test weight, kernel elongation ratio.	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, panicle length, productive tillers, test weight, L/B ratio, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, effective tillers per plant, number of grains per panicle, test weight, grain width, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to maturity, effective tillers per plant, grain length.	P	Berhanu <i>et al.</i> (2013)
			Number of tillers, number of effective tillers, number of spikelets per plant, test weight	G	Bhabendra <i>et al.</i> (2012)
			Days to 50% flowering, panicle length, kernel breadth, volume expansion ratio,	G	Krishna veni <i>et al.</i> (2013)
			Plant height, total number of productive tillers per plant, number of grains per panicle, milling per cent, Kernel L/B ratio	P,G	Nagaraju <i>et al.</i> (2013)
			Days to maturity, panicle length, number of productive tillers per plant, number of grains per panicle, test weight	G	Mulugeta <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length, number of grains per panicle, test weight	P	Ravindra Babu <i>et al.</i> (2012)
			Panicles per plant, panicle length, spikelets per plant, test weight.	P,G	Sravan <i>et al.</i> (2012)
4	Number of tillers per plant	Positive	Days to 50% flowering, days to maturity, total number of tillers per plant, effective tillers per plant, panicle length.	----	Golam <i>et al.</i> (2015)
			Days to maturity, plant height, number of effective tillers per plant, number of grains per panicle	G	Alam <i>et al.</i> (2014)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle	P	Alam <i>et al.</i> (2014)
			Plant height, number of effective tillers, number of effective spikelets per plant, maximum number of tillers	G	Mamunur <i>et al.</i> (2014)
			Days to 50% flowering, total number of tillers, panicle length, number of grains per panicle, grain length, grain breadth	G	Nitiprasad and Lotan (2014)
			Number of tillers per plant, effective tillers per plant, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Total number of tillers per plant, productive tillers per plant, panicle length	G	Ali <i>et al.</i> (2013)
			Plant height, total number of tillers per plant, productive tillers per plant, panicle length,	P	Ali <i>et al.</i> (2013)
			Days to maturity, number of tillers per plant, effective tillers per plant, grain length	P	Berhanu <i>et al.</i> (2013)

Table 2.7 (Cont.)

			Days to 50% flowering, days to maturity, number of tillers, number of grains, grain length, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, number of tillers, number of grains, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Number of tillers, number of effective tillers, number of spikelets per plant, test weight	G	Bhabendra <i>et al.</i> (2012)
			Days to 50% flowering, , number of tillers per plant, number of grains per panicle, test weight	G	Mulugeta <i>et al.</i> (2012)
			Number of grains per panicle, number of tillers per plant, plant height, days to maturity	----	Akhtar <i>et al.</i> (2011)
			Plant height, number of tillers per plant, number of panicles per plant,	G	Yadav <i>et al.</i> (2010)
			Plant height, total tillers per plant, panicle length, filled grains per plant, test weight	G	Rahim <i>et al.</i> (2007)
			Plant height, cooked grain length	----	Afzal <i>et al.</i> (2006)
		Negative	Plant height, number of filled grains per plant, test weight.	----	Golam <i>et al.</i> (2015)
			Number of grains per panicle, test weight.	----	Sarfraz <i>et al.</i> (2015)
			Days to 50% flowering, number of tillers per plant, panicle length, test weight.	G	Alam <i>et al.</i> (2014)
			Days to 50% flowering, number of tillers per plant, , test weight.	P	Alam <i>et al.</i> (2014)
			Days to 50% flowering, plant height, panicle length, productive tillers, test weight, grain length, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of grains per panicle	G	Satish Kumar <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of grains per panicle, kernel width	P	Aditya and Anuradha (2013)
			Days to 50% flowering, plant height, test weight, grain width.	P	Berhanu <i>et al.</i> (2013)
			Plant height, panicle length, test weight, grain width,	G	Gulzar <i>et al.</i> (2013)
			Days to maturity, plant height, panicle length, test weight, grain width	P	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length,	G	Bhabendra <i>et al.</i> (2012)
			Days to maturity, Plant height, panicle length, number of productive tillers per plant	G	Mulugeta <i>et al.</i> (2012)
			Days to 50% flowering, panicle length, number of spikelets per plant, test weight	G	Yadav <i>et al.</i> (2010)
			Days to 50% flowering, effective tillers per plant	G	Rahim <i>et al.</i> (2007)
5	Number of productive tillers per plant	Positive	Days to 50% flowering, days to maturity, total number of tillers per plant, effective tillers per plant, panicle length.	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle	P	Alam <i>et al.</i> (2014)
			Days to maturity, plant height, productive tillers, panicle length	G	Dilruba <i>et al.</i> (2014)
			Days to 50% flowering, number of effective tillers per plant, panicle length, number of grains per panicle, test weight, kernel length, kernel breadth, L/B ratio, kernel length after cooking, test weight.	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, productive tillers, panicle length	G	Imad <i>et al.</i> (2014)
			Days to 50% flowering, productive tillers, panicle length, total number of grains per panicle	P,G	Khare <i>et al.</i> (2014)
			Days to maturity, number of tillers per plant, total number of grains per panicle, test weight, grain	G	Patel <i>et al.</i> (2014)

Table 2.7 (Cont.)

			breadth, L/B ratio		
			Plant height, productive tillers, panicle length, total number of grains per panicle, test weight	G	Rahman <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of grains per panicle	G	Satish Kumar <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, effective tillers per plant, panicle length, number of grains per panicle, kernel width	P	Aditya and Anuradha (2013)
			Days to 50% flowering, plant height, number of tillers per plant, effective tillers per plant, number of grains per panicle, test weight, grain width	G	Awaneet and Senapati (2013)
			Days to 50% flowering, ear bearing tillers, panicle length, head rice recovery, kernel elongation ratio, water uptake, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)
			Total number of productive tillers per plant, plant length, number of grains per panicle, milling per cent, Kernel L/B ratio	P,G	Nagaraju <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, number of productive tillers per plant, number of grains per panicle, test weight	G	Mulugeta <i>et al.</i> (2012)
			Number of productive tillers per plant, number of grains per panicle, test weight	P	Ravindra Babu <i>et al.</i> (2012)
			Plant height, panicles per plant, panicle length, spikelet per plant, test weight.	P	Sravan <i>et al.</i> (2012)
			Days to flowering, days to maturity, plant height, panicle length, number of productive tillers per plant, number of grains per panicle	P	Sayed (2011)
			Plant height, panicles per plant, days to maturity,	G	Khatu <i>et al.</i> (2010)
			Days to 50% flowering, panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, L/B ratio,	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, number of spikelet per plants, test weight, volume expansion ratio hulling per cent, milling per cent, head rice recovery, kernel breadth	----	Praveen <i>et al.</i> (2010)
		Negative	Plant height, number of filled grains per plant, test weight.	----	Golam <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, panicle length, test weight.	G	Pradhan <i>et al.</i> (2015)
			Number of tillers per plant,, test weight.	P	Alam <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, Effective tillers per plant, Plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Number of grains per panicle, test weight	G	Dilruba <i>et al.</i> (2014)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, test weight.	P,G	Dhurai <i>et al.</i> (2014)
			Maximum number of tillers, number of effective spikelets per plant, test weight	G	Mamunur <i>et al.</i> (2014)
			Plant height, productive tillers, panicle length, number of grains per panicle, grain length, grain breadth	G	Nitiprasad and Lotan (2014)
			Days to 50% flowering, plant height, panicle length, productive tillers, grain length, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of grains per panicle	G	Satish Kumar <i>et al.</i> (2014)

Table 2.7 (Cont.)

6	Panicle length	Positive	Plant height, productive tillers, panicle length, number of grains per panicle, test weight	G	Thirumala rao <i>et al.</i> (2014)
			Number of tillers per plant, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Plant height, test weight, kernel length, kernel breadth, L/B ratio, kernel length after cooking, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, number of spikelets per plant	G	Bhabendra <i>et al.</i> (2012)
			Plant height, panicle length, number of grains per panicle	G	Bhadru <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length, number of grains per panicle, test weight	G	Ravindra Babu <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length	P	Ravindra Babu <i>et al.</i> (2012)
			Plant height, panicle length, spikelets per plant, test weight.	G	Sravan <i>et al.</i> (2012)
			Days to 50 % flowering, panicle length, test weight, kernel length, milling percent, head rice recovery	G	Ruth <i>et al.</i> (2011)
			Plant height, number of filled grains per plant, test weight.	----	Golam <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, panicle length, test weight.	G	Pradhan <i>et al.</i> (2015)
			Days to maturity, plant height, number of effective tillers per plant, number of grains per panicle	G	Alam <i>et al.</i> (2014)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle	P	Alam <i>et al.</i> (2014)
			Days to maturity, number of tillers per plant, panicle length, total number of grains per panicle, , grain length, grain breadth, amylose content	G	Patel <i>et al.</i> (2014)
			Plant height, total number of tillers per plant, productive tillers per plant, panicle length, test weight	G	Ali <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of grains per panicle, kernel width	P	Aditya and Anuradha (2013)
			Days to maturity, number of tillers per plant, panicle length, grain length, grain width	G	Awaneet and Senapati (2013)
			Days to 50% flowering, days to maturity, plant height, number of tillers, panicle length, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, ear bearing tillers, panicle length, head rice recovery, kernel elongation ratio, water uptake, volume expansion ratio,	G	Krishna veni <i>et al.</i> (2013)
			Days to maturity, panicle length, number of tillers per plant, number of productive tillers per plant, number of grains per panicle, test weight	G	Mulugeta <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length, number of grains per panicle, test weight	P,G	Ravindra Babu <i>et al.</i> (2012)
			Plant height, panicles per plant, panicle length, spikelets per plant, test weight.	P,G	Sravan <i>et al.</i> (2012)
			Plant height, number of effective tillers per plant, panicle length, days to maturity, test weight	----	Hasan <i>et al.</i> (2011)
			Days to 50 % flowering, panicle length, test weight, kernel breadth, head rice recovery	G	Ruth <i>et al.</i> (2011)
			Days to flowering, days to maturity, plant height, grain length, grain width, panicle length, number of grains per panicle	P	Seyed (2011)
			Plant height, ear bearing tillers per plant, test weight, protein content, amylose content	G	Garg <i>et al.</i> (2010)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation	----	Nandan <i>et al.</i> (2010)

Table 2.7 (Cont.)

			ratio, water uptake		
		Negative	Days to 50% flowering, days to maturity, total number of tillers per plant, effective tillers per plant.	----	Golam <i>et al.</i> (2015)
			Plant height, productive tillers, panicle length, number of grains per panicle	G	Dilruba <i>et al.</i> (2014)
			Days to 50% flowering, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, L/B ratio,	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, productive tillers, panicle length, test weight	G	Imad <i>et al.</i> (2014)
			Days to maturity, productive tillers, panicle length, total number of grains per panicle, test weight	P,G	Khare <i>et al.</i> (2014)
			Maximum number of tillers, number of effective tillers, test weight	G	Mamunur <i>et al.</i> (2014)
			Number of tillers per plant, effective tillers per plant, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to 50% flowering, plant height, effective tillers per plant, number of grains per panicle, test weight, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to maturity, number of tillers, number of grains, test weight, grain length, grain width	P	Gulzar <i>et al.</i> (2013)
			Test weight, kernel length, kernel breadth, L/B ratio, kernel length after cooking, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Plant height, total number of productive tillers per plant, plant length, number of grains per panicle, milling per cent,	P,G	Nagaraju et at. (2013)
			Day to 50% flowering, plant height, number of productive tillers, panicle length, number of spikelets,	G	Bineeta <i>et al.</i> (2012)
			Effective tillers per plant, plant height, filled grains per panicle, kernel length, milling percent	G	Ruth <i>et al.</i> (2011)
			Number of productive tillers per plant, , test weight	P	Sayed (2011)
			Days to 50% flowering, tillers per plant, panicle length	G	Jayasudha and Deepak (2010)
			Tillers per plant, filled grains per panicle, test weight, protein content, amylose content.	P	Garg <i>et al.</i> (2010)
			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, kernel breadth after cooking, L/B ratio, kernel breadth	----	Nandan <i>et al.</i> (2010)
7	Number of total grains per panicle	Positive	Days to maturity, plant height.	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, Days to maturity, plant height, filled grains per plant, test weight	----	Islam <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, panicle length	G	Pradhan <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of ear bearing tillers, grain length, L/B ratio	P	Sathisha <i>et al.</i> (2015)
			Days to maturity, plant height, number of effective tillers per plant, number of grains per panicle	G	Alam <i>et al.</i> (2014)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle	P	Alam <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, Plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, test weight, kernel length, L/B ratio, ratio.	P,G	Dhurai <i>et al.</i> (2014)

Table 2.7 (Cont.)

			Days to 50% flowering, days to maturity, plant height, total number of grains per panicle, test weight	P,G	Khare <i>et al.</i> (2014)
			Days to 50% flowering, number of tillers per plant, total number of grains per panicle, test weight, grain length, grain breadth, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, panicle length, number of grains per panicle, test weight, kernel width	P	Aditya and Anuradha (2013)
			Days to 50% flowering, days to maturity, number of tillers per plant, panicle length, number of grains per panicle, test weight, grain width	G	Awaneet and Senapati (2013)
			Days to 50% flowering, days to maturity, plant height, number of tillers, number of grains, panicle length, test weight, grain length, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, panicle length, test weight, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Total number of productive tillers per plant, plant length, number of grains per panicle, milling per cent, Kernel L/B ratio	P,G	Nagaraju <i>et al.</i> (2013)
			Number of grains per panicle, number of tillers per plant, plant height, test weight,	----	Akhtar <i>et al.</i> (2011)
			Plant height, number of productive tillers,	G	Bineeta <i>et al.</i> (2012)
			Day to 50% flowering, panicle length, number of spiklets, days to maturity, test weight	P	Bineeta <i>et al.</i> (2012)
			Number of grains per panicle, leaf area	----	Zulqarnain <i>et al.</i> (2012)
			Days to 50 % flowering, panicle length, filled grains per panicle, kernel breadth, milling percent, head rice recovery,	G	Ruth <i>et al.</i> (2011)
			Days to flowering, days to maturity, plant height, grain length, panicle length, number of productive tillers per plant, number of grains per panicle	P	Sayed (2011)
			Number of panicles per plant, number of spiklets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, hulling per cent, elongation ratio, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
		Negative	Days to 50% flowering, total number of tillers per plant, effective tillers per plant, panicle length, number of filled grains per plant, test weight.	----	Golam <i>et al.</i> (2015)
			Number of effective tillers, plant height, number of grains per panicle, test weight.	P,G	Shajedur <i>et al.</i> (2015)
			Days to 50% flowering, number of tillers per plant, panicle length, test weight.	G	Alam <i>et al.</i> (2014)
			Days to 50% flowering, number of tillers per plant, test weight.	P	Alam <i>et al.</i> (2014)
			Days to maturity, plant height, productive tillers, number of grains per panicle, test weight	G	Dilruba <i>et al.</i> (2014)
			Days to 50% flowering, panicle length, number of grains per panicle, kernel breadth, kernel length after cooking, kernel elongation	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, productive tillers, panicle length, number of grains per panicle, test weight	G	Imad <i>et al.</i> (2014)
			Days to 50% flowering, productive tillers, panicle length	P,G	Khare <i>et al.</i> (2014)

Table 2.7 (Cont.)

			Panicle length, number of effective tillers, maximum number of tillers,, test weight	G	Mamunur <i>et al.</i> (2014)
			Days to 50% flowering, plant height, total number of tillers, productive tillers, number of grains per panicle, test weight	G	Nitiprasad and Lotan (2014)
			Day to 50% flowering, panicle length, number of spiklets, days to maturity, test weight	G	Bineeta <i>et al.</i> (2012)
			Days to 50% flowering, plant height, number of tillers per plant, number of productive tillers per plant,	G	Mulugeta <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length, number of grains per panicle	G	Ravindra Babu <i>et al.</i> (2012)
			Days to 50% flowering, plant height, panicle length, number of productive tillers per plant, number of grains per panicle, test weight	P	Ravindra Babu <i>et al.</i> (2012)
			Panicle length, test weight, kernel length, kernel length after cooking, kernel breadth after cooking, L/B ratio,	----	Nandan <i>et al.</i> (2010)
			Test weight, head rice recovery, kernel breadth, kernel length,	----	Praveen <i>et al.</i> (2010)
			Number of tillers per plant, number of panicles per plant, panicle length, test weight	G	Yadav <i>et al.</i> (2010)
			Days to 50% flowering, panicle number per plant, panicle length, test weight, grain length, L/B ratio	G	Nayak <i>et al.</i> (2001)
			Days to 50% flowering, panicle number per plant, panicle length, test weight, L/B ratio	P	Nayak <i>et al.</i> (2001)
8	Test weight	Positive	Days to maturity, plant height.	----	Golam <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, panicle length, number grains per panicle	G	Pradhan <i>et al.</i> (2015)
			Plant height, panicle length, test weight, grain length, L/B ratio	P	Sathisha <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, Plant height, panicle length, number of spikelets per panicle, test weight	P	Bornare <i>et al.</i> (2014)
			Days to maturity, , number of effective tillers per plant, panicle length, number of grains per panicle, L/B ratio, , kernel elongation ratio test weight	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, productive tillers, panicle length, number of grains per panicle, test weight	G	Imad <i>et al.</i> (2014)
			Days to 50% flowering, number of tillers per plant, panicle length, number of grains per panicle, test weight, grain length, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to 50% flowering, plant height, number of tillers per plant, test weight, grain length, grain width.	P	Berhanu <i>et al.</i> (2013)
			Plant height, number of tillers, test weight, grain width, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to maturity, plant height, test weight, grain width, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, ear bearing tillers, panicle length, test weight, head rice recovery, L/B ratio, kernel elongation ratio, volume expansion ratio,	G	Krishna veni <i>et al.</i> (2013)
			Day to 50% flowering, plant height, number of spiklets, days to maturity, test weight	P,G	Bineeta <i>et al.</i> (2012)
			Days to 50% flowering, days to maturity, plant height, number of tillers, number of effective tillers, panicle length, number of spikelets per plant, test weight	G	Bhabendra <i>et al.</i> (2012)

Table 2.7 (Cont.)

			Days to flowering, days to maturity, plant height, grain length, number of productive tillers per plant, number of grains per panicle, test weight	P	Seyed (2011)
			Ear bearing tillers per plant, panicle length, protein content, grain length	G	Garg <i>et al.</i> (2010)
			Ear bearing tillers per plant, amylose content, grain length	P	Garg <i>et al.</i> (2010)
			Plant height, panicles per plant, days to maturity,	G	Khatu <i>et al.</i> (2010)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, test weight, elongation ratio, water uptake	----	Nandan <i>et al.</i> (2010)
			Number of spiklets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
		Negative	Ear bearing tillers per plant	G	Pradhan <i>et al.</i> (2015)
			Plant height, productive tillers per plant	----	Singh <i>et al.</i> (2015)
			Days to 50% flowering, total number of tillers per plant, effective tillers per plant, panicle length, number of filled grains per plant, test weight.	----	Golam <i>et al.</i> (2015)
			Days to 50% flowering, Days to maturity, plant height, filled grains per plant, test weight, grain length	----	Islam <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, number of ear bearing tillers, number of grains per panicle	P	Sathisha <i>et al.</i> (2015)
			Days to maturity, number of effective tillers per plant, plant height, number of grains per panicle	G	Alam <i>et al.</i> (2014)
			Days to maturity, number of effective tillers per plant, plant height, panicle length, number of grains per panicle,	P	Alam <i>et al.</i> (2014)
			Productive tillers, panicle length, number of grains per panicle, test weight	G	Dilruba <i>et al.</i> (2014)
			Plant height, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel length after cooking	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of tillers per plant, effective tillers per plant, number of grains per panicle, test weight, kernel length, kernel width, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to 50% flowering, days to maturity, number of grains, panicle length, grain length,	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, number of tillers, number of grains, panicle length, grain length	P	Gulzar <i>et al.</i> (2013)
			Kernel length, kernel breadth, kernel length after cooking, water uptake, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Days to 50% flowering, panicle length, number of productive tillers per plant, test weight	G	Ravindra Babu <i>et al.</i> (2012)
			Plant height, tillers per plant, filled rains per panicle, amylose content	G	Garg <i>et al.</i> (2010)
			Panicle length, hulling per cent, kernel length, kernel length after cooking, kernel breadth after cooking, L/B ratio, kernel breadth	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
			Panicle length, kernel elongation ratio	P, G	Krishna <i>et al.</i> (2009a)
			Effective tillers per plant, panicle length, filled grains per plant,	G	Rahim <i>et al.</i> (2007)
			Plant height, cooked grain length	----	Afzal <i>et al.</i> (2006)

Table 2.7 (Cont.)

9	Hulling percentage	Positive	Productive tillers per plant, panicle length	P, G	Nagajyothi (2001)
			Days to 50% flowering, panicle length, grains per panicle, test weight, hulling per cent, kernel length, kernel length after cooking, kernel breadth, L/B ratio, kernel breadth	----	Nandan <i>et al.</i> (2010)
			Ear bearing tillers per plant, days to 50% flowering, grain width, test weight, kernel length and head rice recovery percentage	P, G	Parvathi (2010)
			Number of panicles per plant, number of spiklets per plants, test weight, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Hulling per cent, milling per cent, kernel length after cooking, water uptake	G	Prem Kumar <i>et al.</i> (2010)
		Negative	Test weight, amylose content, protein content	P, G	Nagajyothi (2001)
			Effective tillers, days to maturity, plant height, elongation ratio, water uptake	----	Nandan <i>et al.</i> (2010)
			Head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
			Kernel length, kernel breadth after cooking	G	Prem Kumar <i>et al.</i> (2010)
10	Milling percentage	Positive	Plant height, plant length	P,G	Nagaraju et at. (2013)
			Days to 50 % flowering, test weight, head rice recovery, plant height, kernel length, milling percent	G	Ruth <i>et al.</i> (2011)
			Productive tillers per plant, test weight, amylose content and head rice recovery percentage	P, G	Parvathi (2010)
			Number of panicles per plant, number of spiklets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Hulling per cent, milling per cent, kernel length after cooking, , water uptake	G	Prem Kumar <i>et al.</i> (2010)
			Amylose content	P, G	Nagajyothi (2001)
		Negative	Productive tillers per plant, panicle length, test weight, hulling per cent	P, G	Nagajyothi (2001)
			Total number of productive tillers per plant, plant length, number of grains per panicle, milling per cent, Kernel L/B ratio	P,G	Nagaraju et at. (2013)
			Effective tillers per plant, panicle length, filled grains per panicle, kernel breadth	G	Ruth <i>et al.</i> (2011)
			Test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
			Kernel length, kernel breadth after cooking	G	Prem Kumar <i>et al.</i> (2010)
11	Head rice recovery (HRR)	Positive	Days to 50% flowering, ear bearing tillers, panicle length, head rice recovery, kernel length after cooking, kernel elongation ratio, water uptake, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)
			Days to 50 % flowering, test weight, kernel breadth, head rice recovery, plant height, milling percent	G	Ruth <i>et al.</i> (2011)
			Number of spiklets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Plant height, panicle length and grains/panicle	P, G	Nayak <i>et al.</i> (2001)
		Negative	Plant height, test weight, kernel length, kernel breadth, L/B ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Effective tillers per plant, panicle length, filled grains per panicle, kernel length	G	Ruth <i>et al.</i> (2011)
			Number of panicles per plant, test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)

Table 2.7 (Cont.)

12	Kernel length	Positive	Test weight, kernel length, kernel breadth	----	Islam <i>et al.</i> (2015)
			Plant height, panicle length, number of ear bearing tillers	P	Sathisha <i>et al.</i> (2015)
			Days to 50% flowering, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, L/B ratio	P,G	Dhurai <i>et al.</i> (2014)
			Days to maturity, productive tillers, total number of grains per panicle, test weight, grain length, grain breadth,, amylose content	G	Patel <i>et al.</i> (2014)
			Panicle length, number of grains per panicle, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to maturity, number of tillers per plant, panicle length, number of grains per panicle, L/B ratio.	G	Awaneet and Senapati (2013)
			Number of tillers, number of grains, panicle length, test weight, grain width, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to maturity, number of grains, panicle length, test weight, grain width, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, ear bearing tillers, panicle length, head rice recovery, kernel elongation ratio, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)
			Effective tillers , panicle length, test weight, grain length	----	Ghaffar <i>et al.</i> (2012)
			Days to 50 % flowering, Effective tillers per plant, plant height, kernel length, panicle length, test weight, kernel breadth, head rice recovery	G	Ruth <i>et al.</i> (2011)
			Plant height, grain length, test weight	P	Sayed (2011)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation ratio, , kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, number of spiklets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Hulling per cent, milling per cent, kernel length, kernel length after cooking, kernel breadth after cooking, water uptake	G	Prem Kumar <i>et al.</i> (2010)
		Negative	Days to 50% flowering, Days to maturity, plant height, filled grains per plant	----	Islam <i>et al.</i> (2015)
			Days to 50% flowering, days to maturity, number of grains per panicle, test weight, grain length, L/B ratio	P	Sathisha <i>et al.</i> (2015)
			Days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, kernel breadth, kernel length after cooking, kernel, test weight, elongation ratio.	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, number of grains per panicle, test weight, grain length, grain breadth	G	Nitiprasad and Lotan (2014)
			Days to 50% flowering, plant height, panicle length, number of tillers per plant, L/B ratio	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of tillers per plant, effective tillers per plant, test weight, kernel length, kernel width	P	Aditya and Anuradha (2013)
			Days to 50% flowering, plant height, effective tillers per plant, test weight, grain length, grain width	G	Awaneet and Senapati (2013)
			Test weight, kernel length, kernel breadth, L/B ratio, kernel length after cooking, water uptake, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Plant height, grain width, number of grains per panicle	----	Ghaffar <i>et al.</i> (2012)

Table 2.7 (Cont.)

13	Kernel Breadth		Filled grains per panicle, milling percent	G	Ruth <i>et al.</i> (2011)
			Days to flowering, days to maturity, grain width, panicle length, number of productive tillers per plant, number of grains per panicle,	P	Seyed (2011)
			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, kernel breadth, L/B ratio	----	Nandan <i>et al.</i> (2010)
			Test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
			Plant height, number of grains per panicle, cooked grain length	----	Afzal <i>et al.</i> (2006)
		Positive	Days to 50% flowering, Days to maturity, plant height, filled grains per plant, test weight	----	Islam <i>et al.</i> (2015)
			Days to 50% flowering, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, test weight, kernel breadth, kernel elongation ratio.	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, productive tillers, panicle length, L/B ratio	G	Patel <i>et al.</i> (2014)
			Panicle length, number of grains per panicle, test weight,	P	Aditya and Anuradha (2013)
			Days to 50% flowering, number of tillers per plant, number of grains per panicle, grain length, grain width, L/B ratio.	G	Awaneet and Senapati (2013)
			Number of tillers, number of grains, test weight, , grain width, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Plant height, test weight, kernel length, kernel breadth, kernel length after cooking, water uptake, amylose content.	G	Krishna Veni <i>et al.</i> (2013)
			Plant height, effective tillers , panicle length, test weight, grain width,	----	Ghaffar <i>et al.</i> (2012)
			Filled grains per panicle, kernel length, milling percent, test weight, kernel breadth,	G	Ruth <i>et al.</i> (2011)
			Grain length, grain width, number of productive tillers per plant,, test weight	P	Seyed (2011)
			Days to 50% flowering, days to maturity, grains per panicle, elongation ratio, kernel breadth after cooking, L/B ratio, kernel breadth	----	Nandan <i>et al.</i> (2010)
			Number of spiklets per plants, test weight, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
		Negative	Kernel length, kernel breadth	----	Islam <i>et al.</i> (2015)
			Days to maturity, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, L/B ratio, kernel length after cooking	P,G	Dhurai <i>et al.</i> (2014)
			Grain length	P,G	Mohammad and Kayvan (2014)
			Days to 50% flowering, plant height, panicle length, number of grains per panicle, grain length, grain breadth	G	Nitiprasad and Lotan (2014)
			Days to maturity, number of tillers per plant, total number of grains per panicle, test weight, grain length, grain breadth, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of tillers per plant, effective tillers per plant, kernel length, kernel width, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to maturity, plant height, effective tillers per plant, panicle length, test weight	G	Awaneet and Senapati (2013)

Table 2.7 (Cont.)

			Days to maturity, effective tillers per plant, grain length	P	Berhanu <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length, grain length	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, number of tillers, panicle length, grain length, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, ear bearing tillers, panicle length, head rice recovery, L/B ratio, kernel elongation ratio, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)
			Grain length, number of grains per panicle	----	Ghaffar <i>et al.</i> (2012)
			Days to 50 % flowering, Effective tillers per plant, plant height, panicle length, head rice recovery	G	Ruth <i>et al.</i> (2011)
			Days to flowering, days to maturity, plant height, panicle length, number of grains per panicle	P	Seyed (2011)
			Effective tillers, plant height, panicle length, test weight, hulling per cent, kernel length, kernel length after cooking,, water uptake	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
14	L/B ratio	Positive	Panicle length, number of ear bearing tillers, number of grains per panicle, test weight, grain length, L/B ratio	P	Sathisha <i>et al.</i> (2015)
			Days to maturity, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, L/B ratio	P,G	Dhurai <i>et al.</i> (2014)
			Days to maturity, total number of grains per panicle, grain length, grain breadth, amylose content	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, days to maturity, plant height, number of tillers per plant, effective tillers per plant, test weight, kernel length, L/B ratio.	P	Aditya and Anuradha (2013)
			Days to maturity, number of tillers per plant, effective tillers per plant, panicle length, test weight, grain length, grain width, L/B ratio.	G	Awaneet and Senapati (2013)
			Days to 50% flowering, days to maturity, plant height, panicle length, test weight, L/B ratio	G	Gulzar <i>et al.</i> (2013)
			Days to 50% flowering, plant height, number of tillers, panicle length, test weight, L/B ratio	P	Gulzar <i>et al.</i> (2013)
			Total number of productive tillers per plant, number of grains per panicle, milling per cent, Kernel L/B ratio	P,G	Nagaraju et at. (2013)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation ratio, kernel breadth after cooking, L/B ratio, kernel breadth	----	Nandan <i>et al.</i> (2010)
		Negative	Days to 50% flowering, days to maturity, plant height	P	Sathisha <i>et al.</i> (2015)
			Days to 50% flowering, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, kernel breadth, kernel length after cooking, kernel. Test weight, elongation ratio.	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, plant height, panicle length, number of tillers per plant, productive tillers, test weight, L/B ratio	G	Patel <i>et al.</i> (2014)
			Panicle length, number of grains per panicle, kernel width	P	Aditya and Anuradha (2013)
			Days to 50% flowering, plant height, number of grains per panicle	G	Awaneet and Senapati (2013)
			Number of tillers, number of grains, grain length, grain width	G	Gulzar <i>et al.</i> (2013)

Table 2.7 (Cont.)

			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, water uptake	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
15	Kernel length after cooking	Positive	Test weight, head rice recovery, kernel length, kernel breadth, L/B ratio, kernel length after cooking, kernel elongation ratio, water uptake, volume expansion ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, kernel after cooking, breadth, L/B ratio	----	Nandan <i>et al.</i> (2010)
			Number of productive tillers per plant, test weight, amylose content and protein percentage.	P,G	Parvathi (2010)
			Hulling per cent, milling per cent, kernel length after cooking, kernel breadth after cooking	G	Prem Kumar <i>et al.</i> (2010)
			Tillers per plant, test weight, number of grains per panicle, grain length	----	Afzal <i>et al.</i> (2006)
		Negative	Days to 50% flowering, plant height, ear bearing tillers, panicle length,	G	Krishna veni <i>et al.</i> (2013)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation ratio, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Kernel length, water uptake	G	Prem Kumar <i>et al.</i> (2010)
			Plant height, cooked grain length	----	Afzal <i>et al.</i> (2006)
16	Kernel breadth after cooking	Positive	Effective tillers, plant height, panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, , kernel breadth after cooking, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Hulling per cent, milling per cent, kernel length, kernel length after cooking	G	Prem Kumar <i>et al.</i> (2010)
		Negative	Days to 50% flowering, days to maturity, grains per panicle, elongation ratio, L/B ratio	----	Nandan <i>et al.</i> (2010)
			Kernel breadth after cooking, water uptake	G	Prem Kumar <i>et al.</i> (2010)
17	Kernel elongation ratio	Positive	Number of effective tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, L/B ratio,, kernel elongation ratio.	P,G	Dhurai <i>et al.</i> (2014)
			Plant height, test weight, kernel length, kernel breadth, L/B ratio, water uptake, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Panicle length, test weight, hulling per cent, kernel length, kernel length after cooking, kernel breadth after cooking, L/B ratio, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Test weight, amylose content, and head rice recovery percentage.	P,G	Parvathi (2010)
		Negative	Days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, kernel length after cooking. Test weight	P,G	Dhurai <i>et al.</i> (2014)
			Days to 50% flowering, ear bearing tillers, panicle length, head rice recovery, kernel length after cooking, elongation ratio, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)
			Effective tillers, days to 50% flowering, days to maturity, plant height, grains per panicle, elongation ratio	----	Nandan <i>et al.</i> (2010)
			Days to 50% flowering, no. Of effective tillers per plant, plant height	P, G	Krishna <i>et al.</i> (2009a)
18	Volume expansion	Positive	Days to 50% flowering, plant height, ear bearing tillers, panicle length, head rice recovery, L/B ratio, kernel length after cooking, kernel elongation ratio, water uptake, volume expansion ratio	G	Krishna veni <i>et al.</i> (2013)

Table 2.7 (Cont.)

	ratio		Days to 50% flowering, days to maturity, panicle length, grains per panicle, test weight, hulling per cent, kernel length, kernel length after cooking, elongation ratio,, kernel breadth, water uptake	----	Nandan <i>et al.</i> (2010)
			Number of panicles per plant, number of spikelets per plants, volume expansion ratio hulling per cent, milling per cent, L/B ratio	----	Praveen <i>et al.</i> (2010)
			Test weight and protein content	P, G	Satyavathi <i>et al.</i> (2001)
		Negative	Test weight, kernel length, kernel breadth, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Effective tillers, plant height, kernel breadth after cooking, L/B ratio	----	Nandan <i>et al.</i> (2010)
			Test weight, head rice recovery, kernel breadth, kernel length	----	Praveen <i>et al.</i> (2010)
			Plant height, no. Of productive tillers per plant, panicle length, No. of grains per panicle, test weight.	P, G	Satyavathi <i>et al.</i> (2001)
19	Water uptake	Positive	Days to 50% flowering, plant height, ear bearing tillers, panicle length, test weight, head rice recovery, kernel length, kernel breadth, kernel length after cooking, water uptake, volume expansion ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Number of productive tillers per plant, test weight, amylose content and protein percentage.	P,G	Parvathi (2010)
			Hulling per cent, milling per cent, kernel length after cooking, kernel breadth after cooking, water uptake	G	Prem Kumar <i>et al.</i> (2010)
		Negative	L/B ratio, kernel elongation ratio	G	Krishna veni <i>et al.</i> (2013)
			Kernel length	G	Prem Kumar <i>et al.</i> (2010)
20	Amylose content	Positive	Days to maturity, , number of tillers per plant, panicle length, grain breadth, L/B ratio	G	Patel <i>et al.</i> (2014)
			Days to 50% flowering, test weight, kernel length, kernel breadth, kernel length after cooking, kernel elongation ratio, water uptake, volume expansion ratio, amylose content.	G	Krishna veni <i>et al.</i> (2013)
			Plant height, ear bearing tillers per plant, filled grains per panicle, test weight.	G	Garg <i>et al.</i> (2010)
			Plant height, ear bearing tillers per plant, panicle length, filled grains per panicle , protein content	P	Garg <i>et al.</i> (2010)
			Ear bearing tillers/ plant, panicle length, test weight, protein content	P, G	Nagajyothi (2001)
		Negative	Days to 50% flowering, plant height, productive tillers, total number of grains per panicle, test weight, grain length, , amylose content	G	Patel <i>et al.</i> (2014)
			Plant height, ear bearing tillers, panicle length, head rice recovery, L/B ratio,	G	Krishna veni <i>et al.</i> (2013)
			Plant height, ear bearing tillers per plant, filled grains per panicle, test weight.	G	Garg <i>et al.</i> (2010)
			Tillers per plant, test weight, grain length	P	Garg <i>et al.</i> (2010)
			Hulling %	P, G	Nagajyothi (2001)
21	Leaf area index	Positive	Number of grains per panicle, test weight, leaf area	----	Zulqarnain <i>et al.</i> (2012)

2.6 COMBINING ABILITY

Combining ability helps in the identification of parents with good general and specific combining ability and also to determine the gene action. The concept of combining ability as a measure of gene action was proposed by Sprague and Tatum (1942). They defined “General Combining ability” as an average performance of a line in hybrid combination, while specific combining ability” referred to those crosses which did relatively better or worse than would be expected on the basis of average performance of the lines involved. They further reported that general combining ability was primarily due to additive gene effect, while specific combining ability was due to non-additive effect. The review of literature on gene action governing the inheritance of different traits in rice is summarized and presented in table 2.7.

Table 2.8. Review of literature on gene action for yield, yield component characters in rice (*Oryza sativa* L.)

Gene action		
1. Days to 50 % flowering		
Additive	Non additive	Additive and non additive
Patil and Mehta (2014)	Premkumar <i>et al.</i> (2015)	Faiz <i>et al.</i> (2006)
Koli <i>et al.</i> (2013)	Damodar <i>et al.</i> (2014)	Sanjeev Kumar <i>et al.</i> (2008)
Gonya Nayak <i>et al.</i> (2012)	Kolom <i>et al.</i> (2014)	Ganesan <i>et al.</i> (1997)
Sharma <i>et al.</i> (2012)	Gopikannan and Ganesh (2013)	Gupta <i>et al.</i> (1999)
Shyam <i>et al.</i> (2012)	Satheeshkumar and Sravanan (2013)	Honarnejad (1999)
Sandhyakishore <i>et al.</i> (2011)	Sanghera and Hussain (2013)	Singh <i>et al.</i> (1993)
Dijee <i>et al.</i> (2010)	Sharma <i>et al.</i> (2013)	Jain Ying Peng and Virmani (1990)
Dalvi and Patel (2009)	Utharasu and Anandakumar (2013)	Manuel and Palanisamy (1989)
Salgotra <i>et al.</i> (2009)	Veerasha <i>et al.</i> (2013b)	Tripathy and Mishra (1987)
Sanjeev Kumar <i>et al.</i> (2009)	Damodar <i>et al.</i> (2012)	
Edgar and Isaias (2007)	Gulzar and Wassem (2012)	
Indira and Ananda (2007)	Gulzar and Wassem (2012)	
Sanjeev Kumar <i>et al.</i> (2007)	Srivastava <i>et al.</i> (2012)	
Anand Kumar <i>et al.</i> (2006)	Amudha <i>et al.</i> (2011)	
Gnanasekaran <i>et al.</i> (2006)	Saiaiah <i>et al.</i> (2011)	
Rosamma and Vijayakumar (2005)	Saiaiah <i>et al.</i> (2010a)	
Patil <i>et al.</i> (2003a)	Selvaraj <i>et al.</i> (2011)	
Shanthi <i>et al.</i> (2003)	Tiwari <i>et al.</i> (2011)	
Swamy <i>et al.</i> (2003)	Waghmode <i>et al.</i> (2011)	
Vanaja <i>et al.</i> (2003)	Kumar Babu <i>et al.</i> (2010a)	
Hasib <i>et al.</i> (2002)	Muthuramu <i>et al.</i> (2010)	
Sharma <i>et al.</i> (2001)	Nadali Bagheri and Babaeian (2010)	
Meenakshi and Amirthadevarathinam (1999)	Saiaiah <i>et al.</i> (2010)	
Padmavathi <i>et al.</i> (1997)	Jayasudhan and Deepak Sharma (2009)	
Ganesan and Rangaswamy (1998)	Pradhan and Singh (2008)	
Sharma and Koranne (1995)	Sanjeev Kumar <i>et al.</i> (2008)	
Sreedhar and Kulkarni (1995)	Sharma and Mani (2008)	
	Venkatesan <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	
	Dhakar and Vinitvyas (2006)	
	Sharat <i>et al.</i> (2006)	
	Sharma (2006)	
	Sharma <i>et al.</i> (2006)	
	Panwar (2005)	
	Rita Bisne and Motiramani (2005)	
	Sanjeev Kumar <i>et al.</i> (2005)	

Table 2.8 (Cont.)

	Sharma <i>et al.</i> (2005)	
	Banumathy <i>et al.</i> (2003)	
	Bhave <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Swain <i>et al.</i> (2003)	
	Vanaja <i>et al.</i> (2003)	
	Babu <i>et al.</i> (2000)	
	Satyanarayana <i>et al.</i> (2000)	
	Selvarani and Rangaswamy (1999)	
	Yadav <i>et al.</i> (1999)	
	Ramalingam <i>et al.</i> (1997)	
	Singh and Maurya (1997)	
	Manuel and Rangaswamy (1995)	
2. Days to maturity		
Upadhyay and Jaiswal (2015)	Upadhyay and Jaiswal (2015)	Bagheri <i>et al.</i> (2008)
Zaazaa and Anis (2014)	Sanghera and Hussain (2013)	Gupta <i>et al.</i> (1999)
Koli <i>et al.</i> (2013)	Gulzar and Wassem (2012)	Honarnejad (1999)
Sharma <i>et al.</i> (2012)	Srivastava <i>et al.</i> (2012)	Ganesan <i>et al.</i> (1997)
Akter <i>et al.</i> (2010)	Saidaiah <i>et al.</i> (2011)	
Dalvi and Patel (2009)	Kumar Babu <i>et al.</i> (2010a)	
Sanjeev Kumar <i>et al.</i> (2009)	Nadali Bagheri and Babaeian (2010)	
Anand Kumar <i>et al.</i> (2006)	Saidaiah <i>et al.</i> (2010a)	
Gnanasekaran <i>et al.</i> (2006)	Jayasudhan and Deepak Sharma (2009)	
	Salgotra <i>et al.</i> (2009)	
	Bagheri <i>et al.</i> (2008)	
	Sanjeev Kumar <i>et al.</i> (2008)	
	Sharat <i>et al.</i> (2006)	
	Vanaja <i>et al.</i> (2003)	
3. Plant Height		
Upadhyay and Jaiswal (2015)	Premkumar <i>et al.</i> (2015)	Sanjeev Kumar <i>et al.</i> (2008)
Koli <i>et al.</i> (2013)	Damodar <i>et al.</i> (2014)	Zhao (2008)
Damodar <i>et al.</i> (2012)	Kolom <i>et al.</i> (2014)	Faiz <i>et al.</i> (2006)
Shyam <i>et al.</i> (2012)	Patil and Mehta (2014)	Singh (2005)
Akter <i>et al.</i> (2010)	Zaazaa and Anis (2014)	Sharma <i>et al.</i> (2005)
El-Namaky <i>et al.</i> (2010)	Gopikannan and Ganesh (2013)	Swamy <i>et al.</i> (2003)
Muthuramu <i>et al.</i> (2010)	Sanghera and Hussain (2013)	Singh (2002)
Nadali Bagheri and Babaeian (2010)	Sharma <i>et al.</i> (2013)	Honarnejad (1999)
Rahimi <i>et al.</i> (2010)	Satheeshkumar and Sravanan (2013)	Li <i>et al.</i> (1998)
Bagheri <i>et al.</i> (2008)	Veerasha <i>et al.</i> (2013b)	Manuel and Palanisamy (1989)
Edgar and Isaias (2007)	Utharasu and Anandakumar (2013)	
Indira and Ananda (2007)	Gulzar and Wassem (2012)	
Sanjeev Kumar <i>et al.</i> (2007)	Gulzar and Wassem (2012)	
Senguttuvel and Kannan (2007)	Srivastava <i>et al.</i> (2012)	
Rashid <i>et al.</i> (2007)	Amudha <i>et al.</i> (2011)	

Table 2.8 (Cont.)

Anand Kumar <i>et al.</i> (2006)	Saidaiah <i>et al.</i> (2011)	
Gnanasekaran <i>et al.</i> (2006)	Sandhyakishore <i>et al.</i> (2011)	
Shanthi <i>et al.</i> (2003)	Selvaraj <i>et al.</i> (2011)	
Swain <i>et al.</i> (2003)	Tiwari <i>et al.</i> (2011)	
Swamy <i>et al.</i> (2003)	Waghmode <i>et al.</i> (2011)	
Vanaja <i>et al.</i> (2003)	Dijee <i>et al.</i> (2010)	
Rao <i>et al.</i> (2001)	Kumar Babu <i>et al.</i> (2010a)	
Ganesan and Rangaswamy (1998)	Saidaiah <i>et al.</i> (2010a)	
Shanthakumar <i>et al.</i> (1998)	Saidaiah <i>et al.</i> (2010)	
Ramalingam <i>et al.</i> (1997)	Dalvi and Patel (2009)	
Manuel and Rangaswamy (1995)	Jayasudhan and Deepak Sharma (2009)	
Sharma and Koranne (1995)	Sanjeev Kumar <i>et al.</i> (2009)	
	Salgotra <i>et al.</i> (2009)	
	Akarsh and Pathak (2008)	
	Pradhan and Singh (2008)	
	Sanjeev Kumar <i>et al.</i> (2008)	
	Venkatesan <i>et al.</i> (2007)	
	Hariprasanna <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Sharma <i>et al.</i> (2006)	
	Sharma (2006)	
	Rita Bisne and Motiramani (2005)	
	Panwar (2005)	
	Sanjeev Kumar <i>et al.</i> (2005)	
	Singh <i>et al.</i> (2005)	
	Sharma <i>et al.</i> (2005)	
	Banumathy <i>et al.</i> (2003)	
	Bhave <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Hasib <i>et al.</i> (2002)	
	Umakanta <i>et al.</i> (2002)	
	Kalita and Upadhaya (2000)	
	Satyanarayana <i>et al.</i> (2000)	
	Dwivedi <i>et al.</i> (1999)	
	Yadav <i>et al.</i> (1999)	
	Sreedhar and Kulkarni (1995)	
	Honarnejad (1994)	
4. Number of tillers per plant		
Shyam <i>et al.</i> (2012)	Gulzar and Wassem (2012)	Bagheri <i>et al.</i> (2008)
Edgar and Isaias (2007)	Gulza and Wassem (2012)	
Padmavathi <i>et al.</i> (1997)	El-Namaky <i>et al.</i> (2010)	
Honarnejad (1994)	Muhammad Yussouf <i>et al.</i> (2010)	
	Jayasudha and Deepak (2009)	
	Bagheri <i>et al.</i> (2008)	
	Rita Bisne and Motiramani (2005)	
5. Number of ear bearing tillers plant per plant		
Zaazaa and Anis (2014)	Premkumar <i>et al.</i> (2015)	Rahimi (2010)
Veeresha <i>et al.</i> (2013b)	Upadhyay and Jaiswal (2015)	Zhao (2008)
Veeresha <i>et al.</i> (2013b)	Damodar <i>et al.</i> (2014)	Fiaz <i>et al.</i> (2006)

Table 2.8 (Cont.)

Sharma <i>et al.</i> (2012)	Kolom <i>et al.</i> (2014)	Sawant (2006)
Sandhyakishore <i>et al.</i> (2011)	Patil and Mehta (2014)	Singh (2005)
Waghmode <i>et al.</i> (2011)	Gopikannan and Ganesh (2013)	Sharma <i>et al.</i> (2005)
Rahimi <i>et al.</i> (2010)	Sanghera and Hussain (2013)	Sharma <i>et al.</i> (2001)
Dalvi and Patel (2009)	Satheeshkumar and Sravanan (2013)	Meenakshi and Amirthadevarathinam (1999)
Ahangar <i>et al.</i> (2008)	Sharma <i>et al.</i> (2013)	Li <i>et al.</i> (1998)
Indira and Ananda (2007)	Utharasu and Anandakumar (2013)	Ganesan <i>et al.</i> (1997)
Rashid <i>et al.</i> (2007)	Damodar <i>et al.</i> (2012)	
Gnanasekaran <i>et al.</i> (2006)	Gonya Nayak <i>et al.</i> (2012)	
Rosamma and Vijayakumar (2005)	Gulzar and Wassem (2012)	
Sharma <i>et al.</i> (2005)	Gulzar and Wassem (2012)	
Vanaja <i>et al.</i> (2003)	Srivastava <i>et al.</i> (2012)	
Hasib <i>et al.</i> (2002)	Amudha <i>et al.</i> (2011)	
Rao <i>et al.</i> (2001)	Selvaraj <i>et al.</i> (2011)	
Padmavathi <i>et al.</i> (1997)	Tiwari <i>et al.</i> (2011)	
Mishra <i>et al.</i> (1996)	Dijee <i>et al.</i> (2010)	
	Kumar Babu <i>et al.</i> (2010a)	
	Muthuramu <i>et al.</i> (2010)	
	Nadali Bagheri and Babaeian (2010)	
	Saidaiah <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010a)	
	Jayasudhan and Deepak Sharma (2009)	
	Karthikeyan <i>et al.</i> (2009)	
	Salgotra <i>et al.</i> (2009)	
	Pradhan and Singh (2008)	
	Sharma and Mani (2008)	
	Venkatesan <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	
	Anand Kumar <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Sharma (2006)	
	Panwar (2005)	
	Rita Bisne and Motiramani (2005)	
	Singh <i>et al.</i> (2005)	
	Banumathy <i>et al.</i> (2003)	
	Bhave <i>et al.</i> (2003)	
	Patil <i>et al.</i> (2003a)	
	Shanthi <i>et al.</i> (2003)	
	Swain <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Babu <i>et al.</i> (2000)	
	Kalita and Upadhaya (2000)	
	Satyanarayana <i>et al.</i> (2000)	
	Selvarani and Rangaswamy	

Table 2.8 (Cont.)

	(1999)	
	Yadav <i>et al.</i> (1999)	
	Ganesan and Rangaswamy (1998)	
	Ramalingam <i>et al.</i> (1997)	
	Sharma and Koranne (1995)	
	Sreedhar and Kulkarni (1995)	
	Siddiq <i>et al.</i> (1992)	
6. Panicle length		
Patil and Mehta (2014)	Premkumar <i>et al.</i> (2015)	Bagheri <i>et al.</i> (2008)
Veerasha <i>et al.</i> (2013b)	Damodar <i>et al.</i> (2014)	Sanjeev Kumar <i>et al.</i> (2008)
Veerasha <i>et al.</i> (2013b)	Kolom <i>et al.</i> (2014)	Zhao (2008)
Verica <i>et al.</i> (2013)	Gopikannan and Ganesh (2013)	Anand Kumar <i>et al.</i> (2006)
Damodar <i>et al.</i> (2012)	Sanghera and Hussain (2013)	Sawant (2006)
Sharma <i>et al.</i> (2012)	Satheeshkumar and Sravanan (2013)	Singh (2005)
Shyam <i>et al.</i> (2012)	Utharasu and Anandakumar (2013)	Sharma <i>et al.</i> (2005)
Sandhyakishore <i>et al.</i> (2011)	Gonya Nayak <i>et al.</i> (2012)	Singh (2002)
El-Namaky <i>et al.</i> (2010)	Gulzar and Wassem (2012)	Sharma <i>et al.</i> (2001)
Rahimi <i>et al.</i> (2010)	Gulzar and Wassem (2012)	Honarnejad (1999)
Sanjeev Kumar <i>et al.</i> (2009)	Srivastava <i>et al.</i> (2012)	Li <i>et al.</i> (1998)
Sharma and Mani (2008)	Sharma <i>et al.</i> (2012)	Ganesan <i>et al.</i> (1997)
Edgar and Isaias (2007)	Amudha <i>et al.</i> (2011)	Manuel and Palanisamy (1989)
Indira and Ananda (2007)	Pradeep Kumar and Reddy (2011)	
Rashid <i>et al.</i> (2007)	Saidaiah <i>et al.</i> (2011)	
Sharma <i>et al.</i> (2006)	Selvaraj <i>et al.</i> (2011)	
Swain <i>et al.</i> (2003)	Tiwari <i>et al.</i> (2011)	
Vanaja <i>et al.</i> (2003)	Waghmode <i>et al.</i> (2011)	
Rao <i>et al.</i> (2001)	Akter <i>et al.</i> (2010)	
Kalita and Upadhaya (2000)	Bagheri and Babaeian Jelodar (2010)	
Dwivedi <i>et al.</i> (1999)	Dijee <i>et al.</i> (2010)	
Sawant <i>et al.</i> (1995)	Kumar Babu <i>et al.</i> (2010a)	
	Mahammad Yussouf <i>et al.</i> (2010)	
	Muthuramu <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010a)	
	Dalvi and Patel (2009)	
	Jayasudhan and Deepak Sharma (2009)	
	Karthikeyan <i>et al.</i> (2009)	
	Salgotra <i>et al.</i> (2009)	
	Bagheri <i>et al.</i> (2008)	
	Pradhan and Singh (2008)	
	Sanjeev Kumar <i>et al.</i> (2008)	
	Sanjeev Kumar <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	

Table 2.8 (Cont.)

	Dhakar and Vinitvyas (2006)	
	Gnanasekaran <i>et al.</i> (2006)	
	Hariprasanna <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Sharma (2006)	
	Panwar (2005)	
	Rita Bisne and Motiramani (2005)	
	Sanjeev Kumar <i>et al.</i> (2005)	
	Sharma <i>et al.</i> (2005)	
	Banumathy <i>et al.</i> (2003)	
	Bhave <i>et al.</i> (2003)	
	Shanthi <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Vanaja <i>et al.</i> (2003)	
	Umakanta <i>et al.</i> (2002)	
	Babu <i>et al.</i> (2000)	
	Satyanarayana <i>et al.</i> (2000)	
	Yadav <i>et al.</i> (1999)	
	Ganesan and Rangaswamy (1998)	
	Padmavathi <i>et al.</i> (1997)	
	Ramalingam <i>et al.</i> (1997)	
	Singh and Maurya (1997)	
	Sreedhar and Kulkarni (1995)	
7. Number of filled grains panicle per plant		
Verica <i>et al.</i> (2013)	Preemkumar <i>et al.</i> (2015)	Anand Kumar <i>et al.</i> (2006)
Sharma <i>et al.</i> (2012)	Upadhyay and Jaiswal (2015)	Swamy <i>et al.</i> (2003)
Tiwari <i>et al.</i> (2011)	Damodar <i>et al.</i> (2014)	
Rahimi <i>et al.</i> (2010)	Kolom <i>et al.</i> (2014)	
Bagheri <i>et al.</i> (2008)	Patil and Mehta (2014)	
Edgar and Isaías (2007)	Gopikannan and Ganesh (2013)	
Indira and Ananda (2007)	Satheeshkumar and Sravanan (2013)	
Rosamma and Vijayakumar (2005)	Sanghera and Hussain (2013)	
Vanaja <i>et al.</i> (2003)	Sharma <i>et al.</i> (2013)	
Ganesan and Rangaswamy (1998)	Utharasu and Anandakumar (2013)	
	Veeresha <i>et al.</i> (2013b)	
	Gonya Nayak <i>et al.</i> (2012)	
	Gulzar and Wassem (2012)	
	Gulzar and Wassem (2012)	
	Srivastava <i>et al.</i> (2012)	
	Saidaiah <i>et al.</i> (2011)	
	Sandhyakishore <i>et al.</i> (2011)	
	Waghmode <i>et al.</i> (2011)	
	Akter <i>et al.</i> (2010)	
	El-Namaky <i>et al.</i> (2010)	
	Kumar Babu <i>et al.</i> (2010a)	
	Mahammad Yussouf <i>et al.</i> (2010)	
	Nadali Bagheri and Babaeian	

Table 2.8 (Cont.)

	(2010)	
	Saidaiah <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010a)	
	Dalvi and Patel (2009)	
	Salgotra <i>et al.</i> (2009)	
	Ahangar <i>et al.</i> (2008)	
	Pradhan and Singh (2008)	
	Sharma and Mani (2008)	
	Narasimman <i>et al.</i> (2007)	
	Venkatesan <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	
	Gnanasekaran <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Panwar (2005)	
	Banumathy <i>et al.</i> (2003)	
	Patil <i>et al.</i> (2003a)	
	Babu <i>et al.</i> (2000)	
	Yadav <i>et al.</i> (1999)	
	Ramalingam <i>et al.</i> (1997)	
	Siddiq <i>et al.</i> (1992)	
8. Test weight		
Upadhyay and Jaiswal (2015)	Preemkumar <i>et al.</i> (2015)	Rahimi (2010)
Gnanamalar and Vivekanandam (2013)	Damodar <i>et al.</i> (2014)	Zhao (2008)
Damodar <i>et al.</i> (2012)	Kolom <i>et al.</i> (2014)	Sawant (2006)
Gonya Nayak <i>et al.</i> (2012)	Patil and Mehta (2014)	Singh (2005)
Shyam <i>et al.</i> (2012)	Zaazaa and Anis (2014)	Sharma <i>et al.</i> (2005)
Waghmode <i>et al.</i> (2011)	Gopikannan and Ganesh (2013)	Bagheri <i>et al.</i> (2008)
El-Namaky <i>et al.</i> (2010)	Satheeshkumar and Sravanan (2013)	Sanjeev Kumar <i>et al.</i> (2008)
Sanjeev Kumar <i>et al.</i> (2009)	Sharma <i>et al.</i> (2013)	Patil <i>et al.</i> (2003a)
Ahangar <i>et al.</i> (2008)	Utharasu and Anandakumar (2013)	Patil <i>et al.</i> (2003)
Edgar and Isaias (2007)	Veerasha <i>et al.</i> (2013b)	Dwivedi <i>et al.</i> (1999)
Indira and Ananda (2007)	Sharma <i>et al.</i> (2012)	Honarnejad (1999)
Rashid <i>et al.</i> (2007)	Srivastava <i>et al.</i> (2012)	Ganesan <i>et al.</i> (1997)
Senguttuvel and Kannan (2007)	Pradeep Kumar and Reddy (2011)	Manuel and Palanisamy (1989)
Sanjeev Kumar <i>et al.</i> (2007)	Selvaraj <i>et al.</i> (2011)	
Gnanasekaran <i>et al.</i> (2006)	Sandhyakishore <i>et al.</i> (2011)	
Sharma (2006)	Tiwari <i>et al.</i> (2011)	
Rosamma and Vijayakumar (2005)	Akter <i>et al.</i> (2010)	
Vanaja <i>et al.</i> (2003)	Kumar Babu <i>et al.</i> (2010a)	
Swain <i>et al.</i> (2003)	Mahammad Yussouf <i>et al.</i> (2010)	
Shanthi <i>et al.</i> (2003)	Muthuramu <i>et al.</i> (2010)	
Hasib <i>et al.</i> (2002)	Saidaiah <i>et al.</i> (2010)	
Ganesan and Rangaswamy (1998)	Rahimi <i>et al.</i> (2010)	
Padmavathi <i>et al.</i> (1997)	Salgotra <i>et al.</i> (2009)	
Mishra <i>et al.</i> (1996)	Akarsh and Pathak (2008)	

Table 2.8 (Cont.)

Sawant <i>et al.</i> (1995)	Bagheri <i>et al.</i> (2008)	
	Pradhan and Singh (2008)	
	Sanjeev Kumar <i>et al.</i> (2008)	
	Venkatesan <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	
	Anand Kumar <i>et al.</i> (2006)	
	Hari prasanna <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Panwar (2005)	
	Rita Bisne and Motiramani (2005)	
	Sanjeev Kumar <i>et al.</i> (2005)	
	Sharma <i>et al.</i> (2005)	
	Bhave <i>et al.</i> (2003)	
	Banumathy <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Singh (2002)	
	Umakanta <i>et al.</i> (2002)	
	Babu <i>et al.</i> (2000)	
	Kalita and Upadhaya (2000)	
	Satyanarayana <i>et al.</i> (2000)	
	Meenakshi and Amirthadevarathinam (1999)	
	Selvarani and Rangaswamy (1999)	
	Ramalingam <i>et al.</i> (1997)	
	Sharma and Koranne (1995)	
	Siddiq <i>et al.</i> (1992)	
9. Leaf area index		
Sanjeev Kumar <i>et al.</i> (2009)	Akter <i>et al.</i> (2010)	Sanjeev Kumar <i>et al.</i> (2008)
Vanaja <i>et al.</i> (2003)	Jayasudha and Deepak (2009)	
10. Grain yield plant per plant		
Koli <i>et al.</i> (2013)	Premkumar <i>et al.</i> (2015)	Veerasha <i>et al.</i> (2013b)
Verica <i>et al.</i> (2013)	Upadhyay and Jaiswal (2015)	Sanjeev Kumar <i>et al.</i> (2008)
Sharma <i>et al.</i> (2012)	Adilakshmi and Upendra (2014)	Zhao (2008)
Shyam <i>et al.</i> (2012)	Damodar <i>et al.</i> (2014)	Faiz <i>et al.</i> (2006)
Selvaraj <i>et al.</i> (2011)	Kolom <i>et al.</i> (2014)	Panwar (2005)
Rahimi <i>et al.</i> (2010)	Malini <i>et al.</i> (2014)	Sharma <i>et al.</i> (2005)
Sanjeev Kumar <i>et al.</i> (2009)	Patil and Mehta (2014)	Singh (2005)
Ahangar <i>et al.</i> (2008)	Zaazaa and Anis (2014)	Swamy <i>et al.</i> (2003)
Sanjeev Kumar <i>et al.</i> (2008)	Gopikannan and Ganesh (2013)	Sharma <i>et al.</i> (2001)
Sharma and Mani (2008)	Gnanamalar and Vivekanandan (2013)	Ganesan <i>et al.</i> (1997)
Rashid <i>et al.</i> (2007)	Sanghera and Hussain (2013)	
Senguttuvel and Kannan (2007)	Satheeshkumar and Sravanan (2013)	
Sharma <i>et al.</i> (2006)	Sharma <i>et al.</i> (2013)	
Shanthi <i>et al.</i> (2003)	Utharasu and Anandakumar (2013)	
Hasib <i>et al.</i> (2002)	Veerasha <i>et al.</i> (2013b)	

Table 2.8 (Cont.)

Meenakshi and Amirthadevarathinam (1999)	Damodar <i>et al.</i> (2012)	
Mishra <i>et al.</i> (1996)	Gulzar and Wassem (2012)	
Sawant <i>et al.</i> (1995)	Gulzar and Wassem (2012)	
	Srivastava <i>et al.</i> (2012)	
	Amudha <i>et al.</i> (2011)	
	Pradeep Kumar and Reddy (2011)	
	Saidaiah <i>et al.</i> (2011)	
	Sandhyakishore <i>et al.</i> (2011)	
	Tiwari <i>et al.</i> (2011)	
	Waghmode <i>et al.</i> (2011)	
	Akter <i>et al.</i> (2010)	
	Bagheri and Babaeian Jelodar (2010)	
	Dijee <i>et al.</i> (2010)	
	El-Namaky <i>et al.</i> (2010)	
	Kumar Babu <i>et al.</i> (2010a)	
	Muhammad Yussouf <i>et al.</i> (2010)	
	Muthuramu <i>et al.</i> (2010)	
	Nadali Bagheri and Babaeian (2010)	
	Thakare <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010)	
	Saidaiah <i>et al.</i> (2010a)	
	Dalvi and Patel (2009)	
	Jayasudhan and Deepak Sharma (2009)	
	Karthikeyan <i>et al.</i> (2009)	
	Salgotra <i>et al.</i> (2009)	
	Akarsh and Pathak (2008)	
	Bagheri <i>et al.</i> (2008)	
	Pradhan and Singh (2008)	
	Venkatesan <i>et al.</i> (2007)	
	Abhinav and Motiramani (2006)	
	Anand Kumar <i>et al.</i> (2006)	
	Gnanasekaran <i>et al.</i> (2006)	
	Hariprasanna <i>et al.</i> (2006)	
	Pradhan <i>et al.</i> (2006)	
	Saravanan <i>et al.</i> (2006)	
	Sharat <i>et al.</i> (2006)	
	Sharma (2006)	
	Panwar (2005)	
	Rita Bisne and Motiramani (2005)	
	Rosamma and Vijayakumar (2005)	
	Singh <i>et al.</i> (2005)	
	Banumathy <i>et al.</i> (2003)	
	Bhave <i>et al.</i> (2003)	
	Patil <i>et al.</i> (2003)	

Table 2.8 (Cont.)

	Shanthi <i>et al.</i> (2003)	
	Swain <i>et al.</i> (2003)	
	Swamy <i>et al.</i> (2003)	
	Vanaja <i>et al.</i> (2003)	
	Singh (2002)	
	Umakanta <i>et al.</i> (2002)	
	Babu <i>et al.</i> (2000)	
	Satyanarayana (2000)	
	Dwivedi <i>et al.</i> (1999)	
	Selvarani and Rangaswamy (1999)	
	Yadav <i>et al.</i> (1999)	
	Ganesan and Rangaswamy (1998)	
	Padmavathi <i>et al.</i> (1997)	
	Ramalingam <i>et al.</i> (1997)	
	Singh and Maurya (1997)	
	Sharma and Koranne (1995)	
	Siddiq <i>et al.</i> (1992)	
11. Hulling per cent		
Thakare <i>et al.</i> (2010)	Gnanamalar and Vivekanandam (2013)	Srivastava <i>et.al.</i> (1978)
Li <i>et al.</i> (1999)	Adilakshmi and Upendra (2014)	
Paramasivam <i>et al.</i> (1996)	Raju <i>et.al.</i> (2003)	
Wang and Tang (1989)	Sreedhar (1999)	
Clement and Poisson (1984)	Sharma and Mani (1998)	
Sonrexa and Prarthna Sonerexa (1984)	Murthy (1994)	
	Sonrexa and Prarthna Sonerexa (1984)	
12. Milling per cent		
Waghmode <i>et al.</i> (2011)	Adilakshmi and Upendra (2014)	
Thakare <i>et al.</i> (2010)	Gnanamalar and Vivekanandam (2013)	
Li <i>et al.</i> (1999)	Sreedhar (1999)	
Paramasivam <i>et al.</i> (1996)	Sharma and Mani (1998)	
Wang and Tang (1989)	Singh and Singh (1985)	
13. Head rice Recovery per cent		
Asfaliza <i>et al.</i> (2012)	Adilakshmi and Upendra (2014)	Wang and Tang (1989)
Shyam <i>et al.</i> (2012)	Gnanamalar and Vivekanandam (2013)	
Waghmode <i>et al.</i> (2011)	Sreedhar (1999)	
Thakare <i>et al.</i> (2010)	Sharma and Mani (1998)	
Li <i>et al.</i> (1999)		
14. Kernel length		
Gnanamalar and Vivekanandam (2013)	Upadhyay and Jaiswal (2015)	Sanjeev Kumar <i>et al.</i> (2008)
Asfaliza <i>et al.</i> (2012)	Damodar <i>et al.</i> (2012)	Sreedhar (1999)
Rahimi <i>et al.</i> (2010)	Gulzar and Wassem (2012)	Mohanty <i>et al.</i> (1995)
Sanjeev Kumar <i>et al.</i> (2009)	Gulzar and Wassem (2012)	Panwar and Paroda (1983)

Table 2.8 (Cont.)

Sharma <i>et.al.</i> (2006).	Srivastava <i>et al.</i> (2012)	Singh (1982)
Raju <i>et.al.</i> (2003)	Waghmode <i>et al.</i> (2011)	Clement and Poisson (1984)
Vivekanandan and Giridharan (1995b)	Thakare <i>et al.</i> (2010)	
Geetha <i>et al.</i> (1994)	Bagheri <i>et al.</i> (2008)	
Honarnejad (1994)	Pradhan and Singh (2008)	
Kato (1990)	Sanjeev Kumar <i>et al.</i> (2008)	
Wang and Tang (1989)	Venkatesan <i>et al.</i> (2007)	
Kuo and Liu (1986)	Sharat <i>et al.</i> (2006)	
Hong <i>et al.</i> (1985)	Saravanan <i>et.al.</i> (2006a)	
Singh and Singh (1985)	Rita Bisne and Motiramani (2005)	
Sukanya and Mahadevamenon (1984b)	Sanjeev Kumar <i>et.al.</i> (2005)	
	Li <i>et al.</i> (1999)	
	Sharma and Mani (1998)	
	Verma <i>et al.</i> (1994b)	
	Singh <i>et al.</i> (1993)	
	Murali and Kinoshita (1986)	
	Singh and Singh (1985)	
15. Kernel Breadth		
Upadhyay and Jaiswal (2015)	Gnanamalar and Vivekanandam (2013)	Sanjeev Kumar <i>et al.</i> (2008)
Asfaliza <i>et al.</i> (2012)	Damodar <i>et al.</i> (2012)	Mohanty <i>et al.</i> (1995)
Rahimi <i>et al.</i> (2010)	Gulzar and Wassem (2012)	Singh and Singh (1985)
Sanjeev Kumar <i>et al.</i> (2009)	Gulzar and Wassem (2012)	Panwar and Paroda (1983)
Li <i>et al.</i> (1999)	Srivastava <i>et al.</i> (2012)	Singh (1982)
Vivekanandan and Giridharan (1995b)	Waghmode <i>et al.</i> (2011)	Sanjeev Kumar <i>et.al.</i> (2007)
Geetha <i>et al.</i> (1994)	Thakare <i>et al.</i> (2010)	Raju <i>et.al.</i> (2003)
Honarnejad (1994)	Bagheri <i>et al.</i> (2008)	Sharma and Mani (1998)
Wang and Tang (1989)	Pradhan and Singh (2008)	Singh <i>et.al.</i> (1993)
Hong <i>et al.</i> (1985)	Sanjeev Kumar <i>et al.</i> (2008)	
Sharma <i>et.al.</i> (2006)	Venkatesan <i>et al.</i> (2007)	
Kato (1990)	Saravanan <i>et.al.</i> (2006a)	
Kuo and Liu (1986)	Sharat <i>et al.</i> (2006)	
Sukanya and Mahadevamenon (1984b)	Rita Bisne and Motiramani (2005)	
	Sreedhar (1999)	
	Sharma and Mani (1998)	
	Verma <i>et al.</i> (1994b)	
	Singh <i>et al.</i> (1993)	
16. L/B ratio		
Gnanamalar and Vivekanandam (2013)	Upadhyay and Jaiswal (2015)	Sanjeev Kumar <i>et.al.</i> (2008)
Asfaliza <i>et al.</i> (2012)	Adilakshmi and Upendra (2014)	Lalitha and Sreedhar (1999)
Sanjeev Kumar <i>et al.</i> (2009)	Malini <i>et al.</i> (2014)	Paramsivan <i>et al.</i> (1996)
Sanjeev Kumar <i>et.al.</i> (2007)	Patil and Mehta (2014)	Singh and Singh (1985)
Sharma <i>et.al.</i> (2006)	Damodar <i>et al.</i> (2012)	Panwar and Paroda (1983)
Raju <i>et.al.</i> (2003)	Gulzar and Wassem (2012)	Singh (1982)
Vanaja <i>et al.</i> (2003)	Gulzar and Wassem (2012)	
Lioa <i>et al.</i> (2000)	Srivastava <i>et al.</i> (2012)	

Table 2.8 (Cont.)

Li <i>et al.</i> (1999)	Waghmode <i>et al.</i> (2011)	
Paramasivam <i>et.al.</i> (1995)	Thakare <i>et al.</i> (2010)	
Vivekanandan and Giridharan (1995b)	Sanjeev Kumar <i>et al.</i> (2008)	
Honarnejad (1994)	Vijaya Lakshmi <i>et.al.</i> (2008)	
Fu <i>et.al.</i> (1994)	Venkatesan <i>et al.</i> (2007)	
Misra and Khare (1991)	Sharat <i>et al.</i> (2006)	
Wang and Tang (1989)	Sreedhar (1999)	
Kuo and Liu (1986)	Sharma and Mani (1998)	
Kuo <i>et.al.</i> (1985)	Verma <i>et al.</i> (1994b)	
Sukanya and Mahadevamenon (1984b)	Singh <i>et al.</i> (1993)	
	Murthy (1994)	
	Dhaliwal and Sharma (1990)	
	Singh and Singh (1985)	
	Kuo <i>et.al.</i> (1985)	
	Srivastava <i>et.al.</i> (1978)	
17. Kernel length after cooking		
Upadhyay and Jaiswal (2015)	Sreedhar (1999)	Sharma and Mani (1998)
Gnanamalar and Vivekanandam (2013)		Singh and Singh (1985)
Li <i>et al.</i> (1999)		
Vivekanandan and Giridharan (1995b)		
Paramasivam <i>et.al.</i> (1995)		
18. Kernel breadth after cooking		
Li <i>et al.</i> (1999)	Sreedhar (1999)	
Vivekanandan and Giridharan (1995b)		
19. Kernel elongation ratio		
Li <i>et al.</i> (1999)	Upadhyay and Jaiswal (2015)	Sharma and Mani (1998)
Vivekanandan and Giridharan (1995b)	Adilakshmi and Upendra (2014)	
Vijaya Kumar <i>et al.</i> (1994)	Malini <i>et al.</i> (2014)	
Murthy <i>et al.</i> (1994)	Gnanamalar and Vivekanandam (2013)	
Sood <i>et.al.</i> (1983)	Sreedhar (1999)	
Tomar and Nanda (1982)	Sharma and Mani (1998)	
	Paramasivam <i>et.al.</i> (1995)	
	Murthy (1994)	
20. Volume expansion		
Li <i>et al.</i> (1999)	Adilakshmi and Upendra (2014)	Sharma and Mani (1998)
Vivekanandan and Giridharan (1995b)	Malini <i>et al.</i> (2014)	
Kuo <i>et al.</i> (1985)	Gnanamalar and Vivekanandam (2013)	
	Gonya Nayak <i>et al.</i> (2012)	
	Lakshmi (2009)	
	Sonrexa and Prathna Sonrexa (1984)	

Table 2.8 (Cont.)

21. Alkali Spreading value Gelatinization temperature		
Upadhyay and Jaiswal (2015)	Adilakshmi and Upendra (2014)	Singh and Singh (1985)
Vanaja <i>et al.</i> (2003)	Gnanamalar and Vivekanandam (2013)	
Lioa <i>et al.</i> (2000)	Gonya Nayak <i>et al.</i> (2012)	
Lalitha and Sreedhar (1999)	Lakshmi (2009)	
Li <i>et al.</i> (1999)	Sreedhar (1999)	
Paramasivam <i>et.al.</i> (1995)	Sharma and Mani (1998)	
Li Guan Tu <i>et.al.</i> (1994)	Kaw and Cruz (1990)	
Puri and Siddiq (1983b)	Kuo <i>et al.</i> (1985)	
22. Gel consistency		
Asfaliza <i>et al.</i> (2012)	Malini <i>et al.</i> (2014)	Wang and Tang <i>et.al.</i> (1989)
Li <i>et al.</i> (1999)	Gnanamalar and Vivekanandam (2013)	
Zaman <i>et al.</i> (1985)	Sreedhar (1999)	
	Kaw and Cruz (1990)	
	Kuo <i>et al.</i> (1985)	
	Sreedhar (1999)	
23. Water uptake		
	Malini <i>et al.</i> (2014)	
	Gnanamalar and Vivekanandam (2013)	
	Gonya Nayak <i>et al.</i> (2012)	
	Sharma and Mani (1998)	
	Zaman <i>et.al.</i> (1987)	
24. Amylose content		
Asfaliza <i>et al.</i> (2012)	Adilakshmi and Upendra (2014)	Kaw and Cruz (1990)
Waghmode <i>et al.</i> (2011)	Malini <i>et al.</i> (2014)	Singh and Singh (1985)
Sanjeev Kumar <i>et al.</i> (2009)	Patil and Mehta (2014)	
Indira and Ananda (2007)	Gnanamalar and Vivekanandam (2013)	
Swain and Nagaraju (2004)	Lakshmi (2009)	
Vanaja <i>et al.</i> (2003)	Sanjeev Kumar <i>et.al.</i> (2005)	
Lioa <i>et al.</i> (2000)	Li <i>et al.</i> (1999)	
Lalitha and Sreedhar (1999)	Sharma and Mani (1998)	
Kuo <i>et.al.</i> (1995)	Kaw and Cruz (1990)	
Li Guan Tu <i>et.al.</i> (1994)		
Puri <i>et.al.</i> (1983)		

2.7 HETEROSIS

Heterosis is the phenomenon in which the F_1 of two genetically dissimilar parents show increased vigour or size for various characters over the mid parent value (relative or mid parent heterosis) or over the better parent (heterobeltiosis) or over the standard check (standard heterosis).

The term heterosis was coined by Shull (1914) and is used to refer to the phenomenon in which the F_1 obtained by crossing two genetically dissimilar individuals showed an increase or decrease in vigour over mid-parent value.

Mather and Jinks (1971) proposed the term standard heterosis to denote the expression of hybrid vigour over the best commercial variety. Virmani *et al.* (1981) suggested that there should be at least 20-30% yield advantage for the hybrid varieties over the standard commercial varieties, to offset the cost of hybrid seed production.

The review of literature on relative heterosis and heterobeltiosis of different traits in rice is summarized and presented in table 2.9.

Table 2.9. Range of Relative heterosis and Heterobeltiosis in per centage reported for yield and yield components in rice (*Oryza sativa* L.)

No. of hybrids	Relative heterosis (%)	Heterobeltiosis (%)	Reference
1. Days to 50 per cent Flowering			
21	-20.37 to 8.81	-25.22 to 0.00	Kumari <i>et al.</i> (2014)
15	-	-2.34 to 3.66	Chandra and Suresh (2012)
60	-	-19.23 to 6.36	Sreedhar <i>et al.</i> (2012)
11	-10.27 to 7.12	-14.71 to 5.49	Vanisree <i>et al.</i> (2011)
6	-3.12 to 7.14	0.85 to 10.65	Borah and Barman (2010)
48	-16.24 to 15.57	-30.53 to 10.59	Gouri Shankar <i>et al.</i> (2010)
45	-13.38 to 20.28	-13.09 to -0.70	Panwar and Mashiat Ali (2010)
48	-	-24.35 to 8.16	Akarsh and Pathak (2008)
32	-6.44 to - 2.06	-12.27 to -7.74	Venkatesan <i>et al.</i> (2008)
5	-9.62 to -1.6	-6.4 to -1.3	Anjuchaudhary <i>et al.</i> (2007)
45	-11.59 to 17.68	-10.94 to 19.35	Deo <i>et al.</i> (2007)
24	-16.91 to 10.27	-3.05 to 24.07	Aananthi and Jebaraj (2006)
30	-8.09 to 20.99	-2.27 to 0.0	Pandya and Tripathi (2006)
21	-17.06 to 5.32	-24.06to 4.58	Raju <i>et al.</i> (2006)
28	-7.402 to 5.51	-13.08 to 4.60	Saravanan <i>et al.</i> (2006b)
20	-5.08 to 15.15	-3.06 to 23.26	Sarial <i>et al.</i> (2006)
8	-10.71 to 12.19	-	Shanthala <i>et al.</i> (2006)
36	-	19.00 to 47.00	Singh <i>et al.</i> (2006a)
36	-	-8.00 to 18.00	Singh <i>et al.</i> (2006b)
2. Day to maturity			
21	-14.65 to 5.47	-20.14 to -18.52	Kumari <i>et al.</i> (2014)
60	-	-19.23 to 6.36	Sreedhar <i>et al.</i> (2012)
36	-	-10.88 to 16.08	Sanjeev kumar <i>et al.</i> (2010)
48	-	-17.86 to 7.69	Akarsh and Pathak (2008)
3. Plant height			
21	-12.33 to 26.78	-16.70 to 12.73	Kumari <i>et al.</i> (2014)
15	-	-30.80 to 50.39	Chandra and Suresh (2012)
60	-	-19.23 to 6.36	Sreedhar <i>et al.</i> (2012)
6	-14.02 to 71.59	-10.53 to 80.49	Borah and Barman (2010)
48	-21.64 to 10.96	-31.18 to 1031	Gouri Shankar <i>et al.</i> (2010)
45	-17.02 to 17.69	-11.18 to -0.41	Panwar and Mashiat Ali (2010)
36	-	60.00	Sanjeev Kumar <i>et al.</i> (2010)
48	-	-37.41 to 13.46	Akarsh and Pathak (2008)
32	-10.29 to 0.52	-14.18 to -1.74	Venkatesan <i>et al.</i> (2008)
5	-12.00 to -1.50	-11.90 to 0.200	Anjuchaudhary <i>et al.</i> (2007)
45	-23.36 to 53.31	-16.14 to 89.75	Deo <i>et al.</i> (2007)
24	-23.13 to 5.25	-4.54 to 8.47	Aananthi and Jebaraj (2006)

Table 2.9 (Cont.)

84	-33.6 to 173.41	-35.98 to 150.66	Ashok <i>et al.</i> (2006)
30	-22.49 to 61.00	-	Pandya and Tripathi (2006)
21	-19.53 to 13.17	-23.71 to 6.60	Raju <i>et al.</i> (2006)
30	-22.49 to 61	-	Pandya and Tripathi (2006)
28	3.95 to 26.29	-6.62 to 18.90	Saravanan <i>et al.</i> (2006b)
8	-35.96 to -3.98	-	Shanthala <i>et al.</i> (2006)
36	-	-19.00 to 47.00	Singh <i>et al.</i> (2006a)
12	-	5.23 to 72.73	Singh <i>et al.</i> (2006b)
21	-19.53 to 16.94	-23.71 to 6.6	Raju <i>et al.</i> (2006)
4. Number of tillers per plant			
60	-	-19.23 to 6.36	Sreedhar <i>et al.</i> (2012)
45	-24.24 to 123.52	-30.55 to 111.11	Deo <i>et al.</i> (2007)
5. Number of productive tillers per plant			
21	-45.29 to 28.81	-51.59 to 10.14	Kumari <i>et al.</i> (2014)
15	-	0.00 to 166.67	Chandra and Suresh (2012)
60	-	-4.52 to 58.31	Sreedhar <i>et al.</i> (2012)
11	-31.93 to 78.43	-40.0 to 68.52	Vanisree <i>et al.</i> (2011)
6	-7.69 to 51.89	-11.76 to 30.69	Borah and Barman (2010)
48	-7.62 to 73.26	-13.03 to 61.51	Gouri Shankar <i>et al.</i> (2010)
45	-2.47 to 94.36	0.20 to 88.22	Panwar and Mashiat Ali (2010)
48	-	-34.08 to 3.29	Akarsh and Pathak (2008)
32	9.56 to 85.36	12.02 to 78.96	Venkatesan <i>et al.</i> (2008)
45	-27.86 to 85.07	-33.33 to 97.05	Deo <i>et al.</i> (2007)
3	-	35.63 to 167.29	Narasimman <i>et al.</i> (2007)
24	-45.28 to 25.54	-57.05 to 22.03	Aananthi and Jebaraj (2006)
84	-10.34 to 136.12	-32.58 to 114.4	Ashok <i>et al.</i> (2006)
30	-15.14 to 45.48	1.44 to 31.59	Pandya and Tripathi (2006)
21	-13.91 to 44.69	-26.98 to 31.58	Raju <i>et al.</i> (2006)
28	-5.78 to 56.10	-23.67 to 53.85	Saravanan <i>et al.</i> (2006b)
8	-26.29 to 55.26	-	Shanthala <i>et al.</i> (2006)
36	-	-42 to 64	Singh <i>et al.</i> (2006a)
21	-21.25 to 25.42	-24.59 to 22.60	Singh <i>et al.</i> (2006b)
30	-5.48 to 45.48	2.80 to 31.59	Pandya and Tripathi (2006)
21	-13.91 to 51.84	-26.98 to 31.58	Raju <i>et al.</i> (2006)
36	-	-42 to 64	Singh <i>et al.</i> (2006)
42	-	-	Ushakumari <i>et al.</i> (2006)
6. Panicle length			
21	-17.16 to 21.87	-36.76 to 6.07	Kumari <i>et al.</i> (2014)
15	-	-19.70 to 41.62	Chandra and Suresh (2012)
60	-	-10.59 to 4.95	Sreedhar <i>et al.</i> (2012)
16	0.6 to 25.0	-1.3 to 24.3	Janardhanam <i>et al.</i> (2001)
11	-8.81 to 29.77	-9.54 to 25.85	Vanisree <i>et al.</i> (2011)
6	-.44 to 64.89	-5.71 to 59.31	Borah and Barman (2010)

Table 2.9 (Cont.)

48	-12.08 to 26.69	-21.34 to 22.79	Gouri Shankar <i>et al.</i> (2010)
45	23.66 to 29.10	0.30 to 21.28	Panwar and Mashiat Ali (2010)
36	-	-19.34 to 27.64	Sanjeev kumar <i>et al.</i> (2010)
48	-	-31.73 to 43.21	Akarsh and Pathak (2008)
32	-5.51 to 16.91	-0.12 to 16.53	Venkatesan <i>et al.</i> (2008)
45	-10.09 to 37.61	-18.42 to 36.84	Deo Raj <i>et al.</i> (2007)
36	-	-	Sanjeev Kumar <i>et al.</i> (2007)
60	-	-43.88 to 30.56	Singh <i>et al.</i> (2007)
24	-10.57 to 22.86	-15.60 to 14.71	Aananthi and Jebaraj (2006)
30	-27.96 to 28.68	0.46 to 25.62	Pandya and Tripathi (2006)
21	-7.60 to 6.21	-16.69 to 3.67	Raju <i>et al.</i> (2006)
8	-20.82 to 7.43	-	Shanthala <i>et al.</i> (2006)
25	-	-18 to 34	Singh <i>et al.</i> (2006)
30	-30.07 to 28.68	0.46 to 27.12	Pandya and Tripathi (2006)
21	-8.17 to 6.21	-16.69 to 3.67	Raju <i>et al.</i> (2006)
36	-	-18 to 34	Singh <i>et al.</i> (2006)
7. Number of filled grains per panicle			
21	-11.63 to 85.83	-25.44 to 76.43	Kumari <i>et al.</i> (2014)
15	-	-45.36 to 71.68	Chandra and Suresh (2012)
60	-	-30.87 to 48.16	Sreedhar <i>et al.</i> (2012)
11	-49.43 to 52.87	-58.32 to 28.85	Vanisree <i>et al.</i> (2011)
6	11.81 to 278.30	-10.10 to 226.6	Borah and Barman (2010)
45	-17.76 to 33.37	0.77 to 16.35	Panwar and Mashiat Ali (2010)
48	-	-32.8 to 26.79	Akarsh and Pathak (2008)
32	-18.39 to 28.97	-2.14 to 28.97	Venkatesan e al. (2008)
45	-2.87 to 47.56	-17.08 to 57.57	Deo <i>et al.</i> (2007)
3	-	61.55 to 138.15	Narasimman <i>et al.</i> (2007)
60	-	-29.9 to 54.73	Singh <i>et al.</i> (2007)
24	5.06 to 40.18	-3.01 to 15.68	Aananthi and Jebaraj (2006)
30	-9.37 to 39.40	1.46 to 34.50	Pandya and Tripathi (2006)
21	-41.83 to 20.18	-48.22 to 15.60	Raju (2006)
36	-	-90.00 to 71.00	Singh <i>et al.</i> (2006)
21	-41.83 to 20.18	-48.22 to 15.60	Raju <i>et al.</i> (2006)
63	-	-90 to 71	Singh <i>et al.</i> (2006a)
12	-	9.21 to 24.43	Singh <i>et al.</i> (2006b)
8. Test weight			
21	-34.70 to 12.37	-39.69 to 4.61	Kumari <i>et al.</i> (2014)
21	-8.50 to 13.65	-35.04 to 12.65	Gnanamalar and Vivekananda (2013)
15	-	-14.36 to 22.22	Chandra and Suresh (2012)
60	-	-6.95 to 16.86	Sreedhar <i>et al.</i> (2012)
11	-3.84 to 30.79	-19.97 to 7.01	Vanisree <i>et al.</i> (2011)
45	-21.33 to 20.64	1.49 to 19.36	Panwar and Mashiat Ali (2010)

Table 2.9 (Cont.)

48	-	-29.12 to 13.12	Akarsh and Pathak (2008)
32	1.17 to 5.47	-6.79 to 4.47	Venkatesan e al. (2008)
45	-22.29 to 45.92	-44 to 24.78	Deo <i>et al.</i> (2007)
3	-	-5.83 to 7.78	Narasimman <i>et al.</i> (2007)
60	-	-28.62 to 42.48	Singh <i>et al.</i> (2007)
24	-17.62 to 24.79	-21.54 to 13.57	Aananthi and Jebaraj (2006)
	-2.73 to 23.50	-18.95 to 12.03	Ashok <i>et al.</i> (2006)
30	-6.12 to 20.13	0.33 to 18.41	Pandya and Tripathi (2006)
21	-4.14 to 16.57	-22.64 to 12.48	Raju <i>et al.</i> (2006)
28	-14.00 to 18.61	-18.77 to 13.69	Saravanan <i>et al.</i> (2006b)
8	-9.27 to 12.61	-	Shanthala <i>et al.</i> (2006)
36	-	26.00 to 48.00	Singh <i>et al.</i> (2006a)
12	-	-9.32 to 25.68	Singh <i>et al.</i> (2006b)
	-6.19 to 19.20	0.33 to 18.41	Pandya and Tripathi (2006)
	-4.14 to 16.73	-22.64 to 12.48	Raju <i>et al.</i> (2006)
	-	-26 to 48	Singh <i>et al.</i> (2006)
9. Grain yield per plant			
21	-34.70 to 12.37	-39.69 to 4.61	Kumari <i>et al.</i> (2014)
21	-3.89 to 88.79	-13.75 to 81.70	Gnanamalar and Vivekananda (2013)
15	-	-25.00 to 269.92	Chandra and Suresh (2012)
60	-	-14.16 to 81.41	Sreedhar <i>et al.</i> (2012)
11	-63.69 to 122.46	-66.98 to 104.19	Vanisree <i>et al.</i> (2011)
6	35.87 to 216.81	-36.36 to 216.81	Borah and Barman (2010)
48	6.94 to 70.82	1.84 to 67.33	Gouri Shankar <i>et al.</i> (2010)
45	-32.28 to 102.70	1.68 to 80.46	Panwar and Mashiat Ali (2010)
36	-	22.59 to 65.32	Sanjeev kumar <i>et al.</i> (2010)
48	-	-21.33 to 29.53	Akarsh and Pathak (2008)
32	59.62 to 75.72	50.45 to 67.66	Venkatesan e al. (2008)
5	-164.2 to 281.6	124.9 to 211	Anjuchaudhary <i>et al.</i> (2007)
45	-43.54 to 121.35	-34.45 to 104.06	Deo <i>et al.</i> (2007)
3	-75.14 to 90.50	-181.57 to 270.98	Narasimman <i>et al.</i> (2007)
60	-	-54.69 to 139.43	Singh <i>et al.</i> (2007)
27	-	-33.93 to 237.33	Anand Kumar <i>et al.</i> (2006)
24	-23.58 to 50.86	-37.20 to 39.41	Aananthi and Jebaraj (2006)
30	0.1 to 64.08	0.24 to 55.32	Pandya and Tripathi (2006)
21	-15.68 to 59.44	-21.66 to 43.47	Raju <i>et al.</i> (2006)
28	25.49 to 76.37	11.98 to 64.95	Saravanan <i>et al.</i> (2006b)
8	-61.81 to 14.79	-	Shanthala <i>et al.</i> (2006)
36	-	-72.00 to 152.00	Singh <i>et al.</i> (2006a)
12	-	11.72 to 89.29	Singh <i>et al.</i> (2006b)
15	-	-53.53 to 237.33	Anandkumar <i>et al.</i> (2006)
84	-33.6 to 173.41	-35.98 to 150.66	Ashok <i>et al.</i> (2006)

Table 2.9 (Cont.)

30	-6.22 to 64.08	0.24 to 55.32	Pandya and Tripathi (2006)
21	-15.68 to 59.44	-29.30 to 43.47	Raju <i>et al.</i> (2006)
21	-36.18 to 67.14	-51.82 to 52.35	Sharma <i>et al.</i> (2006)
36	-	-72.00 to 152.00	Singh <i>et al.</i> (2006)
10. Hulling percent			
21	-2.56 to 11.89	-3.98 to 11.88	Gnanamalar and Vivekananda (2013)
15	-9.77 to 4.18	-11.25 to 2.06	Chandra and suresh (2012)
30	-7.76 to 4.85	0.27 to 3.04	Pandya and Tripathi (2006)
11. Milling percent			
21	-0.89 to 6.60	-3.07 to 6.16	Gnanamalar and Vivekananda (2013)
15	-12.81 to 3.24	-15.16 to -1.53	Chandra and suresh (2012)
12. Head rice recovery percent			
21	-9.73 to 23.32	-11.39 to 16.23	Gnanamalar and Vivekananda (2013)
15	-35.05 to 33.66	-45.36 to 3.80	Chandra and suresh (2012)
13. Kernel length			
21	-15.87 to 15.36	-31.49 to 3.23	Gnanamalar and Vivekananda (2013)
15	-3.75 to 5.17	-10.08 to 2.48	Chandra and suresh (2012)
48	6.94 to 70.82	1.84 to 67.33	Gouri Shankar <i>et al.</i> (2010)
45	-8.89 to 10.83	0.00 to 8.87	Panwar and Mashiat Ali (2010)
36	-	-26.77 to 19.17	Sanjeev kumar <i>et al.</i> (2010)
30	-12.23 to 27.13	0.01 to 13.63	Pandya and Tripathi (2006)
28	-19.34 to 9.54	-21.66 to 1.34	Saravanan <i>et al.</i> (2006b)
14. Kernel breadth			
21	-11.02 to 25.29	-1.18 to 52.83	Gnanamalar and Vivekananda (2013)
15	-16.37 to 8.38	-24.78 to 5.52	Chandra and suresh (2012)
45	-12.70 to 8.96	-12.45 to -0.36	Panwar and Mashiat Ali (2010)
36	-	-10.2 to 16.77	Sanjeev kumar <i>et al.</i> (2010)
30	-13.54 to 12.03	-	Pandya and Tripathi (2006)
28	-6.52 to 10.59	-8.51 to 9.30	Saravanan <i>et al.</i> (2006b)
15. L:B ratio			
21	-23.76 to 23.16	-35.47 to -1.24	Gnanamalar and Vivekananda (2013)
15	-10.78 to 13.85	-12.40 to 3.62	Chandra and suresh (2012)
45	-12.12 to 20.67	0.08 to 18.11	Panwar and Mashiat Ali (2010)
36	-	-16.58 to 10.08	Sanjeev kumar <i>et al.</i> (2010)
16. Kernel length after cooking			
21	-17.89 to 5.83	-30.21 to 4.57	Gnanamalar and Vivekananda (2013)
15	-20.65 to -4.86	-27.00 to -9.67	Chandra and suresh (2012)

Table 2.9 (Cont.)

17. Kernel elongation ratio			
15	-20.73 to -1.91	-29.72 to -4.04	Chandra and suresh (2012)
21	-13.66 to 14.87	-15.54 to 12.35	Gnanamalar and Vivekananda (2013)
18. Volume expansion ratio			
15	-22.20 to 9.60	-33.15 to -1.45	Chandra and suresh (2012)
21	-11.67 to 41.94	-14.18 to 41.94	Gnanamalar and Vivekananda (2013)
19. Alkali Spreading Value			
21	-43.28 to 19.94	-45.28 to 15.61	Gnanamalar and Vivekananda (2013)
15	-32.20 to 70.87	-66.66 to 75.00	Chandra and suresh (2012)
20. Water uptake			
21	-11.09 to 18.21	-15.17 to 12.32	Gnanamalar and Vivekananda (2013)
15	-17.75 to 18.98	-21.81 to 4.44	Chandra and suresh (2012)
21. Gel consistency			
21	-43.05 to 17.26	-49.77 to 17.49	Gnanamalar and Vivekananda (2013)
15	-74.78 to 1.37	-76.19 to 12.50	Chandra and suresh (2012)
22. Amylose content			
21	-14.49 to 20.40	-15.99 to 18.90	Gnanamalar and Vivekananda (2013)
15	-19.92 to 3.01	-44.98 to -0.18	Chandra and suresh (2012)

Chapter III

MATERIAL AND METHODS

The present investigation on "Heterosis and combining ability studies of ratooning in rice (*Oryza sativa* L.)" was carried out in five seasons viz., *Kharif*, 2014., *Rabi*, 2014-15., *Kharif*, 2015., *Rabi*, 2015-16 and *summer*, 2016 with prime objective of identification of entries with good ratooning ability and testing F₁s and their parents for combining ability gene action and heterosis in F₁ main crop and it's ratoon crop. The material used and methods followed to carry out these experiments are presented in this chapter.

EXPERIMENTAL SITE LOCATION AND WEATHER CONDITION

Andhra Pradesh Rice Research Institute (APRRI) and Regional Agricultural Research Station (RARS), Maruteru, West Godavari district, Andhra Pradesh, India, was located at an altitude of 5 m above mean sea level, geographical location was 80° 55' to 82° 30' east longitude and 16° 15' to 18° 20' north latitude. The soils are characterized by black alluvial soils, neutral to slightly alkaline in reaction with medium levels of phosphorus and potassium. The annual rainfall of the location is 1100 mm. The material used and the methods followed in the present investigation are described hereunder.

3.1 MATERIAL

The present investigation on 20 popular rice varieties (Table 3.1) which developed by ANGRAU, were used for screening towards ratoonability during *Kharif*, 2014 as a main crop and in *Rabi*, 2014-15 as a ratoon crop. The ratoonability/ ratooning rate was studied as suggested by Samson (1980) and Chauhan (1989) (Appendix: B and C) along with their yield and quality. Based on the ratoon crop performance for yield and grain quality of 8 parents were identified and crossed in Method-2 and Model-II of diallel design (Griffing, 1956) and generated 28 single crosses (F₁s). These 28 F₁s along with 8 parents were evaluated during *Rabi* 2015-16 (main crop) and summer 2016 (ratoon crop) and studied combining ability, gene action and heterosis for yield, quality and ratooning ability traits. The information about the material used in this study is presented in Table 3.1, 3.2 & 3.3 and Plate 3.1.

3.2 METHODS

3.2.1 Screening of Rice Varieties for Ratoonability

Screening of entries for ratoonability was aimed out at APPRI & RARS, Maruteru, W.G district, A.P. Twenty popular varieties (varieties grown by farmers + pre released cultivars) were raised in randomized complete block design (RCBD), with three replications. Each entry was planted in three rows of three meters length adopting 20 cm x 15 cm spacing. The main crop was harvested at the time of physiological maturity, leaving stubbles of 30 cm height above the ground level. Stubbles left over were then allowed to regenerate. The crop was maintained as per the standard agronomic practices recommended for this region. The fertilizers application was done at the rate of 60 kg nitrogen, 40 kg phosphorus and 30 kg K₂O hectare⁻¹ for main crop, while one fourth of it was applied to the ratoon crop, two days after the harvest of the main crop (Ambili and Rosamma, 2002). The details of the experimental techniques followed in the present investigation are furnished in Table 3.3.

3.2.2 Ratoonability/Ratooning Rate (RR)

Ratooning ability/ratooning rate (RR) of cultivars were measured by using following formulae given by the Samson (1980) (Appendix B):

$$RR = (1.0 - 0.1 \text{ ratooning vigor rating}) \times \left(1.0 - \frac{\text{Missing hills/plot}}{\text{Total hills/plot}}\right) \times \left(\frac{\text{Total tillers/hill}}{16}\right)$$

A high ratoon rating indicates less than 5% missing hills, at least 16 tillers per hill, and excellent vigour. The rating scale for ratoon vigour was given as:

Ratoon extra vigorous (count basal + nodal ratoons):	1
Ratoon normal or intermediate (count only basal ratoons):	5
Ratoon very weak and few (no counting):	9

Basal ratoons : Tillers that grow from the nodes of the stubble from the base up to 1cm above the ground.

Upper nodal ratoons : Tillers that grow from the nodes of the stubble more than 1cm above the ground.

Dead hills : No ratoons.

Chauhan *et al.* (1989) calculated ratooning ability (RA) (Appendix C) as the ratio between the ratoon crop productive tillers to the main crop productive tillers.

$$\text{Ratooning ability (RA)} = \frac{\text{Ratoon crop productive tillers}}{\text{Main crop productive tillers}}$$

3.2.3 Hybridization Programme

The crossing block was laid out at APRRI and RARS, Maruteru, West Godavari district, Andhra Pradesh, India. Twenty eight crosses were effected involving the eight parents in a diallel fashion without reciprocals (Method-2, Model II) during *Kharif*, 2015. Four staggered sowings of parents were undertaken at an interval of seven days to ensure synchronous flowering to produce adequate crossed seed. Twenty eight days old seedlings were transplanted at a spacing of 20 cm × 15 cm for each sowing date. The plots were periodically top dressed with urea, watered regularly and necessary plant protection measures were taken up against pests and diseases in all the three sets studied.

3.2.3.1 Clipping

Healthy female plants with just emerged panicles were uprooted and potted in the evening hours of one day before emasculation into plastic buckets filled with mud and were transferred to the net house. Productive tillers with healthy panicles were selected and the leaf sheaths were removed carefully. Further, florets that had completed anthesis (at the top) and young florets at the bottom of the panicle were also removed. Florets due for anthesis alone were used for crossing. Top 1/3rd of each floret was clipped with scissors and the anthers were removed with the help of forceps and then the emasculated florets were covered with butter paper bags and labelled properly. The emasculation process was carried out during evening hours.

3.2.3.2 Pollination

On the subsequent morning, panicles ready for anthesis were selected from healthy male parents and were brought to the crossing chamber in which temperature, relative humidity and light conducive for anthesis were maintained. When the male parent was ready for dehiscence, the female parent was brought inside the crossing chamber. Butter paper bags covering emasculated panicles of the female parents were removed. Panicles of male parents were then gently shaken over the female parents until adequate pollen was deposited on the stigmas of the emasculated spikelets.

The pollinated spikelets were then covered with fresh butter paper bags, duly labelled and fixed against the support of bamboo stakes. The process of pollination was continued up to 10.00 A.M. Crossed seeds were collected after four weeks from the crossed panicles of the plants maintained in the pots in the net house. The seeds were then sun dried, counted and placed in small envelopes. The number of crossed seed collected for each cross varied from 90-100.

3.2.4 Field Evaluation

In *Rabi*, 2015-16 twenty eight F_1 seeds and their parents were treated with carbendazim solution (0.1%) and soaked in petridishes. Satisfactory germination was observed on the 4th and 5th day of soaking. The seedlings were transferred to small raised beds covered with a layer of sand. Sufficient care was taken to avoid water logging and complete drying up of the nursery beds. Need based plant protection measures were taken up for proper raising of healthy seedlings (F_1 s and parents). Four weeks old seedlings (Twenty eight F_1 hybrids along with six parents) were transplanted in the main field in randomized complete block design (RCBD), with three replications. Each entry was planted in three rows of three meters length at 15 cm $\times$ 15 cm spacing. The main crop (F_1 + parents) was harvested 30 cm above the ground level at the time of physiological maturity. Stubbles left over were then allowed to regenerate and fertilizer schedule of 90 kg nitrogen, 60 kg phosphorus and 40 K_2O hectare⁻¹ was adopted for main crop (F_1 + parents). For ratoon crop applied one fourth of the fertilizer of the main crop (F_1 + parents) two days after the harvest of the main crop (Ambili and Rosamma, 2002). Data was collected on main crop and ratoon crop F_1 s and parents on 10 randomly selected plants in each replication and estimated combining ability, gene action and heterosis.

3.2.3 Experimental Design for Variability, Combining Ability and Heterosis

The 28 F_1 s obtained from crossing programme along with 8 parents were evaluated in a randomized complete block design (RCBD) with three replications during *Rabi*, 2015-16 as F_1 main crop and it's ratoon crop during summer, 2016. Each plot consisted of three rows of 3 m length. Single seedling was planted per hill with a spacing of 15 cm $\times$ 15 cm.

Fertilizers were applied at the rate of 90 kg nitrogen; 60 kg phosphorus and 40 kg K_2O hectare⁻¹ for main crop and 1/4th of the fertilizers of main crop were applied to F_1 ratoon crop. The package of practices recommended to respective location was adopted for raising a good crop.

3.3 Recording of Observations

Observations were recorded on ten randomly selected plants in each replication on both main crop and ratoon crop for 24 characters, consisting of 10 yield attributing characters viz., days to 50% flowering, days to maturity, plant height (cm), number of tillers per plant, number of ear bearing tillers per plant, panicle length (cm), number of grains per panicle, test weight (g), leaf area index at maximum tillering stage, grain yield per plant (g); 6 physical quality traits such as hulling per cent, milling per cent, head rice recovery per cent, kernel length (mm), kernel breadth (mm), kernel L/B ratio; 8 cooking and chemical quality traits such as kernel length after cooking (mm), kernel breadth after cooking (mm), kernel elongation ratio, volume expansion ratio, water uptake (ml), gel consistency, alkali digestion value (mm) and amylose content (%). However, in ratoon crop along with above 24 characters, data on another 3 characters viz., number of ratoon tillers as percentage of main crop tillers, number of vegetative buds after the harvest of main crop, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers were also considered. The traits number of tillers per plant, number of ratoon tillers as percentage of main crop tillers, number of vegetative buds after the harvest of main crop, number of ear bearing tillers and number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers are considered as traits related to ratoonability was also recorded.

The details of the observations recorded and methods followed for both main crop and ratoon crop are presented here under character wise.

3.3.1 Yield Attributing Characters

3.3.1.1 Days to 50% flowering

The number of days taken from the day of sowing to opening of panicles in 50 per cent of the plants in a plot was taken as days to 50% flowering. Based on the maturity duration these genotypes are classified into three groups early duration (<125 days), medium duration (125 to 135 days) and long duration group (> 135 days).

3.3.1.2 Days to maturity

The total number of days taken for the plants in a plot to attain physiological maturity from the date of sowing was recorded as days to maturity.

3.3.1.3 Plant height (cm)

It was measured from bottom of the plant to the tip of the panicle and expressed in centimeters for ten randomly selected plants in each replication at maturity.

3.3.1.4 Total number of tillers per plant

Total number of tillers (ear bearing and non-ear bearing tillers) were counted in each of the ten randomly selected plants at maturity in each replication.

3.3.1.5 Number of ratoon tillers as percentage of main crop tillers

It was measured as the ratio of total number of tillers per plant of ratoon crop to the number of tillers of main crop and expressed in percentage.

3.3.1.6 Number of vegetative buds present after harvest of main crop

After harvest of the main crop the newly sprouted vegetative buds that put forth new tillers were counted randomly for 10 plants.

3.3.1.7 Number of ear bearing tillers per plant (EBT/plant)

Total number of panicle bearing tillers was counted in each of the ten randomly selected plants at maturity in each replication.

3.3.1.8 Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers

It is measured as the ratio of number of ear bearing tillers of ratoon crop to the number of ear bearing tillers of main crop and expressed in percentage.

3.3.1.9 Panicle length (cm)

The length from base (*i.e.*, first node) to the tip of the panicle was measured in centimeters for 10 randomly selected panicles in each replication and mean was taken.

3.3.1.10 Number of grains per panicle

Number of filled grains per each panicle was counted for ten randomly selected panicles from each sample and the average was calculated.

3.3.1.11 Test weight (g)

One thousand well filled grains from each entry were counted and weighed to nearest milligram at 13 % moisture level.

3.3.1.12 Leaf area index (LAI) at maximum tillering stage

Leaf area index was measured by leaf area index meter, where the reading was taken at three parts of the plant, one at the base of the plant, second at the middle of the plant height, third reading at 1/3rd from top from the plant height, in three locations in each plot in each replication.

3.3.1.13 Grain yield per plant (g)

The matured panicles of ten single plants were harvested, threshed, cleaned and seed dried to 13% moisture level and weight of the grain was recorded in grams.

3.3.2 Physical Quality Characters

3.3.2.1 Hulling recovery (%)

One hundred grams of paddy sample after thorough drying to a moisture level of 12-14% from each replication was hulled in Satake THU 35B Rice Huller and the weight of hulled rice/dehusked kernels (brown rice) was recorded in grams. Hulling recovery was calculated by using the following formula.

$$\text{Hulling recovery (\%)} = \frac{\text{Total weight of dehusked kernels (g)}}{\text{Total weight of paddy (g)}} \times 100$$

3.3.2.2 Milling recovery (%)

The dehusked kernels (brown rice) were transferred to rice miller, model (TM 05) and milling 90 seconds *i.e.*, 5% of milling (Chauhan *et al.*, 1994) was carried out. The milled rice/polished kernels/white rice obtained was weighed in grams and the milling recovery was calculated by using the formula.

$$\text{Milling recovery (\%)} = \frac{\text{Total weight of polished kernels (g)}}{\text{Total weight of paddy (g)}} \times 100$$

3.3.2.3 Head rice recovery (%)

The milled rice obtained from the rice miller was separated into broken and non broken in a sizing device (TRG 058). The weight of head rice/ non broken (full sized and 3/4 sized grains) was recorded in grams and head rice recovery was calculated by using the formula.

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of whole polished grains (g)}}{\text{Total weight of paddy (g)}} \times 100$$

3.3.2.4 Kernel length (mm)

Ten grains at random from each replication were dehusked by hand and the length was recorded in millimeters by using dial micro meter.

3.3.2.5 Kernel breadth (mm)

Ten grains at random from each replication were dehusked by hand and the breadth was recorded in millimeters by using dial micro meter.

3.3.2.6 Kernel $\frac{L}{B}$ ratio:

The length and breadth of the ten kernels from each sample were measured with dial micro meter and the ratio was estimated by using the following formula.

$$\text{Kernel } \frac{L}{B} \text{ ratio} = \frac{\text{Mean of the kernel length (mm) of 10 kernels}}{\text{Mean of the kernel breadth (mm) of 10 kernels}} \times 100$$

Based on the $\frac{L}{B}$ ratio, the following categories were made for grain shape. (Jennings *et al.*, 1979)

Grain type	Kernel $\frac{L}{B}$ Ratio
Long slender (LS)	Length 6 mm and above, $\frac{L}{B}$ ratio 3 and above.
Short slender (SS)	Length less than 6 mm, $\frac{L}{B}$ ratio 3 and above.
Medium slender (MS)	Length less than 6 mm, $\frac{L}{B}$ ratio 2.5 to 3.0.
Long bold (LB)	Length 6 mm and above, $\frac{L}{B}$ ratio less than 3.0.
Short bold (SB)	Length less than 6 mm $\frac{L}{B}$ ratio less than 2.5.

3.3.3 Cooking Quality Characters

3.3.3.1 Kernel length after cooking (mm)

A total of five grams of unbroken milled kernels were taken to a test tube and 15 ml of water was added to it. The kernels were soaked for ten minutes then cooked for twenty minutes on a water bath. Put the cooked rice on blotting paper. Select ten cooked grains (intact at both) and measured the length of the kernel using the millimeter scale on a graph sheet for computing the kernel length after cooking (DRR, 2006).

3.3.3.2 Kernel breadth after cooking (mm)

Breadth of ten cooked rice grains was measured to nearest milli meter on a graph sheet.

3.3.3.3 Kernel elongation ratio

The length of the ten rice grains of each sample was measured before and after cooking and elongation ratio was calculated by using the following formula.

$$\text{Kernel elongation ratio} = \frac{\text{Kernel length after cooking (mm)}}{\text{Kernel length before cooking (mm)}}$$

3.3.3.4 Volume expansion ratio

Volume expansion ratio was determined as suggested by Verghese (1950). Five grams of rice sample was soaked in 15ml of water for 5 minutes in 50ml graduated centrifuge tube. The volume of water was recorded after adding rice samples (Y-15). Rice cooked for 20 minutes in water bath was dipped in 100ml measuring cylinder (X) containing 50ml water. The volume raised was recorded (X-50) and was computed by using the following formula.

$$\text{Volume Expansion ratio} = \frac{\text{Increase in volume after cooking (X-50)}}{\text{Increase in volume before cooking (Y-15)}}$$

3.3.3.5 Water uptake (ml)

Two grams of the milled rice was soaked for thirty minutes in a test tube by putting 10 ml of water. Then it was boiled for 45 minutes at 77°C- 80°C in a constant temperature water bath. Two test tubes were kept with 10 ml of water as a control along

with the samples in the water bath. Immediately the tubes were placed in a beaker containing cold water for cooling. The supernatant water in the test tube was poured into graduated cylinder after cooling and the water level was noted (DRR, 2006).

$$\text{Water up take} = \left(\frac{100}{2g} \right) \times \text{Actual water absorbed (ml)}$$

3.3.3.6 Gel consistency (mm)

Gel consistency (GC) measures the tendency of the cooked rice to harden on cooling. Gel consistency (GC) was analyzed based on the method described by Cagampang *et al.* (1973). One hundred milligrams of the rice flour of each sample was weighed accurately, in duplicate, into long narrow pyrex tubes and kept at room temperature for 24 hours, to obtain moisture equilibrium, the sample as wetted with wet 0.2 ml of 95 per cent ethanol containing 0.025 per cent thymol blue. The tubes were shaken to suspend the starch and 2 ml of 0.2 N KOH was added immediately. The tubes were placed on a vortex mixer for vigorous shaking and then put in a boiling water bath for 5 minutes of refluxing. Later the tubes were taken out and cooled at room temperature for 15 minutes and then cooled in an ice water bath (5-7°C) for 20 minutes.

After drying the surface moisture, tubes were placed horizontally over a graph paper graduated in mm without any disturbance. The length of the blue colored gel was measured from inside bottom of the test tube to the gel front after 30 minutes. Based on the length of the gel, rice samples can be categorized as follows.

1. Very flaky rice with hard gel consistency (length of gel <40 mm)
2. Flaky rice with medium gel consistency (length of gel 40-60 mm)
3. Soft rice with soft gel consistency (length of gel >60 mm)

3.3.3.7 Alkali spreading value (Gelatinization Temperature)

The alkali spreading value (ASV) (gelatinization temperature) determines the time required for cooking the rice. For determination of ASV, method given by Little *et al.* (1958) was used. Six whole milled grains without cracks were taken from each replication and spaced evenly in small petri dishes containing 10 ml of 1.7 per cent potassium hydroxide (KOH). The dishes were kept at 30°C for 23 hours undisturbed and replicated twice.

The spreading and clearing of kernels noted in seven point scale was recorded as detailed hereunder (Jennings *et al.*, 1979). The scoring was adopted for all the grain selected and expressed G.T. scores.

S.No.	Spreading	Clearing	Score	Classification of GT
1	Kernel not effected	Kernel chalky	1	High
2	Kernel swollen	Kernel chalky, collar powdery	2	High
3	Kernel swollen, collar incomplete and narrow	Kernel chalky, collar cloudy	3	High to Intermediate
4	Kernel swollen, collar complete and wide	Centre cottony, collar cloudy	4	Intermediate
5	Kernel split or segmented, collar complete and wide	Centre cottony, collar cloudy	5	Intermediate
6	Kernel dispersed, merging with collar	Centre cloudy, collar cleared	6	Low
7	All kernels dispersed and inter mingled	Centre and collar cleared	7	Low

The above scoring was adopted for all the grains selected and expressed as the average gelatinization temperature (GT) score. A rating of 1 to 2 was classified as high gelatinization temperature ($> 74^{\circ}\text{C}$), 3 high to intermediate, 4 to 5 intermediate (70 to 74°C) and 6 to 7 low gelatinization temperature ($< 55^{\circ}\text{C} - 69^{\circ}\text{C}$).

3.3.3.8 Amylose content (%)

Amylose, a linear fraction of starch has a major influence on cooking and eating quality characteristics of rice. It also plays an important role in determining the texture of cooked rice. A variety with high amylose content represents that the rice grain cooks dry, are less tender, and becomes hard upon cooling. If a variety consisting low amylose content, represents that the rice grain cooks moist and are sticky upon cooling. Simplified procedure of Juliano (1971) was used for the estimation of amylose content.

Whole grain milled rice samples were ground separately to pass through a 100 mesh sieve. 100 mg of each sample was weighed accurately in to 50 ml tubes to which 1 ml of 95 % ethanol and 9 ml of 1 N NaOH were added. The contents of the tubes were heated on an electric heater for 10 minutes to gelatinize the starch and then cooled and transferred to a 100 ml volumetric flask, with several distilled water washings. The volume was made up to 100 ml and the contents were shaken vigorously. 5 ml of

aliquot was pipetted in to a 100 ml volumetric flask to which 1ml of 1N acetic acid iodine solution containing 0.2 g of iodine and 20 g of KI in 100 ml of aqueous solution was added. Volume was again made up to 100 ml adding distilled water. The flask was thoroughly shaken and left for 20 minutes in dark for color development. Absorbance of solutions at 620 nm was measured with spectrophotometer.

Amylose content was determined by reference to a standard curve and expressed on dry weight basis. For preparing the standard curve, 40 mg of potato amylose (sigma) was taken and wet with 1 ml ethyl alcohol and 9 ml 1 N NaOH, heated for 10 minute in beakers containing water on an electric heater. Then the content was cooled and volume was made up to 100 ml with several distilled water washings. From this solution 1, 2, 3, 4 and 5 ml portion were placed with a pipette in 100 ml volumetric flask and then these are acidified with 1 N acetic acid (0.2, 0.4, 0.6, 0.8 and 1.0 ml of acetic acid to 1, 2, 3, 4 and 5 ml amylose solutions respectively) and then 2 ml of iodine solution was added. After 20 minutes, absorbance values at 620 nm were recorded on spectrophotometer and were plotted against the concentrations of anhydrous amylose (mg) to determine the conversion factor. The dilution factor of 20 for the sample was included in the conversion factor.

After estimating the amylose content, the samples were classified as low (amylose content 8 - 19%), intermediate (amylose content 20 - 25%) and high (amylose content- above 25%).

3.4 STATISTICAL ANALYSIS

The data recorded on various characters were subjected to the following statistical analysis.

3.4.1 Analysis of Variance

Analysis of variance of the characters was done as per standard statistical procedure for randomized complete block design given by Panse and Sukhatme (1978).

$$Y_{ij} = \mu + t_i + r_j + e_{ij}$$

Where,

Y_{ij} = Performance of i^{th} genotype in j^{th} block

μ = General mean

t_i = i^{th} genotype effect

r_j = j^{th} block effect

e_{ij} = Random error

ANOVA Table for Randomized Block Design

Source of variation	Degrees of freedom	Mean sum of squares	Expected mean sum of squares	“F” calculated value
Replications	r-1	M_r		M_r / M_e
Treatments	t-1	M_t	$\sigma_e^2 + r \sigma_g^2$	M_t / M_e
Error	(r-1)(t-1)	M_e	σ_e^2	
Total	(rt-1)			

Where,

r = Number of replications

g = Number of genotypes

M_r = Mean sum of square of replication

M_t = Mean sum of square of treatment

M_e = Mean sum of square of error

σ_e^2 = Environmental variance

σ_r^2 = Variance due to replications

σ_g^2 = Variance due to genotype

3.4.2 Estimation of Genetic Parameters

In order to assess and quantify the genetic variability among the parents and F_1 s for the characters under study, the following parameters were estimated as given below.

3.4.2.1 Estimation of variance components

Phenotypic and genotypic variances were estimated using the following formula,

$$\text{Genotypic variance } (\sigma_g^2) = \frac{M_t - M_e}{r}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + M_e = \frac{M_t - M_e}{r} + M_e$$

The test of significance was carried out using ‘F’ table value of Fisher and Yates (1963).

3.4.2.2 Coefficient of variation

The genotypic and phenotypic coefficients of variation were calculated using the formula suggested by Burton (1952).

$$\text{a) Genotypic coefficient of variation (GCV)} = \frac{\text{Genotypic standard deviation } (\sigma_g)}{\text{General mean } (\bar{X})} \times 100$$

$$\text{b) Phenotypic coefficient of variation (PCV)} = \frac{\text{Phenotypic standard deviation } (\sigma_p)}{\text{General mean } (\bar{X})} \times 100$$

The GCV and PCV values were classified as described by Sivasubramanian and Menon (1973).

Classification	GCV/ PCV
Low	Less than 10%
Moderate	10 – 20%
High	More than 20%

3.4.2.3 Heritability

Heritability in broad sense and narrow sense was computed as suggested by Hanson *et al.* (1956) and expressed as percentage by using following formulae.

$$\text{Heritability in broad sense } (h_{bs}^2) = \frac{\text{Genotypic variance } (\sigma_g^2)}{\text{Phenotypic variance } (\sigma_p^2)} \times 100$$

$$\text{Heritability in narrow sense } (h_{ns}^2) = \frac{\text{Additive variance } (\sigma_g^2)}{\text{Phenotypic variance } (\sigma_p^2)} \times 100$$

Heritability in broad sense was categorized as per the classification given by Johnson *et al.* (1955).

Classification	Heritability
Low	Less than 30%
Moderate	30 – 60%
High	More than 60%

3.4.2.4 Expected Genetic Advance (GA)

Genetic advance was calculated based on the formula given by Johnson *et al.* (1955).

$$\text{Expected genetic advance (GA)} = K \times \sigma_p \times h^2$$

Where,

K = Selection differential at 5% selection intensity (2.06)

σ_p = Phenotypic standard deviation

h^2 = Heritability in broad sense

3.4.2.5 Genetic Advance as Per Cent of Mean (GAM)

$$\text{GAM} = \frac{\text{GA}}{\bar{X}} \times 100$$

Where,

GA = Genetic advance

$\bar{X}$ = Grand mean of the character

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al.* (1955).

Classification	GAM
Low	Less than 10%
Moderate	10 – 20%
High	More than 20%

3.4.3 Combining Ability Analysis

The combining ability analysis of parents and crosses was taken up for different characters using the Diallel analysis without reciprocals (Method-2, Model II) as given by Griffing (1956).

Mathematical model for combining ability analysis is

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + \frac{1}{r_k} \sum r_k + \frac{1}{r_k} \sum (rv)_{ijk} + \sum_k \sum_l e_{ijkl}$$

Where,

Y_{ijk} = Any measurable character of the cross $i \times j$

μ = Population mean effect

g_i = General combining ability effect of i^{th} parent

g_j = General combining ability effect of j^{th} parent

s_{ij} = Specific combining ability effect of $i \times j^{\text{th}}$ cross

r_k = Effect due to k^{th} replication

rv = Effect due to replication $\times$ variety interaction

e_{ijkl} = Environmental effect on $ijkl^{\text{th}}$ individual

ANOVA for Combining Ability

Source of variation	Degrees of freedom	SS	MSS	Expected MSS
<i>gca</i> effects	$(p-1)$	S_g	M_g	$\sigma_e^2 + \sigma_s^2 + (p+2)\sigma_g^2$
<i>sca</i> effects	$p(p-1)/2$	S_s	M_s	$\sigma_e^2 + \sigma_s^2$
Error	$(c-1)(r-1)$	S_e	M_e	σ_e^2

Where,

r = Number of replications

p = Number of parents

c = Number of crosses

σ_e^2 = Error variance

σ_g^2 = Variance due to general combining ability

σ_s^2 = Variance due to specific combining ability

3.4.3.1 Estimation of genetic components of variation

Based on expected MSS from ANOVA table for combining ability, variance components are calculated as follows

$$\sigma_g^2 = \frac{(M_g - M_s)}{p+2}$$

$$\sigma_s^2 = M_s - M_e$$

$$\sigma_e^2 = M_e$$

Hence,

$$V_A \text{ (Additive variance)} = 2 \sigma_g^2$$

$$V_D \text{ (Dominance variance)} = \sigma_s^2$$

3.4.3.2 Estimation of combining ability effects

i. *gca* effects (g_i)

$$g_i = \frac{1}{p+2} \left[\sum (Y_{i.} + Y_{ii}) - \frac{2}{p} Y_{..} \right]$$

ii. *sca* effects (s_{ij})

$$s_{ij} = Y_{ij} - \frac{1}{p+2} (Y_{i.} - Y_{ii} + Y_{.j} + Y_{jj}) + \frac{2}{(p+1)+(p+2)} Y_{..}$$

Where,

p = Number of parents

$Y_{i.}$ = Total of i^{th} line over replications and lines

Y_{ii} = Mean value of selfed i^{th} line over replications

$Y_{..}$ = Total of F_{1s} and parental selfs

Y_{ij} = Mean value of ij^{th} cross over replications

$Y_{.j}$ = Total of j^{th} line over replications and lines

Y_{jj} = Mean value of selfed j^{th} line over replications

3.4.3.3 Computation of individual *gca* and *sca* variances

gca and *sca* variances for each parent are calculated as follows

$$\sigma_{g_i}^2 = g_i^2 - \frac{(p-1)}{p(p-2)} M_e$$

$$\sigma_{s_i}^2 = \frac{1}{p-2} \sum_j^p s_{ij}^2 - \frac{(p-3)}{(p-2)} M_e \dots \dots \dots (i=j)$$

3.4.3.4 Standard errors and standard error differences for combining ability effects

Standard errors to test the accuracy of *gca* and *sca* effects of different combinations were calculated as follows:

$$S.E(g_i) = \sqrt{\frac{(p-1)M_e}{p(p+2)}}$$

$$S.E(s_{ij}) = \sqrt{\frac{p^2 + (p+2)M_e}{(p+1)(p+2)}}$$

The *gca* and *sca* effects were tested for significance by calculating 't' value by using the following formulae.

$$t_i = \frac{g_i}{SE(g_i)} \quad (\text{at } p-1 \text{ degrees of freedom})$$

$$t_{ij} = \frac{s_{ij}}{SE(s_{ij})} \quad (\text{at } p(p-1)/2 \text{ degrees of freedom})$$

Standard error difference is developed to test the significance of differences between any two g_i 's or s_{ij} 's

$$S.Ed (g_i - g_j) = \sqrt{\frac{2M_e}{p+2}}$$

$$S.Ed (s_{ij} - s_{ik}) = \sqrt{\frac{2(p+1)M_e}{p+2}}$$

$$S.Ed (s_{ij} - s_{kl}) = \sqrt{\frac{2p \times M_e}{p+2}}$$

Critical difference (CD) for each pair of g_{is} , and that of s_{ijs} is as follows

$$CD (g_i - g_j) = S.Ed (g_i - g_j) \times t_{5\%} \text{ or } t_{1\%} \quad (\text{at } p-1 \text{ degrees of freedom})$$

$$CD (s_{ij} - s_{ik}) = S.Ed (s_{ij} - s_{ik}) \times t_{1\%} \quad (\text{at } p(p-1)/2 \text{ degrees of freedom})$$

Between crosses with common mother

$$CD (s_{ij} - s_{kl}) = S.Ed(s_{ij} - s_{kl}) \times t_{1\%} \quad (\text{at } p(p-1)/2 \text{ degrees of freedom})$$

3.4.4 Estimation of Heterosis

The heterotic effects were measured as deviation of F_1 mean from mid parent (relative heterosis) and better parent (heterobeltiosis) mean.

The per cent of heterosis was calculated as follows:

$$\text{Relative heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$$\overline{MP} = \frac{\overline{P_1} + \overline{P_2}}{2}$$

$$\text{Heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ = Mean value of F_1

$\overline{MP}$ = Mean value of mid parent

$\overline{BP}$ = Mean value of better parent

$\overline{P_1}$ = Mean of first parent

$\overline{P_2}$ = Mean of second parent

3.4.4.1 Test of significance of heterosis

The test of significance of heterosis over mid parent, better parent and standard check was done by 't' test as suggested by Snedecor and Cochran (1967) as follows:

$$\text{Heterosis } t = \frac{\text{Mean of } F_1 - \text{Mean of mid parent (or) better parent (or) standard check}}{\sqrt{\frac{2EMS}{r}}}$$

The estimated 't' value was compared with 't' values at error degrees of freedom.

3.4.5 Correlation Studies

The phenotypic and genotypic correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components by using covariance technique as per Falconer (1964).

$$\text{Phenotypic coefficients of correlation } (r_p) = r(x_i x_j)_p = \frac{\text{Cov}(x_i x_j)_p}{\sqrt{V(x_i)_p \times V(x_j)_p}}$$

Where,

- $r(x_i x_j)_p$ = Phenotypic correlation between i^{th} and j^{th} characters
 $\text{Cov}(x_i x_j)_p$ = Phenotypic covariance between i^{th} and j^{th} characters
 $V(x_i)_p$ and $V(x_j)_p$ = Phenotypic variance of i^{th} and j^{th} characters, respectively

$$\text{Genotypic coefficients of correlation } (r_g) = r(x_i x_j)_g = \frac{\text{Cov}(x_i x_j)_g}{\sqrt{V(x_i)_g \times V(x_j)_g}}$$

Where,

- $r(x_i x_j)_g$ = Genotypic correlation between i^{th} and j^{th} characters
 $\text{Cov}(x_i x_j)_g$ = Genotypic covariance between i^{th} and j^{th} character
 $V(x_i)_g$ and $V(x_j)_g$ = Genotypic variance of i^{th} and j^{th} characters, respectively

3.4.5.1 Test of significance

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1963) at $(n-2)$ degrees of freedom at 5% and 1% level where 'n' denotes the number of paired observations used in the calculation.

3.4.6 Path Coefficient Analysis

Path coefficient analysis was carried out by using the correlation coefficients to know the direct and indirect effects of the component characters on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Path coefficients were obtained by solving the simultaneous equations which express the basic relationship between correlations and path coefficients.

The equations are as follows:

$$\begin{bmatrix} r_{1,y} = P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} P_{3,y} + \dots + r_{1,k} P_{k,y} \\ r_{2,y} = r_{2,1} P_{1,y} + P_{2,y} + r_{2,3} P_{3,y} + \dots + r_{2,k} P_{k,y} \\ \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\ \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\ \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\ \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\ r_{k,y} = r_{k,1} P_{1,y} + r_{k,2} P_{2,y} + r_{k,3} P_{3,y} + \dots + r_{k,k} P_{k,y} \end{bmatrix}$$

Where,

$r_{1,y}$ to $r_{k,y}$ = Correlation coefficients between independent characters

$r_{1,2}$ to $r_{k-1,k}$ = Correlation coefficients between all possible combinations of independent characters

$P_{1,y}$ to $P_{k,y}$ = Direct effects of characters 1 to k on character y

The above equations were written in a matrix form as under:

$$\begin{matrix} & \text{A} & & \text{C} & & \text{B} \\ \begin{bmatrix} r_{1,y} \\ r_{2,y} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ r_{i,y} \end{bmatrix} & = & \begin{bmatrix} 1 & r_{1,2} & r_{1,i} \\ r_{2,1} & 1 & r_{2,i} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ r_{i,1} & r_{i,2} & 1 \end{bmatrix} & \begin{bmatrix} P_{1,y} \\ P_{2,y} \\ \cdot \\ \cdot \\ \cdot \\ P_{i,y} \end{bmatrix} \end{matrix}$$

Then $B = [C]^{-1} A$

Where,

$$[C]^{-1} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdot & \cdot & C_{1i} \\ C_{21} & C_{22} & C_{23} & \cdot & \cdot & C_{2i} \\ C_{i1} & C_{i2} & C_{i3} & \cdot & \cdot & C_{ii} \end{bmatrix}$$

The direct effects were calculated as follows

$$P_{1,Y} = \sum_{i=1}^k = C_{1i} r_{iY}$$

$$P_{2,Y} = \sum_{i=1}^k = C_{1i} r_{iY}$$

$$P_{i,y} = \sum_{i=1}^k = C_{1i} r_{iy}$$

3.4.7 Residual Effect

In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In other words residual effect measures a role of other possible independent variables which were not included in the study on the dependent variable. The residual effect estimated with the help of direct effects and simple correlation coefficients. The residual effect was computed by using the formula.

$$R = [1 - (P_{1,y}r_{1,y} + P_{2,y}r_{2,y} + P_{3,y}r_{3,y} + \dots)]^{1/2}$$

Where,

R = Residual effect

$P_{1,y}$ = Direct effect of independent character '1' on dependent character 'y'

$r_{1,y}$ = Correlation coefficient of independent character '1' on dependent character 'y'.

Table 3.1. Source of origin employed in the study and morphological characters of rice (*Oryza sativa* L.)

S. No	Varieties	Pedigree/ Parentage	Year of release	Source/ Origin	Duration and Suitable season	Description
1	MTU 1121 (Sri Druthi)	(BPT 5204) × (MTU BB 8-24-1)	2015	RARS & ARS, Maruteru, (W.G district), A.P., India	125 days (<i>Rabi</i>)	Suitable for cultivation during <i>Rabi</i> season, habitat semi tall and erect, non lodging, leaf sheath is dark in colour, leaf blade dark green in colour, leaf juncture green in colour, internodes and nodes are green in colour, auricles are pale green, panicle is compact well exerted, panicle length is long, awns are absent, grain is medium slender, abdominal white is absent, hairiness on grain is absent, apicules are straw colour, glumes are straw colour, stigma is white in colour, low grain shattering (<2 per cent) at harvest with dormancy of 2 to 3 weeks. Is a high yielding, non-lodging, possessing tolerance to Blast and BPH with good cooking quality.
2	MTU 1001 (Vijetha)	MTU 5249 (Vajram) × MTU 7014	1995	RARS & ARS, Maruteru, (W.G district), A.P., India	135 days (<i>Kharif</i>) 125 days (<i>Rabi</i>)	Suitable for <i>Kharif</i> and <i>Rabi</i> , habit of growth is semi-dwarf, erect, compact, leaf sheath is green in color, leaf blade green, leaf juncture is green in color, internodes are green in color, node green in color, auricles green in color, panicle type is compact , fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, abdominal white absent, apicules are green in color, glumes are straw, stigma is green, non-shattering habit, dormancy for sixt weeks. Resistant to blast and leaf hopper.
3	MTU 1075 (Pushyami)	MTU 2716 × MTU 1010	2008	RARS & ARS, Maruteru, (W.G district), A.P., India	135-140 days (<i>Kharif</i>)	Compact, erect, and semi tall type of growth habit in nature, leaf sheath, leaf blade, leaf juncture are green in color, hairiness of leaf is intermediate, internodes are green, nodes are green, auricles are pale green, compact. moderately exerted type of panicles are present, panicle length is long, awns are absent, grain size and shape is medium slender, white kernel, abdominal white is absent, hairiness on grain is absent, apiculus is absent, glumes are absent, stigma green in color, non-shattering in habit, dormancy is of one week. Non lodging, tolerant to BLB and blast, with good cooking qualities.
4	MTU 3626 (Prabhat)	IR-8 × MTU 3	1976	RARS & ARS, Maruteru, (W.G district), A.P., India	125 days (<i>Rabi</i>)	Suitable for <i>Kharif</i> and <i>Rabi</i> , habit of growth is semi-dwarf, short and dense, leaf sheath is green in color, leaf blade green, leaf juncture is green in color, internodes are green in color, nodes are light green in color, auricles light green in color, panicle type is compact and fully exerted panicle length is medium, awns absent, grain shape and size is course and long bold, kernel is white in color, abdominal white absent, apicules are straw, glumes are straw, stigma is green, non-shattering habit, dormancy for three weeks.
5	MTU 7029 (Swarna)	Vasista × Mahsuri	1982	RARS & ARS, Maruteru, (W.G district), A.P., India	145 days (<i>Kharif</i>)	Habit of growth is semi-dwarf, leaf sheath is dark green, leaf blade is dark green, leaf juncture is dark green, internodes are green in color, node is green, auricle is green, panicle is compact and fully exerted, panicle length is medium, awns are absent, grain size, shape is medium slender, kernel white, abdominal white is absent, apicules are straw, glumes brown in color, stigma are green, non-shattering in habit, dormancy is of three weeks. Profuse tillering, dark brown glumes and resistant to BLB.

Table 3.1. (Cont.)

S. No	Varieties	Pedigree/ Parentage	Year of release	Source/ Origin	Duration and Suitable season	Description
6	MTU 1061 (Indra)	PLA 1100 (Bhadava Mahsuri) × MTU 1010 (Cottondora sannalu)	2006	RARS & ARS, Maruteru, (W.G district), A.P., India	150 days (Kharif)	Erect, semi-tall and non-lodging in growth habit, leaf sheath is green in color, leaf blade is pale green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles pale green, compact and fully exerted type of panicle, panicle length is long, awns absent, grain size and shape is medium slender, kernel is white in color, abdominal white is absent, apicules are absent, glumes are straw type, stigma is white, non-shattering type, dormancy is of three weeks. Resistant to BPH and BLB.
7	MTU 1064 (Amara)	PLA 1100 (Bhadava mahsuri) × MTU 1010 (Cottondora sannalu)	2009	RARS & ARS, Maruteru, (W.G district), A.P., India	150 days (Kharif)	Suitable for Kharif, habit of growth is erect, semi-tall and non-lodging, leaf sheath is green in color, leaf blade green, leaf juncture is light green in color, internodes are green in color, nodes are green in color, auricles pale green in color, panicle type is compact, fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, apicules are straw in, color, glumes are brown, stigma is white, non-shattering habit, dormancy for 3 weeks. High yielding, non-lodging, tolerant to blast.
8	MTU 2077 (Krishnaveni)	Sowbhagya × ARC- 5984	1989	RARS & ARS, Maruteru, (W.G district), A.P., India	155 days (Kharif)	Erect, semi-dwarf and non-lodging in growth habit, leaf sheath is light green in color, leaf blade is light green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles green in color, panicle type is compact, fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, abdominal white is absent, apicules are straw in color, glumes are brown, stigma is green, non-shattering of habit, dormancy for four weeks.
9	MTU 2716 (Pre released culture)	Vijaya × Mahsuri	----	RARS & ARS, Maruteru, (W.G district), A.P., India	145 days (Kharif)	Erect and non-lodging in growth habit, leaf sheath is green in color, leaf blade is green, leaf juncture is green, internodes are green in color, nodes are green in color, auricles pale green in color, panicle is compact, well exerted, short and partially awned, grain shape and size is medium slender, kernel is white in color, abdominal white is absent, apicules are straw in color, glumes are brown, stigma is white, low grain shattering of habit, dormancy for two weeks. Good cooking quality, tolerant to BPH
10	MTU 1140 (Bhima)	MTU 5249 × PLA 8572	2016	RARS & ARS, Maruteru, (W.G district), A.P., India	155 days (Kharif)	Erect, semi-tall and in growth habit, leaf sheath is light green in color, leaf blade is pale green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles pale green, compact long and fully exerted type of panicle, awns absent, grain size and shape is medium slender, kernel is white in color, abdominal white is absent, apicules are absent, glumes are straw type, stigma is white, non-shattering type, dormancy is of 2 weeks. Non-lodging, tolerates 10 days flash floods suitable for stagnant flooding possess and 2 weeks anaerobic germination.
11	MTU 1112 (Pre released culture)	MTU1071× MTU1003	----	RARS & ARS, Maruteru, (W.G district), A.P., India	155 days (Kharif)	Habit is erect, semi-tall, leaf sheath is green in color, leaf blade is pale green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles absent, panicle is compact, long and well exerted, awns present and yellowish white, grain size and shape is medium slender, kernel is white in color, abdominal white is absent, apicules are absent, glumes are straw type, stigma is white, non-shattering type, dormancy is of 3 to 4 weeks. Non lodging fine grain with good cooking quality.

Table 3.1. (Cont.)

S. No	Varieties	Pedigree/ Parentage	Year of release	Source/ Origin	Duration and Suitable season	Description
12	MTU 4870 (Deepthi)	Sowbhagya × ARC-6650	1997	RARS & ARS, Maruteru, (W.G district), A.P., India	155 days (Kharif)	Semi-dwarf, non-lodging, with green color leaf sheath, leaf blade green, leaf juncture is green in color, internodes is green in color, node green in color, auricles green in color, panicle type is compact, fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, apicules are straw in, color, glumes are straw, stigma is white, non-shattering habit, dormancy for three weeks, with good cooking quality, tolerant to BPH and also to salinity.
13	BPT 3291 (Sona Mahsuri)	Sona × Mahsuri	1982	Bapatla, Guntur district, A.P., India.	135-140 days (Kharif)	Suitable for <i>Kharif</i> and <i>Rabi</i> , habit of growth is semi-dwarf, erect, compact, leaf sheath is green in color, leaf blade green, leaf juncture is green in color, internodes are green in color, node green in color, auricles green in color, panicle type is compact, fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, abdominal white absent, apicules are green in color, glumes are straw, stigma is green, non-shattering habit, dormancy for eight weeks.
14	BPT 5204 (Samba Mahsuri)	{{(GEB 24)× T (N) 1}} × Mahsuri	1986	Bapatla, Guntur district, A.P., India.	145 days (Kharif)	Suitable for rainfed shallow low land conditions, habit of growth is semi-dwarf, leaf sheath is green in color, leaf blade green, leaf juncture is green in color, internodes is green in color, node green in color, auricles green in color, panicle type is erect slightly drooping with complete excretion, panicle length medium, awns absent, grain shape and size is medium slender (fine), kernel is white in color, abdominal white absent, apicules are straw color, glumes are straw, stigma is green, non-shattering habit, dormancy for two weeks. Fine grain variety with excellent cooking quality. Susceptible to blast, bacterial leaf blight and BPH.
15	PLA 1100 (Badava Mahsuri)	Mahsuri × Vijaya	1982	Pulla	155-160 days (Kharif)	Suitable for <i>Kharif</i> habit of growth is semi-dwarf, erect, leaf sheath is light green in color, leaf blade light green, leaf juncture is green in color, internodes is green in color, node green in color, auricles pale green in color, panicle type is compact, moderately exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, apicules are straw colored, glumes are brown, stigma is green, non-shattering habit, dormancy for two to three weeks. Possess submergence tolerance and good cooking quality
16	MTU-1166 (Pre released culture)	BPT 5204 × MTU 1071	----	RARS & ARS, Maruteru, (W.G district), A.P., India	150 days (Kharif)	Erect and non-lodging in growth habit, leaf sheath, leaf blade, leaf juncture, internodes, nodes are green in color, auricles are pale green in color, panicle is compact, well exerted, short and partially awned, grain shape and size is medium slender, fine grain, kernel is white in color, abdominal white is absent, apicules are straw in color, glumes are brown, stigma is white, low grain shattering of habit, dormancy for 2 weeks. Good cooking quality and tolerant to BPH.

Table 3.1. (Cont.)

S. No	Varieties	Pedigree/ Parentage	Year of release	Source/ Origin	Duration and Suitable season	Description
17	MTU 1078 (Pre released culture)	BPT 5204 × MTU-II-104-3	----	RARS & ARS, Maruteru, (W.G district), A.P., India	150 days (<i>Kharif</i>)	Erect, semi-tall in growth habit, leaf sheath is light green in color, leaf blade is pale green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles pale green, compact long and fully exerted type of panicle, awns absent, grain size and shape is medium slender, kernel is white in color, abdominal white is absent, apicules are absent, glumes are straw type, stigma is white, long duration, medium slender, non-lodging, semi-dwarf, tolerant to BPH and BLB and suitable for early <i>Kharif</i> .
18	MTU 2067 (Chaitanya)	Sowbhagya × ARC 5984	1988	RARS & ARS, Maruteru, (W.G district), A.P., India	150 days (<i>Kharif</i>)	Habit of growth is semi-dwarf and non lodging, leaf sheath is light green in color, leaf blade light green, leaf juncture is light green in color, internode, nodes and auricles are green in color, panicle type is compact, fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, abdominal white absent, apicules are green in color, glumes are straw, stigma is green, non-shattering habit, dormancy for 4 weeks.
19	MCM 100	MTU 1042 × MTU 1061	----	Machilipatanam Krishna district, A.P., India.	130-135 days	Erect, resistant to salt tolerance, non-lodging in growth habit, leaf sheath is light green in color, leaf blade is light green, leaf juncture is light green, internodes are green in color, nodes are green in color, auricles green in color, panicle type is compact , fully exerted, panicle length medium, awns absent, grain shape and size is medium slender, kernel is white in color, abdominal white is absent, apicules are straw in color, glumes are brown, stigma is green and non-shattering of habit.
20	MTU 1071 (Pre released culture)	BPT 5204/(IET9762 × Swarna)/ MTU2716	----	RARS & ARS, Maruteru, (W.G district), A.P., India	155 days (<i>Kharif</i>)	Suitable for <i>Kharif</i> habit of growth is semi-dwarf, erect, leaf sheath is light green in color, leaf blade light green, leaf juncture is green in color, internodes is green in color, node green in color, auricles pale green in color, panicle type is compact, moderately exerted, panicle length long, awns absent, grain shape and size is medium slender, kernel is white in color, apicules are straw colored, glumes are brown, stigma is green, non-shattering habit, dormancy for two to three weeks. Non-lodging variety and BPH tolerant.

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Table 3.2. Material used in Diallel analysis in rice (*Oryza sativa* L.)

Experimental material		Source/origin
Varieties/Entries used for crossing were selected based on differences in the performance of ratooning rate (Samson, 1980) and ratooning ability (Chauhan <i>et al.</i> 1989) - (Appendix B & C)		
1.	MTU 1001	Maruteru, (W.G district), A.P., India
2.	BPT 3291	Bapatla, (Guntur district), A.P., India
3.	MCM 100	Machilipatnam, (Krishna district), A.P., India
4.	MTU 1121	Maruteru, (W.G district), A.P., India
5.	MTU 1140	Maruteru, (W.G district), A.P., India
6.	MTU 1064	Maruteru, (W.G district), A.P., India
7.	MTU 1061	Maruteru, (W.G district), A.P., India
8.	MTU 7029	Maruteru, (W.G district), A.P., India
Crosses effected by using above 8 parents		
1.	MTU 1001 × BPT 3291	
2.	MTU 1001 × MCM 100	
3.	MTU 1001 × MTU 1121	
4.	MTU 1001 × MTU 1140	
5.	MTU 1001 × MTU 1064	
6.	MTU 1001 × MTU 1061	
7.	MTU 1001 × MTU 7029	
8.	BPT 3291 × MCM 100	
9.	BPT 3291 × MTU 1121	
10.	BPT 3291 × MTU 1140	
11.	BPT 3291 × MTU 1064	
12.	BPT 3291 × MTU 1061	
13.	BPT 3291 × MTU 7029	
14.	MCM 100 × MTU 1121	
15.	MCM 100 × MTU 1140	
16.	MCM 100 × MTU 1064	
17.	MCM 100 × MTU 1061	
18.	MCM 100 × MTU 7029	
19.	MTU 1121 × MTU 1140	
20.	MTU 1121 × MTU 1064	
21.	MTU 1121 × MTU 1061	
22.	MTU 1121 × MTU 7029	
23.	MTU 1140 × MTU 1064	
24.	MTU 1140 × MTU 1061	
25.	MTU 1140 × MTU 7029	
26.	MTU 1064 × MTU 1061	
27.	MTU 1064 × MTU 7029	
28.	MTU 1061 × MTU 7029	

Table 3.3. The experimental details of the present investigation are detailed hereunder

Season	<i>Kharif</i> , 2014	<i>Rabi</i> , 2014-15	<i>Kharif</i> , 2015	<i>Rabi</i> , 2015-16	<i>Summer</i> ,2016
Experiment	Growing of popular rice varieties for yield and quality analysis	Evaluation of ratoon crop of popular rice varieties for ratoonability and quality traits; Identification of parents for crossing	Crosses were effected among the parents selected in half diallel.	Evaluation of selected parents and their F ₁ s to study heterosis and combining ability	Evaluation of ratoon crop of parents and F ₁ s to study heterosis and combining ability with respect to ratoonability related traits
Experimental Design	Randomized Complete Block Design (RCBD)	Randomized Complete Block Design (RCBD)	Griffings Diallel method II (F ₁ + Parents)	Randomized Complete Block Design (RCBD)	Randomized Complete Block Design (RCBD)
Number of entries	20 popular varieties	20 popular varieties	8 good ratoonability parents	28 (21 F ₁ + 8 Parents)	28 (21 F ₁ + 8 Parents)
Replications	3	3	3 different dates of staggered sowings	3	3
Inter-row spacing (cm)	20 cm	20 cm	20 cm	15cm	15 cm
Intra-row spacing (cm)	15 cm	15 cm	15 cm	15 cm	15 cm
Row length (m)	3 m	3 m	3 m	3 m	3 m
No. of rows per genotype per replication	3 rows	3 rows	3 rows	3 rows	3 rows
Plot size Gross:	2.40 Sq.m	2.40 Sq.m	2.40 Sq.m	1.80 Sq.m	1.35 Sq.m
Net:	1.80 Sq.m	1.80 Sq.m	1.80 Sq.m	1.35 Sq.m	1.80 Sq.m
Fertilizers used					
N kg ha⁻¹	60	1/4 th of main crop	60	90	1/4 th of main crop
P₂O₅ kg ha⁻¹	40	1/4 th of main crop	40	60	1/4 th of main crop
K₂O kg ha⁻¹	30	1/4 th of main crop	30	40	1/4 th of main crop
Plant protection	Need based	Need based	Need based	Need based	Need based

Chapter IV

RESULTS AND DISCUSSION

Variability in a crop species is of utmost importance as it provides the basis for effective selection. The amount of variability present in a population is generally measured in terms of phenotypic and genotypic coefficients of variation. The information on the nature and magnitude of genetic variability present in a population is a prerequisite to start any crop improvement programme.

Yield being a complex character is dependent on many component traits. It is necessary to have knowledge on the extent of association between yield and yield contributing characters. Expression of various traits often varies with breeding material and environment. Therefore, the information on character association among the traits and with the yield for the specific breeding material being used at a particular location is important for breeding high yielding genotypes. Apart from the information on degree and direction of relationship between two or more traits it is very important to know the cause of association by knowing the direct and indirect effects of independent characters on dependent character.

Selection of parents on the basis of phenotypic performance alone may be misleading many a times, since phenotypically superior lines may yield poor hybrid combinations. It is, therefore essential that parents should be chosen on the basis of their combining ability.

The knowledge on general and specific combining ability (Sprague and Tatum, 1942) helps the breeder in assessing lines to be used as parents in the hybridization programmes. It also helps in exploiting the gene action involved in the inheritance of a particular trait. The magnitude of heterosis is strongly influenced by genetic variability and combining ability of parents. Many mating designs are adopted to elicit information on combining ability and nature of gene action. However, the Diallel analysis (Griffing, 1956) has been one of the simplest and efficient methods of evaluating large number of lines/varieties for combining ability.

The present investigation entitled "Heterosis and combining ability studies of ratooning in rice (*Oryza sativa* L.)" was conducted at APRRI and RARS, Maruteru from *kharif*, 2014 to summer, 2016 (5 seasons) under different experiments viz.,

screening of 20 popular rice varieties for yield, quality, ratoonability (*kharif*, 2014, *rabi*, 2014-15) and to identify parents for crossing (*kharif*, 2015), to estimate heterosis and combining ability effects of F₁s and parents in main crop and ratoon crop for yield, quality and ratoonability traits (*rabi*, 2015-16 and *summer*, 2016).

Data was recorded on 24 characters in both main crop and ratoon crop, consisting of 10 yield attributing characters viz., days to 50% flowering, days to maturity, plant height (cm), number of tillers per plant, number of ear bearing tillers per plant, panicle length (cm), number of grains per panicle, test weight (g), leaf area index at maximum tillering stage, grain yield per plant (g); 6 physical quality traits such as hulling recovery, milling recovery, head rice recovery, kernel length (mm), kernel breadth (mm), kernel L/B ratio; 8 cooking and chemical quality traits such as kernel length after cooking (mm), kernel breadth after cooking (mm), kernel elongation ratio, volume expansion ratio, water uptake value (ml), gel consistency (mm), alkali digestion value and amylose content (%). However, in ratoon crop along above traits, additionally another 3 characters contributing to ratoonability viz., number of ratoon tillers as percentage of main crop tiller, number of vegetative buds after the harvest of main crop, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers were recorded. The data obtained in each experiment was subjected to standard statistical analysis for drawing valid conclusions on character-wise has been discussed under the following headings.

4.1 EXPERIMENT-I: SCREENING OF POPULAR RICE VARIETIES FOR GRAIN YIELD AND QUALITY IN MAIN CROP (*KHARIF*, 2014) AND GRAIN YIELD, QUALITY AND RATOONABILITY IN RATOON CROP (*RABI*, 2014-15)

4.1.1 Main Crop

4.1.1.1 Analysis of variance

4.1.1.2 Mean, genetic variability, heritability and genetic advance

4.1.1.3 Character association

4.1.1.4 Path coefficient analysis

4.1.2 Ratoon Crop

4.1.2.1 Screening for Ratoonability/Ratooning rate in rice

4.1.2.2 Analysis of variance

4.1.2.3 Mean, genetic variability, heritability and genetic advance

4.1.2.4 Character association

4.1.2.5 Path coefficient analysis

4.2 IDENTIFICATION OF PARENTS FOR CROSSING BASED ON THE DATA ON YIELD AND RATOONABILITY STUDIES CONDUCTED DURING *KHARIF*, 2015 AND *RABI*, 2014-15 AND EFFECTING CROSSES (*KHARIF*, 2015)

4.2.1 Griffing's (1956) diallel, model II method 2 (F_1 s + Parents)

4.3 EXPERIMENT-II: EVALUATION OF SELECTED PARENTS AND THEIR F_1 s TO STUDY HETEROSIS AND COMBINING ABILITY IN MAIN CROP (*RABI*, 2015-16) AND RATOON CROP (*SUMMER*, 2016)

4.3.1 F_1 Main Crop

4.3.1.1 Analysis of variance

4.3.1.2 Mean, genetic variability, heritability and genetic advance

4.3.1.3 Combining ability

4.3.1.4 Heterosis

4.3.1.5 Character association

4.3.1.6 Path coefficient analysis

4.3.2 F_1 Ratoon Crop

4.3.2.1 Analysis of variance

4.3.2.2 Mean, genetic variability, heritability and genetic advance

4.3.2.3 Combining ability

4.3.2.4 Heterosis

4.3.2.5 Character association

4.3.2.6 Path coefficient analysis

4.1 EXPERIMENT-I: SCREENING OF POPULAR RICE VARIETIES FOR GRAIN YIELD AND QUALITY IN MAIN CROP (*KHARIF*, 2014) AND GRAIN YIELD, QUALITY AND RATOONABILITY IN RATOON CROP (*RABI*, 2014-15)

4.1.1 Main Crop

4.1.1.1 Analysis of variance

The analysis of variance (ANOVA) of 20 elite rice varieties for yield, yield components and grain quality characters are presented in Table 4.1. The results revealed existence of significant differences among the rice varieties for all the characters under study.

4.1.1.2 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any breeding programme depends upon the quantum of genetic variability present in the population. Wider range of genetic variability helps in selecting desired genotypes. In addition to the genetic variability, knowledge on heritability and genetic advance helps the breeder to employ the suitable breeding strategy. Therefore, it is necessary to have knowledge on genetic variability, heritability and genetic advance present in the available genetic material.

Genetic variability together with the heritability estimates would give a better idea on the amount of genetic gain expected out of selection (Burton, 1952 and Swarup and Chaugle, 1962). Further, the magnitude of heritable variability is the most important aspect (Panse, 1957), which has close relationship with response to selection. Heritability estimates along with genetic advance are more helpful in predicting the gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will always exhibit high genetic advance (Johanson *et al.*, 1955).

In the present investigation, the mean values of the genotypes for 24 characters are presented in Table 4.2. The analysis of variance revealed significant differences among the genotypes for all the characters indicating a high degree of variability in the material. The details are presented in Table 4.3. The PCV values are higher than the GCV values indicating the influence of environment in the expression of these traits.

4.1.1.2.1 Days to 50% Flowering

The variation for number of days to 50% flowering ranged from 96.33 days (MTU 3626) to 122.33 days (MTU 1071) with a mean of 112.37 days. The PCV (6.997) and GCV (6.649) estimates were low indicating less variation for days to 50% flowering among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment on the expression of this trait. The results are in accordance with by Allam *et al.* (2015), Navin Kumar *et al.* (2015), Arpita *et al.* (2014), Lingaiah *et al.* (2014), Aditya Kumar *et al.* (2013), Paikhomba *et al.* (2013) and Shiva Prasad *et al.* (2013)

For this trait, the estimates of high heritability (90.30%) coupled with moderate genetic advance as per cent of mean (13.018) was noticed which may be due to the predominance of both additive and non-additive gene actions. The heritability is being

exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding. These results were in agreement with Keya *et al.* (2015), Sameera *et al.* (2015), Gokulakrishnan *et al.* (2014), Atif and Khalid (2013), Awaneet Kumar and Senapati (2013) and Gangashetty *et al.* (2013)

4.1.1.2.2 Days to Maturity

Days to maturity varied from 126.00 days (MTU 3626) to 152.33 days (MTU 1071) with a mean of 142.83 days. The estimates of PCV (5.596) and GCV (5.268) were low indicating less variation among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment on the expression of this trait. Similar results were reported by Allam *et al.* (2015), Navin Kumar *et al.* (2015), Vijay Kumar *et al.* (2015), Alam *et al.* (2014), Sandhya *et al.* (2014), Ashok Kumar *et al.* (2013), Gulzar *et al.* (2013) and Toshimenla and Sapu (2013).

High heritability (88.60%) accompanied with moderate genetic advance as per cent of mean (10.215) was observed for this trait indicating the operation of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding. These findings are corroborated by Allam *et al.* (2015), Arpita *et al.* (2014), Ashok Kumar *et al.* (2013), Sangam Kumar Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Vange (2009).

4.1.1.2.3 Plant Height (cm)

The plant height ranged from 94.88 cm (MTU 3626) to 119.34 cm (MTU 1112) with a mean of 109.48 cm. The estimates of PCV (7.709) and GCV (7.072) were low indicating less variation among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment on the expression of this trait. Similar results were reported by Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013) and Mulugeta *et al.* (2012).

The results indicated the role of both additive and non-additive gene action in governing this trait, which indicated by high heritability (84.20%) combined with moderate genetic advance as per cent of mean (13.365). The heritability is being exhibited due to favourable influence of environment rather than genotype. These findings are in accordance with Keya *et al.* (2015), Navin Kumar *et al.* (2015), Rahman *et al.* (2014), Paikhomba *et al.* (2013), Toshimenla and Sapu (2013), Mulugeta *et al.* (2012), Ravindra Babu *et al.* (2012) and Dinesh *et al.* (2011).

4.1.1.2.4 Total Number of Tillers per Plant

The range of variation for this character ranged from 8.67 (MTU 2077) to 14.00 (MTU 1075) with a mean of 11.82. The estimates of PCV (12.822) and GCV (10.215) were moderate indicating moderate variation among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment expression on this trait. Similar results were reported by Vijay Kumar *et al.* (2015), Sandhya *et al.* (2014), Gulzar *et al.* (2013), Sathya and Jebaraj (2013) and Yadav *et al.* (2010).

The trait exhibited high heritability (63.50%) in conjunction with moderate genetic advance as per cent of mean (16.764) indicating the operation of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype. These findings are corroborated by Atif and Khalid (2013).

4.1.1.2.5 Number of Ear Bearing Tillers per Plant

For this character the variation ranged from 5.67 (MTU 2077) to 11.33 (MTU 1140) with a mean of 7.97. The estimates of PCV (18.198) and GCV (15.508) were moderate indicating moderate variability among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment on this trait. Similar results were earlier reported by Keya *et al.* (2015), Navin Kumar *et al.* (2015), Gokulakrishnan *et al.* (2014), Mamunur *et al.* (2014), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011) and Ullah *et al.* (2011).

High heritability (72.60%) supplemented with high genetic advance as per cent of mean (27.224) was established for this trait; indicative of heritability is due to additive gene action. These findings are in accordance with Allam *et al.* (2015), Sameera *et al.* (2015), Bornare *et al.* (2014), Rahman *et al.* (2014), Aditya Kumar *et al.* (2013), Ashok Kumar *et al.* (2013), Gangashetty *et al.* (2013) and Ukaoma *et al.* (2013).

4.1.1.2.6 Panicle Length (cm)

There is significant variation for panicle length per plant in the material studied which ranged from 21.34 (BPT 3291) to 28.14 (MTU 1071) with a mean of 25.10. The estimates of PCV (6.958) and GCV (5.991) for this trait were low indicating narrow variability among the entries studied. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These findings are corroborated by Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Bornare *et al.* (2014), Gokulakrishnan *et al.* (2014), Aditya Kumar *et al.* (2013), Atif and Khalid (2013) and Sathya and Jebaraj (2013).

The estimates of high heritability (74.10%) along with moderate genetic advance as per cent of mean (10.626) were recorded for this trait indicating the operation of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding. The above findings are in agreement with Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Lingaiah *et al.* (2014), Mamunur *et al.* (2014), Sandhya *et al.* (2014), Singh *et al.* (2014) and Ashok Kumar *et al.* (2013).

4.1.1.2.7 Number of Grains per Panicle

The range of variation for number of number of grains per panicle varied from 158.00 (MTU 3626) to 242.00 (MTU 1071) with a mean of 199.30. The estimates of PCV (14.663) and GCV (13.803) for this trait were moderate indicating moderate variation among the genotypes studied. The magnitude of PCV was higher than GCV revealing the influence of environment on this trait. Similar results were reported by Shajedur Hossain *et al.* (2015), Bornare *et al.* (2014), Gokulakrishnan *et al.* (2014), Mamunur *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Paikhomba *et al.* (2013) and Sathya and Jebaraj (2013).

High heritability (88.60%) together with high genetic advance as per cent of mean (26.765) was observed that most likely the heritability is due to additive gene effects and selection may be effective. These results were in broad agreement with the findings of Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Alam *et al.* (2014), Lingaiah *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Mamunur *et al.* (2014) and Rahman *et al.* (2014).

4.1.1.2.8 Test Weight (g)

There is significant variation for test weight which ranged from 15.07 (MTU 1078) to 25.54 (MTU 3626) with a mean of 19.26 g. The estimates of PCV (13.635) and GCV (13.422) for this trait were moderate, indicating moderate variability. These findings were in line with the results obtained by Keya *et al.* (2015), Alam *et al.* (2014), Arpita *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Awaneet Kumar and Senapati (2013), Gulzar *et al.* (2013) and Shiva Prasad *et al.* (2013).

The trait, test weight had showed high heritability (96.90%) coupled with high genetic advance as per cent of mean (27.216) revealing that the heritability is due to additive gene action and any selection methods may effective for the improvement of this trait. These results are in accordance with Allam *et al.* (2015), Sameera *et al.* (2015), Mamunur *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Swati Sharma *et al.* (2014) and Thirumala Rao *et al.* (2014).

4.1.1.2.9 Leaf Area Index at Maximum Tillering Stage

This character possessed significant variation which was ranged from 2.30 (MTU 2077) to 3.47 (MTU 1140) with a mean of 2.84. The estimates of PCV (14.242) and GCV (14.123) were moderate, indicating moderate variability. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These findings are in conformity with the results of Ullah *et al.* (2011)

The results showed that inheritance of this trait is due to role of additive gene action, which was observed by high heritability (98.30%) coupled with high genetic advance as per cent of mean (28.848). These findings are in conformity with the results of Zulqarnain *et al.* (2012), Surender Raju (2002), Shivani and SriramaReddy (2000) and Niranjana Murthy *et al.* (1999).

4.1.1.2.10 Grain Yield per Plant (g)

There was significant variation for this character which was ranged from 18.12 g (MTU 2077) to 25.66 g (MTU 1075) with a mean of 21.51 g. The estimates of PCV (11.261) and GCV (8.181) for this trait were moderate, showing moderate variability. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment on expression of this trait. Selection for such traits sometimes may be misleading. These findings were in line with the results of Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013), Venkata Subbaiah *et al.* (2011), Saidaiah *et al.* (2010b), Yadav *et al.* (2010) and Satish Chandra *et al.* (2009).

Moderate heritability (52.80%) accompanied with moderate genetic advance as per cent of mean (12.245) was observed for this trait revealing the role of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for this trait may not be rewarding. These findings are corroborated by Vijay Kumar *et al.* (2015) and Mulugeta *et al.* (2012).

4.1.1.2.11 Hulling Recovery (%)

The range of variation for hulling recovery varied from 77.46% (MTU 4870) to 82.24% (MTU 1166) with a mean of 80.29%. The estimates of PCV (1.863) and GCV (1.453) were low revealing the less influence of environment in inheritance of this trait (Plate 4.1.). These findings are in conformity with the results of Venkanna *et al.* (2014), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Vanaja and Luckins (2006), Mishra and Pravin (2004) and Nagajyothi (2001).

High heritability (60.80%) in conjunction with low genetic advance as per cent of mean (2.335), indicative of non-additive gene action. Heritability was being exhibited due to favourable influence of environment rather than genotype and selection for this trait may not be rewarded. These results are in accordance with Venkata Subbaiah *et al.* (2011), Satish Chandra *et al.* (2009) and Vanaja and Luckins (2006).

4.1.1.2.12 Milling Recovery (%)

The mean of value of 20 rice varieties for this trait was 73.29%, which range from 68.09% (MTU 2067) to 76.60% (MTU 1166) and observed low values of PCV (3.467) and GCV (2.648), indicated narrow genetic variability (Plate 4.1.). These findings are corroborated by Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Satish Chandra *et al.* (2009), Krishna Naik (2004), Chaudhry & Motiramani (2003) and Nagajyothi (2001).

The estimates of moderate heritability (58.30%) along with low genetic advance as per cent of mean (4.166) indicated, that the inheritance of this trait is highly influenced by environmental effects and selection would be ineffective. These findings were in line with the results obtained by Ravindra Babu *et al.* (2012) and Nagajyothi (2001).

4.1.1.2.13 Head Rice Recovery (%)

There is significant variation for head rice recovery in the material studied which ranged from 57.78% (MTU 3626) to 71.03% (MCM 100) with a mean of 65.05%. The estimates of PCV (5.925) and GCV (5.553) were low, indicated narrow variability (Plate 4.1.). Similar results were earlier reported by Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Sivaparvathi *et al.* (2011), Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009), Krishna Naik (2004) and Patil *et al.* (2003b).

The inheritance of this trait may be due to role of both additive and non-additive gene action, by possessing high heritability (87.80%) together with moderate genetic advance as per cent of mean (10.722). These results were in broad agreement with the findings of Sivaparvathi *et al.* (2011), Krishna Naik (2004) and Patil *et al.* (2003).

4.1.1.2.14 Kernel Length (mm)

The range of variation for kernel length ranged from 4.98 mm (MTU 1112) to 6.11 mm (MTU 1075) with a mean of 5.60 mm. Low PCV (5.421) and GCV (5.355), indicating less variability. The magnitude of PCV was higher than GCV revealed the

influence of environment on expression of this trait. These findings are in conformity with the results of Tuhina-Khatun *et al.* (2015), Gokulakrishnan *et al.* (2014), Aditya Kumar *et al.* (2013), Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011) and Rita Bisne *et al.* (2009).

This trait showed high heritability (97.60%) coupled with moderate genetic advance as per cent of mean (10.899) indicated the role of both additive and non-additive gene action in the inheritance of this trait. These results are in accordance with Tuhina-Khatun *et al.* (2015), Gokulakrishnan *et al.* (2014), Awaneet Kumar and Senapati (2013), Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Bharadwaj *et al.* (2007) and Rita Binse *et al.* (2006).

4.1.1.2.15 Kernel Breadth (mm)

Kernel breadth possessed significant variation which was ranged from 1.64 mm (BPT 5204) to 2.30 mm (MTU 3626) with a mean of 2.04 mm. The estimates of PCV (8.439) and GCV (8.313) were low, exhibiting less variability. These findings are corroborated by Allam *et al.* (2015), Venkanna *et al.* (2014), Awaneet Kumar and Senapati (2013), Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Rita Bisne *et al.* (2009).

High heritability (97.00%) combined with moderate genetic advance as per cent of mean (16.869) showed that the role of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype. These findings were in line with the results obtained by Allam *et al.* (2015), Singh *et al.* (2014), Awaneet Kumar and Senapati (2013) and Rita Bisne *et al.* (2009).

4.1.1.2.16 Kernel Length (L)/Breadth (B) Ratio

Kernel length/breadth ratio was ranged from 2.53 (MTU 2077) to 3.04 (BPT 5204) with a mean of 2.75. The estimates of PCV (6.341) and GCV (6.188) were low, showed low variability. Similar results were earlier reported by Venkanna *et al.* (2014) and Venkata Subbaiah *et al.* (2011).

This character exhibited high heritability (95.30%) along with moderate genetic advance as per cent of mean (12.442) indicated the role of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding.

Contrary, high heritability and low genetic advance of mean was reported by Mohan Lal and Chauhan (2011), Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Verma *et al.* (2011), this might be due to differences in breeding material studied under different environments.

4.1.1.2.17 Kernel Length after Cooking (mm)

This character possessed significant variation which was ranged from 7.91 (MTU 2077) to 10.45 (MTU 1140) with a mean of 9.35. The estimates of PCV (8.081) and GCV (7.87) were low. The magnitude of PCV was higher than GCV, indicated the influence of environment on expression of this trait (Plate 4.2). These results were in broad agreement with the findings of Venkata Subbaiah *et al.* (2011).

The results indicated the role of both additive and non-additive gene action in governing this trait, which indicated by high heritability (94.90%) and moderate genetic advance as per cent of mean (15.790) and selection for this trait may not be rewarded. Contrary, Venkata Subbaiah *et al.* (2011), Sarkar *et al.* (2007) and Krishna Naik (2004) reported high heritability and low genetic advance of mean; this might be due to differences in breeding material studied under different environments.

4.1.1.2.18 Kernel Breadth after Cooking (mm)

The variation for kernel breadth after cooking varied from 2.15 (MTU 1166) to 3.47 (MTU 7029) with a mean of 2.78. The estimates of PCV (12.488) and GCV (10.208) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait (Plate 4.2). Contrary, low PCV and GCV were observed with the results of Venkata Subbaiah *et al.* (2011), this might be due to differences in breeding material studied under different environments.

High heritability (66.80%) supplemented with moderate genetic advance as per cent of mean (17.190) indicated the role of additive and non-additive gene action in governing the inheritance of this character and simple selection procedure are ineffective. These results are in accordance with Venkata Subbaiah *et al.* (2011).

4.1.1.2.19 Kernel Elongation Ratio

This character was ranged from 1.50 (MTU 2077) to 1.88 (MTU 1112) with a mean of 1.70. The estimates of PCV (6.167) and GCV (5.885) were low. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These findings are corroborated by Allam *et al.* (2015), Venkata Subbaiah *et al.* (2011), Sunayana *et al.* (2010), Vanaja and Luckins (2006), Krishna Naik (2004) and Mishra and Pravin (2004).

High heritability (91.10%) along with moderate genetic advance as per cent of mean (11.57) indicated the role of both additive and non-additive gene action in governing the inheritance of this character. Heritability is being exhibited due to favourable influence of environmental rather than genotypic and selection for such traits may not be rewarding. These findings were in line with the results obtained by Vanaja and Luckins (2006).

4.1.1.2.20 Volume Expansion Ratio

Volume expansion ratio ranged from 3.70 (MTU 2067) to 5.06 (MTU 3626) with a mean of 4.45. The estimates of PCV (9.079) and GCV (7.906) were low. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. Similar results were earlier reported by Venkata Subbaiah *et al.* (2011).

The results showed high heritability (75.80%) and moderate genetic advance as per cent of mean (14.183) indicates the role of both additive and non additive gene action in governing the inheritance of this character and selection would be ineffective. These results are contrary to the observations of Ravindra Babu *et al.* (2012), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006) with high heritability and high genetic advance as per cent of mean; this might be due to differences in breeding material studied under different environments.

4.1.1.2.21 Water Uptake (ml)

This character possessed significant variation which was ranged from 145.00 (MTU 1078) to 285.00 (MTU 1001) with a mean of 200.05. The estimates of PCV (15.746) and GCV (15.339) were moderate, indicated moderate variability. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These results were in broad agreement with the findings of Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006).

High heritability (94.90%) in conjunction with high genetic advance as per cent of mean (30.781) indicated the role of additive gene action in governing the inheritance of this trait. These findings are in conformity with the results of Sivaparvathi *et al.* (2011), Chakraborty *et al.* (2010), Umadevi *et al.* (2010b), Vanaja and Luckins (2006) and Yadav *et al.* (2002).

4.1.1.2.22 Gel Consistency (mm)

The variation for gel consistency ranged from 40.23 (MTU 4870) to 68.08 (MTU 1064) with a mean of 67.69. The estimates of PCV (14.467) and GCV (14.236) were moderate showing moderate variability (4.3). These results are in accordance with Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011).

High heritability (96.80%) combined with high genetic advance as per cent of mean (28.856) indicated that most likely the heritability is due to additive gene effects and selection may be effective. These findings are corroborated by Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b), Asish Binodh *et al.* (2007), Singh and Singh (2005), Yadav *et al.* (2002) and Nagajyothi (2001).

4.1.1.2.23 Alkali Spreading Value/ Gelatinization Temperature (mm)

The range of variation for alkali spreading value is 2.06 (MTU 1166) to 6.72 (MTU 1064) with a mean of 4.21. The estimates of PCV (32.342) and GCV (32.079) were high, indicating wider variability (Plate 4.4). These findings were in line with the results obtained by Allam *et al.* (2015), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010), Krishna Naik (2004) and Nagajyothi (2001).

The inheritance of this trait may be due to predominance of additive gene action, by the indicative of high heritability (98.40%) together with high genetic advance as per cent of mean (65.544). Hence, simple selection may be effective. Similar results were earlier reported by Allam *et al.* (2015), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Asish Binodh *et al.* (2007), Vanaja and Luckins (2006), Singh and Singh (2005) and Patil *et al.* (2003b).

4.1.1.2.24 Amylose Content (%)

Amylose content possessed significant variation which was ranged from 21.34 (MCM 100) to 26.86 (MTU 1001) with a mean of 23.77. The estimates of PCV (6.501) and GCV (5.607) were low, exhibited low variability. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These results were in broad agreement with the findings of Allam *et al.* (2015), Aditya Kumar *et al.* (2013), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Rajeswari *et al.* (2010), Krishna Naik (2004) and Satish (2000).

High heritability (74.40%) combined with low genetic advance as per cent of mean (9.964) indicated the role of non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype. These findings are in conformity with the results of Aditya Kumar *et al.* (2013), Kumar *et al.* (2006) and Satish (2000).

In the present study analysis of variance revealed significant differences among the entries for all the characters studied indicating the existence of high degree of variability in the material. Genetic parameters studies showed that the magnitude of difference between PCV and GCV was relatively low for all the traits except for total number of tillers per plant, number of ear bearing tillers per plant, number of grains per panicle, panicle length, grain yield per plant and kernel breadth after cooking. The magnitude of PCV was higher than GCV for all the traits, which revealed the influence of environment on the expression of these traits. Wider variability was observed in case of alkali spreading value which indicated their amenability towards directional selection. The traits, viz., total number of tillers per plant, number of ear bearing tillers per plant, number of grains per panicle, test weight, leaf area index, kernel breadth after cooking, water uptake, gel consistency and alkali spreading value recorded moderate variability, whereas the remaining traits showed low variability.

The traits viz., number of ear bearing tillers per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, water uptake, gel consistency and alkali spreading value showed high heritability coupled with high genetic advance of mean, suggested the role of additive gene action in the inheritance of these traits and hence, improvement for this character can be achieved by pure line selection, mass selection, progeny selection and hybridization & selection with pedigree breeding.

Moderate to high heritability along with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, total number of tillers per plant, panicle length per plant, head rice recovery, kernel length, kernel breadth, L/B ratio, kernel length after cooking, kernel breadth after cooking, kernel linear elongation ratio, volume expansion ratio and grain yield per plant revealed that the role of both additive and non-additive gene action in the inheritance of these traits, whereas biparental crosses, diallel selective mating, population improvement programme and recombination breeding with postponement of selection at later generations should be taken up for the development of these traits. Moderate to high

heritability and low genetic advance as per cent of mean was observed for hulling percentage, milling percentage and amylose content. It revealed non-additive gene action in the inheritance of these traits. Hence improvement of these traits was being difficult through simple selection, whereas heterosis breeding or recombination breeding with postponement of selection at later generations was effective.

4.1.1.3 CHARACTER ASSOCIATION

Yield is a complex and polygenically inherited character resulting from multiplicative interaction of its component traits. The cumulative effect of such traits determines the yield. These traits play an important role in modification of yield as a whole in magnitude as well as in direction. The change in one character brings about a series of changes in the other characters, since they are interrelated. Therefore, the correlation studies are of considerable importance in any selection programme as they provide degree and direction of relationship between two or more component traits.

The phenotypic and genotypic correlation coefficients between grain yield, yield component characters and quality traits and among themselves were estimated and presented in Table 4.4 and Table 4.5. The results were discussed character wise hereunder. Genotypic correlations in general are higher than phenotypic correlations indicating that the apparent associations are largely due to genetic reasons.

4.1.1.3.1 Days to 50% Flowering

This trait showed significant positive association with days to maturity (0.983**, 0.957**), plant height (0.377**, 0.333**), number of grains per panicle (0.413**, 0.369**) and whereas, negative significant correlation with total number of ear bearing tillers per plant (-0.260*, -0.263*), test weight (-0.735**, -0.683**), kernel length (-0.427**, -0.435**), kernel breadth (-0.295*, -0.272*), kernel length after cooking (-0.338**, -0.318*), kernel breadth after cooking (-0.458**, -0.397**), volume expansion ratio (-0.476**, -0.372**) and grain yield per plant (-0.370**, -0.313*) at both genotypic and phenotypic levels.

This character also recorded significant positive association with total number of tillers per plant (0.270*), hulling recovery (0.334**) and milling recovery (0.259*) at genotypic level and it also showed negative significant correlation with alkali spreading value (-0.315*) at phenotypic level. Similar kind of relation was reported by Bornare *et al.* (2014), Imad *et al.* (2014), Satish Kumar Rai *et al.* (2014), Arulmozhi and Muthuswamy (2013), Gangashetty (2013) and Ukaoma *et al.* (2013).

4.1.1.3.2 Days to Maturity

At both genotypic and phenotypic levels, this character, exhibited significant positive association with plant height (0.418**, 0.336**), number of grains per panicle (0.414**, 0.344**) and it also had significant negative correlation with test weight (-0.728**, -0.677**), kernel length (-0.410**, -0.372**), kernel length after cooking (-0.299**, 0.257*), kernel breadth after cooking (-0.468**, -0.343**), volume expansion ratio (-0.540**, -0.407**), alkali spreading value (-0.348, -0.319*) and grain yield per plant (-0.356**, -0.294*).

It showed positive significant correlation with total number of tillers per plant (0.255**), hulling recovery (0.300*), milling recovery (0.279*), head rice recovery (0.254*), while significant negative association was recorded with kernel breadth (-0.281*) at genotypic level. These results are in consonance with findings of Alam *et al.* (2014), Imad *et al.* (2014) and Gulzar *et al.* (2013).

4.1.1.3.3 Plant Height (cm)

Plant height recorded significant positive association with total number of tillers per plant (0.479**, 0.378**), panicle length (0.663**, 0.592**), head rice recovery (0.388**, 0.302*), gel consistency (0.365**, 0.333**), amylose content (0.504**, 0.442**) at both genotypic and phenotypic levels.

This character also recorded positive significant correlation with number of grains per panicle (0.267*), kernel length after cooking (0.257*), water uptake (0.488**) and grain yield per plant (0.272*) and significant negative association with kernel breadth after cooking (-0.332**) at genotypic level. These results are in accordance with Anis *et al.* (2016), Islam *et al.* (2015), Sathisha *et al.* (2015) Nabedita Mohanty *et al.* (2015), Singh *et al.* (2015) and Vijay Kumar *et al.* (2015).

4.1.1.3.4 Total Number of Tillers per plant

This trait, recorded significant positive association with number of grains per panicle (0.615**, 0.478**), leaf area index (0.481**, 0.392**), head rice recovery (0.361**, 0.264*), L/B ratio (0.490**, 0.400**), kernel linear elongation ratio (0.425**, 0.273*) and grain yield per plant (0.527**, 0.304*) and negative significant association with kernel breadth after cooking (-0.389**, -0.303*) at both genotypic and phenotypic levels.

It showed positive significant association with kernel length after cooking (0.269*) and negative significant correlation with test weight (-0.287*), kernel breadth (-0.286*) at genotypic level. Golam Sarwar *et al.* (2015), Kundu Sritama *et al.* (2015), Sathisha *et al.* (2015) and Vijay Kumar *et al.* (2015) also reported similar relationship.

4.1.1.3.5 Number of Ear Bearing Tillers per Plant

Number of bearing tillers per plant recorded significant positive association with leaf area index (0.461**, 0.411**), milling recovery (0.477**, 0.282*), head rice recovery (0.737**, 0.568**), kernel length (0.363**, 0.289*), kernel length after cooking (0.611**, 0.512**), kernel linear elongation ratio (0.382**, 0.314*), gel consistency (0.469**, 0.388**), alkali spreading value (0.459**, 0.373**) and grain yield per plant (0.657**, 0.488**) at both genotypic and phenotypic levels.

It also showed positive significant association with volume expansion ratio (0.354**) at genotypic level. Similar kind of association was earlier reported by Golam Sarwar *et al.* (2015), Keya *et al.* (2015), Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015) and Nabedita Mohanty *et al.* (2015).

4.1.1.3.6 Panicle Length (cm)

This trait, exhibited significant positive association with kernel length (0.346**, 0.277*), kernel breadth (0.358**, 0.308*) and grain yield per plant (0.425**, 0.263*) at both genotypic and phenotypic levels. It also exhibited positive significant correlation with gel consistency (0.279*) at genotypic level. These results were in agreement with the findings of Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015), Nabedita Mohanty *et al.* (2015) and Sathisha *et al.* (2015).

4.1.1.3.7 Number of Grains per Panicle

Number of grains per panicle recorded significant positive association with leaf area index (0.500*, 0.472**), hulling recovery (0.701**, 0.487**), milling recovery (0.491*, 0.324*), L/B ratio (0.811**, 0.761**), kernel linear elongation ratio (0.628**, 0.568**), gel consistency (0.343**, 0.335**) and significant negative association with test weight (-0.583**, -0.531**), kernel breadth (-0.735**, -0.695**), kernel breadth after cooking (-0.841**, -0.634**) at both genotypic and phenotypic levels. These findings are corroborated by Anis *et al.* (2016), Golam Sarwar *et al.* (2015), Keya *et al.* (2015), Pradhan *et al.* (2015) and Nabedita Mohanty *et al.* (2015).

4.1.1.3.8 Test Weight (g)

This trait, showed significant positive association with kernel length (0.543**, 0.528**), kernel breadth (0.623**, 0.598**), kernel length after cooking (0.565**, 0.529**), kernel breadth after cooking (0.621**, 0.503**), volume expansion ratio (0.382**, 0.343*), water uptake (0.347**, 0.343**), alkali spreading value (0.651**, 0.635**), grain yield per plant (0.523**, 0.411**) and exhibited significant negative association with hulling recovery (-0.602**, -0.466**), milling recovery (-0.353**, -0.274*), L/B ratio (-0.383**, -0.361**) at both genotypic and phenotypic levels. Similar kind of relation was reported by Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015), Sarafraz *et al.* (2015) and Sathisha *et al.* (2015).

4.1.1.3.9 Leaf Area Index at Maximum Tillering Stage

At both genotypic and phenotypic levels leaf area index at maximum tillering stage showed significant positive association with milling recovery (0.498**, 0.373**), head rice recovery (0.412**, 0.380**), L/B ratio (0.402**, 0.390**), kernel length after cooking (0.388**, 0.376**), kernel linear elongation ratio (0.366**, 0.350**) and grain yield per plant (0.671**, 0.501**) and significant negative association with water uptake (-0.347**, -0.335**). It also exhibited positive significant association with hulling recovery (0.254*) at genotypic level. The above results were in agreement with Keya *et al.* (2015), Ganghua *et al.* (2014) and Hashem and Peyman (2011).

4.1.1.3.10 Hulling Recovery (%)

This character exhibited significant positive association with milling recovery (0.318*, 0.316*), L/B ratio (0.436**, 0.370**), gel consistency (0.485**, 0.350**) and negative significant association with kernel breadth (-0.632**, -0.506**), kernel breadth after cooking (-0.627**, -0.367**). It also exhibited significant negative association with kernel length (-0.378**) at phenotypic levels. Similar association was reported by Nagajyothi (2001).

4.1.1.3.11 Milling Recovery (%)

This trait, recorded significant positive correlation with head rice recovery (0.714**, 0.548**), L/B ratio (0.301*, 0.260*), kernel linear elongation ratio (0.487**, 0.341**) and it also expressed significant negative association with kernel breadth after cooking (-0.445**, -0.376**), water uptake (-0.416**, -0.304*), amylose content (-0.498**, -0.269*) at both genotypic and phenotypic levels. It also possess positive

significant association with kernel length after cooking (0.312*) at genotypic level. These results are in consonance with findings of Manonmani *et al.* (2010) and Nagajyothi (2001).

4.1.1.3.12 Head Rice Recovery (%)

Head rice recovery was found significant positive association with kernel length after cooking (0.410**, 0.362**), kernel linear elongation ratio (0.425**, 0.372**) and gel consistency (0.0350**, 0.332**) at both genotypic and phenotypic level. It also recorded significant negative association with amylose content (-0.258*) at genotypic level. These results are in accordance with Ruth Elizabeth Ekka *et al.* (2011) and Praveen *et al.* (2010).

4.1.1.3.13 Kernel Length (mm)

At both genotypic and phenotypic, levels kernel length exhibited significant positive association with kernel breadth (0.690**, 0.6579*), kernel length after cooking (0.264**, 0.252**), kernel breadth after cooking (0.379**, 0.289*) and grain yield per plant (0.591**, 0.420**) at both genotypic and phenotypic levels. Nabedita Mohanty *et al.* (2015), Sathisha *et al.* (2015), Nitiprasad and Lotan Kumar (2014) and Norain *et al.* (2014) also reported similar association.

4.1.1.3.14 Kernel Breadth (mm)

Kernel breadth found positive significant correlation with kernel breadth after cooking (0.612**), water uptake (0.325*, 0.313*), alkali spreading value (0.0342**, 0.338**) and this trait, also exhibited significant negative association with L/B ratio (-0.798**, -0.799**), kernel linear elongation ratio (-0.595**, -0.562**) at both genotypic and phenotypic levels. It also had negative significant association with amylose content (-0.269*) at genotypic levels. Similar association was reported by Islam *et al.* (2015), Nabedita Mohanty *et al.* (2015), Dhurai *et al.* (2014) and Norain *et al.* (2014).

4.1.1.3.15 Kernel Length/Breadth Ratio

This character exhibited significant positive association with kernel linear elongation ratio (0.525**, 0.476**) and neagtive significant correlation with kernel breadth after cooking (0.672**, -0.586**) and water uptake (-0.331**, -0.315*) at both genotypic and phenotypic levels. These findings are corroborated by Sathisha *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014) and Venkata Lakshmi *et al.* (2014).

4.1.1.3.16 Kernel Length after Cooking (mm)

At both genotypic and phenotypic levels, this trait, exhibited significant positive association with kernel linear elongation ratio (0.536**, 0.550**), volume expansion ratio (0.513**, 0.427**), alkali spreading value (0.693**, 0.673**) and grain yield per plant (0.733**, 0.479**). Contrary, positive low association was reported by Dhurai *et al.* (2014) and Prem Kumar *et al.* (2010), this might be due to differences in breeding material studied under different environments.

4.1.1.3.17 Kernel Breadth after Cooking (mm)

Kernel breadth after cooking recorded significant positive association with alkali spreading value (0.468**, 0.361**) and also recorded significant negative association with kernel linear elongation ratio (-0.372**, -0.284*) at both genotypic and phenotypic levels. It showed positive significant association with grain yield per plant (0.252**), water uptake (0.335**) and negative significant association with amylose content (-0.301*) at genotypic level. Similar association was reported by Arulmozhi and Muthuswamy (2013) and Prem Kumar *et al.* (2010).

4.1.1.3.18 Kernel Elongation Ratio

This character was found to have significant positive association with volume expansion ratio (4.58**, 0.377**) and alkali spreading value (0.256*, 0.245*) at both genotypic and phenotypic levels. It showed positive significant correlation with grain yield per plant (0.276*) at genotypic level. The above results were in agreement with Dhurai *et al.* (2014) and Chaudhary and Motiramani (2003).

4.1.1.3.19 Volume Expansion Ratio

This trait had significant positive association with alkali spreading value (0.296*, 0.266*) and significant negative association with gel consistency (-0.471**, -0.384**), at both genotypic and phenotypic levels. This trait also showed positive significant association with grain yield per plant (0.252*) and significant negative association with amylose content (-0.263*) at genotypic level. The above results were in agreement with Arulmozhi and Muthuswamy (2013), Krishna Veni *et al.* (2013) and Manonmani *et al.* (2010) and Satyavathi *et al.* (2001).

4.1.1.3.20 Water Uptake (ml)

Both genotypic and phenotypic correlations indicated that this trait had positive correlation with alkali spreading value (0.363**, 0.351**) and amylose content (0.371**, 0.296*). This is in conformity with the results of Krishna Veni *et al.* (2013) and Malini *et al.* (2011).

4.1.1.3.21 Gel Consistency (mm)

This trait, exhibited significant positive association with grain yield per plant (0.312*) at genotypic level. These results are in consonance with findings of Malini *et al.* (2011) and Nagajyothi (2001).

4.1.1.3.22 Alkali Spreading Value (mm)

Alkali spreading value found to have significant positive association with grain yield per plant (0.510**, 0.369**) at both genotypic and phenotypic level. These results were in agreement with the findings of Tushara *et al.* (2013).

4.1.1.3.23 Amylose Content (%)

This character exhibited significant positive association with grain yield per plant (0.278*) at genotypic level. The above results were in agreement with Arulmozhi and Muthuswamy (2013), Nagajyothi (2001), Malini *et al.* (2011), Manonmani *et al.* (2010) and Pankaj Garg *et al.* (2010).

Thus, in the present investigation, the genotypic correlations were, in general higher than the phenotypic correlations and thus suggested that the observed relationships among the characters were due to genetic causes. The traits, which showed highly significant positive correlation with grain yield were days to maturity, plant height, total number of tillers per plant, panicle length per plant, test weight, leaf area index at maximum tillering stage, kernel length, kernel breadth, kernel length after cooking, kernel linear elongation ratio, volume expansion ratio and amylose content, were found to possess significant association in desirable direction with grain yield per plant either at both genotypic and phenotypic levels. Further, it was also observed that days to 50% flowering were found to be negative and significantly associated with grain yield. Therefore, these characters might be considered during selection process to bring about improvement for higher grain yield with good grain quality with short duration.

4.1.1.4 PATH COEFFICIENT ANALYSIS

The observed correlation between yield and its component character is the net result of direct and indirect effects of the component characters through other yield attributes. The total correlation between yield and its component characters may sometimes be misleading. Since, it may be over or under estimate because of its association with other characters which are also associated with grain yield. Hence,

direct selection on correlated response basis may not be worthy. The correlation coefficients need to be split into direct and indirect effects, using path coefficient analysis for critical evaluation as many characters affect a given trait. Thus, the correlation and path analysis in combination, can give a better insight, into cause and effect relationship between different pairs of characters. As a guideline for interpretation of path analysis, the following broad points may be kept in view (Singh and Chaudhary, 1977).

- If the correlation coefficient between a causal factor and the effect is almost equal to its direct effects, then correlation explains the true relationship and selection through this trait will be effective.
- If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.
- Correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed i.e. restrictions to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.
- If the correlation coefficient is negative and direct effect is also negative, then we have to drop the selection based on that character.

The residual effect determines how best the causal factors account for the variability of the dependent factor. If residual effect is high, some other factors, which have not been considered here, need to be included in this analysis to account fully for the variation in yield. Considering the above aspects, path analysis for 24 characters with yield was computed to furnish information on direct and indirect contribution of various yield components to yield and to formulate a sound basis for selection in rice.

In the present study, path analysis was used to work out the direct and indirect effects of grain yield contributing and grain quality characters on grain yield of 20 varieties, results are presented (Table 4.6) character wise hereunder. The path diagrams were given in Figures 4.1.

4.1.1.4.1 Days to 50% Flowering

At genotypic level, days to 50% flowering exhibited significant negative association (-0.370^{**}) and positive direct effect (4.041) on grain yield per plant. It also exhibited prominent positive indirect effect *via.*, plant height (0.588), total number of

tillers per plant (0.005), number of grains per panicle (0.487), hulling recovery (1.228), head rice recovery (0.376), kernel breadth (7.592), L/B ratio (0.135), kernel length after cooking (0.925), water uptake (0.224) and amylose content (0.164). It also exerts negative indirect effects mainly through days to maturity (-0.342), total number of ear bearing tillers per plant (-0.124), panicle length (-0.580), test weight (-3.154), leaf area index (-0.247), milling recovery (-0.289), kernel length (-9.191), kernel breadth after cooking (-0.302), kernel linear elongation ratio (-0.021), volume expansion ratio (-0.974), gel consistency (-0.315) and alkali spreading value (-0.597).

Thus, days to 50% flowering recorded positive direct effects and significant negative association with grain yield per plant at genotypic levels. These results are in accordance with Keya *et al.* (2015), Imad *et al.* (2014), Patel *et al.* (2014), Krishna Veni *et al.* (2013) and Ravindra Babu *et al.* (2012), Ruth *et al.* (2011) and Nandan *et al.* (2010). Since, the direct effects are positive and the correlation coefficients are significantly negative, the indirect causal factors which are having positive effects with days to 50% flowering are to be considered simultaneously during the process of selection.

4.1.1.4.2 Days to Maturity

The trait showed negative significant genotypic association (-0.356**) and showed direct negative effect (-0.337) on grain yield per plant. It showed positive indirect effects *via* days to 50% flowering (4.100), plant height (0.653), total number of tillers per plant (0.004), number of grains per panicle (0.489), hulling recovery (1.104), head rice recovery (0.401), kernel breadth (7.216), kernel length after cooking (0.967), water uptake (0.196) and amylose content (0.177), while it had negative effects *via*, total number of ear bearing tillers per plant (-0.132), panicle length (-0.661), test weight (-3.123), leaf area index (-0.303), milling recovery (-0.311), kernel length (-8.235), L/B ratio (-0.140), kernel breadth after cooking (-0.308), kernel linear elongation ratio (-0.017), volume expansion ratio (-1.103), gel consistency (-0.382) and alkali spreading value (-0.610).

Thus days to maturity showed negative direct effect coupled with negative association with grain yield per plant at genotypic levels. These findings are corroborated by Singh *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Khare *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013), Mulugeta *et al.* (2012) and Nandan *et al.* (2010). Since both direct effects as well as correlation coefficients are negative at genotypic levels, the casual factors which had positive indirect effects on grain yield per plant may be considered during the process of selection.

4.1.1.4.3 Plant Height (cm)

This trait, had significant positive genotypic correlation (0.272*) and showed direct positive direct effect (1.561) on grain yield per plant and showed positive indirect effects *via* days to 50% flowering (1.523), total number of tillers per plant (0.008), total number of ear bearing tillers per plant (0.029), number of grains per panicle (0.315), hulling recovery (0.222), milling recovery (0.087), head rice recovery (0.613), kernel length (0.302), L/B ratio (0.842), alkali spreading value (0.049) and amylose content (0.638). It also exerts negative indirect effects through days to maturity (-0.141), panicle length (-1.874), test weight (-0.086), leaf area index (-0.271), kernel breadth (-0.499), kernel length after cooking (-0.704), kernel breadth after cooking (-0.218), kernel linear elongation ratio (-0.021), volume expansion ratio (-0.160), water uptake (-0.874) and gel consistency (-1.068).

Thus the trait showed significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. These findings were in line with the results obtained by Keya *et al.* (2015), Alam *et al.* (2014), Patel *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013), Krishna Veni *et al.* (2013), Mulugeta *et al.* (2012), and Ruth *et al.* (2011). In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive.

4.1.1.4.4 Total Number of Tillers per Plant

The trait, total number of tillers per plant had positive direct effect (0.017) and significant positive association (0.527**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (1.092), plant height (0.747), total number of ear bearing tillers per plant (0.113), number of grains per panicle (0.726), hulling recovery (0.695), head rice recovery (0.571), kernel length (2.429), kernel breadth (7.355), volume expansion ratio (0.083) and amylose content (0.192), while it had in direct effects in negative direction through days to maturity (-0.086), panicle length (-0.664), test weight (-1.230), leaf area index (-0.921), milling recovery (-0.214), L/B ratio (-8.564), kernel length after cooking (-0.736), kernel breadth after cooking (-0.256), kernel linear elongation ratio (-0.059), water uptake (-0.172), gel consistency (-0.568) and alkali spreading value (-0.023).

Thus the total number of tillers per plant showed significant positive correlation on grain yield per plant at genotypic levels coupled with positive direct effect. In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive. Similar results were earlier reported by Golam *et al.* (2015), Nitiprasad and Lotan (2014), Patel *et al.* (2014), Ali *et al.* (2013), Gulzar *et al.* (2013), Bhabendra *et al.* (2012), Uddin *et al.* (2007) and Afzal *et al.* (2006).

4.1.1.4.5 Number of Ear Bearing Tillers per Plant

At genotypic level, it possessed positive significant association (0.657**) and positive direct effect (0.475) on grain yield per plant at genotypic level. It showed positive indirect effects through days to maturity (0.093), plant height (0.096), total number of tillers per plant (0.004), number of grains per panicle (0.258), test weight (1.007), hulling recovery (0.886), head rice recovery (1.164), kernel length (7.293), kernel breadth after cooking (0.135), volume expansion ratio (0.724) and alkali spreading value (0.805). It also exerts negative indirect effects mainly through days to 50% flowering (-1.051), panicle length (-0.399), leaf area index (-0.883), milling recovery (-0.531), kernel breadth (-5.163), L/B ratio (-0.394), kernel length after cooking (-1.671), kernel linear elongation ratio (-0.053), water uptake (-0.389), gel consistency (-1.369) and amylose content (-0.380).

Thus the trait showed significant positive correlation on grain yield per plant at genotypic levels coupled with positive direct effect at genotypic levels. In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive. Similar results were confirmed by Golam *et al.* (2015), Pradhan *et al.* (2015), Alam *et al.* (2014), Dilruba *et al.* (2014), Dhurai *et al.* (2014), Thirumala Rao (2014), Krishna Veni *et al.* (2013), Jayasudha and Deepak (2010), Nandan *et al.* (2010) and Praveen *et al.* (2010).

4.1.1.4.6 Panicle Length (cm)

This trait possessed significant positive association (0.425**) and negative direct effect (-2.827) on grain yield per plant at genotypic level. It also showed positive indirect effects via days to 50% flowering (0.829), plant height (1.035), total number of tillers per plant (0.004), total number of ear bearing tillers per plant (0.067), number of grains per panicle (0.223), test weight (0.908), head rice recovery (0.333), kernel length

(6.943), L/B ratio (3.909), kernel linear elongation ratio (0.014), volume expansion ratio (0.147), alkali spreading value (0.273) and amylose content (0.063); while negative indirect effects *via* days to maturity (-0.079), leaf area index (-0.313), hulling recovery (-0.115), milling recovery (-0.153), kernel breadth (-9.195), kernel length after cooking (-0.369), kernel breadth after cooking (-0.142), water uptake (-0.315) and gel consistency (-0.814).

Thus the trait exhibited negative direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process. These results were in conformity with the findings of by Golam *et al.* (2015), Pradhan *et al.* (2015), Patel *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013), Krishna Veni *et al.* (2013), Bhabendra *et al.* (2012) and Ravindra Babu *et al.* (2012).

4.1.1.4.7 Number of Grains per Panicle

At genotypic level, the trait number of grains per panicle had positive direct effect (1.181) and non-significant positive association (0.238) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (1.665), plant height (0.416), total number of tillers per plant (0.011), total number of ear bearing tillers per plant (0.104), hulling recovery (2.581), head rice recovery (0.391), kernel breadth (18.892), water uptake (0.437) and amylose content (0.238), while negative indirect effects was observed through days to maturity (-0.139), panicle length (-0.534), test weight (-2.501), leaf area index (-0.958), milling recovery (-0.547), kernel length (-4.394), L/B ratio (-14.171), kernel length after cooking (-0.274), kernel breadth after cooking (-0.554), kernel linear elongation ratio (-0.086), volume expansion ratio (-0.076), gel consistency (-1.003) and alkali spreading value (-0.442).

Thus number of grains per panicle has positive direct effect and non-significant positive association with grain yield per plant genotypic levels. The positive indirect effects contributed to the total correlation on grain yield per plant. This type of correlation indicates that, direct selection will be effective. These results were in broad agreement with the findings of Islam *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Nagaraju *et al.* (2013) and Bhabendra *et al.* (2012).

4.1.1.4.8 Test Weight (g)

This trait had significant positive genotypic correlation (0.523**) and showed direct positive effect (4.292) with grain yield per plant. This trait exhibited negative indirect effect *via* days to maturity (0.245), total number of ear bearing tillers per plant (0.111), leaf area index (0.305), milling recovery (0.393), kernel length (10.918), L/B ratio (6.694), kernel breadth after cooking (0.409), kernel linear elongation ratio (0.031), volume expansion ratio (0.780), gel consistency (0.224) and alkali spreading value (1.141). It also negative indirect effect mainly through days to 50% flowering (-2.969), plant height (-0.031), total number of tillers per plant (-0.005), panicle length (-0.598), number of grains per panicle (-0.688), hulling recovery (-2.218), head rice recovery (-0.267), kernel breadth (-16.022), kernel length after cooking (-1.547), water uptake (-0.622) and amylose content (-0.052).

Thus test weight exhibited positive direct effect coupled with significant positive correlation at genotypic levels on grain yield per plant. As the direct effect of test weight on grain yield per plant at genotypic level accounted for the major portion in the total correlation between them, direct selection on test weight will be rewarding. Similar results were confirmed by Pradhan *et al.* (2015), Dhurai *et al.* (2014), Imad *et al.* (2014), Berhanu *et al.* (2013), Bhabendra *et al.* (2012), Garg *et al.* (2010), Nandan *et al.* (2010) and Praveen *et al.* (2010).

4.1.1.4.9 Leaf area Index at Maximum Tillering Stage

Leaf area index at maximum tillering stage recorded negative direct effect (-1.917) and significant positive association (0.671**) on grain yield per plant at genotypic level. It also disclosed prominent positive indirect effect *via* days to 50% flowering (0.521), plant height (0.221), total number of tillers per plant (0.008), total number of ear bearing tillers per plant (0.219), number of grains per panicle (0.590), hulling recovery (0.935), head rice recovery (0.651), kernel length (4.362), kernel breadth (4.319), volume expansion ratio (0.186), water uptake (0.622) and alkali spreading value (0.134), amylose content (0.026). It also exerts negative indirect effects mainly through days to maturity (-0.053), panicle length (-0.462), test weight (-0.682), milling recovery (-0.555), L/B ratio (-7.033), kernel length after cooking (-1.063), kernel breadth after cooking (-0.089), kernel linear elongation ratio (-0.0050) and gel consistency (-0.218).

Thus, it exhibited negative direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process. These results are in accordance with Zulqarnain *et al.* (2012) and Ullah *et al.* (2011).

4.1.1.4.10 Hulling Recovery (%)

At genotypic level, this trait had positive direct effect (3.684) and non-significant positive association (-0.174) with grain yield per plant. It also displayed positive indirect effects *via* days to 50% flowering (1.348), plant height (0.094), total number of tillers per plant (0.003), total number of ear bearing tillers per plant (0.114), panicle length (0.089), number of grains per panicle (0.828), head rice recovery (0.390), kernel breadth (16.260), kernel length after cooking (0.536), water uptake (0.313) and amylose content (0.083). Similar results were confirmed by Mahalingam *et al.* (2013), Parvathi (2010), Praveen *et al.* (2010) and Prem Kumar *et al.* (2010). This trait also, recorded negative indirect effects through days to maturity (-0.101), test weight (-2.585), leaf area index (-0.486), milling recovery (-0.354), kernel length (-10.207), L/B ratio (-7.628), kernel breadth after cooking (-0.413), kernel linear elongation ratio (-0.029), volume expansion ratio (-0.160), gel consistency (-1.418) and alkali spreading value (-0.536).

Thus the trait, hulling percentage recorded positive direct effects and significant negative association with grain yield per plant at genotypic levels. Since, the direct effects are positive and the correlation coefficients are significantly negative, the indirect causal factors which are having positive effects with hulling percentage are to be considered simultaneously during selection. These findings are corroborated by Nagajyothi (2001), Nandan *et al.* (2010), Praveen *et al.* (2010) and Prem Kumar *et al.* (2010).

4.1.1.4.11 Milling Recovery (%)

The trait, milling recovery had negative direct effect (-1.115) and significant positive association (-0.046**) on grain yield per plant at phenotypic level. It also had positive indirect effects through days to 50% flowering (1.046) total number of tillers per plant (0.003), total number of ear bearing tillers per plant (0.226), number of grains per panicle (0.580), hulling recovery (1.169), head rice recovery (1.128), kernel breadth (5.525), volume expansion ratio (0.496), water uptake (0.747), gel consistency (0.311)

and alkali spreading value (0.067). Similar results were confirmed by Madhusoodanan (2013), Ruth *et al.* (2011), Parvathi (2010), Prem Kumar *et al.* (2010) and Nagajyothi (2001). Negative indirect effects through days to maturity (-0.094), plant height (-0.121), panicle length (-0.389), test weight (-1.513), leaf area index (-0.955), kernel length (-0.105), L/B ratio (-5.262), kernel length after cooking (-0.853), kernel breadth after cooking (-0.293), kernel linear elongation ratio (-0.067) and amylose content (-0.630).

Thus milling percentage showed negative direct effect coupled with significant negative association with grain yield per plant at genotypic levels. These findings were in line with the results obtained by Nagaraju *et al.* (2013), Nagajyothi (2001), Ruth *et al.* (2011), Praveen *et al.* (2010) and Prem Kumar *et al.* (2010). Since both direct effects as well as correlation coefficients are negative genotypic levels, the casual factors which had positive indirect effects on grain yield per plant may be considered during the process of selection.

4.1.1.4.12 Head Rice Recovery (%)

This character expressed positive direct effect (1.579) and non-significant positive association (0.236) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.963), plant height (0.606), total number of tillers per plant (0.006), total number of ear bearing tillers per plant (0.350), number of grains per panicle (0.293), hulling recovery (0.910), head rice recovery (1.579), kernel length (1.701), L/B ratio (0.931), volume expansion ratio (0.273) and alkali spreading value (0.214). It also exerts negative indirect effects through days to maturity (-0.086), panicle length (-0.597), test weight (-0.725), leaf area index (-0.790), milling recovery (-0.796), kernel breadth (-1.905), kernel length after cooking (-1.122), kernel breadth after cooking (-0.058), kernel linear elongation ratio (-0.058), water uptake (-0.105), gel consistency (-1.022) and amylose content (-0.326). Similar results were confirmed by Krishna Veni *et al.* (2013), Ruth *et al.* (2011), Praveen *et al.* (2010) and Nayak *et al.* (2005)

Thus the trait showed non-significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. Similar results were earlier reported by Krishna Veni *et al.* (2013), Ruth *et al.* (2011), Praveen *et al.* (2010). In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive.

4.1.1.4.13 Kernel Length (mm)

At genotypic level, kernel length showed significant positive correlation (0.591**) and positive direct effect (20.096) on grain yield per plant. It also showed positive indirect effects *via* days to maturity (0.138), plant height (0.023), total number of tillers per plant (0.002), total number of ear bearing tillers per plant (0.172), test weight (2.332), milling recovery (0.006), head rice recovery (0.134), L/B ratio (2.053), kernel breadth after cooking (0.249), kernel linear elongation ratio (0.048) and alkali spreading value (0.437), while it had negative indirect effects mainly through days to 50% flowering (-1.848), panicle length (-0.977), number of grains per panicle (-0.258), leaf area index (-0.416), hulling recovery (-1.871), kernel breadth (-17.749), kernel length after cooking (-0.722), volume expansion ratio (-0.250), water uptake (-0.262), gel consistency (-0.565) and amylose content (-0.182).

Thus the trait showed significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive. These results were in broad agreement with the findings of Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Krishna Veni *et al.* (2013), Ruth *et al.* (2011), Nandan *et al.* (2010), Praveen *et al.* (2010) and Prem Kumar *et al.* (2010).

4.1.1.4.14 Kernel Breadth (mm)

Kernel breadth had non-significant positive association (0.195) and negative direct effect (-25.717) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to maturity (0.095), plant height (0.030), total number of ear bearing tillers per plant (0.095), test weight (2.674), leaf area index (0.322), milling recovery (0.239), head rice recovery (0.117), kernel length (13.869), L/B ratio (13.957), kernel breadth after cooking (0.472), kernel linear elongation ratio (0.082) and alkali spreading value (0.600). It also exerts negative indirect effects mainly through days to 50% flowering (-1.193), total number of tillers per plant (-0.005), panicle length (-1.011), number of grains per panicle (-0.868), hulling recovery (-2.329), kernel length after cooking (-0.197), volume expansion ratio (-0.072), water uptake (-0.583), gel consistency (-0.044) and amylose content (-0.340).

Thus the trait exhibited negative direct effect coupled with non-significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process. These results were in conformity with the findings of Golam *et al.* (2015), Pradhan *et al.* (2015), Patel *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013), Krishna Veni *et al.* (2013), Bhabendra *et al.* (2012) and Ravindra Babu *et al.* (2012)

4.1.1.4.15 Kernel Length/Breadth Ratio

At genotypic level, the trait had negative direct effect (-17.482) and non-significant positive association (0.220) on grain yield per plant. This trait exhibited positive indirect effect *via* total number of tillers per plant (0.009), total number of ear bearing tillers per plant (0.011), panicle length (0.632), number of grains per panicle (0.957), hulling recovery (1.607), kernel breadth (20.532), water uptake (0.593) and amylose content (0.304). This trait exerts negative indirect effect mainly through days to 50% flowering (-0.031), days to maturity (-0.003), plant height (-0.075), test weight (-1.644), leaf area index (-0.771), milling recovery (-0.336), head rice recovery (-0.084), kernel length (-2.360), kernel length after cooking (-0.356), kernel breadth after cooking (-0.442), kernel linear elongation ratio (-0.072), volume expansion ratio (-0.038), gel consistency (-0.299) and alkali spreading value (-0.433).

Thus the trait exhibited negative direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process. These results are in accordance with Shathisha *et al.* (2015), Dhurai *et al.* (2014), Gulzar *et al.* (2013), Krishna Veni *et al.* (2013), Awaneet and Senapati (2013), Nagaraju *et al.* (2013) and Nandan *et al.* (2010).

4.1.1.4.16 Kernel Length after Cooking (mm)

This trait had significant positive genotypic correlation (0.733**) and showed negative direct effect (-2.737) on grain yield per plant. It also exerts positive indirect effects mainly through days to maturity (0.119), plant height (0.401), total number of tillers per plant (0.005), total number of ear bearing tillers per plant (0.290), number of grains per panicle (0.118), test weight (2.427), head rice recovery (0.647), kernel length (5.302), kernel breadth after cooking (0.063), volume expansion ratio (1.050), alkali spreading value (1.215) and amylose content (0.053), while it exhibited positive indirect

effect *via* days to 50% flowering (-1.366), panicle length (-0.381), leaf area index (-0.744), hulling recovery (-0.722), milling recovery (-0.347), kernel breadth (-1.848), L/B ratio (-2.272), kernel linear elongation ratio (-0.074), water uptake (-0.394) and gel consistency (-0.074).

Thus, it showed negative direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process. These findings are corroborated by Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Prem Kumar *et al.* (2010) and Afzal *et al.* (2006).

4.1.1.4.17 Kernel Breadth after Cooking (mm)

This character expressed significant positive association (0.252*) and positive direct effect (0.658) on grain yield per plant at genotypic level, following positive indirect effect *via* days to maturity (0.158), total number of ear bearing tillers per plant (0.097), panicle length (0.608), test weight (2.664), leaf area index (0.259), milling recovery (0.496), kernel length (7.611), L/B ratio (11.741), kernel linear elongation ratio (0.051), volume expansion ratio (0.163), gel consistency (0.447) and alkali spreading value (0.820), while it had indirect negative indirect effect *via* days to 50% flowering (-1.852), plant height (-0.518), total number of tillers per plant (-0.007), number of grains per panicle (-0.993), hulling recovery (-2.311), head rice recovery (-0.139), kernel breadth (-18.457), kernel length after cooking (-0.260), water uptake (-0.601) and amylose content (-0.381).

Thus, this trait exhibited non-significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive. These findings were in line with the results obtained by Nandan *et al.* (2010) and Prem Kumar *et al.* (2010).

4.1.1.4.18 Kernel Linear Elongation Ratio

At genotypic level, this trait had negative direct effect (-0.138) and non-significant positive association (0.276) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.618), plant height (0.243), total number of tillers per plant (0.007), total number of ear bearing tillers per plant (0.181), panicle length (0.287), number of grains per panicle (0.742), hulling recovery (0.786),

head rice recovery (0.671), kernel breadth (15.310), volume expansion ratio (0.936), water uptake (0.201), gel consistency (0.022), alkali spreading value (0.449) and amylose content (0.042). This trait exerts negative indirect effect *via* days to maturity (-0.041), test weight (-0.960), leaf area index (-0.701), milling recovery (-0.542), kernel length (-6.946), L/B ratio (-9.182), kernel length after cooking (-1.466) and kernel breadth after cooking (-0.245).

Thus, it showed non-significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive. Similar results were confirmed by Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Parvathi *et al.* (2010) and Krishna *et al.* (2009a).

4.1.1.4.19 Volume Expansion Ratio

Volume expansion ratio had positive direct effect (2.045) and non-significant positive association (0.252) on grain yield per plant at genotypic level. It also had positive indirect effects through days to maturity (0.182), total number of tillers per plant (0.001), total number of ear bearing tillers per plant (0.168 test weight (1.638), head rice recovery (0.211), kernel breadth (0.910), L/B ratio (0.322), kernel breadth after cooking (0.052), water uptake (0.107), gel consistency (1.375) and alkali spreading value (0.519), while this trait showed negative indirect effects through days to 50% flowering (-1.924), plant height (-0.122), panicle length (-0.204),), number of grains per panicle (-0.044), leaf area index (-0.174), hulling recovery (-0.287), milling recovery (-0.271), kernel length (-2.452), kernel length after cooking (-1.405), kernel linear elongation ratio (-0.063) and amylose content (-0.333).

Thus, this trait showed non-significant positive and positive direct effect at genotypic level. However it showed non-significant positive correlation with grain yield at genotypic level. These findings are in agreement with the reports of Krishna Veni *et al.* (2013), Nandan *et al.* (2010) and Praveen *et al.* (2010).

4.1.1.4.20 Water Uptake (ml)

This character expressed non-significant positive correlation (0.168) and negative direct effect (-1.793) on grain yield per plant. It also exerts positive indirect effects mainly through days to maturity (0.037), plant height (0.761), total number of

tillers per plant (0.002), total number of ear bearing tillers per plant (0.103), test weight (1.489), leaf area index (0.665), milling recovery (0.464), head rice recovery (0.092), kernel length (2.938), L/B ratio (5.784), kernel breadth after cooking (0.221), kernel linear elongation ratio (0.015), alkali spreading value (0.636) and amylose content (0.469). It also showed negative indirect effects *via* days to 50% flowering (-0.506), panicle length (-0.497), number of grains per panicle (-0.288), hulling recovery (-0.644), kernel breadth (-8.365), kernel length after cooking (-0.601), volume expansion ratio (-0.122) and gel consistency (-0.692).

Thus, this trait showed non-significant positive and positive direct effect at genotypic level. However, it showed non-significant positive correlation with grain yield at genotypic level. These results were in broad agreement with the findings of Krishna Veni *et al.* (2013), Parvathi *et al.* (2010) and Prem Kumar *et al.* (2010).

4.1.1.4.21 Gel Consistency (mm)

Gel consistency had significant positive association (0.312*) and negative direct effect (-2.921) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to 50% flowering (0.436), plant height (0.570), total number of tillers per plant (0.003), total number of ear bearing tillers per plant (0.223), number of grains per panicle (0.405), hulling recovery (1.788), milling recovery (0.119), head rice recovery (0.553), kernel length (3.887), kernel linear elongation ratio (0.001), alkali spreading value (0.008) and amylose content (0.280), while this trait showed negative indirect effects *via* days to maturity (-0.044), panicle length (-0.788), test weight (-0.329), leaf area index (-0.143), kernel breadth (-0.388), L/B ratio (-1.789), kernel length after cooking (-0.069), kernel breadth after cooking (-0.101), volume expansion ratio (-0.963) and water uptake (-0.425).

Thus, this trait found to have negative direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process.

4.1.1.4.22 Alkali Spreading Value (mm)

At genotypic level, alkali spreading value had positive direct effect (1.753) and significant positive association (0.510**) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.117), plant height (0.043), total number of tillers per plant (0.000), total number of ear bearing tillers per plant (0.218), test

weight (2.794), head rice recovery (0.193), kernel length (5.013), L/B ratio (4.318), kernel breadth after cooking (0.308) and volume expansion ratio (0.605). This trait also exerts negative indirect effect *via* days to 50% flowering (-1.377), panicle length (-0.440), number of grains per panicle (-0.298), leaf area index (-0.147), hulling recovery (-1.127), milling recovery (-0.043), kernel breadth (-8.806), kernel length after cooking (-1.897), kernel linear elongation ratio (-0.035), water uptake (-0.651), gel consistency (-0.013) and amylose content (-0.018).

Thus the trait exhibited positive direct effect coupled with significant positive correlation at genotypic level. In such situations, the above mentioned high positive indirect causal factors are to be considered during selection process.

4.1.1.4.23 Amylose Content (%)

At genotypic level, the trait amylose content had positive direct effect (1.265) and significant positive association (0.278*) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.524), plant height (0.787), total number of tillers per plant (0.003), number of grains per panicle (0.223), hulling recovery (0.243), milling recovery (0.555) and kernel breadth (6.905), while it had indirect effects in negative direction *via*, days to maturity (-0.047), total number of ear bearing tillers per plant (-0.143), panicle length (-0.140), test weight (-0.177), leaf area index (-0.039), head rice recovery (-0.407), kernel length (-2.886), L/B ratio (-4.195), kernel length after cooking (-0.115), kernel breadth after cooking (-0.198), kernel linear elongation ratio (-0.005), volume expansion ratio (-0.538), water uptake (-0.665), gel consistency (-0.647) and alkali spreading value (-0.024).

Thus, it showed significant positive correlation on grain yield per plant coupled with positive direct effect at genotypic levels. These findings are in conformity with results of Patel *et al.* (2014), Krishna Veni *et al.* (2013), Garg *et al.* (2010) and Nagajyothi (2001). In such situations for improvement of grain yield per plant, selection has to be carried out on traits through which indirect effects are positive.

In plant breeding it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield *i.e.*, residual effect measures the role of the possible independent variables which were not included in the study on the dependent variable. In the present study, the residual effect at genotypic level was

0.2792 indicating that the characters included in the present investigation are contributing more than 72 per cent of variability pertaining the dependent variable *i.e.*, yield. Less than twenty eight per cent of contribution is from the few other characters which were not included in the present study.

Path analysis revealed the true relationship of plant height, total number of tillers per plant, number of ear bearing tillers per plant, number of grains per panicle, test weight, alkali spreading value and amylose content by establishing significant positive association and positive direct effect on grain yield per plant whereas days to maturity showed true relationship by establishing significant negative association and negative direct effect on grain yield per plant.

Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that simultaneous improvement of grain yield per plant is possible through manifestation of days to maturity, plant height, and total number of tillers per plant, test weight, alkali spreading value and amylose content.

4.1.2 Ratoon Crop

The ratoonability screening was laid at APPRI & RARS, Maruteru, W.G district, A.P., where 20 popular varieties (varieties grown by farmers + pre released cultivars), were raised in randomized complete block design (RCBD), with three replications, each entry was planted in three rows of three meters length at 20 cm x 15 cm spacing during *rabi* 2015-16 for various qualitative and quantitative characters. The main crop was harvested at the time of physiological maturity, leaving a stubble height of 30 cm above the ground level. Stubbles left over were then allowed to regenerate. Fertilizer schedule of 60:40:30 kg NPK ha⁻¹ was adopted for main crop. Fertilizer application was one fourth of the main crop recommendations were applied to the ratoon crop two days after the harvest of the main crop (Ambili and Rosamma, 2002), ten randomly selected plants of each parent and F₁ from each replication were used to estimate the regenerated tillers and ratoon yield.

The data collected on 20 parents for 27 different traits on ratoon crop was subjected to standard statistical analysis for drawing valid conclusions. The details of results obtained from the above investigation are discussed character-wise and presented here under the following headings.

4.1.2.1 Screening for Ratoonability/Ratooning rate in rice

4.1.2.2 Analysis of variance

4.1.2.3 Mean, genetic variability, heritability and genetic advance

4.1.2.4 Character association

4.1.2.5 Path coefficient analysis

4.1.2.1 SCREENING FOR RATOONABILITY/RATOONING RATE IN RICE

Among the 20 varieties (Table. 3.1) studied for ratoonability, the following eight varieties viz., MTU 1001, MTU 1061, MTU 1140, MTU 1064, BPT 3291, MCM 100, MTU 7029, MTU 1121 and MTU 1075, exhibited higher ratooning rate (Samson, 1980) (Appendix. B) (Plate 4.5) and varieties showing good ratoonability (Chauhan *et al.*, 1989) such as MTU 1064, MTU 1140, BPT 3291, MTU 1001, MTU 1061, MTU 1121, MCM 100 and MTU 7029 (Appendix. C), (Plate 4.5) were selected for combining ability, gene action and heterosis in *rabi*, 2015-16 and other parameters like mean, variability, heritability, expected genetic advance, character association and path analysis were also studied in the present experiment, which are had been discussed under the following headings.

4.1.2.2 ANALYSIS OF VARIANCE

The analysis of variance (ANOVA) of ratoon crop obtained after the harvest of main crop, for yield and yield attributing components along with grain quality characters are presented in Table 4.7. The results revealed existence of significant differences among the rice entries studied for all the characters under study.

4.1.2.3 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

In any successful crop improvement programme, the availability of adequate variability in basic genetic stocks and their proper utilization through various breeding programme for building up improved strains are very important. The genetic improvement of plant population depends on the presence of genetic variability and the extent to which the desirable traits are transmissible. Besides genetic variability, knowledge on heritability and genetic advance plays a predictive role in breeding through, expression of the phenotypic reliability which serves as a guide to its breeding value. Higher the heritability, greater would be the response to selection, as heritability is directly proportional to genetic advance making selection more effective (Burton, 1952 and Swarup and Chaungle, 1962). The magnitude of heritable variability is the most vital aspect of genetic contribution to the breeding material, as it fosters close relationship with response to selection (Panse, 1957).

In the present investigation, estimates of mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability h^2 (b) in broad sense and genetic advance as per cent of mean (GAM) were calculated and were presented in Table 4.8. & 4.9.

4.1.2.3.1 Days to 50% Flowering

The variation for number of days to 50% flowering ranged from 43.67 days (MTU 3626) to 56.00 days (MTU 1112) with a mean of 49.73 days. The PCV (7.30) and GCV (7.00) estimates were low indicating less variation for days to 50% flowering among the genotypes studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. Similar estimates of PCV and GCV were earlier reported by Allam *et al.* (2015), Navin Kumar *et al.* (2015), Arpita *et al.* (2014), Lingaiah *et al.* (2014) and Sandhya *et al.* (2014).

High heritability (91.90%) coupled with moderate genetic advance as per cent of mean (13.82) was noted for this trait which may be due to the predominance of both additive and non-additive gene action inheritance of this trait, selection for such traits may not be rewarding. These results are in consonance with findings of Keya *et al.* (2015), Sameera *et al.* (2015), Arpita *et al.* (2014), Gokulakrishnan *et al.* (2014), Aditya Kumar *et al.* (2013) and Toshimenla and Sapu (2013).

4.1.2.3.2 Days to Maturity

There is significant variation for days to maturity varied from 68.00 days (MTU 3626) to 91.00 days (MTU 1112) with a mean of 79.52 days. The estimates of PCV (7.83) and GCV (7.03) were low indicating less variation among the genotypes studied and the magnitude of PCV was higher than GCV indicated the influence of environment on expression of this trait. These results are in accordance with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Sameera *et al.* (2015), Arpita *et al.* (2014), Bornare *et al.* (2014), Osekita *et al.* (2014), Atif and Khalid (2013) and Gulzar *et al.* (2013).

This trait exhibited high heritability (80.60%) together with moderate genetic advance as per cent of mean (13.00) indicating the operation of both additive and non-additive gene action in the inheritance of this trait. These findings are corroborated by Tuhina-Khatun *et al.* (2015), Alam *et al.* (2014), Ashok Kumar *et al.* (2013), Sangam Kumar Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Vange (2009).

4.1.2.3.3 Plant Height (cm)

The plant height ranged from 90.36 cm (BPT 5204) to 116.06 cm (MTU 1112) with a mean of 105.37 cm. The estimates of PCV (8.23) and GCV (7.65) were low indicating less variation among the genotypes studied. The magnitude of PCV was higher than GCV, indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Similar results were reported by Navin Kumar *et al.* (2015), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013) and Mulugeta *et al.* (2012).

High heritability (86.40%) combined with moderate genetic advance as per cent of mean (14.65) was observed for this trait indicating the predominance of both additive and non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding. These results are in consonance with findings of Keya *et al.* (2015), Alam *et al.* (2014), Sathya and Jebaraj (2013), Toshimenla and Sapu (2013), Mulugeta *et al.* (2012) and Dinesh *et al.* (2011).

4.1.2.3.4 Total Number of Tillers per Plant

The range of variation observed for this trait varied from 4.33 (MTU 3626) to 11.67 (MTU 1166) with a mean of 8.72. The estimates of PCV (22.52) and GCV (17.82) were moderate indicating moderate variation among the genotypes studied. The magnitude of PCV was higher than GCV, indicated the influence of environment on expression of this trait. These findings were in line with the results obtained by Nitiprasad and Lotan Kumar (2014), Osekita *et al.* (2014), Singh *et al.* (2014) and Vange (2009).

High heritability (62.60%) along with high genetic advance as per cent of mean (29.03) was observed which indicated that this trait is governed by additive gene action with little influence of environment in inheritance; simple selection is useful in improvement of this trait. Similar results were earlier reported by Sameera *et al.* (2015), Arpita *et al.* (2014), Gangashetty *et al.* (2013), Gulzar *et al.* (2013), Ukaoma *et al.* (2013) and Priyanka Yadav *et al.* (2010).

4.1.2.3.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers

This trait showed range of variation from 43.00 (MTU 3626) to 100.00 (MTU 1001) with a mean of 73.67. The estimates of PCV (20.04) and GCV (13.56) were high indicating high variation among the genotypes studied and the magnitude of PCV was

greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading.

Moderate heritability (45.80%) coupled with moderate genetic advance as per cent of mean (18.91) was observed for this trait indicated that the character was highly influenced by environmental effects and selection would be in effective.

4.1.2.3.6 Number of Vegetative Buds after the Harvest of Main Crop

The trait, ranged from 6.67 (MTU 2077) to 13.00 (MTU 1001) with a mean of 10.50. The estimates of PCV (18.67) and GCV (12.92) were high indicating moderate variation among the genotypes studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading.

High heritability (47.90%) accompanied with moderate genetic advance as per cent of mean (18.43) was observed for this trait indicating inheritance of this trait was governed by both additive and non-additive gene action as well as influenced by environment.

4.1.2.3.7 Number of Ear Bearing Tillers per Plant

There is significant variation for this character ranged from 2.33 (MTU 3626) to 8.67 (MTU 1061) with a mean of 5.19. The estimates of PCV (36.99) and GCV (34.08) were high indicating high variation among the genotypes studied. The magnitude of PCV was higher than GCV indicated the influence of environment on expression of this trait. These results were in broad agreement with the findings of Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Sameera *et al.* (2015), Bornare *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Osekita *et al.* (2014), Awaneet Kumar and Senapati (2013), Shiva Prasad *et al.* (2013) and Ukaoma *et al.* (2013).

High heritability (84.90%) supplemented with high genetic advance as per cent of mean (64.66) was noted for this trait indicated that the heritability is due to additive gene action, with little influence of the environment on this trait. These findings are in conformity with the results of Allam *et al.* (2015), Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Thirumala Rao *et al.* (2014) and Ukaoma *et al.* (2013).

4.1.2.3.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

The variation for this trait ranged from 31.22 cm (MTU 3626) to 79.17 cm (MTU 1001) with a mean of 64.38 cm. The estimates of PCV (27.54) and GCV (22.34) were high represented that the higher variation exists for this trait and the magnitude of the PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading.

High heritability (65.80%) together with high genetic advance as per cent of mean (37.33) was observed which indicated that this trait is governed by additive gene action with little influence of environment in its inheritance.

4.1.2.3.9 Panicle Length (cm)

There is significant variation for panicle length per plant in the material studied which ranged from 18.37 (MTU 3626) to 21.64 (MTU 1001) with a mean of 22.43, with estimates of PCV (7.84) and GCV (7.23) for this trait were low indicating less variation among the genotypes studied. The above results were in agreement with Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Vijay Kumar *et al.* (2015), Alam *et al.* (2014), Bornare *et al.* (2014), Rahman *et al.* (2014), Atif and Khalid (2013), Paikhomba *et al.* (2013) and Sathya and Jebaraj (2013).

High heritability (85.10%) supplemented with moderate genetic advance as per cent of mean (13.75) was recorded for this trait indicating the operation of both additive and non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These results are in accordance with Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Lingaiah *et al.* (2014), Thirumala Rao *et al.* (2014), Ashok Kumar *et al.* (2013) and Venkata Subbaiah *et al.* (2011).

4.1.2.3.10 Number of Grains per Panicle

The range for number of grains per panicle varied from 99.18 (MTU 2067) to 186.60 (MTU 1071) with a mean of 148.81. The estimates of PCV (16.79) and GCV (15.66) for this trait were moderate indicating moderate variation among the genotypes studied. The magnitude of PCV was higher than GCV indicated the influence of

environment on expression of this trait. These findings are corroborated by Keya *et al.* (2015), Shajedur Hossain *et al.* (2015), Bornare *et al.* (2014), Mamunur *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Paikhomba *et al.* (2013) and Sathya and Jebaraj (2013).

High heritability (86.90%) coupled with high genetic advance as per cent of mean (30.07) was observed for this trait, revealed that the heritability most likely due to the preponderance of additive gene action. This may be exploited through simple selection procedures. These results are in consonance with findings of Allam *et al.* (2015), Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Gokulakrishnan *et al.* (2014), Lingaiah *et al.* (2014), Mamunur *et al.* (2014) and Rahman *et al.* (2014).

4.1.2.3.11 Test Weight (g)

There is significant variation for test weight which ranged from 14.96 (MTU 1078) to 22.62 (MTU 3626) with a mean of 18.32. The estimates of PCV (11.77) and GCV (11.46) for this trait were moderate represents moderate variation. These findings were in line with the results obtained by Allam *et al.* (2015), Keya *et al.* (2015), Arpita *et al.* (2014), Bornare *et al.* (2014), Lingaiah *et al.* (2014), Awaneet Kumar and Senapati (2013) and Shiva Prasad *et al.* (2013).

High heritability (94.90%) together with high genetic advance as per cent of mean (23.01) was observed that this trait is governed by additive gene action with little influence of environment in its inheritance. Similar results were earlier reported by Allam *et al.* (2015), Sameera *et al.* (2015), Alam *et al.* (2014), Swati Sharma *et al.* (2014) and Thirumala Rao *et al.* (2014).

4.1.2.3.12 Leaf Area Index at Maximum Tillering Stage

This trait, possessed significant variation which was ranged from 1.69 (MTU 1121) to 3.03 (MTU 4870) with a mean of 2.13. The estimates of PCV (19.01) and GCV (14.48) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Ullah *et al.* (2011).

Moderate heritability (58.00%) along with high genetic advance as per cent of mean (22.70) reveals the role of both additive gene and non-additive gene action in governing the inheritance of this trait as well as influence of environmental effects. These results were in broad agreement with the findings of Satish *et al.* (2004) and Prasanthi (1993).

4.1.2.3.13 Grain Yield per Plant (g)

There is significant variation for this character which was ranged from 5.68 g (MTU 3626) to 26.07 g (MTU 1064) with a mean of 14.63 g. The estimates of PCV (45.27) and GCV (44.53) for this trait were moderate, respectively, showing wider variability and the magnitude of PCV was greater than GCV represented indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. These findings are in conformity with the results of Allam *et al.* (2015), Keya *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Aditya Kumar *et al.* (2013), Ashok Kumar *et al.* (2013), Gulzar *et al.* (2013) and Ukaoma *et al.* (2013).

High heritability (96.80%) in conjunction with high genetic advance as per cent of mean (90.24) was noted for this trait which may be due to additive gene action with little influence of environment in its inheritance. The above results were in agreement with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Alam *et al.* (2014), Sandhya *et al.* (2014), Singh *et al.* (2014), Swati Sharma *et al.* (2014) and Thirumala Rao *et al.* (2014).

4.1.2.3.14 Hulling Recovery (%)

The trait, hulling recovery ranged from 75.18% (MTU 1075) to 80.48% (MTU 1140) with a mean of 78.52% the estimates of PCV (2.21) and GCV (1.47) were low, revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Venkanna *et al.* (2014), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b) and Satish Chandra *et al.* (2009).

Moderate heritability (43.80%) along with low genetic advance as per cent of mean (2.00) indicated that the character is highly influenced by environmental effects and selection would be ineffective. These results are in accordance with Sivaparvathi *et al.* (2011).

4.1.2.3.15 Milling Recovery (%)

This character possessed significant variation which was ranged from 62.80% (MTU 3626) to 74.80% (MCM 100) with a mean of 72.65%. The estimates of PCV (4.38) and GCV (4.10) were low indicating low variability. These findings are corroborated by Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Satish Chandra *et al.* (2009).

High heritability (87.60%) coupled with low genetic advance as per cent of mean (7.90) indicated the role of non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype. These results are in consonance with findings of Venkata Subbaiah *et al.* (2011) Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009) and Krishna Naik (2004).

4.1.2.3.16 Head Rice Recovery (%)

The range of variation noted for this trait varied from 54.84% (MTU 3626) to 70.82% (MTU 1061) with a mean of 66.59%. The estimates of PCV (5.69) and GCV (5.35) were low indicated low variability. These findings were in line with the results obtained by Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Sivaparvathi *et al.* (2011), Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009) and Krishna Naik (2004).

High heritability (88.40%) in conjunction with moderate genetic advance as per cent of mean (10.37) indicated the role of both additive and non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. Similar results were earlier reported by Sivaparvathi *et al.* (2011), Krishna Naik (2004) and Patil *et al.* (2003).

4.1.2.3.17 Kernel Length (mm)

The range of variation observed for this trait varied from 4.82 mm (MTU 1166) to 5.83 mm (MTU 1001) with a mean of 5.24 mm. The estimates of PCV (6.21) and GCV (5.25) were low. These results were in broad agreement with the findings of Tuhina-Khatun *et al.* (2015), Gokulakrishnan *et al.* (2014), Osekita *et al.* (2014), Venkanna *et al.* (2014), Aditya Kumar *et al.* (2013), Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011).

High heritability (71.30%) together with low genetic advance as per cent of mean (9.12) indicated the role of non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype. These findings are in conformity with the results of Seyed Mustafa Sadeghi (2011) and Prasad *et al.* (2009).

4.1.2.3.18 Kernel Breadth (mm)

The range for this trait varied from 1.73 mm (MTU 1166) to 2.32 mm (MTU 1001) with a mean of 2.03 mm. The estimates of PCV (8.13) and GCV (7.60) were low indicated low variation. The above results were in agreement with Allam *et al.* (2015), Venkanna *et al.* (2014), Aditya Kumar *et al.* (2013), Awaneet Kumar and Senapati (2013) and Ravindra Babu *et al.* (2012).

High heritability (87.30%) coupled with moderate genetic advance as per cent of mean (14.63), noticed the role of both additive and non-additive gene action in the inheritance of this character. Heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These results are in accordance with Allam *et al.* (2015), Nitiprasad and Lotan Kumar (2014), Singh *et al.* (2014), Awaneet Kumar and Senapati (2013) and Rita Bisne *et al.* (2009).

4.1.2.3.19 Kernel Length (L)/Breadth (B) Ratio

The range of variation for kernel length/breadth ratio was ranged from 2.37 (MTU 2077) to 2.96 (MTU 1075) with a mean of 2.59. The estimates of PCV (8.00) and GCV (6.23) were low. The magnitude of PCV was higher than GCV revealing the influence of environment on the expression of the character. These findings are corroborated by Venkanna *et al.* (2014) and Venkata Subbaiah *et al.* (2011).

High heritability (60.60%) along with low genetic advance as per cent of mean (9.99) indicated the role of non-additive gene action. The heritability is being exhibited due to favourable influence of environment rather than genotype. These results are in consonance with findings of Mohan Lal and Chauhan (2011), Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Verma *et al.* (2011).

4.1.2.3.20 Kernel Length after Cooking (mm)

This character possessed significant variation which was ranged from 7.05 (MTU 2077) to 10.13 (MTU 1001) with a mean of 9.01. The estimates of PCV (7.93) and GCV (7.81) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings were in line with the results obtained by Venkata Subbaiah *et al.* (2011).

High heritability (96.90%) supplemented with moderate genetic advance as per cent of mean (15.83) indicated the role of both additive and non-additive gene action in governing the inheritance of this character, as well as influence of environment. Contrary, Venkata Subbaiah *et al.* (2011), Sarkar *et al.* (2007) and Krishna Naik (2004) reported high heritability and low genetic advance as percentage; this might be due to differences in breeding material studied under different environments.

4.1.2.3.21 Kernel Breadth after Cooking

The range of variation for this trait, varied from 2.17 (MTU 1166) to 3.34 (MTU 7029) with a mean of 2.63. The estimates of PCV (10.29) and GCV (10.04) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. Contrary, low PCV and GCV were reported by Venkata Subbaiah *et al.* (2011), this might be due to differences in breeding material studied under different environments.

High heritability (95.30%) in conjunction with high genetic advance as per cent of mean (20.19) was noted for this trait, revealed that most likely the heritability is due to additive gene action. Contrary, Venkata Subbaiah *et al.* (2011), reported high heritability and moderate genetic advance as percentage of mean, this might be due to differences in breeding material studied under different environments.

4.1.2.3.22 Kernel Elongation Ratio

This trait, possessed significant variation which was ranged from 1.44 (MTU 2077) to 1.93 (MTU 1112) with a mean of 1.72. The estimates of PCV (7.25) and GCV (6.37) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. Similar results were earlier reported by Allam *et al.* (2015), Venkata Subbaiah *et al.* (2011) and Sunayana *et al.* (2010).

High heritability (77.30%) coupled with moderate genetic advance as per cent of mean (11.54) indicated the role of both additive and non-additive gene action in governing the inheritance of this character. Heritability is being exhibited due to favourable influence of environmental rather than genotypic and selection for such traits may not be rewarding. These results were in broad agreement with the findings of Vanaja and Luckins (2006).

4.1.2.3.23 Volume Expansion Ratio

Volume expansion ratio ranged from 4.22 (MCM 100) to 5.34 (MTU 1140) with a mean of 4.85. The estimates of PCV (7.55) and GCV (3.87) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Venkata Subbaiah *et al.* (2011).

Low heritability (26.30%) along with low genetic advance as per cent of mean (4.09) indicated that the character is highly influenced by environmental effects and selection would be ineffective. Contrary, Ravindra Babu *et al.* (2012), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006) reported high heritability and high genetic advance as per cent of mean, this might be due to differences in breeding material studied under different environments.

4.1.2.3.24 Water Uptake (ml)

The range of variation noted for this trait, varied from 140.50 (MTU 2067) to 264.17 (MTU 1001) with a mean of 193.91. The estimates of PCV (16.53) and GCV (16.17) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. The above results were in agreement with Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006).

High heritability (95.70%) accompanied with high genetic advance as per cent of mean (32.60) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selections. These results are in accordance with Sivaparvathi *et al.* (2011), Chakraborty *et al.* (2010), Umadevi *et al.* (2010b), Vanaja and Luckins (2006) and Yadav *et al.* (2002).

4.1.2.3.25 Gel Consistency (mm)

The variation for gel consistency ranged from 39.92 (MTU 3626) to 63.83 (MTU 2067) with a mean of 53.19. The estimates of PCV (13.42) and GCV (13.14) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are corroborated by Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011)

High heritability (95.80%) along with high genetic advance as per cent of mean (26.49) indicated that most likely the heritability is due to additive gene action with less influence of environment. These results are in consonance with findings of Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Manonmani *et al.* (2010) and Umadevi *et al.* (2010b).

4.1.2.3.26 Alkali Spreading Value (mm)

The trait, alkali spreading value varied from 2.89 (MTU 1075) to 6.94 (MTU 1061) with a mean of 4.21. The estimates of PCV (34.58) and GCV (34.40) were high represents high variability. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These findings were in line with the results obtained by Allam *et al.* (2015), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Sunayana *et al.* (2010).

High heritability (99.00%) coupled with high genetic advance as per cent of mean (70.50) indicated that heritability is due to additive gene action and offers the scope for improvement through simple selection. Similar results were earlier reported by Allam *et al.* (2015), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011) and Venkata Subbaiah *et al.* (2011).

4.1.2.3.27 Amylose Content (%)

Amylose content possessed significant variation which was ranged from 20.49 (MCM 100) to 25.26 (MTU 1001) with a mean of 23.42. The estimates of PCV (7.64) and GCV (6.27) were low, respectively. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These results were in broad agreement with the findings of Allam *et al.* (2015), Aditya Kumar *et al.* (2013), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011) and Rajeswari *et al.* (2010).

High heritability (67.30%) supplemented with moderate genetic advance as per cent of mean (10.60) indicated the role of both additive and non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These findings are in conformity with the results of Allam *et al.* (2015), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Chakraborty *et al.* (2010), Krishna Naik (2004) and Nagajyothi (2001).

Thus, in the present study analysis of variance revealed significant differences among the genotypes for all the characters studied indicating the existence of high degree of variability in the material. The magnitude of difference between PCV and GCV was relatively low for all the traits except plant height, total number of tillers per plant, number of ratoon tillers as percentage of main crop tillers, number of vegetative buds after the harvest of main crop, total ear bearing tillers per plant, number of ear bearing tillers as percentage of main crop ear bearing tillers, number of grains per panicle, LAI, grain yield per plant, hulling percentage, kernel length, L/B ratio, kernel linear elongation ratio, volume expansion ratio and amylose content which revealed the least influence of environment on these traits. The magnitude of PCV was higher than GCV for all the characters which revealed the influence of environment on the expression of these traits. Wider variability was observed in case of total ear bearing tillers per plant, ear bearing tillers as percentage of main crop tillers, grain yield per plant and alkali spreading value which indicated their amenability towards direct selection. The traits number of vegetative buds after the harvest of main crop, number of grain per panicle, test weight, LAI, kernel breadth after cooking, water uptake and gel consistency recorded moderate variability, while the remaining characters exhibited low variability.

The estimates of heritability and genetic advance as per cent of mean were high for the characters viz., total number of tillers per plant, total number of ear bearing tillers per plant, number of ear bearing tillers as percentage of main crop ear bearing tillers per plant, number of grains per panicle, test weight, grain yield per plant, kernel breadth after cooking, water uptake, gel consistency and alkali spreading value which suggested the role of additive gene action in the inheritance of these traits and reliance should be placed on pure line selection, mass selection, progeny selection and hybridization & selection with pedigree breeding.

Moderate to high heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, number of ratoon tillers as percentage of main crop and number of vegetative buds after harvest of main crop, panicle length, head rice recovery, kernel breadth, kernel length after cooking, kernel linear elongation ratio and amylose content, revealed the involvement of both additive and non-additive gene action in the inheritance of these traits. Improvement in these traits is possible by adopting breeding procedures like recombination breeding with postponement of selection at later generations and also by

population improvement programme such as cyclic hybridization, biparental mating and diallel selective mating systems should be taken up for the development of superior lines with results desirable genes.

While, moderate heritability coupled with high genetic advance as per cent of mean was observed for leaf area index at maximum tillering stage. High heritability and low genetic advance as per cent of mean was observed for milling recovery, kernel length and L/B ratio and low heritability coupled with low genetic advance of mean was observed for volume expansion ratio. It revealed the non-additive gene action in the inheritance of these traits. Hence, improvement of these traits was being difficult through simple selections, whereas heterosis breeding and recombination breeding with postponement of selection was effective.

4.1.2.4 CHARACTER ASSOCIATION

The phenotypic and genotypic correlation coefficients for different grain yield components and grain quality parameters were presented in Table 4.10 and 4.11. Direct selection for yield and quality traits is not effective as they are complex quantitative characters, highly influenced by environment. High genotype and environment interaction will restrict improvement, if selection is based on yield *per se*. The effective improvement in yield may be brought about through selection on yield component characters. The aim of correlation studies is primarily to know the suitability of various characters for indirect selection because any particular trait may bring about undesirable changes in other associated characters (Singh, 1982).

Yield component characters show associations among themselves and also with yield. Unfavorable associations between the desired attributes under selection may limit genetic advance. Hence, knowledge of associations between the yield and yield components and also among the yield components was essential for planning a sound selection programme (Falconer, 1964).

In general, the results revealed that the genotypic correlation coefficients were higher than the phenotypic correlation coefficients for almost all the characters under study. This may be due to the relative stability of genotypes as majority of them were subjected to certain amount of selection (Johnson *et al.*, 1955).

4.1.2.4.1 Days to 50% Flowering

At both phenotypic and genotypic levels, this trait exhibited positive significant correlation with days to maturity (0.921**, 0.998**), plant height (0.422**, 0.478**), total number of tillers per plant (0.279*, 0.416**), number of vegetative buds after the harvest of main crop (0.376**), total number of ear bearing tillers per plant (0.537**, 0.600**), number of ratoon productive tillers as percentage of main crop productive tillers (0.440**, 0.568**), panicle length (0.378**, 0.413**), number of grains per panicle (0.538**, 0.619**), milling recovery (0.316*, 0.400**), head rice recovery (0.350**, 0.416**), L/B ratio (0.326*, 0.406**), kernel length after cooking (0.326*, 0.346**), kernel linear elongation ratio (0.475**, 0.580**), volume expansion ratio (0.305*), grain yield per plant (0.527**, 0.547**) and significant negative association with test weight (-0.314*, -0.351**) and kernel breadth (-0.404**, -0.441**).

It showed significant positive association with leaf area index (0.288*) at genotypic level. Similar kind of relation was reported by Islam *et al.* (2015), Sathisha *et al.* (2015), Singh *et al.* (2015), Shajedur Hossain *et al.* (2015) and Dhurai *et al.* (2014).

4.1.2.4.2 Days to Maturity

Days to maturity had significant positive association with plant height (0.388**, 0.492**), total number of tillers per plant (0.330**, 0.456**), number of vegetative buds after the harvest of main crop (0.272*, 0.407**), total number of ear bearing tillers per plant (0.470**, 0.591**), number of ratoon productive tillers as percentage of main crop productive tillers (0.372**, 0.579**), panicle length (0.357**, 0.451**), number of grains per panicle (0.565**, 0.651**), hulling recovery (0.372**, 0.455**), milling recovery (0.402**, 0.467**), head rice recovery (0.372**, 0.455**), kernel length after cooking (0.258*, 0.309*), kernel linear elongation ratio (0.495**, 0.593**) and grain yield per plant (0.452**, 0.500**) and significant negative association with test weight (-0.401**, -0.480**) and kernel breadth (-0.415**, -0.531**) at both phenotypic and genotypic levels.

This trait also showed positive significant correlation with leaf area index (0.383**), L/B ratio (0.458**) and gel consistency (0.285*) at genotypic level. These results are in consonance with findings of Golam Sarwar *et al.* (2015), Islam *et al.* (2015), Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015), Sathisha *et al.* (2015) and Dhurai *et al.* (2014).

4.1.2.4.3 Plant Height (cm)

The trait, plant height showed significant positive association with total number of tillers per plant (0.355**, 0.477**), number of vegetative buds after the harvest of main crop (0.298*, 0.441**), total number of ear bearing tillers per plant (0.286*, 0.352**), number of ratoon productive tillers as percentage of main crop productive tillers (0.307*, 0.446**), panicle length (0.584**, 0.658**), head rice recovery (0.333**, 0.399**), kernel length after cooking (0.283*, 0.316*), volume expansion ratio (0.331*, 0.713*), water uptake (0.296*, 0.330**), gel consistency (0.448**, 0.489**) and grain yield per plant (0.296*, 0.326*) at both phenotypic and genotypic levels.

This character also recorded significant positive correlation with L/B ratio (0.355**), alkali spreading value (0.258*) and amylose content (0.360**) at genotypic level. Similar results were confined by Anis *et al.* (2016), Islam *et al.* (2015), Sathisha *et al.* (2015) and Singh *et al.* (2015)

4.1.2.4.4 Total Number of Tillers per plant

Total number of tillers per plant recorded significant positive correlation with number of ratoon tillers as percentage of main crop tillers per plant (0.845**, 0.864**), number of vegetative buds after the harvest of main crop (0.859**, 0.999**), total number of ear bearing tillers per plant (0.536**, 0.699**), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.596**, 0.828**), number of grains per panicle (0.0.274*, 0.446**), milling recovery (0.265*, 0.322*), head rice recovery (0.507**, 0.672**), L/B ratio (0.469**), kernel length after cooking (0.541**, 0.733**), kernel linear elongation ratio (0.471**, 0.666**), gel consistency (0.306*, 0.416**) and grain yield per plant (0.485**, 0.633**) at both phenotypic and genotypic levels. It showed only positive correlation with panicle length (0.307*) and amylose content (0.297*) at genotypic level. The above results were in agreement with Golam Sarwar *et al.* (2015), Kundu sritama *et al.* (2015), Sathisha *et al.* (2015) and Vijay Kumar *et al.* (2015).

4.1.2.4.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers per Plant

Number of ratoon tillers as percentage of main crop tillers per plant found to have significant positive correlation with number of vegetative buds after the harvest of main crop (0.746**, 0.860**), total number of ear bearing tillers per plant (0.482**, 0.763**), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.589**, 0.949**), milling recovery (0.307*, 0.439**), head rice recovery (0.519**, 0.787**), kernel length after cooking (0.392**, 0.620**), kernel linear elongation ratio (0.288*, 0.436**) and grain yield per plant (0.470**, 0.709**) at both phenotypic and genotypic levels. It showed positive significant association with panicle length (0.228*), number of grains per panicle (0.278*), kernel length (0.387**), gel consistency (0.321*), alkali spreading value (0.256*) and amylose content (0.349**) at genotypic level.

4.1.2.4.6 Number of Vegetative Buds after the Harvest of Main Crop

Both phenotypic and genotypic correlations indicated that this trait had significant positive association with total number of ear bearing tillers per plant (0.434**, 0.749**), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.441**, 0.833**), head rice recovery (0.489**, 0.654**), kernel length (0.259*, 0.406**), kernel length after cooking (0.505**, 0.798**), kernel linear elongation ratio (0.342**, 0.665**), alkali spreading value (0.292*, 0.445**) and grain yield per plant (0.399**, 0.0631**). It also exhibited positive significant association with number of grains per panicle (0.298*), milling recovery (0.295*), L/B ratio (0.489**) and gel consistency (0.420**) at genotypic level.

4.1.2.4.7 Total Number of Ear Bearing Tillers per Plant

Total number of ear bearing tillers per plant showed significant positive association with number of ear bearing ratoon tillers as percentage of main crop ear bearing tillers (0.872**, 0.917**), panicle length (0.277*, 0.378**), number of grains per panicle (0.292*, 0.341**), milling recovery (0.291*, 0.377**), head rice recovery (0.559**, 0.684**), kernel length (0.284*, 0.385**), kernel length after cooking (0.556**, 0.609**), kernel linear elongation ratio (0.363**, 0.426**), gel consistency (0.378**, 0.441**), alkali spreading value (0.288*, 0.315*) and grain yield per plant (0.860**, 0.948**) at both phenotypic and genotypic levels. It also exhibited positive significant association with L/B ratio (0.267*) at genotypic level. These results were in

agreement with the findings Golam Sarwar *et al.* (2015), Keya *et al.* (2015), Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015) and Nabedita Mohanty *et al.* (2015).

4.1.2.4.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

This character, exhibited significant positive association with panicle length (0.314*, 0.496**), number of grains per panicle (0.290*, 0.407**), grain yield per plant (0.754**, 0.937**), milling recovery (0.252, 0.394**), head rice recovery (0.508**, 0.661**), kernel length after cooking (0.487**, 0.591**), kernel linear elongation ratio (0.382**, 0.491**) and gel consistency (0.293*, 0.400**) at both phenotypic and genotypic levels. It showed positive significant correlation with kernel length (0.280*) and volume expansion ratio (0.383**) at genotypic level.

4.1.2.4.9 Panicle Length (cm)

This character, panicle length showed significant positive association with head rice recovery (0.374**, 0.368**), volume expansion ratio (0.318*, 0.808**), gel consistency (0.617**, 0.695**) and grain yield per plant (0.266*, 0.292*) at both phenotypic and genotypic levels, respectively. These findings are corroborated by Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015) and Sathisha *et al.* (2015).

4.1.2.4.10 Number of Grains per Panicle

This character exhibited significant positive association with milling recovery (0.491**, 0.556**), L/B ratio (0.368**, 0.581**), kernel length after cooking (0.230*, 0.320*), kernel linear elongation ratio (0.665**, 0.752**), grain yield per plant (0.275*, 0.284*). Whereas significant negative association with test weight (-0.494**, -0.549**), kernel length (-0.361**, -0.402**), kernel breadth (-0.636**, -0.745**), kernel breadth after cooking (-0.459**, -0.511**) at both phenotypic and genotypic levels.

It showed positive significant association with head rice recovery (0.320*) and negative association with hulling recovery (-0.341**) at genotypic level. Similar kind of association was earlier reported by Islam *et al.* (2015), Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015) and Sandhyarani Das (2015).

4.1.2.4.11 Test Weight (g)

At both phenotypic and genotypic levels, this trait exhibited significant positive correlation with kernel length (0.739**, 0.936**), kernel breadth (0.676**, 0.739**), kernel length after cooking (0.330**, 0.343**), kernel breadth after cooking (0.416**, 0.446**), water uptake (0.349**, 0.369**), alkali spreading value (0.375**, 0.386**) and grain yield per plant (0.293*, 0.301*). Whereas significant negative association with milling recovery (-0.433**, -0.480**) and kernel linear elongation ratio (-0.282*, -0.362*). It also recorded positive association with hulling recovery (0.305*) at genotypic level. These results are in accordance with the results of Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015), Sarafraz *et al.* (2015) and Sathisha *et al.* (2015) also reported similar association.

4.1.2.4.12 Leaf Area Index at Maximum Tillering Stage

This trait, showed significant positive association with hulling recovery (0.257*, 0.444**), alkali spreading value (0.272*, 0.363**) at both phenotypic and genotypic levels. It also showed significant positive correlation with milling recovery (0.281*) and significant negative association with gel consistency (-0.331*) at genotypic level. These results are in accordance with Bhabendra *et al.* (2012).

4.1.2.4.13 Hulling Recovery (%)

Hulling recovery was found to have significant positive association with volume expansion ratio (0.823**) at phenotypic level and alkali spreading value (0.344**) at genotypic level. These results are in consonance with findings of Nagajyothi (2001).

4.1.2.4.14 Milling Recovery (%)

The character, milling percentage recorded significant positive correlation with head rice recovery (0.698**, 0.789**), kernel linear elongation ratio (0.259*, 0.278*), and grain yield per plant (0.302*, 0.349**). It also exhibited significant negative association with kernel length (-0.299*, -0.332*), kernel breadth (-0.309*, -0.360**), water uptake (-0.315*, -0.335**) at both phenotypic and genotypic levels and showed negative significant association with kernel breadth after cooking (-0.286*) at genotypic level. Similar kind of relation was reported by Nagaraju *et al.* (2013), Ruth Elizabeth Ekka *et al.* (2011) and Prem Kumar *et al.* (2010).

4.1.2.4.15 Head Rice Recovery (%)

Head rice recovery found to have significant positive correlation with L/B ratio (0.297*, 0.374**), kernel length after cooking (0.344**, 0.539**), kernel linear elongation ratio (0.262*, 0.342**), gel consistency (0.417**, 0.474**) and grain yield per plant (0.519**, 0.567**) and significant negative association with water uptake (-0.261*, -0.278*) at both phenotypic and genotypic levels. It also recorded volume expansion ratio (0.342**) and significant negative association with kernel breadth (-0.254*) and kernel breadth after cooking (-0.322*) at genotypic levels. The above results were in agreement with Krishna Veni *et al.* (2013) and Prem Kumar *et al.* (2010).

4.1.2.4.16 Kernel Length (mm)

At both genotypic and phenotypic levels, kernel length exhibited significant positive association with kernel breadth (0.452**, 0.615**), kernel length after cooking (0.539**, 0.626**), kernel breadth after cooking (0.322*, 0.375**), alkali spreading value (0.383**, 0.454**) and grain yield per plant (0.396**, 0.488**).

It showed positive significant correlation with L/B ratio (0.338**), water uptake (0.375**). Whereas kernel length exhibited significant negative association with kernel linear elongation ratio (-0.277*) at phenotypic level. These results were in agreement with the findings Nabedita Mohanty *et al.* (2015), Sathisha *et al.* (2015), Nitiprasad and Lotan Kumar (2014) and Norain *et al.* (2014).

4.1.2.4.17 Kernel Breadth (mm)

This character, had significant positive correlation with kernel breadth after cooking (0.595**, 0.642**), alkali spreading value (0.279*, 0.306*). Whereas, significant negative association with L/B ratio (-0.685**, -0.724**), kernel linear elongation ratio (-0.479**, -0.621**) at both phenotypic and genotypic levels. It showed negative association with volume expansion ratio (-0.260*) at genotypic level. The above results were in agreement with Nabedita Mohanty *et al.* (2015), Dhurai *et al.* (2014) and Norain *et al.* (2014).

4.1.2.4.18 Kernel Length/Breadth Ratio

Kernel L/B ratio showed significant positive association with kernel length after cooking (0.505**, 0.643**), kernel linear elongation ratio (0.281*, 0.744**), gel

consistency (0.290*, 0.374**) and significant negative association with kernel breadth after cooking (-0.361**, -0.475**) at both phenotypic and genotypic levels, respectively. Similar results were confined by Sathisha *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014) and Venkata Lakshmi *et al.* (2014).

4.1.2.4.19 Kernel Length after Cooking (mm)

Kernel length after cooking found to have significant positive correlation with kernel linear elongation ratio (0.659**, 0.741**), water uptake (0.305*, 0.308*) and grain yield per plant (0.590**, 0.607**) at both phenotypic and genotypic levels. Similar kind of relation was reported by Dhurai *et al.* (2014) and Prem Kumar *et al.* (2010).

4.1.2.4.20 Kernel Breadth after Cooking (mm)

This character possessed significant negative association with significant negative association with kernel linear elongation ratio (-0.322*) at phenotypic and volume expansion ratio (-0.281*) at genotypic levels, respectively. These results are in consonance with findings of Arulmozhi and Muthuswamy (2013).

4.1.2.4.21 Kernel Elongation Ratio

The trait, kernel elongation ratio recorded significant positive association with grain yield per plant (0.300*, 0.336**) both at phenotypic and genotypic level. These results are in accordance with Dhurai *et al.* (2014) and Chaudhary and Motiramani (2003).

4.1.2.4.22 Volume Expansion Ratio

Volume expansion exhibited significant positive association with gel consistency (0.258*) at genotypic level. Manonmani *et al.* (2010) and Satyavathi *et al.* (2001), also reported similar association.

4.1.2.4.23 Water Uptake (ml)

Water uptake showed significant positive association with alkali spreading value (0.583**, 0.597**) at both phenotypic and genotypic levels and positive significant association with amylose content (0.294**) at genotypic level. Similar kind of association was earlier reported by Krishna Veni *et al.* (2013) and Malini *et al.* (2011).

4.1.2.4.24 Gel Consistency (mm)

At both phenotypic and genotypic levels, gel consistency recorded significant positive association with grain yield per plant (0.297*, 0.305*). Contrary, positive low association was reported by Malini *et al.* (2011) and Nagajyothi (2001), this might be due to differences in breeding material studied under different environments.

4.1.2.4.25 Alkali Spreading Value (mm)

This character possessed significant positive association grain yield per plant (0.257*, 0.260*) at both phenotypic and genotypic levels, respectively. Similar association was reported by Tushara *et al.* (2013).

4.1.2.4.26 Amylose Content (%)

Amylose content showed non-significant negative association with grain yield per plant (-0.079, -0.113) at both phenotypic and genotypic levels, respectively. These findings are corroborated by Patel *et al.* (2014), Krishna Veni *et al.* (2013), Pankaj Garg *et al.* (2010) and Sivaparvathi (2010).

Thus in the present study, the genotypic correlations were, in general are higher than phenotypic correlations indicating that the apparent associations are largely due to genetic reasons. The traits, days to 50% flowering, days to maturity, plant height, total number of tillers per plant, total number of tillers as percentage of main crop total number of tillers, number of vegetative buds after harvest of main crop, number of ear bearing tillers, number of ear bearing tillers as percentage of main crop ear bearing tillers, panicle length per plant, number of grains per panicle, test weight, milling percentage, head rice recovery, kernel length, kernel length after cooking, kernel linear elongation ratio, gel consistency and alkali spreading value were found to possess significant association in desirable direction with grain yield per plant. Therefore, these characters can also be considered during selection process to bring about improvement for higher grain yield coupled with good quality traits and good ratoonability.

4.1.2.5 PATH COEFFICIENT ANALYSIS

Yield being a complex character, is composed of several components some of which affect yield directly while others contribute towards it indirectly. Correlation studies provide an opportunity to study the magnitude and direction of association of yield with its components and also among various components. To accumulate optimum

combination of yield contributing characters in a single genotype, it is essential to know the amplification of interrelationship of various characters with standard partial correlation or regression.

Hence, in the present study, path analysis was used to work out the direct and indirect effects of yield contributing characters and quality traits on grain yield of ratoon rice crop of 20 varieties, results are presented (Table 4.12) character wise hereunder. The path diagrams were given in Figures 4.2.

4.1.2.5.1 Days to 50% Flowering

At genotypic level days to 50% flowering exhibited significant positive correlation (0.547**) and positive direct effect (0.298) on grain yield per plant. It also exhibited positive indirect effect *via* days to maturity (0.801), number of vegetative buds after harvest of main crop (0.139), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.600), test weight (0.129), kernel breadth (5.322), kernel length after cooking (2.042), kernel breadth after cooking (0.000), volume expansion ratio (0.039), gel consistency (0.124) and amylose content (0.042). It also exerts negative indirect effect *via* plant height (-0.150), total number of tillers per plant (-0.143), number of ratoon tillers as percentage of main crop tillers per plant (-0.010), total number of ear bearing tillers per plant (-0.535), panicle length (-0.131), number of grains per panicle (-0.215), leaf area index (-0.033), hulling recovery (-0.047), milling recovery (-0.027), head rice recovery (-0.004), kernel length (-0.935), L/B ratio (-4.245), kernel linear elongation ratio (-2.434), alkali spreading value (-0.034) and water uptake (-0.048). The above results were in agreement with Islam *et al.* (2015), Keya *et al.* (2015), Shajedur *et al.* (2015), Alam *et al.* (2014), Khare *et al.* (2014) and Krishna Veni *et al.* (2013).

4.1.2.5.2 Days to Maturity

This trait had significant positive genotypic correlation (0.500**) and positive direct effect (0.802) on grain yield per plant at genotypic level. It also expressed positive indirect effects *via* days to 50% flowering (0.298), number of vegetative buds after harvest of main crop (0.151), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.611), test weight (0.176), kernel breadth (6.408), kernel length after cooking (1.823), kernel breadth after cooking (0.022), volume expansion ratio (0.019), gel consistency (0.177) and amylose content (0.064). It also showed negative indirect effects *via* plant height (-0.155), total number of tillers per plant

(-0.157), number of ratoon tillers as percentage of main crop tillers per plant (-0.011), total number of ear bearing tillers per plant (-0.528), panicle length (-0.143), number of grains per panicle (-0.226), leaf area index (-0.043), hulling recovery (-0.035), milling recovery (-0.032), head rice recovery (-0.004), kernel length (-1.293), L/B ratio (-4.782), kernel linear elongation ratio (-2.489), water uptake (-0.110), alkali spreading value (-0.046). These results were in broad agreement with the findings of Golam *et al.* (2015), Islam *et al.* (2015), Singh *et al.* (2015), Bornare *et al.* (2014), Dilruba *et al.* (2014), Bineeta *et al.* (2012) and Khatu *et al.* (2010).

4.1.2.5.3 Plant Height (cm)

This character expressed negative direct effect (-0.314) and positive significant association (0.326*) on grain yield per plant. This trait also expressed positive indirect effects *via* days to 50% flowering (0.143), days to maturity (0.395), number of vegetative buds after harvest of main crop (0.163), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.471), test weight (0.008), hulling recovery (0.000), kernel length (0.947), kernel breadth (1.950), kernel length after cooking (1.869), volume expansion ratio (0.090), water uptake (0.284) and gel consistency (0.304); while it had indirect effects in negative direction *via* total number of tillers per plant (-0.164), number of ratoon tillers as percentage of main crop tillers per plant (-0.014), total number of ear bearing tillers per plant (-0.314), panicle length (-0.208), number of grains per panicle (-0.071), leaf area index (-0.030), milling recovery (-0.015), head rice recovery (-0.004), L/B ratio (-3.702), kernel breadth after cooking (-0.001), kernel linear elongation ratio (-1.036), alkali spreading value (-0.175) and amylose content (-0.250). These findings were in line with the results obtained by Golam *et al.* (2015), Islam *et al.* (2015), Keya *et al.* (2015), Dilruba *et al.* (2014), Mamunur *et al.* (2014), Ali *et al.* (2013), Mulugeta *et al.* (2012) and Ravindra Babu *et al.* (2012).

4.1.2.5.4 Total Number of Tillers per Plant

The trait, total number of tillers per plant had negative direct effect (-0.344) and significant positive association (0.633**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.124), days to maturity (0.365), number of vegetative buds after harvest of main crop (0.370), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.873), test weight (0.029), kernel length (1.618), kernel breadth (1.989), kernel length after

cooking (4.330), kernel breadth after cooking (0.051), volume expansion ratio (0.023), water uptake (0.133) and gel consistency (0.259). It also exerts negative indirect effects through number of ratoon tillers as percentage of main crop tillers per plant (-0.058), total number of ear bearing tillers per plant (-0.624), plant height (-0.150), panicle length (-0.097), number of grains per panicle (-0.155), leaf area index (-0.007), hulling recovery (-0.013), milling recovery (-0.022), head rice recovery (-0.006), L/B ratio (-4.894), kernel linear elongation ratio (-2.798), alkali spreading value (-0.159) and amylose content (-0.206). These findings are corroborated by Golam *et al.* (2015), Mohammad and Kayvan (2014), Patel *et al.* (2014), Satish Kumar *et al.* (2014), Ali *et al.* (2013) and Bhabendra *et al.* (2012).

4.1.2.5.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers per Plant

This character expressed significant positive association (0.709**) and negative direct effect (-0.067) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.045), days to maturity (0.136), total number of tillers per plant (0.297), number of vegetative buds after harvest of main crop (0.319), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (1.002), leaf area index (0.019), hulling recovery (0.027), kernel length (2.069), kernel length after cooking (3.660), water uptake (0.121) and gel consistency (0.200). This trait also had negative indirect effects through plant height (-0.068), total number of ear bearing tillers per plant (-0.681), panicle length (-0.072), number of grains per panicle (-0.096), test weight (-0.031),), milling recovery (-0.030), head rice recovery (-0.007), kernel breadth (-0.937), L/B ratio (-2.341), kernel breadth after cooking (-0.014), kernel linear elongation ratio (-1.829), volume expansion ratio (-0.002), alkali spreading value (-0.173) and amylose content (-0.243).

4.1.2.5.6 Number of Vegetative Buds after the Harvest of Main Crop

This trait, had significant positive association (0.631**) and positive direct effect (0.371) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.112), days to maturity (0.327), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.879), hulling recovery (0.010), kernel length (2.171), kernel breadth (1.384), kernel length after cooking (4.711), kernel breadth after cooking (0.092), volume expansion ratio (0.024), water uptake (0.156) and gel consistency (0.262). It also had negative indirect effects through plant height (-0.138), total number of tillers per plant (-0.344), number of

ratoon tillers as percentage of main crop tillers per plant (-0.057), total number of ear bearing tillers per plant (-0.669), panicle length (-0.059), number of grains per panicle (-0.103), test weight (-0.015), leaf area index (-0.013), milling recovery (-0.020), head rice recovery (-0.006), L/B ratio (-5.112), kernel linear elongation ratio (-2.794), alkali spreading value (-0.302) and amylose content (-0.237).

4.1.2.5.7 Total Number of Ear Bearing Tillers per Plant

The trait, total number of ear bearing tillers per plant had negative direct effect (-0.893) and significant positive association (0.948**) on grain yield per plant at phenotypic level. It also had positive indirect effects through days to 50% flowering (0.179), number of vegetative buds after harvest of main crop (0.278), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.968), leaf area index (0.014), hulling recovery (0.023), kernel length (2.062), kernel length after cooking (3.597), volume expansion ratio (0.025), water uptake (0.050), gel consistency (0.275) and amylose content (0.112). Whereas this traits showed negative indirect effects through days to maturity (0.474), plant height (-0.110), total number of tillers per plant (-0.240), number of ratoon tillers as percentage of main crop tillers per plant (-0.051), panicle length (-0.119), number of grains per panicle (-0.118), test weight (-0.065), milling recovery (-0.026), head rice recovery (-0.006), kernel breadth (-0.615), L/B ratio (-2.784), kernel breadth after cooking (-0.078), kernel linear elongation ratio (-1.790) and alkali spreading value (-0.214). These findings are in conformity with the results of Keya *et al.* (2015), Golam *et al.* (2015), Pradhan *et al.* (2015), Shajedur *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Krishnamurthy *et al.* (2013), Sravan *et al.* (2012) and Rani and Reddy (2010).

4.1.2.5.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

The character expressed significant positive association (0.937**) and had positive direct effect (1.055) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.169), days to maturity (0.464), number of vegetative buds after harvest of main crop (0.309), leaf area index (0.023), hulling recovery (0.009), kernel length (1.497), kernel length after cooking (3.489), volume expansion ratio (0.048), water uptake (0.126) and gel consistency (0.249). It also exhibited negative indirect effects through plant height (-0.140), total number of tillers per plant (-0.285), number of ratoon tillers as percentage of main crop

tillers per plant (-0.063), total number of ear bearing tillers per plant (-0.819), panicle length (-0.157), number of grains per panicle (-0.141), test weight (-0.046), milling recovery (-0.027), head rice recovery (-0.006), kernel breadth (-0.831), L/B ratio (-1.572), kernel breadth after cooking (-0.066), kernel linear elongation ratio (-2.061), alkali spreading value (-0.169) and amylose content (-0.122).

4.1.2.5.9 Panicle Length

Panicle length per plant possessed significant positive association (0.292*) and negative direct effect (-0.316) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to 50% flowering (0.123), days to maturity (0.362), number of vegetative buds after harvest of main crop (0.069) number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.523), test weight (0.089), leaf area index (0.006), kernel breadth (2.321), kernel linear elongation ratio (0.198), volume expansion ratio (0.102), gel consistency (0.433) and alkali spreading value (0.127); while it had indirect effects in negative direction *via* plant height (-0.207), total number of tillers per plant (-0.105), number of ratoon tillers as percentage of main crop tillers per plant (-0.015), total number of ear bearing tillers per plant (-0.337), number of grains per panicle (-0.031), hulling recovery (-0.064), milling recovery (-0.016), head rice recovery (-0.003), kernel length (-0.785), L/B ratio (-1.115), kernel length after cooking (-0.727), kernel breadth after cooking (-0.069), water uptake (-0.108) and amylose content (-0.164). These results were in broad agreement with the findings of Golam *et al.* (2015), Pradhan *et al.* (2015), Shajedur *et al.* (2015), Alam *et al.* (2014), Dilruba *et al.* (2014), Khare *et al.* (2014), Dhurai *et al.* (2014), Rahman *et al.* (2014) and Thirumala Rao (2014).

4.1.2.5.10 Number of Grains per Panicle

At genotypic level, the trait number of grains per panicle had negative direct effect (-0.347) and significant positive association (0.284*) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.185), days to maturity (0.522), number of vegetative buds after harvest of main crop (0.110), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.430), test weight (0.202), kernel breadth (8.978), kernel length after cooking (1.892), kernel breadth after cooking (0.206), water uptake (0.038), gel consistency (0.036), alkali spreading value (0.089) and amylose content (0.042). This trait also exhibited negative indirect effect through plant height (-0.065), total number of tillers per plant (-0.154),

number of ratoon tillers as percentage of main crop tillers per plant (-0.019), total number of ear bearing tillers per plant (-0.304), panicle length (-0.028), leaf area index (-0.021), hulling recovery (-0.097), milling recovery (-0.038), head rice recovery (-0.004), kernel length (-2.151), L/B ratio (-6.063), kernel linear elongation ratio (-3.158) and volume expansion ratio (-0.001). These results are in consonance with findings of Pradhan *et al.* (2015), Islam *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013), Zulqarnain *et al.* (2012) and Rani and Reddy (2010).

4.1.2.5.11 Test Weight (g)

At genotypic level the trait, test weight had negative direct effect (-0.367) and significant positive association (0.301*) on grain yield per plant. This trait exhibited positive indirect effect *via* plant height (0.007), total number of tillers per plant (0.028), number of vegetative buds after harvest of main crop (0.015), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.131), panicle length (0.077), number of grains per panicle (0.191), leaf area index (0.028), hulling recovery (0.087), milling recovery (0.033), head rice recovery (0.002), kernel length (5.007), L/B ratio (1.166), kernel length after cooking (2.028), kernel linear elongation ratio (1.519), water uptake (0.317) and amylose content (0.133). Whereas this trait exhibited negative indirect effect *via* days to 50% flowering (-0.105), days to maturity (-0.385), number of ratoon tillers as percentage of main crop tillers per plant (-0.006), total number of ear bearing tillers per plant (-0.159), kernel breadth (-8.914), kernel breadth after cooking (-0.180), volume expansion ratio (-0.013), gel consistency (-0.076) and alkali spreading value (-0.262). These findings are corroborated by Pradhan *et al.* (2015), Alam *et al.* (2014), Dilruba *et al.* (2014), Mamunur *et al.* (2014), Nitiprasad and Lotan (2014), Thirumala Rao (2014), Seyoum *et al.* (2012) and Khatu *et al.* (2010)

4.1.2.5.12 Leaf Area Index at Maximum Tillering Stage

Leaf area index at maximum tillering stage at genotypic level had negative direct effect (-0.113) and non-significant negative association (-0.038) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.086), days to maturity (0.307), number of ratoon tillers as percentage of main crop tillers per plant (0.011), number of vegetative buds after harvest of main crop (0.042), total number of ear bearing tillers per plant (0.113), panicle length (0.018), test weight (0.092), hulling recovery (0.126), kernel breadth (0.459), L/B ratio (0.829), kernel linear elongation

ratio (0.192), volume expansion ratio (0.017), water uptake (0.022) and amylose content (0.158). It also showed negative indirect effects mainly through plant height (-0.082), total number of tillers per plant (-0.023), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.217), number of grains per panicle (-0.063), milling recovery (-0.019), head rice recovery (-0.001), kernel length (-0.730), kernel length after cooking (-0.799), kernel breadth after cooking (-0.011), gel consistency (-0.206) and alkali spreading value (-0.246). These results are in accordance with Zulqarnain *et al.* (2012) and Ullah *et al.* (2011).

4.1.2.5.13 Hulling Recovery (%)

This trait had non-significant negative genotypic correlation (-0.130) and showed positive effects (0.284) direct with grain yield per plant. This trait exhibited positive indirect effects through plant height (0.000), total number of tillers per plant (0.016), number of vegetative buds after harvest of main crop (0.013), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.033), panicle length (0.072), number of grains per panicle (0.118), milling recovery (0.009), head rice recovery (0.000), kernel length (0.381), L/B ratio (1.273), kernel linear elongation ratio (0.369), volume expansion ratio (0.104) and amylose content (0.118). It also showed negative indirect effects through days to 50% flowering (-0.049), days to maturity (-0.100), number of ratoon tillers as percentage of main crop tillers per plant (-0.006), total number of ear bearing tillers per plant (-0.072), test weight (-0.112), leaf area index (-0.050), kernel breadth (-1.642), kernel length after cooking (-0.176), kernel breadth after cooking (-0.059), water uptake (-0.148), gel consistency (-0.159) and alkali spreading value (-0.346). The above results were in agreement with Mahalingam *et al.* (2013), Nandan *et al.* (2010), Praveen *et al.* (2010) and Prem Kumar *et al.* (2010).

4.1.2.5.14 Milling Recovery (%)

The trait, milling recovery had negative direct effect (-0.068) and significant positive association (0.349**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.119), days to maturity (0.374), number of vegetative buds after harvest of main crop (0.109), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.416), test weight (0.176), kernel breadth (4.341), kernel length after cooking (0.039), kernel breadth after cooking (0.116), volume expansion ratio (0.000), gel consistency (0.127), alkali spreading value (0.081) and amylose content (0.132). It also had negative indirect

effects through plant height (-0.071), total number of tillers per plant (-0.111), number of ratoon tillers as percentage of main crop tillers per plant (-0.029), total number of ear bearing tillers per plant (-0.336), panicle length (-0.072), number of grains per panicle (-0.193), leaf area index (-0.032), hulling recovery (-0.039), head rice recovery (-0.007), kernel length (-1.773), L/B ratio (-1.495), kernel linear elongation ratio (-1.167) and water uptake (-0.289). These findings are corroborated by Madhusoodanan (2013), Nagaraju *et al.* (2013) and Nagajyothi (2001).

4.1.2.5.15 Head Rice Recovery (%)

Head rice recovery had negative direct effect (-0.009) and significant positive association (0.567**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.124), days to maturity (0.365), number of vegetative buds after harvest of main crop (0.243), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.698), test weight (0.068), hulling recovery (0.013), kernel length (0.469), kernel breadth (3.066), kernel length after cooking (2.030), kernel breadth after cooking (0.033), volume expansion ratio (0.043), gel consistency (0.295), alkali spreading value (0.022) and amylose content (0.034). Whereas negative indirect effects through plant height (-0.125), total number of tillers per plant (-0.231), number of ratoon tillers as percentage of main crop tillers per plant (-0.052), total number of ear bearing tillers per plant (-0.610), panicle length (-0.116), number of grains per panicle (-0.141), leaf area index (-0.015), milling recovery (-0.054), kernel linear elongation ratio (-1.436), L/B ratio (-3.907) and water uptake (-0.240). These results are in consonance with findings of Krishna Veni *et al.* (2013), Ruth *et al.* (2011) and Praveen *et al.* (2010).

4.1.2.5.16 Kernel Length (mm)

At genotypic level, kernel length exhibited significant positive correlation (0.488**) and positive direct effect (5.349) on grain yield per plant. It also showed positive indirect effects *via* number of vegetative buds after harvest of main crop (0.150), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.295), panicle length (0.046), number of grains per panicle (0.140), leaf area index (0.015), hulling recovery (0.020), milling recovery (0.023), kernel length after cooking (3.695), kernel linear elongation ratio (0.250), water uptake (0.393), gel consistency (0.049) and amylose content (0.100). It exerts negative indirect effects through days to 50% flowering (-0.052), days to maturity (-0.194), plant height (-

0.056), total number of tillers per plant (-0.104), number of ratoon tillers as percentage of main crop tillers per plant (-0.026), total number of ear bearing tillers per plant (-0.344), test weight (-0.344), head rice recovery (-0.001), kernel breadth (-7.418), L/B ratio (-1.022), kernel breadth after cooking (-0.151), volume expansion ratio (-0.020) and alkali spreading value (-0.308). Similar results were earlier reported by Islam *et al.* (2015), Mohammad and Kayvan (2014), Patel *et al.* (2014), Awaneet and Senapati (2013) and Nayak *et al.* (2001).

4.1.2.5.17 Kernel Breadth (mm)

Kernel breadth had non-significant positive association (0.170) and negative direct effect (-12.059) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* plant height (0.051), total number of tillers per plant (0.057), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.073), panicle length (0.061), number of grains per panicle (0.258), leaf area index (0.004), hulling recovery (0.039), milling recovery (0.024), head rice recovery (0.002), kernel length (3.290), L/B ratio (7.566), kernel linear elongation ratio (2.608) and water uptake (0.164), amylose content (0.014). It also showed negative indirect effects *via* days to 50% flowering (-0.132), days to maturity (-0.426), number of ratoon tillers as percentage of main crop tillers per plant (-0.005), number of vegetative buds after harvest of main crop (-0.043), total number of ear bearing tillers per plant (-0.046), test weight (-0.271), kernel length after cooking (-0.408), kernel breadth after cooking (-0.259), volume expansion ratio (-0.033), gel consistency (-0.153) and alkali spreading value (-0.207). The above results were in agreement with Islam *et al.* (2015), Nitiprasad and Lotan (2014), Patel *et al.* (2014), Awaneet and Senapati (2013) and Ruth *et al.* (2011).

4.1.2.5.18 Kernel Length/Breadth Ratio

At genotypic level, L/B ratio had negative direct effect (-10.445) and non-significant positive association (0.206) on grain yield per plant. This trait exhibited positive indirect effect days to 50% flowering (0.121), days to maturity (0.367), number of vegetative buds after harvest of main crop (0.181), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.159), test weight (0.041), leaf area index (0.009), kernel length (0.524), kernel breadth (8.735), kernel length after cooking (3.797), kernel breadth after cooking (0.192), volume expansion ratio (0.023), water uptake (0.138), gel consistency (0.233) and amylose content (0.065). This trait

exhibited negative indirect effect plant height (-0.111), total number of tillers per plant (-0.161), number of ratoon tillers as percentage of main crop tillers per plant (-0.015), total number of ear bearing tillers per plant (-0.238), , panicle length (-0.034), number of grains per panicle (-0.202), hulling recovery (-0.035), milling recovery (-0.010), head rice recovery (-0.004), kernel linear elongation ratio (-3.124) and alkali spreading value (-0.004). These findings are corroborated by Shathisha *et al.* (2015), Dhurai *et al.* (2014), Awaneet and Senapati (2013) and Khatu *et al.* (2010).

4.1.2.5.19 Kernel Length after Cooking (mm)

Kernel length after cooking had positive direct effect (5.906) and significant positive association (0.607**) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.103), days to maturity (0.248), number of vegetative buds after harvest of main crop (0.296), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.623), panicle length (0.039), leaf area index (0.015), milling recovery (0.000), kernel length (3.346), kernel breadth (0.834), kernel breadth after cooking (0.006), volume expansion ratio (0.004), water uptake (0.265), gel consistency (0.065) and amylose content (0.035). This trait exhibited negative indirect effect *via* plant height (-0.099), total number of tillers per plant (-0.252), number of ratoon tillers as percentage of main crop tillers per plant (-0.041), total number of ear bearing tillers per plant (-0.544), number of grains per panicle (-0.111), test weight (-0.126), hulling recovery (-0.009), head rice recovery (-0.003), L/B ratio (-6.714), kernel linear elongation ratio (-3.112) and alkali spreading value (-0.167). These findings were in line with the results obtained by Krishna Veni *et al.* (2013), Prem Kumar *et al.* (2010), Nandan *et al.* (2010), Dhurai *et al.* (2014) and Afzal *et al.* (2006).

4.1.2.5.20 Kernel Breadth after Cooking (mm)

This trait had non-significant negative direct effect (-0.404) and non-significant positive association (02.15) on grain yield per plant at genotypic level. This trait exhibited positive indirect effect *via* days to 50% flowering (0.000), total number of tillers per plant (0.043), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.172), number of grains per panicle (0.177), hulling recovery (0.041), milling recovery (0.019), head rice recovery (0.001), kernel length (2.006), L/B ratio (4.960), kernel linear elongation ratio (1.492) and amylose content (0.200); while negative indirect effect *via* days to maturity (-0.044), plant height (-0.001), number of

ratoon tillers as percentage of main crop tillers per plant (-0.002), number of vegetative buds after harvest of main crop (-0.085), total number of ear bearing tillers per plant (-0.172), panicle length (-0.054), test weight (-0.164), leaf area index (-0.003), kernel breadth (-7.747), kernel length after cooking (-0.089), volume expansion ratio (-0.035), water uptake (-0.040), gel consistency (-0.051) and alkali spreading value (-0.004). These results were in broad agreement with the findings of Prem Kumar *et al.* (2010) and Nandan *et al.* (2010).

4.1.2.5.21 Kernel Linear Elongation Ratio

The direct effects of this trait on grain yield was low and negative (-4.199) and it showed significant positive association (0.336**) on grain yield per plant at genotypic level. This trait exhibited positive indirect effect *via* days to 50% flowering (0.173), days to maturity (0.475), number of vegetative buds after harvest of main crop (0.247), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.518), panicle length (0.015), test weight (0.133), leaf area index (0.005), kernel breadth (7.491), kernel length after cooking (4.378), kernel breadth after cooking (0.143), volume expansion ratio (0.019), water uptake (0.005), gel consistency (0.034) and alkali spreading value (0.044); while it exhibited negative indirect effect *via* plant height (-0.078), total number of tillers per plant (-0.229), number of ratoon tillers as percentage of main crop tillers per plant (-0.029), total number of ear bearing tillers per plant (-0.381), number of grains per panicle (-0.261), hulling recovery (-0.025), milling recovery (-0.019), head rice recovery (-0.003), kernel length (-0.319), L/B ratio (-7.770) and amylose content (-0.035). The above results were in agreement with Krishna Veni *et al.* (2013), Prem Kumar *et al.* (2010), Nandan *et al.* (2010) and Parvathi *et al.* (2010).

4.1.2.5.22 Volume Expansion Ratio

This trait exerts positive direct effect (0.126) and non-significant positive association (0.142) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.091), days to maturity (0.117), number of ratoon tillers as percentage of main crop tillers per plant (0.001), number of vegetative buds after harvest of main crop (0.070), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.404), number of grains per panicle (0.004), test weight (0.037), hulling recovery (0.234), milling recovery (0.000), kernel breadth (3.130), kernel length after cooking (0.192), kernel breadth after cooking (0.113), water uptake (0.043) and gel consistency (0.161). Whereas, it showed negative

indirect effects through plant height (-0.224), total number of tillers per plant (-0.063), total number of ear bearing tillers per plant (-0.174), panicle length (-0.256), leaf area index (-0.015), head rice recovery (-0.003), kernel length (-0.827), L/B ratio (-1.929), kernel linear elongation ratio (-0.638), alkali spreading value (-0.007) and amylose content (-0.446). These results are in accordance with Krishna Veni *et al.* (2013) and Praveen *et al.* (2010).

4.1.2.5.23 Water Uptake (ml)

At genotypic level, water uptake exhibited non-significant positive correlation (0.186) and positive direct effect (0.861) on grain yield per plant. It also showed positive indirect effects *via* number of vegetative buds after harvest of main crop (0.067), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.155), panicle length (0.040), milling recovery (0.023), head rice recovery (0.003), kernel length (2.444), kernel length after cooking (1.816), kernel breadth after cooking (0.019) and volume expansion ratio (0.006). It also showed negative indirect effects *via* days to 50% flowering (-0.017), days to maturity (-0.102), plant height (-0.104), total number of tillers per plant (-0.053), number of ratoon tillers as percentage of main crop tillers per plant (-0.009), total number of ear bearing tillers per plant (-0.052), number of grains per panicle (-0.015), test weight (-0.135), leaf area index (-0.003), hulling recovery (-0.049), L/B ratio (-1.677), kernel linear elongation ratio (-0.026), kernel breadth (-2.299), gel consistency (-0.098), alkali spreading value (-0.404) and amylose content (-0.205). These results are in consonance with findings of Krishna Veni *et al.* (2013), Prem Kumar *et al.* (2010) and Parvathi *et al.* (2010).

4.1.2.5.24 Gel Consistency (mm)

This trait, showed significant positive association (0.305*) and negative direct effect (0.623) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to 50% flowering (0.059), days to maturity (0.229), number of vegetative buds after harvest of main crop (0.156), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.422), test weight (0.045), leaf area index (0.037), kernel length (0.424), kernel breadth (2.956), kernel length after cooking (0.620), kernel breadth after cooking (0.033), volume expansion ratio (0.033), alkali spreading value (0.080) and amylose content (-0.098). It also exhibits negative indirect effects *via* plant height (-0.153), total number of tillers per plant (-0.143), number of ratoon tillers as percentage of main crop tillers per plant (-0.021), total number of ear

bearing tillers per plant (-0.394), panicle length (-0.220), number of grains per panicle (-0.020), hulling recovery (-0.072), milling recovery (-0.014), head rice recovery (-0.004), L/B ratio (-3.908), kernel linear elongation ratio (-0.228) and water uptake (-0.135).

4.1.2.5.25 Alkali Spreading Value (mm)

Alkali spreading value recorded negative direct effect (-0.678) and significant positive association (0.260*) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.015), days to maturity (0.055), number of vegetative buds after harvest of main crop (0.165), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.263), panicle length (0.059), number of grains per panicle (0.045), hulling recovery (0.145), milling recovery (0.008), head rice recovery (0.000), kernel length (2.431), kernel length after cooking (1.455), kernel linear elongation ratio (0.273), volume expansion ratio (0.001) and water uptake (0.514); and exhibited negative indirect effect *via* plant height (-0.081), total number of tillers per plant (-0.081), number of ratoon tillers as percentage of main crop tillers per plant (-0.017), total number of ear bearing tillers per plant (-0.281), test weight (-0.142), leaf area index (-0.041), kernel breadth (-3.683), L/B ratio (-0.054), kernel breadth after cooking (-0.002), gel consistency (-0.074) and amylose content (-0.036).

4.1.2.5.26 Amylose Content (%)

At genotypic level, the trait amylose content showed negative direct effect (-0.696) and non-significant negative association (-0.113) on grain yield per plant. This trait exhibited positive indirect effect through number of vegetative buds after harvest of main crop (0.126), total number of ear bearing tillers per plant (0.144), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.185), number of grains per panicle (0.021), test weight (0.070), leaf area index (0.026), milling recovery (0.013), head rice recovery (0.001), kernel breadth (0.248), L/B ratio (0.979), kernel breadth after cooking (0.116), volume expansion ratio (0.081), water uptake (0.253) and gel consistency (0.088); and exhibited negative indirect effect *via* days to 50% flowering (-0.018), days to maturity (-0.074), plant height (-0.113), total number of tillers per plant (-0.102), number of ratoon tillers as percentage of main crop tillers per plant (-0.023), panicle length (-0.075), hulling recovery (-0.048), kernel length (-0.772), kernel length after cooking (-0.297), kernel linear elongation ratio (-0.210) and alkali spreading value (-0.035). Similar results were earlier reported by Patel *et al.* (2014), Krishna Veni *et al.* (2013), Garg *et al.* (2010) and Nagajyothi (2001).

In plant breeding it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield *i.e.*, residual effect measures the role of the possible independent variables which were not included in the study on the dependent variable. In the present study, the residual effect at genotypic level was 0.1420 indicating that the characters included in the present investigation are contributing more than 86.80 per cent of variability pertaining the dependent variable *i.e.*, yield. Less than 14 per cent of contribution is from the few other characters which were not included in the present study.

Path analysis revealed the true relationship of days to 50% flowering, days to maturity, number of vegetative buds after harvest of main crop, number of ear bearing tillers as percentage of main crop ear bearing tillers, hulling percentage, kernel length, kernel length after cooking, volume expansion ratio, water uptake and gel consistency by establishing significant positive association and positive direct effect on grain yield per plant. Closer scrutiny of correlation and path coefficient analysis further revealed that, that simultaneous improvement of grain yield per plant is possible through manifestation of days to 50% flowering, days to maturity, number of vegetative buds after harvest of main crop, number of ear bearing tillers as percentage main crop ear bearing tillers, kernel length, kernel length after cooking and gel consistency.

4.2 IDENTIFICATION OF PARENTS FOR CROSSING BASED ON THE DATA ON YIELD TRAITS, RATOONINGABILITY STUDIES CONDUCTED DURING *KHARIF*, 2014 AND *RABI*, 2014-15 AND EFFECTING CROSSES (*KHARIF*, 2015)

4.2.1 Griffing's (1956) Diallel Model II Method 2 (F_1 s + Parents)

The improvement of any crop mainly depends upon selection of promising parents for hybridization but all the available parents with high per se performance may not be able to transmit their superior traits into their progenies. To start a breeding programme, knowledge on genetic architecture and estimated prepotency of parents in specific cross combinations is necessary. Therefore, a study on combining ability is essential in choosing parents and in identifying the better specific cross combinations. Many biometrical procedures have been developed to obtain information on combining ability. Diallel analysis approach (Griffing, 1956) is the one among them, which is widely used to study combining ability of the parents. It also provides a guideline to

determine the value of source populations and appropriate procedures to use in crop improvement programme. This knowledge infact helps in planning further breeding programme

Hybridization/crossing programme was carried out in *Kharif*, 2015 for the eight selected parents viz., MTU 1001, BPT 3291, MCM 100, MTU 1121, MTU 1140, MTU 1064, MTU 1061 and MTU 7029 based on the performance of high ratooning ability (RA) as suggested by Chauhan *et al.*, (1989) (Appendix C) and ratooning rating (RR) as suggested by Samson (1980) (Appendix B) and also considering the grain yield per plant of ratoon crop (*Rabi*, 2014-15), in Griffing's (1956) diallel analysis of model II, method 2 (F_1 s + parents) and generated twenty eight F_1 s (Table.3.2) to study the combining ability, gene action and heterosis studies in *Rabi*, 2015-16 and its ratoon crop in *summer*, 2016.

4.3 EXPERIMENT II: EVALUATION OF SELECTED PARENTS AND THEIR F_1 s TO STUDY HETEROSIS AND COMBINING ABILITY IN MAIN CROP (*RABI*, 2015-16) AND RATOON CROP (*SUMMER*, 2016)

Diallel mating design involving hybridization among 8 selected lines of showing good performance towards ratoonability/ratooning rate in *rabi*, 2014-2015, by Griffing (1956) diallel model II method 2, generated 28 F_1 s during *kharif*, 2015 and these 28 hybrids and their 8 parents were evaluated at Andhra Pradesh Rice Research Institute (APRRI) and Regional Agricultural Research Station (RARS), Maruteru, West Godavari, Andhra Pradesh during *rabi* 2015-16 for various yield attributing traits and quality characters.

The data collected on 28 F_1 s along with eight lines for 24 yield attributing traits and grain quality characters for F_1 crop was subjected to standard statistical analysis for drawing valid conclusions. The details of results obtained from the above investigation are discussed character-wise and presented here under the following headings.

4.3.1 F_1 Main Crop

4.3.1.1 Analysis of variance

4.3.1.2 Mean, genetic variability, heritability and genetic advance

4.3.1.3 Combining ability

4.3.1.4 Heterosis

4.3.1.5 Character association

4.3.1.6 Path coefficient analysis

4.3.1.1 ANALYSIS OF VARIANCE

The analysis of variance (ANOVA) of 28 F_1 s along with 8 parents for yield components and grain quality characters are presented in Table 4.13. The results revealed existence of significant differences among the rice varieties/ lines studied for all the characters

4.3.1.2 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The presence of adequate genetic variability is regarded as the fundamental pre-requisite to launch any crop improvement programme and the success depends on its magnitude in a given species. Knowledge on nature and magnitude of genetic variability present in a population is of immense value for planning efficient breeding programme to improve the yield potential of genotypes. The present day breeding activities do involve hybridization, mutation and other such techniques to create variability. It must be said that a proper and thorough examination of the naturally occurring variability in the available sources is essential to identify high yielding genotypes cutivars which can be considered for release of commercial cultivars.

The genotypic coefficient of variation measures the magnitude of genetic variability. Since, it reflects the heritable portion of variability. It is considered to be more useful than phenotypic coefficient of variation. Moreover, the difference between phenotypic and genotypic coefficients of variation indicates the operation of environmental factors on the expression of the characters. Information on heritability along with genetic advance will be helpful in prediction of genetic gain possible in improvement of a character by selection.

Heritability and genetic advance are regarded as important selection parameters. Burton (1952) suggested that genetic variation along with heritability estimates would give a better idea about the efficiency of selection. Heritability is a good index of the transmission of hereditary values from parent to their offspring. The estimates of heritability help the plant breeder in selection of the elite genotypes from diverse genetic populations. Thus, heritability values coupled with genetic advance would be more reliable and useful in predicting the genetic gain under selection than heritability estimates alone.

The results obtained on the mean performances of the F_1 s and parents are presented in Table 4.14. The analysis of variance revealed significant differences among the genotypes for all the characters indicating a high degree of variability in the material. The details are presented in Tables 4.15. The PCV values are higher than the GCV values and the difference between them is indicating the little role of environment in the expression of these traits.

4.3.1.2.1 Days to 50% Flowering

The variation for days to 50% flowering ranged from 68.67 days (BPT 3291 $\times$ MCM 100) to 107.00 days (MTU 1061 $\times$ MTU 7029) with a mean of 94.35 days. The PCV (8.96) and GCV (8.73) estimates were low indicating less variation for days to 50% flowering among the genotypes studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. Similar estimates of PCV and GCV were earlier reported by Allam *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Vijay Kumar *et al.* (2015), Arpita *et al.* (2014), Gokulakrishnan *et al.* (2014), Lingaiah *et al.* (2014), Osekita *et al.* (2014) and Sandhya *et al.* (2014).

High heritability (94.80%) coupled with moderate genetic advance as per cent of mean (17.50) was noted for this trait which may be due to the predominance of both additive and non-additive gene actions. These findings are corroborated by Keya *et al.* (2015), Sameera *et al.* (2015), Arpita *et al.* (2014), Gokulakrishnan *et al.* (2014), Sandhya *et al.* (2014), Swati Sharma *et al.* (2014), Aditya Kumar *et al.* (2013), Atif and Khalid (2013) and Toshimenla and Sapu (2013).

4.3.1.2.1 Days to Maturity

There is significant variation for days to maturity varied from 97.67 days (3291 $\times$ 100) to 138.00 days (1064 $\times$ 7029) with a mean of 123.69 days. The estimates of PCV (6.88) and GCV (6.63) were low indicating less variation among the genotypes studied. These results are in consonance with findings of Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Vijay Kumar *et al.* (2015), Alam *et al.* (2014), Osekita *et al.* (2014), Sandhya *et al.* (2014), Swati Sharma *et al.* (2014) and Atif and Khalid (2013).

High heritability (92.80%) together with moderate genetic advance as per cent of mean (13.16) was observed for this trait indicating the operation of both additive and non-additive gene actions. These results are in accordance with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Arpita *et al.* (2014), Singh *et al.* (2014), Ashok Kumar *et al.* (2013), Seyed Mustafa Sadeghi (2011) and Venkata Subbaiah *et al.* (2011).

4.3.1.2.3 Plant Height (cm)

The plant height ranged from 92.90 cm (BPT 3291 $\times$ MTU 7029) to 130.18 cm (MCM 100 $\times$ MTU 7029) with a mean of 114.90 cm. The estimates of PCV (7.56) and GCV (7.35) were low indicated less variation among the genotypes studied (Plate 4.6). These findings were in line with the results obtained by Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013), Mulugeta *et al.* (2012), Akhtar *et al.* (2011) and Venkata Subbaiah *et al.* (2011).

High heritability (94.50%) combined with moderate genetic advance as per cent of mean (14.72) was observed for this trait indicating the predominance of both additive gene action and non-additive gene action. Similar results were earlier reported by Keya *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Sathya and Jebaraj (2013), Ravindra Babu *et al.* (2012) and Akinwale *et al.* (2011).

4. 3.1.2.4 Total Number of Tillers per Plant

The range of variation observed for this trait, varied from 10.33 (MTU 1121) to 17.67 (MTU 1001 $\times$ MTU 1140) with a mean of 14.87. The estimates of PCV (14.29) and GCV (12.73) were moderate indicating moderate variation among the genotypes studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. These results were in broad agreement with the findings of Vijay Kumar *et al.* (2015), Sandhya *et al.* (2014), Gulzar *et al.* (2013), Sathya and Jebaraj (2013) and Yadav *et al.* (2010).

High heritability (79.40%) accompanied with high genetic advance as per cent of mean (23.36) was observed for this trait indicating the predominance of additive gene action and hence simple selection may be rewarding. These findings are in conformity with the results of Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Vijay Kumar *et al.* (2015), Perera *et al.* (2014), Swati Sharma *et al.* (2014) and Gulzar *et al.* (2013).

4.3.1.2.5 Number of Ear Bearing Tillers per Plant

The range of variation noted for this character ranged from 8.67 (MCM 100 × MTU 7029) to 14.00 (BPT 3291) with a mean of 11.85. The estimates of PCV (12.75) and GCV (9.38) were moderate indicating moderate variation among the genotypes studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. The above results were in agreement with Perera *et al.* (2014), Sandhya *et al.* (2014), Toshimenla and Sapu (2013), Saidaiah *et al.* (2010b), Satish Chandra *et al.* (2009), Vange (2009) and Vijayalakshmi *et al.* (2008).

Moderate heritability (54.10%) in conjunction with moderate genetic advance as per cent of mean (14.21) was observed for this trait indicated the predominance of both additive and non-additive gene action. These findings are corroborated by Navin Kumar *et al.* (2015), Gokulakrishnan *et al.* (2014), Pankaj Garg *et al.* (2010), Vange (2009), Bharadwaj *et al.* (2007), Karim *et al.* (2007) and Monalisa Manna *et al.* (2006).

4.3.1.2.6 Panicle Length (cm)

The range for panicle length per plant in the material studied varied from 24.47 (BPT 3291) to 31.20 (MTU 1140 × MTU 1064) with a mean of 28.73. The estimates of PCV (6.66) and GCV (4.99) for this trait were low indicating low variation among the genotypes studied (Plate 4.7). These results are in consonance with findings of Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Alam *et al.* (2014), Bornare *et al.* (2014), Gokulakrishnan *et al.* (2014), Osekita *et al.* (2014), Aditya Kumar *et al.* (2013), Atif and Khalid (2013) and Sathya and Jebaraj (2013).

Moderate heritability (56.10%) together with low genetic advance as per cent of mean (7.69) was recorded for this trait indicating the operation of both additive and non-additive gene actions in the inheritance of this trait and the desired results may not be obtained by simple selection. These results are in accordance with Navin Kumar *et al.* (2015), Perera *et al.* (2014), Rahman *et al.* (2014), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013), Ullah *et al.* (2011) and Bhavana (2003).

4.3.1.2.7 Number of Grains per Panicle

The range of variation for number of grains per panicle varied from 141.23 (BPT 3291) to 270.89 (MTU 1140 $\times$ MTU 1064) with a mean of 213.78. The estimates of PCV (13.74) and GCV (12.69) for this trait were moderate indicating moderate variation among the genotypes studied. These findings were in line with the results obtained by Keya *et al.* (2015), Shajedur Hossain *et al.* (2015), Bornare *et al.* (2014), Mamunur *et al.* (2014) and Nitiprasad and Lotan Kumar (2014).

High heritability (85.20%) coupled with high genetic advance as per cent of mean (24.13) was observed for this trait revealing the preponderance of additive gene action which may be exploited through simple selection procedures. Similar results were earlier reported by Allam *et al.* (2015), Sameera *et al.* (2015), Vijay Kumar *et al.* (2015), Alam *et al.* (2014), Bornare *et al.* (2014), Perera *et al.* (2014), Mamunur *et al.* (2014) and Rahman *et al.* (2014).

4.3.1.2.8 Test Weight (g)

There is significant variation for test weight which ranged from 18.20 (MTU 7029) to 24.33 (MTU 1001 $\times$ MCM 100) with a mean of 21.15. The estimates of PCV (7.44) and GCV (7.72) for this trait were low. These results were in broad agreement with the findings of Navin Kumar *et al.* (2015), Shajedur Hossain *et al.* (2015), Osekita *et al.* (2014), Mulugeta *et al.* (2012), Akhtar *et al.* (2011) and Satish (2000).

High heritability (92.90%) supplemented with moderate genetic advance as per cent of mean (14.77) was observed for this trait revealing the preponderance of additive and non-additive gene action. These findings are in conformity with the results of Navin Kumar *et al.* (2015), Gokulakrishnan *et al.* (2014), Mulugeta *et al.* (2012), Ravindra Babu *et al.* (2012), Seyed Mustafa Sadeghi (2011) and Satish (2000).

4.3.1.2.9 Leaf Area Index at Maximum Tillering Stage

The variation for leaf area index at maximum tillering stage varied from 2.09 (BPT 3291 $\times$ MTU 1121) to 3.72 (MTU 1001 $\times$ MTU 1140) with a mean of 2.70. The estimates of PCV (17.49) and GCV (16.85) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Ullah *et al.* (2011).

High heritability (92.80%) supplemented with high genetic advance as per cent of mean (33.45) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. These results were in broad agreement with the findings of Zulqarnain *et al.* (2012), Surender Raju (2002) & Shivani and Sriramareddy (2000).

4.3.1.2.10 Grain Yield per Plant (g)

The trait, grain yield per plant ranged from 20.21 g (MTU 1001 × MTU 1061) to 38.03 g (BPT-329) with a mean of 28.75 g. The estimates of PCV (19.24) and GCV (18.42) for this trait were moderate, respectively, showing moderate variability. These findings are in conformity with the results of Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Vijay Kumar *et al.* (2015), Lingaiah *et al.* (2014), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013), Ullah *et al.* (2011), Venkata Subbaiah *et al.* (2011), Saidaiah *et al.* (2010b) and Yadav *et al.* (2010).

High heritability (91.70%) together with high genetic advance as per cent of mean (36.33) was observed for this trait revealing the preponderance of additive gene action which may be exploited through simple selection procedures. The above results were in agreement with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Gokulakrishnan *et al.* (2014), Lingaiah *et al.* (2014), Singh *et al.* (2014), Swati Sharma *et al.* (2014) and Thirumala Rao *et al.* (2014).

4.3.1.2.11 Hulling Recovery (%)

The variation for hulling recovery ranged from 77.82% (MTU 1061 × MTU 7029) to 82.24% (BPT 3291 × MTU 1064) with a mean of 79.85%. The estimates of PCV (1.69) and GCV (0.91) were low revealing the influence of environment in inheritance of this trait (Plate 4.8). These findings are corroborated by Venkanna *et al.* (2014), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Umadevi *et al.* (2010b).

Low heritability (28.90%) along with low genetic advance as per cent of mean (1.01) indicated that the character is highly influenced by environmental effects and selection would be ineffective. These results are in consonance with findings of Venkanna *et al.* (2014) and Nagajyothi (2001).

4.3.1.2.12 Milling Recovery (%)

This trait, possessed significant variation which was ranged from 67.20% (MTU 7029) to 77.92% (MTU 1001 × MTU 1140) with a mean of 72.65%. The estimates of PCV (3.47) and GCV (3.05) were low (Plate 4.8). These results are in accordance with Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Satish Chandra *et al.* (2009).

High heritability (77.20%) along with low genetic advance as per cent of mean (5.52) indicated the role of non-additive gene action in governing the inheritance of this character, heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These findings were in line with the results obtained by Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009) and Krishna Naik (2004).

4.3.1.2.13 Head Rice Recovery (%)

The variation for head rice recovery ranged from 62.67% (MTU 7029) to 74.98% (MTU 1001 × MTU 1140) with a mean of 62.09%. The estimates of PCV (4.59) and GCV (4.12) were low (Plate 4.8). Similar results were earlier reported by Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Sivaparvathi *et al.* (2011) and Rajeswari *et al.* (2010).

High heritability (80.70%) together with low genetic advance as per cent of mean (7.63) indicated the role of non-additive gene action in governing the inheritance of this character. Heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These results were in broad agreement with the findings of Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Madhavalatha *et al.* (2005).

4.3.1.2.14 Kernel Length (mm)

The range of variation for this character ranged from 5.31 mm (MTU 7029) to 6.06 mm (BPT 3291 × MTU 1140) with a mean of 5.67 mm. The estimates of PCV (2.99) and GCV (2.61) were low. The revealed that the influence of environment in inheritance of this trait. These findings are in conformity with the results of Tuhina-Khatun *et al.* (2015), Gokulakrishnan *et al.* (2014), Awaneet Kumar and Senapati (2013), Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011).

High heritability (76.20%) coupled with low genetic advance as per cent of mean (4.96) indicated the role of non-additive gene action in governing the inheritance of this character, heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. The above results were in agreement with Seyed Mustafa Sadeghi (2011) and Prasad *et al.* (2009).

4.3.1.2.15 Kernel Breadth (mm)

This range of variation observed for this trait varied from 1.93 mm (MTU 1001 $\times$ MTU 1064) to 2.46 mm (MTU 1001 $\times$ MTU 7029) with a mean of 2.23 mm. The estimates of PCV (4.89) and GCV (4.62) were low. These findings are corroborated by Allam *et al.* (2015), Venkanna *et al.* (2014), Aditya Kumar *et al.* (2013), Awaneet Kumar and Senapati (2013), Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011) and Rita Bisne *et al.* (2009).

High heritability (89.40%) accompanied with low genetic advance as per cent of mean (9.01) indicated the role of non-additive gene action in governing the inheritance of this character, heritability is being due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These results are in consonance with findings of Ravindra Babu *et al.* (2012), Seyed Mustafa Sadeghi (2011), Venkata Subbaiah *et al.* (2011) and Prasad *et al.* (2009).

4.3.1.2.16 Kernel Length (L)/Breadth (B) Ratio

The range of variation for kernel length/breadth ratio noted for this trait varied from 2.37 (MTU 1001 $\times$ MTU 7029) to 2.90 (MTU 1001 $\times$ MTU 1064) with a mean of 2.54. The estimates of PCV (4.62) and GCV (4.30) were low. The magnitude of PCV was higher than GCV revealing the influence of environment on the expression of the character. These results are in accordance with Venkanna *et al.* (2014) and Venkata Subbaiah *et al.* (2011).

High heritability (86.60%) in conjunction with low genetic advance as per cent of mean (8.24) indicated the role of non-additive gene action in governing the inheritance of this character. Heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These findings were in line with the results obtained by Mohan Lal and Chauhan (2011), Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Verma *et al.* (2011).

4.3.1.2.17 Kernel Length after Cooking (mm)

This trait, possessed significant variation which was ranged from 8.73 (MTU 7029) to 10.09 (MTU 1061) with a mean of 9.53. The estimates of PCV (4.00) and GCV (3.60) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait (Plate 4.9). Similar results were earlier reported by Venkata Subbaiah *et al.* (2011).

High heritability (81.10%) together with low genetic advance as per cent of mean (6.68) indicated the role of non-additive gene action in governing the inheritance of this character, heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These results were in broad agreement with the findings of Venkata Subbaiah *et al.* (2011), Sarkar *et al.* (2007) and Krishna Naik (2004).

4.3.1.2.18 Kernel Breadth after Cooking

This range of variation observed for kernel breadth after cooking varied from 2.56 (MTU 1001 $\times$ MTU 1064) to 3.25 (MTU 1001 $\times$ MTU 1140) with a mean of 2.89. The estimates of PCV (8.14) and GCV (7.20) were low (Plate 4.9). The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait, but low PCV and GCV were reported by Venkata Subbaiah *et al.* (2011).

High heritability (78.20%) coupled with moderate genetic advance as per cent of mean (13.12) indicated the role of additive and non-additive gene action in governing the inheritance of this character. Similar results were earlier reported by Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011).

4.3.1.2.19 Kernel Elongation Ratio

This character possessed significant variation which was ranged from 1.55 (MCM 100 $\times$ MTU 7029) to 1.77 (MTU 1001 $\times$ MTU 1121) with a mean of 1.68. The estimates of PCV (3.92) and GCV (3.19) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Allam *et al.* (2015), Venkata Subbaiah *et al.* (2011), Sunayana *et al.* (2010) and Vanaja and Luckins (2006).

High heritability (66.40%) along with low genetic advance as per cent of mean (5.35) indicated the role of non-additive gene action in governing the inheritance of this character. Heritability is being exhibited due to favourable influence of environmental rather than genotypic and selection for such traits may not be rewarding and offers the scope for improvement through simple selection. The above results were in agreement with Sunayana *et al.* (2010) and Madhavalatha *et al.* (2005).

4.3.1.2.20 Volume Expansion Ratio

Volume expansion ratio ranged from 3.79 (BPT 3291 $\times$ MTU 1140) to 5.82 (MTU 1001 $\times$ MTU 7029) with a mean of 4.73. The estimates of PCV (10.63) and GCV (10.12) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are corroborated by Ravindra Babu *et al.* (2012) and Vanaja and Luckins (2006).

High heritability (90.60%) supplemented with moderate genetic advance as per cent of mean (19.83) indicated the role of additive and non-additive gene action in governing the inheritance of this character. Contrary, Ravindra Babu *et al.* (2012) and Umadevi *et al.* (2010b) found high heritability and high genetic advance as per cent of mean; this might be due to differences in breeding material studied under different environments.

4.3.1.2.21 Water Uptake (ml)

The range of variation for this trait, varied from 121.67 (BPT 3291 $\times$ MTU-100) to 256.67 (MTU 1001) with a mean of 183.29. The estimates of PCV (15.54) and GCV (15.08) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These results are in consonance with findings of Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006).

High heritability (94.10%) accompanied with high genetic advance as per cent of mean (30.12) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. These results are in accordance with Sivaparvathi *et al.* (2011), Chakraborty *et al.* (2010), Umadevi *et al.* (2010b), Vanaja and Luckins (2006) and Yadav *et al.* (2002).

4.3.1.2.22 Gel Consistency (mm)

The variation for gel consistency ranged from 41.66 (MTU 1064 × MTU 1061) to 98.27 (MTU 1140 × MTU 1061) with a mean of 67.69. The estimates of PCV (29.28) and GCV (28.98) were high indicated there was greater variation for this trait. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait (Plate 4.10). These findings were in line with the results obtained by Sivaparvathi *et al.* (2011), Umadevi *et al.* (2010b) and Asish Binodh *et al.* (2007)

High heritability (98.00%) in conjunction with high genetic advance as per cent of mean (59.08) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. Similar results were earlier reported by Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Manonmani *et al.* (2010) and Umadevi *et al.* (2010b).

4.3.1.2.23 Alkali Spreading Value (mm)

The range of variation noted for alkali spreading value varied from 2.50 (MCM 100 × MTU 1121) to 6.17 (MTU 1061) with a mean of 4.30. The estimates of PCV (28.08) and GCV (27.77) were high. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These results were in broad agreement with the findings of Allam *et al.* (2015), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Sunayana *et al.* (2010).

High heritability (97.90%) along with high genetic advance as per cent of mean (56.60) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. These findings are in conformity with the results of Allam *et al.* (2015), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011) and Venkata Subbaiah *et al.* (2011).

4.3.1.2.24 Amylose Content (%)

Amylose content possessed significant variation which was ranged from 18.86 (MCM 100 × MTU 1061) to 32.53 (MTU 1121 × MTU 7029) with a mean of 23.70. The estimates of PCV (14.09) and GCV (13.78) were moderate, respectively. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. The above results were in agreement with Sunayana *et al.* (2010), Asish Binodh *et al.* (2007), Vanaja and Luckins (2006) and Patil *et al.* (2003b).

High heritability (95.70%) coupled with high genetic advance as per cent of mean (27.78) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. Similar results were earlier reported by Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010), Sunayana *et al.* (2010), Umadevi *et al.* (2010b) and Asish Binodh *et al.* (2007).

Thus, the present study analysis of variance for combining ability revealed that parents had significant amount of variability for all the characters except total ear bearing tillers per plant and panicle length and hulling recovery, while the F_1 crosses had significant amount of variability for all characters except panicle length included in the present study. The trait leaf area index at maximum tillering stage only showed low amount of variability among the all characters studied for interaction between parents' vs F_1 crosses.

However, the magnitude of difference between PCV and GCV was relatively low for all the traits except for total number of tillers per plant, number of ear bearing tillers panicle length, number of grains per panicle, leaf area index, grain yield per plant, kernel breadth after cooking, gel consistency and amylose content. The magnitude of PCV was higher than GCV for all the characters which revealed the influence of environment on expression of these traits. Wider variability was observed in case of gel consistency and alkali spreading value. The traits, total number of tillers per plant, number of ear bearing tillers per plant, grain yield per plant, leaf area index and grain yield per plant, volume expansion, water uptake and amylose content recorded moderate variability, while the remaining characters exhibited low variability.

The characters viz., total number of tillers per plant, number of grains per panicle, leaf area index at maximum tillering stage, water uptake, gel consistency, alkali spreading value, amylose content and grain yield per plant showed high heritability coupled with high genetic advance, which suggested the role of additive gene action in inheritance of these traits and directional selection could be profitably applied on these traits for improvement.

The estimates of moderate to high heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, number of ear bearing tillers per plant, test weight, kernel breadth after cooking and volume expansion ratio. Improvement in these traits is possible by simultaneous exploitation of both additive and non-additive components by adopting

breeding procedures like recombination breeding with postponement of selection at later generations and also by adopting population improvement programme viz., cyclic hybridization, bi-parental mating and diallel selective mating should be taken up for the development of superior lines with desirable genes.

While moderate to high heritability along with low genetic advance as per cent of mean was observed for panicle length, milling recovery, head rice recovery, kernel length, kernel breadth, L/B ratio, and kernel length after cooking and kernel elongation ratio. Hence improvement of these traits was being difficult through simple selection.

4.3.1.3 COMBINING ABILITY AND GENE ACTION

The concept of combining ability plays a significant role in crop improvement, since it helps the breeder the nature and magnitude of gene action involved in the inheritance of the traits. Combining ability will be useful in selection of desirable parents based on the performance of the hybrids and further it helps in exploitation of heterosis.

The knowledge of combining ability helps in identifying the best combiners, which may be hybridized either to exploit heterosis or to accumulate the genes through selection and to choose the proper selection methods to be followed in breeding programmes.

Exploitation of heterosis is primarily dependent on the screening and selection of available germplasm that could produce better combination of genetically important characters. The entire variability observed in the analysis for each trait was partitioned into its components *i.e.*, general and specific combining ability as defined by Spague and Tatum (1942). General combining ability is used to designate the average performance of a parent in hybrid combinations and the term specific combining ability to define those cases in which certain combinations do relatively better or worse than expected on the basis of average performance of lines involved. Sprague and Tatum (1942) stated that *gca* effects were due to the additive type of gene action whereas, *sca* effects are due to the genes which are non-additive (dominant or epistatic in nature).

The relative importance of general and specific combining ability can be assessed by estimating the components of variance and expressed in the ratio $2\sigma^2_{gca} / 2\sigma^2_{gca} + \sigma^2_{sca}$ (Baker, 1978). The closer the ratio to unity, greater is the

magnitude of additive gene action and *vice versa*. Further, the gene action can be confirmed by the estimates of narrow sense heritability. Higher values of narrow sense heritability indicate the presence of additive gene action.

In the present study, 28 F_1 s and their eight parents (cultivars/entries) were evaluated during *rabi*, 2015-16 to estimate the combining ability for yield and yield components.

Analysis of variance for combining ability for different characters under study is presented in Table 4.16. The results revealed that parents/lines had significant amount of variability for all the characters except plant height, panicle length, hulling recovery, grain yield per plant, while the F_1 crosses had significant amount of variability for all characters included in the present study except, panicle length. Where parents vs. F_1 s showed significant amount of variability for all characters except leaf area index at maximum tillering stage, kernel length and kernel length after cooking. The character-wise estimates of *gca* effects of parents and *sca* effects of crosses are presented in Tables 4.17 and 4.18, respectively and estimates of genetic components of variance are presented in Table 4.19.

4.3.1.3 1 Days to 50% Flowering

Out of eight parents involved, four parents MTU 1001 (-4.583**), BPT 3291 (-4.250**) and MTU 1121 (-3.183**) and MCM-100 (-2.183**) exhibited significant *gca* effects in negative direction suggesting that they were good general combiners with favourable genes for earliness. These lines can be used as parents for evolving early types.

The cross, BPT 3291 $\times$ MCM 100 (-18.252**), with high negative *gca* $\times$ high positive *gca* ($H^- gca \times H^+ gca$) parental combination showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1064 (-10.72**) with high negative *gca* $\times$ high positive *gca* ($H^- gca \times H^+ gca$) parental combination, MTU 1001 $\times$ MTU 1061 (-10.119**) with high negative *gca* $\times$ high positive *gca* ($H^- gca \times H^+ gca$) parental combination and MTU 1001 $\times$ MTU-100 (9.081**) with high negative *gca* $\times$ high negative *gca* ($H^- gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^- gca \times H^+ gca$ and $H^- gca \times H^+ gca$ combinations.

This estimated components of variance due to *gca* (158.533**) was greater in magnitude than *sca* (46.652**). The ratio of general combining ability component of variance to total genetic variance (0.872) was closer to unity. Further, the estimate of narrow sense heritability (40.30) was moderate (Table 4.19). These results confirm the involvement of additive component of gene action in the inheritance of this trait. Similar results were earlier indicated by Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Gopikannan and Ganesh (2013), Damodar *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012) and Amudha *et al.* (2011). As additive gene action was predominant, breeding methods involving pureline selection, mass selection, progeny selection and hybridization & selection with pedigree breeding, etc may helpful to improve this trait.

4.3.1.3.2 Days to Maturity

Among eight parents, four parents such as BPT 3291 (-4.492**), MTU 1001 (-4.092**), MTU 1121 (-3.192**), and MCM 100 (-1.858**) showed significant *gca* effects in negative and desirable direction, suggesting that they were good general combiners with favourable genes for early maturity. These parents can be used as parents for hybridization programme towards plant types for early maturity.

The cross combination, BPT 3291 $\times$ MCM 100 (-18.344**) ($H^- gca \times H^- gca$), showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1064 (-11.944**) ($H^- gca \times H^+ gca$) and MTU 1001 $\times$ MTU 1061 (-11.044**) ($H^- gca \times H^+ gca$) parental combination in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^- gca$, $H^- gca \times H^+ gca$ and $H^+ gca \times H^+ gca$ combinations.

The *gca* component of variance (143.879**) was significantly greater than the *sca* components of variance (50.295**), indicating the role of additive gene action in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.851) was closer to unity. Further, the estimate of narrow sense heritability (36.10) was moderate, indicates the role of both additive and non-additive gene action. Hence, these results confirm the role of both additive and non-additive gene action, reliance should be placed on recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes. These results were in accordance with the findings of Upadhyay and Jaiswal (2015), Zaazaa and Anis (2014), Koli et al (2013), Sanghera & Hussain (2013) and Gulzar & Wassem (2012).

4.3.1.3.3 Plant Height (cm)

Out of eight parents evaluated, BPT 3291 (-5.074**), MCM 100 (-2.630**), MTU 7029 (-2.596**) and MTU 1001 (-1.168**) exhibited significant negative *gca* effects in desired direction, suggesting that they are good general combiners with favourable genes for dwarfness. These parents can be used for developing short stature plants. Whereas, parents such as MTU 1140 (7.239**), MTU 1061 (2.514**) and MTU 1121 (1.419**) recorded significant positive *gca* effect, where suggesting that these parents are good general combiners and can be used for developing for long stature plants.

The cross combination BPT 3291 × MTU 7029 (-14.330**) with high negative *gca* × non-significant negative *gca* ($H^- gca \times H^- gca$) parental combination showed highest significant *sca* effect followed by MTU 1001 × MTU 7029 (-15.132**) ($H^- gca \times H^- gca$) and BPT 3291 × MTU 1064 (-6.217**) ($H^- gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^- gca$, $H^- gca \times H^- gca$ and $H^- gca \times H^+ gca$ combinations.

The *gca* component of variance (145.117**) was significantly greater than *sca* components of variance (54.567**), indicating the role of additive gene action in the inheritance of this trait. The ratio of *gca* component of variance to total genetic variance (0.842) was closer to unity, the estimate of narrow sense heritability (34.50) was moderate (Table 4.19), indicates the role of both additive and non-additive gene action. For improvement of this trait breeding programmes like recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes. These results are corroborated by Upadhyay and Jaiswal (2015), Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Patil and Mehta (2014), and Koli *et al.* (2013).

4.3.1.3.4 Total Number of Tillers per Plant

Out of eight parents studied, only three parents MTU 1121 (0.517**), MTU 1061 (0.417*) and MTU 1140 (0.383*) showed significant positive *gca* effect in desired direction. Hence, these parents were identified as good combiners for improving this trait through hybridization programme.

The cross combination, MTU 1001 $\times$ MTU 1140 (2.696**) with non-significant negative *gca* $\times$ high positive *gca* ($L^- gca \times H^+ gca$) showed highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1061 (2.196*) with non-significant negative *gca* $\times$ high positive *gca* ($L^- gca \times H^+ gca$) and MCM 100 $\times$ MTU 7029 (2.130**) with high positive *gca* $\times$ high negative *gca* ($H^- gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times H^+ gca$, $L^- gca \times H^+ gca$ and $H^- gca \times L^- gca$ combinations. The cross combination involving both low $\times$ high and high $\times$ low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

This trait had significant *sca* (4.457**) as well as *gca* (1.641**) components of variance, where showing role of non-additive gene action in the inheritance of this trait. Further, it was confirmed by the ratio of *gca* component of variance to total genetic variance (0.424) was away from the unity, and the estimate of narrow sense heritability (5.60) was low (Table 4.19). Hence, these results confirm the possible involvement of non-additive gene actions in the inheritance of this character. These results are in accordance with Gulzar and Wassem (2012), Shyam *et al.* (2012), El-Namaky *et al.* (2010), Muhammad Yussouf *et al.* (2010). As non-additive gene action was a predominant, breeding method involving heterosis breeding and recombination breeding with postponement of selection at later generations may be used for the improvement of this trait.

4.3.1.3.5 Number of Ear Bearing Tillers per Plant

Among the eight parents selected, none of the parents registered significantly positive *gca* effects but MTU 1140 (0.333), MTU 7029 (0.167) and MTU 1121 (0.067) exhibited non-significant positive *gca* effects in desired direction. Hence, parent may be taken for crossing programme for improvement of this trait.

The cross combination, MCM 100 $\times$ MTU 7029 (2.215**) with non-significant positive *gca* $\times$ non-significant negative *gca* ($L^+ gca \times L^- gca$) parental combination showed the highest significant *sca* effects followed by BPT 3291 $\times$ MTU 1121 (1.715**) ($L^- gca \times L^+ gca$) and MTU 1001 $\times$ MTU 1061 (1.681**) with non-significant positive *gca* $\times$ high negative *gca* ($L^+ gca \times L^- gca$) parental combination in the desirable direction indicating that the crosses with high specific combining ability are possible even from $L^+ gca \times L^- gca$, $L^- gca \times L^+ gca$ and $L^+ gca \times L^- gca$ along with other combinations. Thus, in practice, some of the low combiners can also be recommended along with high combiners in hybridization programme.

Predominance of non-additive gene action was established in the inheritance of this trait by possessing significance of *sca* (1.895**) and non-significance of *gca* components of variance (0.340). This was in conformity with the ratio of *gca* component of variance to total genetic variance (0.264) was away from unity and estimate of narrow sense heritability (-0.10) was low. These findings were in conformity with Premkumar *et al.* (2015), Upadhyay and Jaiswal (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Patil and Mehta (2014), Gopikannan and Ganesh (2013), Sanghera and Hussain (2013) and Satheeshkumar and Sravanan (2013). As this trait was governed by non-additive gene action, the breeding methods involving heterosis breeding and recombination breeding with postponement of selection at later may help to improve this trait.

4.3.1.3.6 Panicle Length (cm)

Based on the *gca* effects, MTU 1121 (0.280), MTU 1061 (0.225), MTU 1064 (0.167) and MTU 1140 (0.077) recorded non-significant positive and in desirable direction. Hence, these parents could be useful for improvement of panicle length in hybridization programme.

The cross combination, BPT 3291 $\times$ MTU 1140 (2.435**) with non-significant negative *gca* $\times$ non-significant positive *gca* ($L^- gca \times L^+ gca$) parental combination showed the highest significant *sca* effect followed by MTU 1140 (2.277**) ($L^+ gca \times L^+ gca$) and BPT 3291 $\times$ MCM 100 (1.712*) ($L^- gca \times L^- gca$) in the desirable direction indicating that the crosses with high specific combining ability are possible even from $L^- gca \times L^+ gca$, $L^+ gca \times L^+ gca$ and $L^+ gca \times L^+ gca$ combinations. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, it can be recommended to include, some of the low combiners along with high combiners in hybridization programmes.

The *sca* component of variance (3.113**) was significantly higher than *gca* components of variance (0.486). The ratio of *gca* component of variance to total genetic variance (0.238) was away from unity, the estimate of narrow sense heritability (-0.30) was low (Table 4.19). These results, confirm involvement of non-additive gene action in the inheritance of this character. This trait can be exploited by using the breeding procedures such as heterosis breeding and recombination breeding with postponement of selection at later generations. These results are in consonance with findings of Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Gopikannan and

Ganesh (2013), Sanghera and Hussain (2013), Satheeshkumar and Sravanan (2013), Utharasu and Anandakumar (2013), Gonya Nayak *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012), Sharma *et al.* (2012) and Amudha *et al.* (2011).

4.3.1.3.7 Number of Grains per Panicle (g)

The best general combiners identified for number of grains per panicle on their positive significant *gca* effects were MTU 1140 (19.235**), MTU 1061 (14.663**), MTU 1064 (8.052**) and MTU 1121 (5.920**) in desirable direction. These parents may be utilized in breeding programmes for improvement of this trait.

The cross combination MTU 1061 $\times$ MTU 7029 (48.555**) ($H^- gca \times H^+ gca$) showed highest significant *sca* effect followed by MTU 1140 $\times$ MTU 1064 (29.829**) ($H^+ gca \times H^- gca$), MTU 1001 $\times$ BPT 3291 (22.485**) ($H^- gca \times H^- gca$), in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^+ gca \times H^- gca$ and $H^- gca \times H^- gca$ combinations.

The variance due to *gca* (1869.201**) was lesser than the *sca* variance (505.179**) for this trait, showed the role of additive gene action. The ratio of *gca* component of variance to total genetic variance (0.881) was near to unity and the estimate of narrow sense heritability (42.00) was moderate (Table 4.19), which showed the involvement of both additive and non-additive gene action. These findings were in line with the results obtained by Verica *et al.* (2013), Sharma *et al.* (2012), Tiwari *et al.* (2011), Rahimi *et al.* (2010), Bagheri *et al.* (2008), Edgar and Isaias (2007), Anand Kumar *et al.* (2006), Swamy *et al.* (2003). Thus, these components may be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes.

4.3.1.3.8 Test Weight (g)

The estimate of *gca* effects were significant and positive for parents, MTU 1001 (1.362**) and MTU 1140 (0.755**) for test weight in desirable direction. These may be utilized in hybridization programmes for improving this important grain yield parameter.

The cross combination, BPT 3291 $\times$ MCM 100 (2.321**) ($H^- gca \times L^+ gca$), parental combination showed highest significant *sca* effect followed by MTU 1121 $\times$ MTU 1064 (1.942**) ($L^+ gca \times H^- gca$) and MCM 100 $\times$ MTU 7029 (1.549**) ($L^+ gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times L^+ gca$, $L^- gca \times H^- gca$ and $L^+ gca \times H^+ gca$ combinations. The cross combination involving high $\times$ low and low $\times$ high general combiners producing significant *sca* effects might be due to dominant $\times$ recessive type of interaction with non-additive, non-fixable genetic components.

The estimated components of variance due to *gca* (5.980**) was significantly higher than *sca* (1.678**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.877) was near to unity and the estimate of narrow sense heritability (41.40) was moderate (Table 4.19). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character and can be improved either by recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes. These results are conformity with Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gonya Nayak *et al.* (2012), Shyam *et al.* (2012), Waghmode *et al.* (2011), El-Namaky *et al.* (2010), Zhao (2008), Sawant (2006) and Singh (2005).

4.3.1.3.9 Leaf Area Index at Maximum Tillering Stage

Among parents, MTU 1140 (0.556*) and MTU 1001 (0.052*), showed significant positive general combining ability effects which revealed that they are good general combiners for bringing improvement of leaf area index.

The combination, MTU 1001 $\times$ BPT 3291 (0.814**) ($H^+ gca \times H^- gca$) showed highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1121 (-0.470**) ($H^- gca \times H^- gca$) and MCM 100 $\times$ MTU 1140 (0.448***) ($H^- gca \times H^+ gca$), in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^- gca \times H^- gca$ and $H^- gca \times H^+ gca$ combinations.

This trait had significant *gca* (0.610**) as well as *sca* (0.112**) components. The ratio of *gca* component of variance to total genetic variance (0.916) was near to unity and the estimate of narrow sense heritability (51.80) was moderate (Table 4.19). These results confirm the possible involvement of both both additive and non-additive gene actions are of equal magnitude. Hence, these components may be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes. These results were in broad agreement with the findings of Sanjeev Kumar *et al.* (2009), Vanaja *et al.* (2003) and Sanjeev Kumar *et al.* (2008).

4.3.1.3.10 Grain Yield per Plant (g)

Based on *gca* effects, MTU 1001 (1.871**), MTU 1140 (1.627**) and MTU 1061 (0.986**) were found to be good general combiners. These parents could be useful for improvement of grain yield in hybridization programmes.

The cross combinations MTU 1121 × MTU 1140 (7.501**) ($L^+ gca \times H^+ gca$), showed highest significant *sca* effects followed by MCM 100 × MTU 1064 (6.558**) ($H^- gca \times L^+ gca$) and MTU 1001 × MTU 1061 (6.417**) ($H^+ gca \times H^+ gca$) parental combinations in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are resulted from the parents having both high and low *gca* effects. This indicates that one can include few low combiners along with high combiners in hybridization programme.

The estimated component of variance due to *sca* (22.843**) was greater than *gca* (30.403**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.600) was away from unity and the estimate of narrow sense heritability (12.60) was low (Table 4.19) indicating the operation of non-additive gene actions and could better exploited through heterosis breeding and recombination breeding with postponement of selection at later generations. These findings are in conformity with the results of Premkumar *et al.* (2015), Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014), Damodar *et al.* (2014), Gopikannan and Ganesh (2013), Gnanamalar and Vivekanandan (2013), Veeresha *et al.* (2013b), Veeresha *et al.* (2013b), Damodar *et al.* (2012) and Sanjeev Kumar *et al.* (2008).

4.3.1.3.11 Hulling Recovery (%)

Among the parents, MTU 1061 (-0.424*) recorded significant negative general combining ability effects while lines MTU 1064 (0.389), BPT 3291 (0.285), MTU 1140 (0.274) and MTU 1121 (0.248*) recorded non-significant positive general combining ability effects, whereas MCM 100 (-0.329), MTU 7029 (-0.244) and MTU 1001 (-0.193) possessed negative *gca* effects.

The cross combination, BPT 3291 $\times$ MTU 1064 (1.721**), ($L^+ gca \times L^+ gca$) showed highest significant *sca* effect followed by MTU 1121 $\times$ MTU 7029 (1.706**) ($L^+ gca \times L^- gca$) and MTU 1061 $\times$ MTU 7029 (-1.359**) ($H^- gca \times L^- gca$), parental combinations in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

The estimated components of variance due to *gca* (1.072*) was greater than *sca* (0.933**) components of variance. The ratio of general combining ability component of variance to total genetic variance (0.697) was intermediate. The estimate of narrow sense heritability (12.00) was also low (Table 4.19). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character and can be improved either by population improvement methods or recombination breeding with postponement of selection at later generations. The above results were in agreement with Gnanamalar and Vivekanandam (2013), Adilakshmi and Upendra (2014), Thakare *et al.* (2010) and Sreedhar (1999).

4.3.1.3.12 Milling Recovery (%)

Out of eight parents, MTU 1140 (0.656*) recorded significant positive and desirable general combining ability effects, while lines MCM 100 (-0.987**) and MTU 7029 (-0.939**) possessed *gca* effects in significantly negative direction.

The cross combination, MTU 1001 $\times$ MTU 1140 (4.333**) with non-significant positive *gca* $\times$ high positive *gca* ($L^+ gca \times H^+ gca$) parental combination showed the highest significant *sca* effect followed by BPT 3921 $\times$ MTU 1064 (2.966**) ($L^+ gca \times L^+ gca$) and BPT-3921 $\times$ MTU 1140 (2.962**) ($L^+ gca \times H^+ gca$) in the desirable

direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times H^+ gca$, $L^+ gca \times L^+ gca$ and $L^+ gca \times H^+ gca$ combinations. These results indicate that crosses with high specific combining ability in desirable direction are resulted from the parents having both high and low *gca* effects. This indicates that one can include few low combiners along with high combiners in hybridization programme.

This trait had significant *sca* (5.798**) effect higher than *gca* (3.775**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.566) was intermediate and the estimate of narrow sense heritability (10.20) was low (Table 4.19). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character and can be improved by heterosis breeding and recombination breeding with postponement of selection at later generations. Similar results were earlier reported by Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Waghmode *et al.* (2011), Thakare *et al.* (2010) and Sreedhar (1999).

4.3.1.3.13 Head Rice Recovery

The estimates of *gca* effects, were significant and positive for lines MTU 1140 (2.244**), MTU 1121 (0.943**) and MTU 1001 (0.744**) in desirable direction. These may be utilized in hybridization programmes for improving this important quality trait.

The cross combination MTU 1001 $\times$ MTU 1140 (4.901**) ($H^+ gca \times H^+ gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 7029 (3.3378**) ($H^- gca \times H^- gca$) and MTU 1001 $\times$ MTU 1121 (3.228**) with high *gca* $\times$ high *gca* ($H^+ gca \times H^+ gca$) parental combination in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^+ gca$, $H^- gca \times H^- gca$ and $H^+ gca \times H^+ gca$ combinations. The cross combination involving high $\times$ high general combiners producing significant *sca* effects revealed additive and additive $\times$ additive genetic component of variance are expected to throw some useful transgressive segregates in the breeding programme for pedigree method of selection.

The estimate of *gca* (16.433**) variance was higher than *sca* (6.215**) components of variance and ratio of *gca* component of variance to total genetic variance (0.841) was near to unity and the estimate of narrow sense heritability (33.70) was

moderate (Table 4.19). This indicated the involvements of both the additive and non-additive gene actions. Similar findings were reported by Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Asfaliza *et al.* (2012), Shyam *et al.* (2012) and Waghmode *et al.* (2011). As this trait was governed by both additive and non-additive gene actions are of equal magnitude, recombination breeding with postponement of selection at later generation and population improvement methods *viz.*, bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes.

4.3.1.3.14 Kernel Length (mm)

Among eight parents involved only one parent MTU 1001 (0.076**) recorded significant and positive *gca* effects implying their good general combining ability. This parent may be used in hybrid breeding programmes for improving this trait.

The cross combination BPT 3291 $\times$ MTU 1140 (0.407**) ($L^- gca \times L^- gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1140 (-0.253**) ($L^+ gca \times L^- gca$) and MCM 100 $\times$ 7029 (0.291**) ($L^+ gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times L^- gca$, $L^+ gca \times L^- gca$ and $L^+ gca \times H^- gca$ combinations. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, it can be recommended to include, some of the low combiners along with high combiners in hybridization programmes.

The *sca* component of variance (0.027**) was significantly greater than the *gca* components of variance (0.014**). The ratio of *gca* component of variance to total genetic variance (0.509) was away from unity and the estimate of narrow sense heritability (8.00) was low (Table 4.19). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character. Where, heterosis breeding and recombination breeding with postponement of selection at later generations was effective for improvement of this trait. These findings are corroborated by Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012) and Waghmode *et al.* (2011).

4.3.1.3.15 Kernel Breadth (mm)

The best combiners identified for kernel breadth based on their *gca* effects were MTU 1001 (0.032**) and MTU 7029 (0.027**), in desirable direction for the development of bold grain type, while best general combiners for fine grain type significant negative general combining ability effect were MTU 1064 (-0.036**), MCM 100 (-0.020**) and BPT 3291 (-0.032**).

For fine rice varieties the cross combination, MTU 1001 $\times$ MTU 1064 (-0.299**) with high positive *gca* $\times$ high negative *gca* ($H^+ gca \times H^- gca$) and MCM 100 $\times$ MTU 1140 (-0.097**) ($H^+ gca \times H^- gca$) parental combination showed highest significant *sca* effect. For bold rice varieties the cross combination, MTU 1001 $\times$ MTU 7029 (0.9171**) ($H^+ gca \times H^+ gca$), BPT 3291 $\times$ MTU 1064 (0.159**) ($H^- gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^+ gca \times H^+ gca$ and $H^- gca \times H^- gca$ combinations.

The estimated component of variance *sca* (0.012**) was greater than and *gca* components of variance (0.006**). The ratio of *gca* component of variance to total genetic variance (0.472) was low and the estimate of narrow sense heritability (7.60) was low (Table 4.19). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character and can be improved by heterosis breeding and recombination breeding with postponement of selection at later generations. These results are in accordance with Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012), Waghmode *et al.* (2011) and Thakare *et al.* (2010).

4.3.1.3.16 Kernel Length/Breadth Ratio

The estimate of *gca* effects were significant and positive for lines, MTU 1064 (0.044**), MCM 100 (0.025**) and MTU 1061 (0.024**) These may be utilized in hybridization programmes for improving trait towards the fine type of grain. Whereas parents MTU 7029 (-0.050**), MTU 1121 (-0.032**) and MTU 1140 (-0.021**), with significant *gca* effects in negative direction were used for the hybridization programme for the development of bold type of grain.

The cross combination, MTU 1001 $\times$ MTU 1064 (0.315**) ($L^+ gca \times H^+ gca$) showed highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1064 (-0.162**) ($L^+ gca \times H^+ gca$) and BPT-3921 $\times$ MTU 1140 (0.155**) ($L^+ gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times H^+ gca$, $L^+ gca \times H^- gca$ and $L^- gca \times H^- gca$ combinations. The cross combination involving high $\times$ low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

This trait had high significant *sca* (0.013**) than *gca* (0.010**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.610) was away for unity and the estimate of narrow sense heritability (12.80) was low (Table 4.19). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character and can be improved by heterosis breeding and recombination breeding with postponement of selection at later generations. These results are in consonance with findings of Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014), Malini *et al.* (2014), Patil and Mehta (2014), Damodar *et al.* (2012), Gulzar and Wassem (2012) and Srivastava *et al.* (2012).

4.3.1.3.17 Kernel Length after Cooking (mm)

Out of eight parents, MTU 1001 (0.265**), MTU 1064 (0.173**), and MTU 1061 (0.069*), recorded significant positive general combining ability effects while, lines MTU 7029 (-0.276**) and MTU 1121 (-0.204**) possessed significant *gca* effects in negative direction.

The cross combination, BPT 3291 $\times$ MTU 1061 (-0.525**) ($L^- gca \times H^+ gca$) showed highest significant *sca* effect followed by BPT-391 $\times$ MTU 1121 (0.509**) ($L^- gca \times H^- gca$) and MCM 100 $\times$ MTU 1061 (0.476**) ($L^- gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times H^+ gca$, $L^- gca \times H^- gca$ and $L^- gca \times H^+ gca$ combinations. The cross combination involving high $\times$ low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

This trait had significant *gca* (0.325**) as well as *sca* (0.077**) components of variance indicating the role of preponderance of additive gene action and progeny selection will be effective for the genetic improvement of such traits. The ratio of *gca* component of variance to total genetic variance (0.894) was closer to unity and the estimate of narrow sense heritability (44.90) was moderate (Table 4.19). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character. These findings were in line with the results obtained by Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013) and Sreedhar (1999). For improvement of this trait breeding programmes like population improvement as well as recombination breeding with selection at later generations breeding can be employed for exploitation of both the gene actions.

4.3.1.3.18 Kernel Breadth after Cooking (mm)

The lines, MTU 7029 (0.118**), BPT 3291 (0.084**), MTU 1121 (0.071**), exhibited significant positive general combining ability effects, which indicated that these were good general combiners for improvement of this trait.

The cross combinations MCM 100 × MTU 1140 (90.325**) ($H^+ gca \times L^- gca$) showed highest significant *sca* effects followed by MCM 100 × MTU 1061 (0.286**) ($H^+ gca \times L^- gca$) and BPT 3291 × MTU 1061 (0.282**) ($H^+ gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times L^- gca$, $H^+ gca \times L^- gca$ and $H^+ gca \times L^- gca$ combinations. The cross combination involving high x low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners, may results into transgressive segregants in subsequent generations.

The estimated component of variance due to *sca* (0.012**) was greater than *gca* components of variance (0.006**). The ratio of *gca* component of variance to total genetic variance (0.741) was away from unity and the estimate of narrow sense heritability (21.10) was low (Table 4.19). This indicated the preponderance of non-additive gene actions in the inheritance of this trait. These results were in broad agreement with the findings of Li *et al.* (1999) and Sreedhar (1999). As non-additive gene action was predominant, heterosis breeding and recombination breeding with postponement of selection at later generations was effective.

4.3.1.3.19 Kernel Linear Elongation Ratio

The parents, MTU 1064 (0.032**) and MTU 1001 (0.024**), recorded significant positive general combining ability effects which indicated that these were good general combiners for improvement of this trait. The cross combination, BPT 3291 $\times$ MTU 1140 (-0.115**) ($L^- gca \times L^+ gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1061 (0.084**) ($L^- gca \times L^+ gca$) and MCM 100 $\times$ MTU 7029 (-0.0074**) with non-significant negative *gca* $\times$ high negative *gca* ($L^- gca \times H^- gca$) parental combinations in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times L^+ gca$, $L^- gca \times L^+ gca$ and $L^- gca \times H^- gca$ combinations. The cross combination involving two low general combiners revealed presence of non additive gene action. The superiority of the crosses having low *gca* parents may be due to high nicking ability of those parents. The cross combination involving low $\times$ high general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

The estimate of *gca* (0.062**) was greater than *sca* components of variance (0.043**) and the ratio of general combining ability component of variance to total genetic variance (0.797) was away from unity. The estimate of narrow sense heritability (26.40) was also low (Table 4.19). This indicated the role of both additive and non-additive gene actions in the inheritance of this character. These components may be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes. These findings are in conformity with the results of Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014) and Malini *et al.* (2014) and Gnanamalar and Vivekanandam (2013).

4.3.1.3.20 Volume Expansion Ratio

The parents, MTU 1061 (0.131**), MTU- 1121 (0.107**) and MTU 1064 (0.090**), showed significant positive *gca* effects in desirable direction, where these parents can be used in hybridization programme for improvement of this trait. The cross combination, MTU 1001 $\times$ MTU 1061 (0.913**) with non-significant negative *gca* $\times$ high positive *gca* ($L^+ gca \times H^+ gca$) parental combinations showed highest significant *sca* effect followed by MTU 1001 $\times$ MTU 7029 (1.033**) ($L^+ gca \times L^+ gca$) and MTU

1121 × MTU 7029 (0.720**) ($H^+ gca \times L^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times H^+ gca$, $L^+ gca \times L^+ gca$ and $H^+ gca \times L^+ gca$ combinations. Low × low general combiners resulted in presence of non additive gene action. The cross combination involving high × low general combiners producing significant *sca* effects might be due to dominant x recessive type of interaction with non-additive, non-fixable genetic components.

This trait had high significant *sca* variance (0.253**) than *gca* components of variance (0.173**). The ratio of *gca* component of variance to total genetic variance (0.577) was away from the unity and the estimate of narrow sense heritability (11.50) was low (Table 4.19). Thus, the results showed that the inheritance of the character was governed by non-additive gene action. Hence, heterosis breeding and recombination breeding with postponement of selection at later generation was effective. The above results were in agreement with Adilakshmi and Upendra (2014), Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013) and Gonya Nayak *et al.* (2012).

4.3.1.3.21 Water Uptake (ml)

Out of eight parents, MTU 1001 (16.042**), MTU 1061 (10.542**) and MTU 1064 (5.875**), recorded significant positive general combining ability effects while lines BPT 3291 (-15.958**), MTU 1121 (-14.458**) and MCM 100 (-3.125**), possessed significant *gca* effects in negative direction.

The cross combinations MTU 1001 × BPT 3291 (-31.704**) ($H^+ gca \times H^- gca$) showed highest significant *sca* effects followed by MTU 1001 × MCM 100 (-31.537**) ($H^+ gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$ and $H^+ gca \times H^- gca$ combinations. The cross combination involving high x high general combiners producing significant *sca* effects can utilized for improvement through single plant selection in segregating generations.

This trait was found to have high significance *gca* (1254.187**) than *sca* components of variance (660.756**), indicated additive gene action. Contrary, the ratio of *gca* component of variance to total genetic variance (0.792) was near to unity and the estimate of narrow sense heritability (27.30) was low (Table 4.19), indicated the trait was governed by non-additive gene action. Hence, indicated this trait was governed by

both additive and non-additive gene action, improved can be done either by population improvement methods or recombination breeding with postponement of selection at later generations. Similar results were earlier reported by Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013), Gonya Nayak *et al.* (2012) and Sharma and Mani (1998).

4.3.1.3.22 Gel Consistency (mm)

The estimates of *gca* effects were significant and positive for parents MTU 1140 (6.196**), MTU 1121 (2.637**) and MTU 7029 (1.706**). Whereas, the parents MTU 1064 (-9.676**) and MCM 100 (1.629**), possessed significant *gca* effects in negative direction. The cross combination, MCM 100 × MTU 1061 (26.673**) with high negative *gca* × non-significant positive *gca* ($H^- gca \times L^+ gca$) showed highest significant *sca* effect followed by BPT 3291 × MTU 7029 (29.291**) ($L^- gca \times H^+ gca$) and BPT 3291 × MTU 1061 (-24.841**) ($L^- gca \times L^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times L^+ gca$, $L^- gca \times H^+ gca$ and $L^- gca \times L^+ gca$ combinations. The cross combination involving high × low and low × high general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners. Low × low general combiners revealed that superiority of the crosses having low *gca* parents may be due to high nicking ability/genetic diversity of those parents.

The estimate of *sca* (432.004**) was higher than *gca* (208.891**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.492) was away from unity and the estimate of narrow sense heritability (8.70) was low (Table 4.19). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character. These findings are corroborated by Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013), Sreedhar (1999) and Kaw and Cruz (1990). For improvement of this trait breeding programmes like heterosis breeding and recombination with selection at later generations.

4.3.1.3.23 Alkali Spreading Value (mm)

Among the parents, MTU 1001 (0.693**), MTU 1061 (0.538**) and MTU 1064 (0.499**) recorded significant positive general combining ability effects, while lines MTU 1121 (-0.779**), MTU 1140 (-0.501**), MCM 100 (-0.401**) and BPT 3291 (-0.179**), possessed significant negative *gca* effects.

The cross combination, MTU 1061 $\times$ MTU 1061 (-2.721**) ($H^+ gca \times H^+ gca$), showed highest significant *sca* effect followed by MTU 1140 $\times$ MTU 1064 (-1.739**) ($H^- gca \times H^+ gca$) and BPT 3291 $\times$ MTU 7029 (1.631**) ($H^- gca \times L^+ gca$), parental combinations in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^+ gca$, $H^- gca \times H^+ gca$ and $H^- gca \times L^+ gca$ combinations. Thus, indicating crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

The variance due to *gca* (2.988**) was significant and greater than *sca* (1.047**) components of variance. The ratio of general combining ability component of variance to total genetic variance (0.851) was near to unity. The estimate of narrow sense heritability (36.20) was also low (Table 4.19). These results, showed that role of both additive and non-additive gene actions in the inheritance of this character. These findings were in conformity with Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Gonya Nayak *et al.* (2012), Lakshmi (2009) and Sreedhar (1999).

4.3.1.3.24 Amylose Content (%)

Based on the *gca* effects, MCM 100 (1.184**), BPT 3291 (0.680**) and MTU 7029 (0.402**), found significantly positive, can be used as good general combiners for sticky type after cooking and the parents MTU 1061 (-0.877**), MTU 1121 (-0.736**), MTU 1064 (-0.300*) and MTU 1001 (-0.042*) possessed significant *gca* effects in negatively significant, can be used as good general combiners for non-sticky type after cooking.

The sticky type of rice after cooking the cross combination, BPT 3291 $\times$ MTU 1061 (7.541**) ($H^+ gca \times H^- gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1064 (6.558**) ($H^- gca \times H^+ gca$) and MTU 1001 $\times$ MTU 1061 (6.417**) ($H^+ gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^- gca \times H^+ gca$ and $H^+ gca \times H^- gca$ combinations. For non-sticky type of rice the cross combination, BPT 3291 $\times$ MTU 1064 (-4.239**) ($H^+ gca \times H^- gca$)

MCM 100 $\times$ MTU 1061 (-3.223**) ($H^+ gca \times H^- gca$). The cross combination involving high $\times$ high general combiners revealed additive and additive $\times$ additive genetic component of variance.

This trait, had higher significant *sca* (12.290**) than *gca* components of variance (4.996**). The ratio of *gca* component of variance to total genetic variance (0.448) was away from unity and the estimate of narrow sense heritability (7.30) was low (Table 4.19). These results, showed the role of non-additive gene actions in the inheritance of this character. These results are in accordance with Adilakshmi and Upendra (2014), Malini *et al.* (2014), Patil and Mehta (2014), Gnanamalar and Vivekanandam (2013), Lakshmi (2009) and Sanjeev Kumar *et al.* (2005). For improvement of this trait heterosis breeding and recombination breeding with postponement of selection at later generations can be employed for exploitation of this trait.

The studies on general combining ability of parents revealed that among the eight parents tested pertaining to 24 different characters (quantitative and qualitative), the line, MTU 1001 recorded significant *gca* effects in desirable direction for majority of the characters viz., days to 50% flowering, days to maturity, plant height (cm), test weight (g), leaf area index at maximum tillering stage, head rice recovery (%), kernel length (mm), kernel linear elongation ratio, alkali spreading value (mm), amylose content (%) and grain yield per plant (g) and MTU 1121 recorded significant *gca* effects in desirable direction for days to 50% flowering, days to maturity, total number of tillers per plant, number of grains per panicle, head rice recovery, L/B ratio, kernel breadth after cooking (mm), volume expansion, water uptake (ml), gel consistency (mm) and amylose content (%) followed by MTU 1140 recorded significant *gca* effects in desirable direction for total number of tillers per plant, number of grains per panicle, test weight (g), leaf area index at maximum tillering stage, milling recovery (%), head rice recovery (%), L/B ratio, gel consistency and grain yield per plant (g) and MTU 1064 recorded significant *gca* effects in desirable direction for number of grains per panicle, kernel breadth (mm), kernel length after cooking (mm), kernel linear elongation ratio, volume expansion ratio, alkali spreading value (mm) and amylose content (%) and MTU 1061 recorded significant *gca* effects in desirable direction for total number of tillers per plant, number of grains per panicle, kernel length after cooking (mm), volume expansion ratio, alkali spreading value (mm), amylose content (%) and grain yield per plant (g) and BPT 3291 recorded significant *gca* effects in desirable direction for days

to 50% flowering, days to maturity, plant height(cm), kernel breadth (mm), kernel breadth after cooking (mm) and water uptake, and MCM 100 recorded significant *gca* effects in desirable direction for days to 50% flowering, days to maturity, plant height(cm), kernel breadth (mm) and water uptake, and MTU 7029 recorded significant *gca* effects in desirable direction for plant height, L/B ratio, kernel breadth after cooking (mm) and Gel consistency (mm) (Table 4.20).

Further, the tested lines were given ranking based on the respective combining abilities of all the characters studied (Table 4.20). The line, MTU 1001 and MTU 1121 ranked first followed by MTU 1140, BPT 3291, MTU 1064, MTU 1061, MCM 100 and MTU 7029. Therefore these lines can be utilized in improvement of the respective traits in any breeding programme wherever hybridization is involved. Due to their good combining ability these lines can also be utilized straightaway as parents for production of good hybrids by crossing with other divergent lines or can also be employed in the development of hybrids/synthetic varieties.

The cross combinations involving high $\times$ high general combiners producing crosses with significant *sca* effects revealed the role of additive and additive genetic component of variance which could be easily improved through simple selection procedures such as pureline selection, mass selection, progeny selection and hybridization & selection with pedigree breeding. The crosses between high $\times$ high or low $\times$ high *gca* combiners resulted in superior cross combinations due to complementary gene action which has arisen out of both additive and non-additive gene action. These crosses may likely throw superior transgressive segregants. These components may be exploited by adopting breeding procedures like population improvement methods such as diallel selective mating systems, bi-parental mating and cyclic hybridization and recombination breeding with selection at later generation. The crosses between low $\times$ low general combiners producing crosses with significant *sca* effects revealed the role of non-additive interallelic interaction. This may be due to high nicking ability/genetic diversity of parents involved. This component may be exploited through breeding procedure such heterosis breeding and recombination breeding with postponement of selection at later generations should be carried out for improvement of the traits controlling these types of gene action.

The perusal of *sca* effects (Table 4.18) revealed that the crosses, MTU 1001 × MTU 1061, MTU 1001 × MTU 1140, MCM 100 × MTU 1064 and MCM 100 × MTU 1140 expressed high *sca* effects with high *per se* performance for grain yield per plant. These crosses did not express high *sca* effects for all the yield attributing traits. This study also revealed that there is no relationship between *per se* performance of hybrids and *gca* effects of parents. In majority of the crosses studied, the *per se* value of crosses were related to their corresponding *sca* effects. Thus, the study revealed the possibility for simultaneous improvement of grain yield and yield attributing traits by exploring these F₁ crosses as basic material in breeding programmes.

4.3.1.4 HETEROSIS

Studies on the magnitude of heterosis in F₁s help to assess the ability of the lines (test genotypes) to transmit the desirable characters to the F₁s upon hybridization. This facilitates in identification of lines that exhibit high amount of heterosis. In the present investigation, heterosis of F₁s over mid parent (relative heterosis), better parent (heterobeltiosis) for grain yield and its component characters was estimated using twenty eight F₁s obtained by crossing eight lines/varieties lines in Diallel fashion (without reciprocals).

The estimates of heterosis for yield and yield components over mid parent, better parent for 28 cross combinations are presented in the Table 4.21 and are described character-wise hereunder.

4.3.1.4.1 Days to 50% Flowering

The heterosis in negative direction was considered to be desirable for days to 50 per cent flowering indicated the earliness. Relative heterosis for this character ranged from -29.69 (BPT 3291 × MCM 100) to 2.53 (MTU 1064 × MTU 7029) with a mean of -7.20; and heterobeltiosis ranged from -31.56 (BPT 3291 × MCM 100) to 2.21 (MTU 1064 × MTU 7029) with a mean of -10.87.

Highest negative heterosis over mid parent was observed in the cross, BPT 3291 × MCM 100 (-29.69**) followed by MCM 100 × MTU 1064 (-19.22**) and MTU 1001 × MTU 1061 (-15.99**), while highest negative heterosis over better parent was observed in the cross, BPT 3291 × MCM 100 (-31.56**) followed by MTU 1001 × MTU 1061 (-23.05**) and MCM 100 × MTU 1064 (-21.02**). These were in conformity with results of Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et*

al. (2012), Vanisree *et al.* (2011) and Borah and Barman (2010). The cross, BPT 3291 $\times$ MCM 100 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MCM 100 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.2 Days to Maturity

Negative heterosis is a desirable feature for this character as it indicates the early maturity or short duration types. Relative heterosis for this character ranged from -23.30 (BPT 3291 $\times$ MCM 100) to 2.99 (MTU 1064 $\times$ MTU 7029) with a mean of -5.78; and heterobeltiosis ranged from -24.68 (BPT 3291 $\times$ MCM 100) to 2.22 (MTU 1064 $\times$ MTU 7029) with a mean of -8.45. The crosses, BPT 3291 $\times$ MCM 100 (-23.30**) followed by MCM 100 $\times$ MTU 1064 (-15.48**), MCM 100 $\times$ MTU 7029 (-10.69**) showed highest negative heterosis over mid parent and the crosses, BPT 3291 $\times$ MCM 100 (-24.68**) followed by MTU 1001 $\times$ MTU 1061 (-18.54**) and MCM 100 $\times$ MTU 7029 (-12.35**) showed highest negative heterosis over better parent.

Similar results of significant negative heterosis over mid parent and better parent for this trait were reported by Kumari *et al.* (2014), Sreedhar *et al.* (2012, Sanjeev kumar *et al.* (2010) and Akarsh and Pathak (2008). The cross, BPT 3291 $\times$ MCM 100 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MCM 100 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.3 Plant Height (cm)

Relative heterosis for this character ranged from -13.92 (BPT 3291 $\times$ MTU 7029) to 21.19 (MCM 100 $\times$ MTU 7029) with a mean of 5.12; and heterobeltiosis ranged from -15.43 (MCM 100 $\times$ MTU 7029) to 18.52 (MCM 100 $\times$ MTU 7029) with a mean of 2.73. Negative heterosis is a desirable feature for this character as it indicates the dwarfness of the F_1 .

For this trait, highest negative heterosis over mid parent BPT 3291 $\times$ MTU 7029 (-13.92**) followed by MTU 1001 $\times$ MTU 7029 (-13.84**), BPT 3291 $\times$ MTU 1064 (-5.14**) and high negative heterosis over better parent was observed in the cross, BPT 3291 $\times$ MTU 7029 (15.43**) followed by MTU 1001 $\times$ MTU 7029 (-15.04**) and BPT 3291 $\times$ MTU 1064 (-8.10**). The results of significant negative heterosis for this trait were in agreement with those of Kumari *et al.* (2014), Chandra and Suresh (2012),

Sreedhar *et al.* (2012), Borah and Barman (2010), Gouri Shankar *et al.* (2010), Panwar and Mashiat Ali (2010) and Sanjeev Kumar *et al.* (2010). The cross, BPT 3291 $\times$ MTU 7029 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 7029 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.4 Total Number of Tillers per Plant

The magnitude of relative heterosis for this trait ranged from 14.67 (MTU 1061 $\times$ MTU 7029) to 51.43 (MTU 1001 $\times$ MTU 1140) with a mean of 34.96; and heterobeltiosis ranged from 7.69 (MTU 1001 $\times$ MTU 7029) to 45.45 (BPT 3291 $\times$ MTU 1121) with a mean of 28.82.

The crosses *viz.*, MTU 1001 $\times$ MTU 1140 (51.43**) followed by MCM 100 $\times$ MTU 1121 (49.25**), BPT 3291 $\times$ MTU 1061 (48.57**) registered highly significant positive heterosis over mid parent and BPT 3291 $\times$ MTU 1121 (45.45**) followed by MTU 1001 $\times$ MTU 1140 (43.24**) and MTU 1064 $\times$ MTU 1061 (40.54**) showed high significant heterosis over better parent. Similar results were earlier reported by Sreedhar *et al.* (2012) and Deo *et al.* (2007). The cross, MTU 1001 $\times$ MTU 1140 recorded highest positive significant heterosis over mid and BPT 3291 $\times$ MTU 1121 over better parent. The lines, MTU 1001 and MTU 1140, BPT 3291 and MTU 1121 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.5 Number of Ear Bearing Tillers per Plant

The range of relative heterosis for this trait, varied from 1.54 (MTU 1061 $\times$ MTU 7029) to 42.86 (BPT $\times$ MTU 1121) with a mean of 23.13; and heterobeltiosis ranged from -3.03 (MCM 100 $\times$ MTU 1061) to 37.93 (BPT $\times$ MTU 1121) with a mean of 17.60. Highest positive heterosis over mid parent BPT $\times$ MTU 1121 (42.86**) followed by BPT 3291 $\times$ MTU 1140 (37.39**), MTU 1001 $\times$ BPT 3291 (35.85**) and high positive significant heterosis over better parent was observed in the cross, BPT $\times$ MTU 1121 (37.93**) MTU 1001 $\times$ BPT 3291 (33.33**) and MCM 100 $\times$ MTU 7029 (32.25**).

The cross, BPT 3291 $\times$ MTU 1121 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 1121 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca*

effects. These findings of significant positive heterosis over mid parent and better parent are corroborated by Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011), Borah and Barman (2010) and Panwar and Mashiat Ali (2010).

4.3.1.4.6 Panicle Length (cm)

Mid-parent heterosis for this trait ranged from 5.88 (MCM $\times$ MTU 1140) to 23.42 (BPT 3291 $\times$ MTU 1140) with a mean of 12.48; and heterobeltiosis ranged from 4.73 (MCM $\times$ MTU 1140) to 17.78 (BPT 3291 $\times$ MTU 1140) with a mean of 9.92. The highest significant positive heterosis over mid parent was exhibited by the crosses BPT 3291 $\times$ MTU 1140 (23.42**) followed by BPT 3291 $\times$ MCM 100 (20.85**), MTU 1140 $\times$ MTU 1064 (18.53**) and high significant positive heterosis over better parent was observed in the cross, BPT 3291 $\times$ MTU 1140 (17.78**), MTU 1140 $\times$ MTU 1064 (17.10**) and BPT 3291 $\times$ MTU 7029 (15.73**).

The cross, BPT 3291 $\times$ MTU 1140 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 1140 had low *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects. These results were in conformity with the findings Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Janardhanam *et al.* (2001), Vanisree *et al.* (2011) and Borah and Barman (2010) for relative heterosis and heterobeltiosis

4.3.1.4.7 Number of Grains per Panicle

For this trait mid-parent heterosis ranged from -9.86 (MTU 1121 $\times$ MTU 1064) to 39.69 (MTU 1001 $\times$ BPT 3291) with a mean of 16.49. Whereas, heterobeltiosis varied from -19.65 (MTU 1121 $\times$ MTU 1064) to 31.11 (MTU 1001 $\times$ BPT 3291) with a mean of 5.69.

The highest positive heterosis over mid parent was registered by the cross MTU 1001 $\times$ BPT 3291 (39.69**) followed by MTU 1061 $\times$ MTU 7029 (39.61**), BPT 3291 $\times$ MCM 100 (34.46**) and high positive heterosis over better parent was observed in the cross, MTU 1001 $\times$ BPT 3291 (31.11**), MTU 1061 $\times$ MTU 7029 (25.63**) and MTU 1001 $\times$ BPT 3291 (31.11**). The cross, MTU 1001 $\times$ BPT 3291 recorded highest positive significant heterosis over mid and better parent. The lines, MTU 1001 and BPT 3291 had low *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects. These results are in accordance with Kumari *et al.* (2014),

Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011), Borah and Barman (2010) and Panwar and Mashiat Ali (2010) for relative heterosis and heterobeltiosis.

4.3.1.4.8 Test Weight (g)

The estimates of mid-parent heterosis for test weight varied from -0.36 (MTU 1001 $\times$ MTU 7029) to 23.90 (BPT 3291 $\times$ MCM 100) with a mean of 8.32; and heterobeltiosis ranged from -10.77 (MTU 1001 $\times$ MTU 7029) to 22.05 (BPT 3291 $\times$ MCM 100) with a mean of 3.75.

Among 28 crosses highest positive significant heterosis over mid parent BPT 3291 $\times$ MCM 100 (23.90**) followed by MTU 1001 $\times$ MCM 100 (17.43**), BPT 3291 $\times$ MTU 1140 (16.70**) and high positive significant heterosis over better parent was observed in the cross, BPT 3291 $\times$ MCM 100 (22.05**) followed by MCM 1001 $\times$ MTU 7029 (17.44**) and MTU 1121 $\times$ MTU 1064 (13.22**).

These results are in consonance with findings of Kumari *et al.* (2014), Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Panwar and Mashiat Ali (2010) for relative heterosis and heterobeltiosis. The cross, BPT 3291 $\times$ MCM 100 recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MCM 100 had low *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.9 Leaf Area Index at Maximum Tillering Stage

The range of -20.49 (MTU 1121 $\times$ MTU 7029) to 66.72 (MTU 1001 $\times$ BPT 3291) of heterosis over mid-parent was observed in this study and heterobeltiosis varied from -35.23 (BPT 3291 $\times$ MTU 1121) to 60.31 (MTU 1001 $\times$ BPT 3291).

Mid-parent heterosis showed significant positive for the crosses viz., MTU 1001 $\times$ BPT 3291 (66.72**) followed by MTU 1001 $\times$ MTU 1140 (40.95**), MCM 100 $\times$ MTU 1140 (37.64**) and high positive heterosis over better parent was observed in the cross, MTU 1001 $\times$ BPT 3291 (60.31**), followed by MTU 1001 $\times$ MTU 1064 (18.61**) and MTU 1001 $\times$ MCM 100 (14.57**). The cross, MTU 1001 $\times$ BPT 3291, recorded highest positive significant heterosis over mid and better parent.

4.3.1.4.10 Grain Yield per Plant (g)

The grain yield per plant showed the variation for relative heterosis from 5.28 (MTU 1121 $\times$ MTU 7029) to 65.85 (MCM 100 $\times$ MTU 1064) with a mean of 37.89; and heterobeltiosis from 4.63 (MTU 1121 $\times$ MTU 1064) to 65.21 (MTU 1001 $\times$ MTU 1061), with a mean of 33.33.

The crosses, MCM 100 $\times$ MTU 1064 (65.85**), MTU 1001 $\times$ MTU 1061 (65.27**), MCM 100 $\times$ MTU 1140 (64.28**) exhibited highest positive significant heterosis over mid parent and the crosses, MTU 1001 $\times$ MTU 1061 (65.21**), followed by MTU 1001 $\times$ MTU 1140 (58.91**) and MTU 1121 $\times$ MTU 1140 (57.42**) observed highest positive significant heterosis over better parent. The cross, MTU 1001 $\times$ MTU 1061, recorded highest positive significant heterosis over mid and better parent. The lines, MTU 1001 and MTU 1061 had poor *per se* performance (Table 4.14). but produced high heterotic F_1 s due to their high *gca* effects. These findings were in line with the results obtained by Kumari *et al.* (2014), Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Borah and Barman (2010) for relative heterosis and heterobeltiosis.

4.3.1.4.11 Hulling Recovery (%)

Relative heterosis for this trait ranged from -1.36 (MTU 1061 $\times$ MTU 7029) to 3.47 (MTU 1001 $\times$ BPT 3291) with a mean of 0.98 and heterobeltiosis ranged from -1.66 (MCM 100 $\times$ MTU 1121) to 2.83 (BPT 3291 $\times$ MTU 1064) with a mean of 0.74.

Mid-parent heterosis for the crosses, MTU 1001 $\times$ BPT 3291 (3.47**), BPT 3291 $\times$ MTU 1064 (3.46**), MTU 1121 $\times$ MTU 7029 (2.65*) recorded positive and significant. Whereas, high significantly positive heterosis over better parent was observed in the cross, BPT 3291 $\times$ MTU 1064 (2.83**), MTU 1001 $\times$ BPT 3291 (2.76*) and MTU 1121 $\times$ MTU 7029 (2.51*). The cross, MTU 1001 $\times$ BPT 3291, recorded highest positive significant heterosis over mid and BPT 3291 $\times$ MTU 1064 over better parent. The lines, MTU 1001, BPT 3291 and MTU 1064 had poor *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects

These results were in broad agreement with the findings of Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Pandya and Tripathi (2006) and Raju *et al.* (2003) for relative heterosis, heterobeltiosis.

4.3.1.4.12 Milling Recovery (%)

The estimates of relative heterosis for this character ranged from -1.46 (MTU 1121 $\times$ MTU 1064) to 12.51 (MTU 1001 $\times$ MTU 1140) with a mean of 4.64; and heterobeltiosis varied from -3.06 (MTU 1121 $\times$ MTU 1064) to 10.50 (MTU 1001 $\times$ MTU 1140) with a mean of 3.07.

The crosses, MTU 1001 $\times$ MTU 1140 (12.51**), BPT 3291 $\times$ MTU 1140 (8.89**) showed highest positive heterosis over mid parent and the cross, MTU 1001 $\times$ MTU 1140 (10.50**), BPT 3291 $\times$ MTU 1140 (8.49**) and MTU 1001 $\times$ MTU 7029 (7.10**) registered high positive heterosis over better parent. The cross, MTU 1001 $\times$ MTU 1140, recorded highest positive significant heterosis over mid and better parent. The lines, MTU 1001 and MTU 1140 had poor *per se* performance (Table 4.14). but produced high heterotic F₁s due to their high *gca* effects. Similar results for significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012).

4.3.1.4.13 Head Rice Recovery (%)

The range of variation of heterosis for head rice recovery for mid-parent heterosis varied from -2.89 (BPT 3291 $\times$ MTU 1061) to 15.35 (MTU 1001 $\times$ MTU 1140) with a mean of 3.87, and heterobeltiosis ranged from -5.26 (MTU 1061 $\times$ MTU 7029) to 13.60 (MTU 1001 $\times$ MTU 1140) with a mean of 2.45.

Significant positive mid-parent heterosis was recorded for the crosses, MTU 1001 $\times$ MTU 1140 (15.35**), followed by MTU 1121 $\times$ MTU 1140 (9.17**), MTU 1001 $\times$ BPT 3291 (8.99**) and high positive heterosis over better parent was observed in the cross, MTU 1001 $\times$ MTU 1140 (13.60**) followed by MTU 1001 $\times$ BPT 3291 (8.88**) and MTU 1001 $\times$ MTU 1121 (8.84**). These findings are in conformity with the results of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, MTU 1001 $\times$ MTU 1140, recorded highest positive significant heterosis over mid and better parent. The lines, MTU 1001 and MTU 1140 had poor *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects

4.3.1.4.14 Kernel Length (mm)

The magnitude of relative heterosis for this trait ranged from -8.27 (MCM 100 × MTU 1140) to 13.35 (BPT 3291 × MTU 1140) with a mean of -0.09, and heterobeltiosis ranged from -10.67 (MCM 100 × MTU 1140) to 6.51 (BPT 3291 × MTU 1140) with a mean of -4.02.

Highest positive significant heterosis over mid parent was BPT 3291 × MTU 1140 (13.35**) followed by BPT 3291 × MTU 7029 (9.44**), BPT 3291 × MTU 1121 (7.11**) and highest positive significant over better parent was observed in the cross, BPT 3291 × MTU 7029 (6.28**), followed BPT 3291 × MTU 1140 (6.51**). The above results were in agreement with Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Gouri Shankar *et al.* (2010) and Panwar and Mashiat Ali (2010). The cross, BPT 3291 × MTU 7029, recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 7029 had poor *per se* performance (Table 4.14). But produced high heterotic F₁s due to their high *gca* effects.

4.3.1.4.15 Kernel Breadth (mm)

The estimates of mid-parent heterosis for kernel breadth varied from -6.01 (MTU 1001 × MTU 1064) to 19.29 (MTU 1001 × MTU 7029) with a mean of 9.55, and heterobeltiosis ranged from -8.39 (MTU 1001 × MTU 1064) to 15.69 (MTU 1001 × MTU 1061) with a mean of 6.51.

Desirable significant heterosis over mid parent was observed in MTU 1001 × MTU 1064 (-6.01**) and desirable high significant heterosis over better parent was observed in MTU 1001 × MTU 1064 (-8.39**) followed by MTU 1121 × MTU 1140 (-4.02**) and MCM 100 × MTU 1140 (-3.73**). Similar results were earlier reported by Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012) and Panwar and Mashiat Ali (2010). The cross, MTU 1001 × MTU 1061, recorded highest positive significant heterosis over mid and better parent.

4.3.1.4.16 Kernel Length/Breadth Ratio

Heterosis over mid-parent for kernel L/B ratio ranged from -16.57 (MTU 1140 × MTU 1061) to 10.02 (MCM 100 × MTU 7029) with a mean of -7.26, and heterobeltiosis ranged from -21.00 (MTU 1001 × MTU 7029) to -0.80 (MCM 100 × MTU 7029) with a mean of -14.16.

Relative heterosis recorded highest significant positive heterosis in the cross MCM 100 × MTU 7029 (9.61**) followed by MCM 100 × MTU 1064 (9.61**), MCM 100 × MTU 1121 (8.26**) and desirable, negative heterosis over better parent was observed in the cross, MCM 100 × MTU 7029 (-0.80) followed by MCM 100 × MTU 1140 (-2.10). The cross, MCM 100 × MTU 7029, recorded highest heterosis over mid-parent and better parent. The lines, MCM 100 and MTU 7029 had poor *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects. These findings are corroborated by Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012) and Panwar and Mashiat Ali (2010).

4.3.1.4.17 Kernel Length after Cooking (mm)

The range of variation for relative heterosis was observed from -6.14 (MTU 1140 × MTU 1061) to 8.35 (BPT 3291 × MTU 1121) with a mean of 0.20, and heterobeltiosis ranged from -10.37 (BPT 3291 × MTU 1061) to 6.26 (BPT 3291 × MTU 7029) with a mean of -3.16.

Significantly high positive relative heterosis was recorded for the crosses BPT 3291 × MTU 1121 (8.35**) followed by BPT 3291 × MTU 7029 (7.90**), MTU 1121 × MTU 7029 (5.38**) and highest positive significant heterosis over better parent was observed in the cross, BPT 3291 × MTU 7029 (6.26**) followed by BPT 3291 × MTU 1121 (6.07**) and MTU 1121 × MTU 7029 (3.78**). These results of significant positive heterosis over mid parent are in accordance with Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, BPT 3291 × MTU 7029, recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 7029 had poor *per se* performance (Table 4.14), but produced high heterotic F₁s due to their high *gca* effects.

4.3.1.4.18 Kernel Breadth after Cooking (mm)

Relative heterosis for this character ranged from -11.33 (MTU 1121 × MTU 1061) to 14.72 (MCM 100 × MTU 1140) with a mean of 1.71 and heterobeltiosis ranged from -14.78 (MTU 1001 × MTU 1064), (MTU 1121 × MTU 1061) to 8.22 (MCM 100 × MTU 1140) with a mean of -2.83.

Highest positive significant heterosis over mid parent was observed in MCM 100 × MTU 1140 (14.72**) followed by BPT 3291 × MTU 1140 (13.19**), BPT 3291 × MTU 7029 (12.02**) and highest positive significant heterosis over better parent was

observed in the cross, MCM 100 × MTU 1140 (8.22**) followed by BPT 3291 × MTU 1061 (7.67*) and MCM 100 × MTU 1061 (7.33**). The cross, MCM 100 × MTU 1140, recorded highest positive significant heterosis over mid and better parent. The lines, MCM 100 and MTU 1140 had poor *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects. Similar results for significant positive heterosis over mid parent are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012).

4.3.1.4.19 Kernel Elongation Ratio

The kernel elongation ratio registered relative heterosis from -15.10 (MCM 100 × MTU 1140) to -2.57 (MTU 1001 × MTU 1121) with a mean of -9.42 and heterobeltiosis ranged from -22.67 (MCM 100 × MTU 7029) to -11.67 (MTU 1001 × MTU 1121) with a mean of -16.16.

Negative significant heterosis over mid parent was observed in MCM 100 × MTU 1140 (-15.10**), and non-significant negative significant heterosis over better parent was observed in the cross, MTU 1001 × MTU 1121 (-11.67**). These findings were in line with the results obtained by Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, MCM 100 × MTU 1140, recorded highest positive significant heterosis over mid and MTU 1001 × MTU 1121 over better parent. The lines, MCM 100, MTU 1140 and MTU 1121 had poor *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects.

4.3.1.4.20 Volume Expansion Ratio

The estimates of mid-parent heterosis varied from -21.64 (BPT 3291 × MTU 1140) to 30.44 (MTU 1001 × MTU 7029) with a mean of 0.87 and heterobeltiosis ranged from -24.20 (BPT 3291 × MTU 1140) to 19.67 (MTU 1064 × MTU 7029) with a mean of -4.40.

The crosses, MTU 1001 × MTU 7029 (30.44**), MTU 1121 × MTU 7029 (22.82**), MTU 1064 × MTU 1061 (20.82**) recorded highest positive significant heterosis over mid parent, and the cross, MTU 1064 × MTU 7029 (19.67**) followed by MTU 1001 × MTU 7029 (16.40**) and MTU 1001 × MTU 1061 (15.93**) showed highest positive heterosis over better parent. The cross, MTU 1001 × MTU 7029, recorded highest positive significant heterosis over mid parent and MTU 1064 × MTU 7029 over better parent. The lines, MTU 1001, MTU 7029 and MTU 1064 had poor *per*

se performance (Table 4.14), due to their high *gca* effects, produced high heterotic F_1 s. These results were in broad agreement with the findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012)

4.3.1.4.21 Water Uptake (ml)

Relative heterosis for this character ranged from -28.12 (MTU 1001 $\times$ BPT 3291) to 26.09 (MCM 100 $\times$ MTU 1064) with a mean of -3.18, and heterobeltiosis ranged from -40.99 (MTU 1001 $\times$ BPT 3291) to 23.40 (MCM 100 $\times$ MTU 1064) with a mean of -12.32.

Negative effects are desirable for this trait where, negative significant heterosis over mid parent was observed in cross MTU 1001 $\times$ BPT 3291 (-28.12**), MTU 1001 $\times$ MCM 100 (-24.65**), MTU 1001 $\times$ MTU 7029 (-23.08**) and for better parent negative significant heterosis was recorded in the cross, MTU 1001 $\times$ BPT 3291 (-40.99**), MTU 1001 $\times$ MCM 100 (-40.34**) and MTU 1001 $\times$ MTU 1140 (-35.80**). These findings for significant positive heterosis over mid parent are in conformity with the results of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, MCM 100 $\times$ MTU 1064, recorded highest positive significant heterosis over mid and better parent. The lines, MCM 100 and MTU 1064 had poor *per se* performance (Table 4.14). but produced high heterotic F_1 s due to their high *gca* effects.

4.3.1.4.22 Gel Consistency (mm)

Gel consistency registered relative heterosis from -33.81 (MTU 1064 $\times$ MTU 1061) to 97.66 (BPT 3291 $\times$ MTU 7029) with a mean of 30.85, and heterobeltiosis ranged from -33.88 (MTU 1064 $\times$ MTU 1061) to 84.84 (BPT 3291 $\times$ MTU 7029) with a mean of 22.53.

Among the crosses highest positive significant heterosis over mid parent was recorded for BPT 3291 $\times$ MTU 7029 (97.66**), MTU 1001 $\times$ MTU 1140 (86.23**), MTU 1140 $\times$ MTU 7029 (84.70**) and highest positive significant heterosis over better parent was observed in the cross, BPT 3291 $\times$ MTU 7029 (84.84**), MTU 1001 $\times$ MTU 1140 (80.93**) and MTU 1140 $\times$ MTU 1061 (79.28**). The cross, BPT 3291 $\times$ MTU 7029, recorded highest positive significant heterosis over mid and better parent. The lines, BPT 3291 and MTU 7029 had poor *per se* performance (Table 4.14) but produced high heterotic F_1 s due to their high *gca* effects. These findings are corroborated by Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012) for relative heterosis and heterobeltiosis.

4.3.1.4.23 Alkali Spreading Value (mm)

Mid-parent heterosis for this character ranged from -57.04 (MTU 1064 × MTU 1061) to 65.59 (BPT 3291 × MTU 7029) with a mean of -1.51, and heterobeltiosis ranged from -57.60 (MTU 1064 × MTU 1061) to 60.77 (MTU 1121 × MTU 7029) with a mean of -16.29.

Highest positive significant heterosis over mid parent was observed in cross, BPT 3291 × MTU 7029 (65.59**) followed by MTU 1121 × MTU 7029 (63.67**), MTU 1061 × MTU 7029 (30.48**) and highest positive significant heterosis over better parent was observed in the cross, MTU 1121 × MTU 7029 (60.77**), BPT 3291 × MTU 7029 (47.17**) and MTU 1140 × MTU 7029 (11.08**).

These results are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012) for relative heterosis and heterobeltiosis. The cross, BPT 3291 × MTU 7029, recorded highest positive significant heterosis over mid and MTU 1121 × MTU 7029 better parent. The lines, BPT 3291, MTU 1121 and MTU 7029 had poor *per se* performance (Table 4.14) but produced high heterotic F₁s due to their high *gca* effects.

4.3.1.4.24 Amylose Content (%)

Relative heterosis for this character ranged from -19.38 (BPT 3291 × MTU 1140) to 46.24 (MTU 1121 × MTU 7029) with a mean of 3.61, and heterobeltiosis ranged from -20.64 (BPT 3291 × MTU 1064) to 44.67 (MTU 1121 × MTU 7029) with a mean of -1.38.

The crosses, MTU 1121 × MTU 7029 (46.24**), MCM 100 × MTU 1121 (45.93**) and BPT 3291 × MTU 1061 (34.83**) showed highest positive significant heterosis over mid parent and the cross, MTU 1121 × MTU 7029 (44.67**), MCM 100 × MTU 1121 (38.68**) and BPT 3291 × MTU 1061 (24.17**) registered high positive significant heterosis over better parent. These results were in conformity with the findings Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012) for relative heterosis, heterobeltiosis. The cross, MTU 1121 × MTU 7029, recorded highest positive significant heterosis over mid and better parent. The lines, MTU 1121 and MTU 7029 had poor *per se* performance (Table 4.14). but produced high heterotic F₁s due to their high *gca* effects.

Based on overall performance (*per se* performance, high *sca* effects and relative heterosis and heterobeltiosis), the best heterotic combinations identified for quantitative and qualitative components are presented in Table 4.22. The best heterotic combinations identified were MTU 1001 $\times$ MTU 1140 for total of tillers per plant, leaf area index at maximum tillering stage, milling percentage, head rice recovery, L/B ratio, gel consistency and grain yield per plant. MTU 1001 $\times$ MTU 1061 for days to flowering, days to maturity, kernel breadth, L/B ratio, and grain yield per plant; MCM 100 $\times$ MTU 1140 for kernel breadth after cooking, kernel linear elongation ratio and grain yield per plant; MCM 100 $\times$ MTU 1064 for days to 50% flowering, days to maturity, water uptake and grain yield.

The cross combination MTU 1001 $\times$ MTU 1140 registered significant relative heterosis and heterobeltiosis for total of tillers per plant, leaf area index at maximum tillering stage, milling percentage, head rice recovery, L/B ratio, gel consistency and grain yield per plant. It also recorded significant *sca* effects and better *per se* performance for all the 7 characters mentioned above. Thus among all the crosses, based on relative heterosis, heterobeltiosis, *sca* effects and *per se* performance, the cross MTU 1001 $\times$ MTU 1140 was identified as a promising hybrid for majority of the characters studied (Table 4.22.).

4.3.1.5 CHARACTER ASSOCIATION

Correlations studies are important to know the relationship of various characters for direct or indirect selection because; selection of a particular trait may bring desirable or undesirable change in the associated characters. Generally, direct selection for yield is difficult as yield is a complex quantitative character and is highly influenced by environment. As such high genotypic and environmental interactions are likely to restrict the improvement. Therefore, correlation between yield and yield components are of considerable importance in selection programme. Some of the yield components are less influenced by environment and are also simple in heritance.

Yield components show different associations among themselves and with yield. Unfavourable association between desired attributes under selection is a limiting factor for planning a selection programme. Hence, the knowledge of inter-relationships between yield and yield components are of considerable importance for planning a sound selection programme. The phenotypic and genotypic correlation coefficients between yield and its components and inter relations among the yield components are presented in Table 4.23 and Table 4.24.

4.3.1.5.1 Days to 50% Flowering

At both phenotypic and genotypic levels, this trait showed significant positive association with days to maturity (0.975**, 0.999*) and water uptake (0.217*, 0.237*). Whereas, significant negative correlation with total number of tillers per plant (-0.290**, -0.323**), total ear bearing tillers per plant (-0.271**, -0.350**), panicle length (-0.288**, -0.389**), test weight (-0.420**, -0.451**), milling percentage (-0.252**, -0.299**), head rice recovery (-0.338**, -0.387**), kernel breadth (-0.248**, -0.264**), gel consistency (-0.273**, -0.284**) and grain yield per plant (-0.250**, -0.271**) at both phenotypic and genotypic levels. It also exhibited negative significant correlation with hulling percentage (-0.299**), kernel length (-0.197*) at genotypic level. Similar association was reported by Bornare *et al.* (2014), Imad *et al.* (2014), Satish Kumar Rai *et al.* (2014) and Arulmozhi and Muthuswamy (2013).

4.3.1.5.2 Days to Maturity

Days to maturity recorded positive significant correlation with water uptake (0.233*, 0.243*). Whereas, significant negative association with total number of tillers per plant (-0.322**, -0.344**), total number of ear bearing tillers per plant (-0.283**, -0.388**), panicle length per plant (-0.288**, -0.381**), test weight (-0.375**, -0.407**), hulling percentage (-0.326**), milling percentage (-0.245**, -0.307**), head rice recovery (-0.323**, -0.379**), kernel breadth (-0.284**, -0.287**), gel consistency (-0.292**, -0.307**) and grain yield per plant (-0.264**, -0.278**) at both genotypic and phenotypic levels. It also exhibited negative association with kernel length (-0.226*) at genotypic level. Similar kind of relation was reported by Alam *et al.* (2014), Imad *et al.* (2014), Gulzar *et al.* (2013) and Akhtar *et al.* (2011).

4.3.1.5.3 Plant Height (cm)

Plant height was found to have significant positive correlation with total number of tillers per plant (0.427**, 0.492**), total ear bearing tillers per plant (0.395**, 0.513**), panicle length (0.272**, 0.358**), number of grains per panicle (0.489**, 0.546**), test weight (0.412**, 0.442**), milling percentage (0.28**, 0.341**), head rice recovery (0.479**, 0.53**), gel consistency (0.272**, 0.281**) and grain yield per plant (0.498**, 0.544**). Whereas negatively significant association was observed with volume expansion ratio (-0.250**, -0.271**) and alkali spreading value (-0.229*, -0.241*) at both phenotypic and genotypic levels. It showed significantly positive

correlation with leaf area index at maximum tillering stage (0.448*) at phenotypic and hulling percentage (0.302**) at genotypic level. These results were in agreement with the findings of Anis *et al.* (2016), Islam *et al.* (2015), Sathisha *et al.* (2015) and Singh *et al.* (2015).

4.3.1.5.4 Total Number of Tillers per plant

At both phenotypic and genotypic levels total number of tillers per plant recorded significant positive association with total ear bearing tillers per plant (0.623**, 0.942**), panicle length per plant (0.619**, 0.846**), number of grains per panicle (0.461**, 0.597**), test weight (0.283**, 0.338**), hulling percentage (0.278**, 0.424**), milling percentage (0.523**, 0.660**), head rice recovery (0.256**, 0.485**), kernel breadth (0.355**, 0.422**), kernel breadth after cooking (0.390**, 0.492**), gel consistency (0.288**, 0.35**) and grain yield per plant (0.662**, 0.752**). The trait also showed negative significant association with L/B ratio (-0.389**, 0.442**) at both phenotypic and genotypic levels. These results are in consonance with findings of Golam Sarwar *et al.* (2015), Kundu sritama *et al.* (2015), Sathisha *et al.* (2015) and Vijay Kumar *et al.* (2015).

4.3.1.5.5 Number of Bearing Tillers per Plant

Number of bearing tillers per plant showed significant positive association with panicle length per plant (0.442**, 0.947**), number of grains per panicle (0.417**, 0.526**), test weight (0.345**, 0.467**), hulling percentage (0.241*, 0.614**), milling percentage (0.341**, 0.710**), head rice recovery (0.394**, 0.571**), kernel breadth (0.308**, 0.486**) kernel breadth after cooking (0.241*, 0.268**), gel consistency (0.240*, 0.349**) and grain yield per plant (0.404**, 0.615**). Whereas negative significant association with L/B ratio (-0.209*, -0.387**) at both phenotypic and genotypic levels. This trait exhibited positive significant correlation with kernel length (0.223*) at genotypic level. Similar relation was confined by Golam Sarwar *et al.* (2015), Keya *et al.* (2015), Kundu Sritama *et al.* (2015) and Marzieh Moosavi *et al.* (2015).

4.3.1.5.6 Panicle Length per Plant (cm)

This character exhibited significant positive correlation with test weight (0.380**, 0.562**), milling percentage (0.443**, 0.750**), head rice recovery (0.292**, 0.481**), kernel length (0.228**, 0.369**), kernel breadth (0.395**, 0.492**), gel consistency (0.288**, 0.35**) and grain yield per plant (0.662**, 0.752**).

0.531**), kernel breadth after cooking (0.338**, 0.477**), gel consistency (0.302**, 0.395**) and grain yield per plant (0.406**, 0.556**). Whereas, negative significant association with L/B ratio (-0.273**, -0.365**) at both phenotypic and genotypic levels. It also had significant positive association with number of grains per panicle (0.451**) at phenotypic and hulling percentage (0.449**) at genotypic level. These results were in agreement with the findings Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015) and Sathisha *et al.* (2015).

4.3.1.5.7 Number of Grains per Panicle

This character was found to have significant positive correlation with milling percentage (0.389**, 0.486**), head rice recovery (0.341**, 0.394**), kernel breadth after cooking (0.238**, 0.292**), gel consistency (0.245*, 0.280**) and grain yield per plant (0.406**, 0.481**). Whereas, negative significant association with amylose content (-0.202**, -0.227**) at both phenotypic and genotypic levels. It also exhibited positive significant correlation with test weight (0.213*) and kernel breadth (0.214*) at genotypic level and leaf area index at maximum tillering stage (0.316**) at phenotypic level. Similar association was observed in the findings of Islam *et al.* (2015), Kundu Sritama *et al.* (2015) and Sandhyarani Das (2015).

4.3.1.5.8 Test Weight (g)

Test weight showed significant positive association with leaf area index at maximum tillering stage (0.419**, 0.450**), milling percentage (0.302**, 0.361**), head rice recovery (0.499**, 0.588**), kernel breadth (0.223**, 0.239**), gel consistency (0.234*, 0.245*) and grain yield per plant (0.322**, 0.327**) at both phenotypic and genotypic levels, respectively. It also had positive significant correlation with kernel length (0.237*) at genotypic level. The above results were in agreement with Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015), Sarafraz *et al.* (2015) and Sathisha *et al.* (2015).

4.3.1.5.9 Leaf Area Index at Maximum Tillering Stage

Leaf area index at maximum tillering stage recorded significant positive association with milling percentage (0.229**, 0.281**), head rice recovery (0.554**, 0.623**) and grain yield per plant (0.281*, 0.291**) at both phenotypic and genotypic levels, respectively and significant positive association with hulling percentage (0.253*)

at genotypic level. Whereas negative significant association with volume expansion ratio (-0.425**) at phenotypic levels. These results are in consonance with findings of Keya *et al.* (2015), Ganghua *et al.* (2014) and Hashem and Peyman (2011).

4.3.1.5.10 Hulling Recovery (%)

This character exhibited significant positive association with milling percentage (0.464**, 0.954**), head rice recovery (0.414**, 0.708**) and grain yield per plant (0.198*, 0.390**) at both phenotypic and genotypic levels, respectively. The trait also showed positive significant correlation with kernel breadth (0.243*), gel consistency (0.312**) at genotypic level. Whereas, negative significant association with water uptake (-0.339**) at phenotypic levels only. These findings are corroborated by Tushara *et al.* (2013) and Prem Kumar *et al.* (2010).

4.3.1.5.11 Milling Recovery (%)

Milling percentage showed significant positive correlation with head rice recovery (0.645**, 0.757**), kernel breadth (0.270**, 0.300**), kernel length after cooking (0.201*, 0.283**), gel consistency (0.512**, 0.584**) and grain yield per plant (0.499**, 0.605**). Whereas, negative significant association with L/B ratio (-0.202*, -0.191*) at both phenotypic and genotypic levels. The trait also showed positive significant correlation with kernel length (0.207*) at genotypic level. Nagaraju *et al.* (2013), Ruth Elizabeth Ekka *et al.* (2011) and Prem Kumar *et al.* (2010), also reported similar association.

4.3.1.5.12 Head Rice Recovery (%)

At both phenotypic and genotypic levels, head rice recovery recorded significant positive correlation with grain yield per plant (0.459**, 0.549**). Whereas, negative significant association was observed with volume expansion ratio (-0.332**, -0.396**), water uptake (-0.258**, -0.317**) and amylose content (-0.199*, -0.243*) at both phenotypic and genotypic levels, respectively. It had significant positive association with gel consistency (0.434**) at phenotypic level. The above results were in agreement with Krishna Veni *et al.* (2013) and Prem Kumar *et al.* (2010).

4.3.1.5.13 Kernel Length (mm)

Kernel length exhibited significant positive association with kernel breadth (0.464**, 0.487**), kernel length after coking (0.387**, 0.494**) and also significant negative association with kernel linear expansion ratio (-0.358**, -0.248**), at both

phenotypic and genotypic level. These findings are corroborated by Nabedita Mohanty *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet Kumar and Senapathi (2013), Islam *et al.* (2015), Singh *et al.* (2014) and Gulzar *et al.* (2013).

4.3.1.5.14 Kernel Breadth (mm)

This character showed significant positive correlation with kernel breadth after coking (0.291**, 0.348**), volume expansion ratio (0.273**, 0.304**) and also significant negative association with L/B ratio (-0.799**, -0.825**) and kernel linear elongation ratio (-0.262**, -0.283**) and at both phenotypic and genotypic levels, respectively. Similar association was reported by Islam *et al.* (2015), Nabedita Mohanty *et al.* (2015), Dhurai *et al.* (2014) and Norain *et al.* (2014).

4.3.1.5.15 Kernel Length/Breadth Ratio

Kernel length/breadth ratio exhibited significant positive association with water uptake (0.278**, 0.306**) and showed significant negative association with kernel breadth after cooking (-0.323**, -0.409**) at both phenotypic and genotypic levels. This trait, showed positive association with kernel length after cooking (0.218*) and negative significant correlation with volume expansion ratio (-0.210*) at genotypic level. These results were in agreement with the findings of Krishna Veni *et al.* (2013) and Pankaj Garg *et al.* (2010).

4.3.1.5.16 Kernel Length after Cooking (mm)

This character was found to have significant positive association with kernel linear elongation ratio (0.721**, 0.720**), water uptake (0.236*, 0.276**) at both phenotypic and genotypic levels and positive significant correlation with alkali spreading value (0.292**) at phenotypic level. These results are in consonance with findings of Dhurai *et al.* (2014) and Prem Kumar *et al.* (2010).

4.3.1.5.17 Kernel Breadth after Cooking (mm)

Kernel breadth after cooking showed significant positive association with grain yield per plant (0.241*, 0.271**) at both phenotypic and genotypic levels, respectively. These results were in agreement with the findings of Prem Kumar *et al.* (2010).

4.3.1.5.18 Kernel Elongation Ratio

At, both phenotypic and genotypic levels kernel this trait exhibits significant positive association with alkali spreading value (0.246**, 0.302**). Similar association was reported by Dhurai *et al.* (2014) and Chaudhary and Motiramani (2003).

4.3.1.5.19 Volume Expansion Ratio

Volume expansion recorded significant positive association with alkali spreading value (0.199*, 0.219*) both phenotypic and genotypic levels, respectively, and significant negative association with grain yield per plant (-0.209*) at genotypic level only. Similar results were confined by Malini *et al.* (2011).

4.3.1.5.20 Water Uptake (ml)

This character exhibited significant negative association with gel consistency (-0.255**) at phenotypic level. Whereas, significant positive association with alkali spreading value (0.246**, 0.255**) both phenotypic and genotypic levels, respectively. These results were in agreement with the findings of Krishna Veni *et al.* (2013) and Malini *et al.* (2011).

4.3.1.5.21 Gel Consistency (mm)

At both genotypic and phenotypic levels gel consistency showed significant positive association with grain yield per plant (0.320**, 0.346**). Contrary, Malini *et al.* (2011) and Nagajyothi (2001) noticed positive low association; this might be due to differences in breeding material studied under different environments.

4.3.1.5.22 Alkali Spreading Value (mm)

Both phenotypic and genotypic correlations indicated that this trait had non-significant positive association with alkali spreading value (0.085, 0.082) and non-significant negative association with grain yield per plant (-0.006, -0.001). The above results were in agreement with Manonmani *et al.* (2010).

4.3.1.5.23 Amylose Content (%)

Amylose content recorded non-significant negative association with grain yield per plant (-0.152, -0.154) at both phenotypic and genotypic levels, respectively. Similar association was reported by Patel *et al.* (2014), Krishna Veni *et al.* (2013), Pankaj Garg *et al.* (2010) and Sivaparvathi (2010).

In the present investigation it was found that the genotypic correlations in general are higher than phenotypic correlations indicating that the apparent associations are largely due to genetic reasons. Hence, it can be suggested that simultaneous selection of traits viz., days to 50% flowering, days to maturity, plant height, total number of tillers per plant, total number of ear bearing tillers per plant, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, hulling percentage, milling percentage, head rice recovery, kernel breadth after cooking, volume expansion ratio and gel consistency, possessing significant association in desirable direction with grain yield per plant leads to improvement towards higher grain yield with good quality characters.

4.3.1.6 PATH COEFFICIENT ANALYSIS

Correlation coefficients, though gives information regarding the association of different component traits, it does not project the complete picture especially when the casual factors were inter-related. Therefore, the correlation coefficients which are found significant between yield and its each component characters were partitioned into corresponding direct and indirect effects of yield contributing characters on grain yield in 28 F₁s and eight parents through path coefficient analysis and were presented (Table 4.25) character wise hereunder. The path diagrams were given in Figures 4.3.

4.3.1.6.1 Days to 50% Flowering

At genotypic level days to 50% flowering exhibited significant negative correlation (-0.271**) and negative direct effect (-0.490) on grain yield per plant. It also exhibited positive indirect effect through days to maturity (0.609), test weight (0.234), hulling recovery (0.036), milling recovery (0.199), kernel breadth (2.007), and kernel breadth after cooking (0.002), water uptake (0.086), alkali spreading value (0.046) and amylose content (0.010). This trait also exhibited negative indirect effect *via* days to 50% flowering (-0.490), plant height (-0.008), total number of tillers per plant (-0.231), total number of ear bearing tillers per plant (-0.051), panicle length (-0.232), number of grains per panicle (-0.019), leaf area index (-0.008), head rice recovery (-0.519), kernel length (-0.605), L/B ratio (-1.076), kernel length after cooking (-0.146), kernel linear elongation ratio (-0.069), volume expansion ratio (-0.021) and gel consistency (-0.026). Similar results were confined by Islam *et al.* (2015), Shajedur *et al.* (2015), Alam *et al.* (2014), Khare *et al.* (2014) and Patel *et al.* (2014).

4.3.1.6.2 Days to Maturity

The trait showed negative significant correlation (-0.278**) and positive direct effect (0.610) on grain yield per plant at genotypic level. It also expressed positive indirect effects *via* days to maturity (0.610), test weight (0.212), hulling recovery (0.040), milling recovery (0.205), kernel breadth (2.186), kernel breadth after cooking (0.003), water uptake (0.088), alkali spreading value (0.051) and amylose content (0.010). It also expressed negative indirect effects through days to 50% flowering (-0.489), plant height (-0.007), total number of tillers per plant (-0.246), total number of ear bearing tillers per plant (-0.056), panicle length (-0.228), number of grains per panicle (-0.015), leaf area index (-0.013), head rice recovery (-0.509), kernel length (-0.691), L/B ratio (-1.136), kernel length after cooking (-0.126), kernel linear elongation ratio (-0.117), volume expansion ratio (-0.021) and gel consistency (-0.028). Similar results were confirmed by Golam *et al.* (2015), Islam *et al.* (2015), Dhurai *et al.* (2014), Khare *et al.* (2014) and Awaneet and Senapati (2013).

4.3.1.6.3 Plant Height (cm)

Plant height showed negative direct effect (-0.147) and positive significant association (0.544**) on grain yield per plant. This trait also expressed positive indirect effects through days to maturity (0.030), total number of tillers per plant (0.352), total number of ear bearing tillers per plant (0.074), panicle length (0.214), head rice recovery (0.728), kernel length (0.402), kernel breadth after cooking (0.001), kernel linear elongation ratio (0.262), water uptake (0.046) and gel consistency (0.026). Whereas, it expressed negative indirect effects *via* days to 50% flowering (-0.028), plant height (-0.147), number of grains per panicle (-0.110), test weight (-0.230), leaf area index (-0.073), hulling recovery (-0.037), milling recovery (-0.228), kernel breadth (-0.294), L/B ratio (-0.171), kernel length after cooking (-0.138), volume expansion ratio (-0.056), alkali spreading value (-0.075) and amylose content (-0.006). These findings are corroborated by Golam *et al.* (2015), Thirumala Rao (2014), Nitiprasad and Lotan (2014), Awaneet and Senapati (2013) and Gulzar *et al.* (2013).

4.3.1.6.4 Total Number of Tillers per Plant

Total number of tillers per plant had positive direct effect (0.0715) and significant positive association (0.752**) on grain yield per plant at genotypic level. It also had positive indirect effects through, days to 50% flowering (0.159), total number

of tillers per plant (0.715), total number of ear bearing tillers per plant (0.137), panicle length (0.505), head rice recovery (0.651), kernel length (0.147), L/B ratio (2.779), kernel linear elongation ratio (0.251) and gel consistency (0.030). This trait also had negative indirect effects through, days to maturity (-0.210), plant height (-0.072), number of grains per panicle (-0.120), test weight (-0.175), leaf area index (-0.021), hulling recovery (-0.052), milling recovery (-0.440), kernel breadth (-3.211), kernel length after cooking (-0.217), kernel breadth after cooking (-0.009), volume expansion ratio (-0.023), water uptake (-0.005), alkali spreading value (-0.058) and amylose content (-0.009). These results are in consonance with findings of Alam *et al.* (2014), Mohammad and Kayvan (2014), Nitiprasad and Lotan (2014), Patel *et al.* (2014), Krishnamurthy *et al.* (2013) and Mulugeta *et al.* (2012)

4.3.1.6.5 Number of Ear Bearing Tillers per Plant

Number of ear bearing tillers per plant had positive direct effect (0.145) and significant positive association (0.615**) on grain yield per plant at genotypic level. It also had positive indirect effects through, days to 50% flowering (0.171), total number of tillers per plant (0.673), total number of ear bearing tillers per plant (0.145), panicle length (0.566), head rice recovery (0.766), kernel length (0.682), L/B ratio (2.432), kernel linear elongation ratio (0.245), volume expansion ratio (0.246) and gel consistency (0.032). It also showed negative indirect effects through, days to maturity (-0.237), plant height (-0.075), number of grains per panicle (-0.106), test weight (-0.243), leaf area index (-0.026), hulling recovery (-0.075), milling recovery (-0.473), kernel breadth (-3.700), kernel length after cooking (-0.024), kernel breadth after cooking (-0.005), water uptake (-0.016), alkali spreading value (-0.070) and amylose content (-0.010). These results are in accordance with Pradhan *et al.* (2015), (2014), Dhurai *et al.* (2014), Imad *et al.* (2014), Patel *et al.* (2014), Thirumala Rao (2014), Krishna Veni *et al.* (2013) and Ravindra Babu *et al.* (2012).

4.3.1.6.6 Panicle Length per Plant (cm)

This character expressed significant positive association (0.556**) and positive direct effect (0.597) on grain yield per plant at genotypic level. It also showed positive indirect effects *via*, days to 50% flowering (0.191), total number of tillers per plant (0.605), total number of ear bearing tillers per plant (0.137), panicle length (0.597), head rice recovery (0.645), kernel length (1.131), L/B ratio (2.295), kernel length after cooking (0.146), kernel linear elongation ratio (0.247), volume expansion ratio (0.000)

and gel consistency (0.037); and showed negative indirect effects through days to maturity (-0.232), plant height (-0.053), number of grains per panicle (-0.144), test weight (-0.292), leaf area index (-0.014), hulling recovery (-0.055), milling recovery (-0.500), kernel breadth (-4.044), kernel breadth after cooking (-0.008), water uptake (-0.084), alkali spreading value (-0.039) and amylose content (-0.009). These results were in broad agreement with the findings of Golam *et al.* (2015), Pradhan *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Patel *et al.* (2014), Rahman *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013) and Krishna Veni *et al.* (2013).

4.3.1.6.7 Number of Grains per Panicle

At genotypic level, the trait number of grains per panicle had negative direct effect (-0.201) and significant positive association (0.481**) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.046), total number of tillers per plant (0.427), total number of ear bearing tillers per plant (0.076), panicle length (0.428), head rice recovery (0.528), kernel length (0.250), L/B ratio (1.173), kernel length after cooking (0.103), gel consistency (0.026) and amylose content (0.031), while negative indirect effect *via* days to 50% flowering (-0.046), plant height (-0.080), number of grains per panicle (-0.201), test weight (-0.111), leaf area index (-0.055), hulling recovery (-0.016), milling recovery (-0.324), kernel breadth (-1.626), kernel breadth after cooking (-0.005), kernel linear elongation ratio (-0.021), volume expansion ratio (-0.025), water uptake (-0.060) and alkali spreading value (-0.035).

4.3.1.6.8 Test Weight (g)

Direct effects of this trait on grain yield was low and negative (-0.520) it showed and significant positive association (0.327**) on grain yield per plant at genotypic level. This trait exhibited positive indirect effect *via* days to 50% flowering (0.221), total number of tillers per plant (0.241), total number of ear bearing tillers per plant (0.068), panicle length (0.335), head rice recovery (0.789), kernel length (0.725), L/B ratio (0.773), kernel length after cooking (0.238), kernel breadth after cooking (0.002), kernel linear elongation ratio (0.015) and gel consistency (0.023); while it exhibited negative indirect effect through days to maturity (-0.248), plant height (-0.065), number of grains per panicle (-0.043), test weight (-0.520), leaf area index (-0.069), hulling recovery (-0.019), milling recovery (-0.240), kernel breadth (-1.823), volume expansion ratio (-0.038), water uptake (-0.015), alkali spreading value (-0.005), amylose content

(-0.020). These results are in consonance with findings of Pradhan *et al.* (2015), Dhurai *et al.* (2014), Imad *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013), Bhabendra *et al.* (2012) and Praveen *et al.* (2010).

4.3.1.6.9 Leaf area Index at Maximum Tillering Stage

The trait had negative direct effect (-0.152) and significant positive association (0.291**) on grain yield per plant at genotypic level. This trait exhibited positive indirect effect through days to maturity (0.052), total number of tillers per plant (0.097), total number of ear bearing tillers per plant (0.025), panicle length (0.054), head rice recovery (0.836), kernel breadth (1.258), kernel length after cooking (0.008), kernel breadth after cooking (0.002), gel consistency (0.007) and amylose content (0.019), whereas negative indirect effect *via* days to 50% flowering (-0.026), plant height (-0.070), number of grains per panicle (-0.073), test weight (-0.234), leaf area index (-0.152), hulling recovery (-0.031), milling recovery (-0.187), kernel length (-0.013), L/B ratio (-1.104), kernel linear elongation ratio (-0.028), volume expansion ratio (-0.093), water uptake (-0.017) and alkali spreading value (-0.038). These results are in accordance with Zulqarnain *et al.* (2012) and Ullah *et al.* (2011).

4.3.1.6.10 Hulling Recovery (%)

At genotypic level, this trait had negative direct effect (-0.122) and significant positive association (0.390**) with grain yield per plant. This trait exhibited positive indirect effects *via* days to 50% flowering (0.147), total number of tillers per plant (0.303), total number of ear bearing tillers per plant (0.089), panicle length (0.268), head rice recovery (0.950), kernel length (0.538), L/B ratio (1.602), kernel length after cooking (0.149), kernel linear elongation ratio (0.013), gel consistency (0.029) and alkali spreading value (0.003). It also showed negative indirect effects *via* days to maturity (-0.199), plant height (-0.044), number of grains per panicle (-0.027), test weight (-0.082), leaf area index (-0.039), hulling recovery (-0.122), milling recovery (-0.636), kernel breadth (-1.853), kernel breadth after cooking (-0.004), volume expansion ratio (-0.032), water uptake (-0.123) and amylose content (-0.001). These results are in accordance with Mahalingam *et al.* (2013), Nandan *et al.* (2010), Parvathi (2010), Praveen *et al.* (2010), Prem Kumar *et al.* (2010) and Nagajyothi (2001).

4.3.1.6.11 Milling Recovery (%)

Milling recovery exerts negative direct effect (-0.667) and significant positive association (0.605**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.147), total number of tillers per plant (0.472), total number of ear bearing tillers per plant (0.103), panicle length (0.448), head rice recovery (1.015), kernel length (0.634), L/B ratio (1.199), kernel length after cooking (0.445), gel consistency (0.054), alkali spreading value (0.035) and amylose content (0.014). It also had negative indirect effects through days to maturity (-0.187), plant height (-0.050), number of grains per panicle (-0.098), test weight (-0.187), leaf area index (-0.043), hulling recovery (-0.116), milling recovery (-0.667), kernel breadth (-2.282), kernel breadth after cooking (-0.004), kernel linear elongation ratio (-0.235), volume expansion ratio (-0.024) and water uptake (-0.067). These findings are corroborated by Madhusoodanan (2013), Nagaraju *et al.* (2013) and Ruth *et al.* (2011).

4.3.1.6.12 Head Rice Recovery (%)

The trait, head rice recovery showed positive direct effect (1.342) and significant positive association (0.549**) on grain yield per plant at phenotypic level. It also had positive indirect effects through days to 50% flowering (0.189), total number of tillers per plant (0.347), total number of ear bearing tillers per plant (0.083), panicle length (0.287), head rice recovery (1.342), kernel length (0.003), L/B ratio (0.965), kernel length after cooking (0.294), kernel breadth after cooking (0.000), gel consistency (0.046) and amylose content (0.033). Whereas, negative indirect effects through days to maturity (-0.231), plant height (-0.080), number of grains per panicle (-0.079), test weight (-0.306), leaf area index (-0.095), hulling recovery (-0.086), milling recovery (-0.505), kernel breadth (-1.103), kernel linear elongation ratio (-0.314), volume expansion ratio (-0.081), water uptake (-0.115) and alkali spreading value (-0.046). These results are in consonance with findings of Krishna Veni *et al.* (2013), Ruth *et al.* (2011), Praveen *et al.* (2010) and Nayak *et al.* (2005).

4.3.1.6.13 Kernel Length (mm)

This character showed non-significant negative correlation (-0.003) and positive direct effect (3.063) on grain yield per plant at genotypic level. It also showed positive indirect effects through days to 50% flowering (0.097), total number of tillers per plant (0.034), total number of ear bearing tillers per plant (0.032), panicle length (0.221), leaf

area index (0.001), head rice recovery (0.001), kernel length (3.063), kernel length after cooking (0.775), kernel breadth after cooking (0.000), kernel linear elongation ratio (0.337), volume expansion ratio (0.038), water uptake (0.064), gel consistency (0.012), alkali spreading value (0.025) and amylose content (0.014); while positive indirect effects *via* days to maturity (-0.138), plant height (-0.019), number of grains per panicle (-0.016), test weight (-0.123), hulling recovery (-0.021), milling recovery (-0.138), kernel breadth (-3.710) and L/B ratio (-0.552). These results were in broad agreement with the findings of Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013) and Krishna Veni *et al.* (2013).

4.3.1.6.14 Kernel Breadth (mm)

Kernel breadth expressed non-significant positive association (0.077) and negative direct effect (-7.616) on grain yield per plant at genotypic level. It also showed positive indirect effects through days to 50% flowering (0.129), total number of tillers per plant (0.301), total number of ear bearing tillers per plant (0.070), panicle length (0.317), leaf area index (0.025), head rice recovery (0.194), kernel length (1.492), L/B ratio (5.184), kernel length after cooking (0.159), kernel linear elongation ratio (0.386), volume expansion ratio (0.062), gel consistency (0.013) and amylose content (0.008). Whereas negative indirect effects *via* days to maturity (-0.175), plant height (-0.006), number of grains per panicle (-0.043), test weight (-0.124), hulling recovery (-0.030), milling recovery (-0.200), kernel breadth (-7.616), kernel breadth after cooking (-0.006), water uptake (-0.057) and alkali spreading value (-0.008). Similar kind of association was earlier reported by Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013) and Krishna Veni *et al.* (2013), Ruth *et al.* (2011) and Nandan *et al.* (2010) and Praveen *et al.* (2010).

4.3.1.6.15 Kernel Length/Breadth Ratio

Kernel L/B ratio expressed negative direct effect (-6.282) and non-significant negative association (-0.086) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.110), number of grains per panicle (0.038), test weight (0.064), hulling recovery (0.021), milling recovery (0.127), kernel length (0.269), kernel breadth (6.285), kernel length after cooking (0.342), kernel breadth after cooking (0.007), water uptake (0.111), alkali spreading value (0.029) and amylose content (0.002); and negative indirect effect through days to 50% flowering (-0.084), plant height (-0.004), total number of tillers per plant (-0.316), total number of ear

bearing tillers per plant (-0.056), panicle length (-0.218), leaf area index (-0.027), head rice recovery (-0.206), L/B ratio (-6.282), kernel linear elongation ratio (-0.247), volume expansion ratio (-0.043) and gel consistency (-0.007). Shathisha *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013), Krishna Veni *et al.* (2013), Awaneet and Senapati (2013), Nagaraju *et al.* (2013), Khatu *et al.* (2010), Nandan *et al.* (2010) and Praveen *et al.* (2010), also reported similar association.

4.3.1.6.16 Kernel Length after Cooking (mm)

The trait, kernel length after cooking expressed positive direct effect (1.570) and non-significant positive association (0.127) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.046), plant height (0.013), panicle length (0.055), head rice recovery (0.251), kernel length (1.512), kernel length after cooking (1.570), kernel breadth after cooking (0.003), water uptake (0.100), gel consistency (0.007), alkali spreading value (0.105) and amylose content (0.027); and exhibited negative indirect effect *via* days to maturity (-0.049), total number of tillers per plant (-0.099), total number of ear bearing tillers per plant (-0.002), number of grains per panicle (-0.013), test weight (-0.079), leaf area index (-0.001), hulling recovery (-0.012), milling recovery (-0.189), kernel breadth (-0.769), L/B ratio (-1.367), kernel linear elongation ratio (-0.980) and volume expansion ratio (-0.002). The above results were in agreement with Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Prem Kumar *et al.* (2010) and Nandan *et al.* (2010), Parvathi (2010), Prem Kumar *et al.* (2010) and Afzal *et al.* (2006).

4.3.1.6.17 Kernel Breadth after Cooking (mm)

At genotypic level, this trait had negative direct effect (-0.018) and significant positive association (0.271**) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.062), plant height (0.009), total number of tillers per plant (0.351), total number of ear bearing tillers per plant (0.039), panicle length (0.285), test weight (0.064), leaf area index (0.016), kernel length (0.018), L/B ratio (2.570), kernel linear elongation ratio (0.277) and gel consistency (0.008); while showed negative indirect effect *via* days to maturity (-0.090), number of grains per panicle (-0.059), hulling recovery (-0.029), milling recovery (-0.161), head rice recovery (-0.015), kernel breadth (-2.650), kernel length after cooking (-0.285), kernel breadth after cooking (-0.018), volume expansion ratio (-0.006), water uptake (-0.062), alkali spreading value (-0.033) and amylose content (-0.021). Similar results were confirmed by Nandan *et al.* (2010) and Prem Kumar *et al.* (2010).

4.3.1.6.18 Kernel Linear Elongation Ratio

At genotypic level, this trait had negative direct effect (-1.361) and non-significant positive association (0.154) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.053), plant height (0.028), test weight (0.006), leaf hulling recovery (0.001), head rice recovery (0.309), kernel breadth (2.158), kernel length after cooking (1.131), kernel breadth after cooking (0.004), water uptake (0.058), alkali spreading value (0.094) and amylose content (0.019). This trait exhibited negative indirect effect through days to 50% flowering (-0.025), total number of tillers per plant (-0.132), total number of ear bearing tillers per plant (-0.026), panicle length (-0.109), number of grains per panicle (-0.003), area index (-0.003), milling recovery (-0.115), kernel length (-0.759), L/B ratio (-1.139), kernel linear elongation ratio (-1.361), volume expansion ratio (-0.034) and gel consistency (-0.001). These findings were in line with the results obtained by Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Parvathi (2010), Prem Kumar *et al.* (2010) and Krishna *et al.* (2009a).

4.3.1.6.19 Volume Expansion Ratio

Volume expansion ratio exhibited positive direct effect (0.205) and significant negative association (-0.209*) on grain yield per plant at genotypic level. It also had negative indirect effects through days to 50% flowering (0.050), plant height (0.040), number of grains per panicle (0.025), test weight (0.095), leaf area index (0.069), hulling recovery (0.019), milling recovery (0.078), kernel length (0.568), L/B ratio (1.322), kernel breadth after cooking (0.001), kernel linear elongation ratio (0.226), volume expansion ratio (0.205), water uptake (0.059) and alkali spreading value (0.069); while it showed negative indirect effects through days to maturity (-0.062), total number of tillers per plant (-0.080), total number of ear bearing tillers per plant (-0.011), panicle length (-0.001), head rice recovery (-0.532), kernel breadth (-2.315), kernel length after cooking (-0.015), gel consistency (-0.016) and amylose content (-0.002). These results were in broad agreement with the findings of Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Praveen *et al.* (2010) and Satyavathi *et al.* (2001).

4.3.1.6.20 Water Uptake (ml)

This character expressed non-significant positive correlation (0.131) and positive direct effect (0.364) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to maturity (0.148), number of grains per panicle

(0.033), test weight (0.021), leaf area index (0.007), hulling recovery (0.041), milling recovery (0.123), kernel length (0.543), kernel breadth (1.196), kernel length after cooking (0.434), kernel breadth after cooking (0.003), volume expansion ratio (0.033), water uptake (0.364), gel consistency (-0.025) and alkali spreading value (0.080); while negative indirect effects through days to 50% flowering (-0.116), plant height (-0.019), total number of tillers per plant (-0.010), total number of ear bearing tillers per plant (-0.016), panicle length (-0.138), head rice recovery (-0.425), L/B ratio (-1.925), kernel linear elongation ratio (-0.216) and amylose content (-0.006). These results were in broad agreement with the findings of Krishna Veni *et al.* (2013), Parvathi *et al.* (2010) and Prem Kumar *et al.* (2010)

4.3.1.6.21 Gel Consistency (mm)

Gel consistency exerts significant positive association (0.320**) and positive direct effect (0.093) on grain yield per plant at genotypic level followed by indirect effects *via* days to 50% flowering (0.139), total number of tillers per plant (0.232), total number of ear bearing tillers per plant (0.051), panicle length (0.236), head rice recovery (0.664), kernel length (0.394), L/B ratio (0.454), kernel length after cooking (0.112), kernel linear elongation ratio (0.021) and gel consistency (0.093); while, it showed negative indirect effects *via* days to maturity (-0.187), plant height (-0.041), number of grains per panicle (-0.056), test weight (-0.127), leaf area index (-0.011), hulling recovery (-0.038), milling recovery (-0.389), kernel breadth (-1.063), kernel breadth after cooking (-0.002), volume expansion ratio (-0.036), water uptake (-0.096), alkali spreading value (-0.001) and amylose content (-0.004).

4.3.1.6.22 Alkali Spreading Value (mm)

Alkali spreading value expressed positive direct effect (0.313) and non-significant negative association (-0.001) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.100), plant height (0.035), number of grains per panicle (0.022), test weight (0.008), leaf area index (0.018), kernel length (0.243), kernel breadth (0.188), kernel length after cooking (0.526), kernel breadth after cooking (0.002), volume expansion ratio (0.045), water uptake (0.093), gel consistency (0.000) and alkali spreading value (0.313). Whereas, this trait exhibited negative indirect effect through days to 50% flowering (-0.072), total number of tillers per plant (-0.132), total number of ear bearing tillers per plant (-0.032), panicle length (-0.075), hulling recovery (-0.001), milling recovery (-0.075), head rice recovery (-0.199), L/B ratio (-0.586), kernel linear elongation ratio (-0.410) and amylose content (-0.011).

4.3.1.6.23 Amylose Content (%)

This character expressed negative direct effect (-0.136) and non-significant negative association (-0.154) on grain yield per plant. This trait exhibited positive indirect effect *via* days to 50% flowering (0.034), total number of tillers per plant (0.049), total number of ear bearing tillers per plant (0.011), panicle length (0.041), number of grains per panicle (0.046), leaf area index (0.021), milling recovery (0.066), kernel breadth (0.468), L/B ratio (0.083), kernel linear elongation ratio (0.194), volume expansion ratio (0.004), water uptake (0.017), gel consistency (0.002) and alkali spreading value (0.026). Whereas negative indirect effect through days to maturity (-0.046), plant height (-0.007), test weight (-0.075), hulling recovery (-0.001), head rice recovery (-0.325), kernel length (-0.314), kernel length after cooking (-0.309), kernel breadth after cooking (-0.003) and amylose content (-0.136). These findings are in conformity with the results of Patel *et al.* (2014), Krishna Veni *et al.* (2013), Garg *et al.* (2010) and Nagajyothi (2001).

In plant breeding it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield *i.e.*, residual effect measures the role of the possible independent variables which were not included in the study on the dependent variable. In the present study, the residual effect at genotypic level was 0.4472 indicating that the characters included in the present investigation are contributing more than 55.28 per cent of variability pertaining the dependent variable *i.e.*, yield. Less than forty-five per cent of contribution is from the few other characters which were not included in the present study.

Path analysis revealed the true relationship of total number of tillers per plant, number of ear bearing tillers per plant, panicle length per plant, head rice recovery and gel consistency by establishing significant positive association and positive direct effect on grain yield per plant whereas days to 50% flowering showed true relationship by establishing significant negative association and negative direct effect on grain yield per plant.

Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that simultaneous improvement of grain yield per plant coupled with good quality traits was possible through manifestation of days to 50% flowering, total number of tillers per plant, number of ear bearing tiller per plant, panicle length, head rice recovery and gel consistency.

The present study, combining ability analysis using diallel analysis (without reciprocals) has identified the lines/varieties lines, MTU 1001, MTU 1121 and MTU 1140, as the good general combiners and the crosses, MTU 1121 $\times$ MTU 1140, MCM 100 $\times$ MTU 1140 and MTU 1001 $\times$ MTU 1061 as the good specific combiners for grain yield per plant. Thus, the identified lines/varieties and hybrids can be used in future breeding programme as follows.

- The lines/varieties having good *gca* effects (MTU 1001, MTU 1121 and MTU 1140) can be used in the heterosis breeding programme for the exploitation of the traits to improve the yield potential.
- The crosses, MTU 1121 $\times$ MTU 1140, MCM 100 $\times$ MTU 1140 and MTU 1001 $\times$ MTU 1061 can be evaluated over environments to confirm their superiority.

4.3.2 F₁ RATOON CROP

Diallel mating design involving hybridization among 8 parents without reciprocals, generated 28 hybrids during *kharif*, 2015 and these 28 F₁s and their 8 parents were evaluated at Andhra Pradesh Rice Research Station (APRRI) and Regional Rice Research Station (RARS), Maruteru, West Godavari, Andhra Pradesh during *Summer*, 2016 after the harvest of the main crop in *rabi*, 2015-16 for various qualitative and quantitative characters.

The data collected on 28 hybrids along with eight parents for 27 different traits for ratoon crop was subjected to standard statistical analysis for drawing valid conclusions. The details of results obtained from the above investigation are discussed character-wise and presented here under the following headings.

4.3.2.1 Analysis of variance

4.3.2.2 Mean, genetic variability, heritability and genetic advance

4.3.2.3 Combining ability

4.3.2.4 Heterosis

4.3.2.5 Character association

4.3.2.6 Path coefficient analysis

4.3.2.1 ANALYSIS OF VARIANCE

The analysis of variance (ANOVA) of 28 F₁s along with their 8 parents for yield components and grain quality traits are presented in Table 4.26. The results revealed existence of significant differences among the rice varieties/ lines studied for all the characters

4.3.2.2 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Presence of wider spectrum of variability will enhance the chances of selecting desired genotypes. Besides genetic variability, knowledge on heritability and genetic advance indicate the extent to which a character is transmitted to progeny, thereby helping the breeder to employ a suitable breeding strategy to achieve the objective quickly. Therefore, for successful improvement of any crop, it is necessary to have a thorough knowledge on the variability present in the available breeding material.

Burton and Devane (1953) and Swarup and Chaugle (1962) indicated that the genetic variability together with the heritability would give a better idea about the extent of genetic advance expected out of selection. The magnitude of heritable variability is the most important aspect of genetic contribution of the breeding material, which has close relationship with response to selection (Panse, 1957).

The mean performance of parents and F₁s ratoon was presented in Table 4.27. The analysis of variance revealed significant differences among the genotypes for all the characters indicating a high degree of variability in the material (Table 4.26). The estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2 broad sense) and genetic advance as per cent of mean (GAM) are presented in Table 4.28 and described character wise here under.

4.3.2.2.1 Days to 50% Flowering

The range of variation for number of days to 50% flowering varied from 55.67 days (MTU 1001 × MTU 1061) to 70.00 days (MTU 1140 × MTU 1064) with a mean of 62.11 days. The PCV (6.08) and GCV (5.19) estimates were low indicating less variation for days to 50% flowering among the entries studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotype but also due to influence of environment. Selection for such traits sometimes may be

misleading. Similar estimates of PCV and GCV were earlier reported by Allam *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Thirumala Rao *et al.* (2014), Aditya Kumar *et al.* (2013), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013) and Shiva Prasad *et al.* (2013).

High heritability (72.80%) in conjunction with low genetic advance as per cent of mean (9.12) was noted for this trait, where the inheritance of this trait may be due to predominance of both additive and non-additive gene actions. These findings are in conformity with the results of Navin Kumar *et al.* (2015), Vijay Kumar *et al.* (2015), Lingaiah *et al.* (2014), Thirumala Rao *et al.* (2014), Mulugeta *et al.* (2012) and Seyoum *et al.* (2012).

4.3.2.2.2 Days to Maturity

There is significant variation for days to maturity varied from 82.67 days (MTU 1001 × MTU 7029) to 104.00 days (MTU 1140 × MTU 1064) with a mean of 92.20 days. The estimates of PCV (6.02) and GCV (5.61) were low indicating less variation among the genotypes studied. These findings are corroborated by Allam *et al.* (2015), Sameera *et al.* (2015), Vijay Kumar *et al.* (2015), Alam *et al.* (2014), Arpita *et al.* (2014), Bornare *et al.* (2014), Atif and Khalid (2013), Awaneet Kumar and Senapati (2013), Gulzar *et al.* (2013) and Toshimenla and Sapu (2013).

High heritability (87.0%) coupled with moderate genetic advance as per cent of mean (10.78) was observed for this trait indicating the operation of both additive and non-additive gene actions in the inheritance of this trait. These results are in accordance with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Alam *et al.* (2014), Arpita *et al.* (2014), Singh *et al.* (2014), Ashok Kumar *et al.* (2013), Atif and Khalid (2013), Toshimenla and Sapu (2013), Sangam Kumar Singh *et al.* (2011) and Seyed Mustafa Sadeghi (2011).

4.3.2.2.3 Plant Height (cm)

The plant height ranged from 85.05 cm (BPT 3291 × MTU 7029) to 122.53 cm (MCM 100 × MTU 7029) with a mean of 106.51 cm. The estimates of PCV (8.54) and GCV (8.25) were low indicated less variation among the genotypes studied. These results are in consonance with findings of Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Thirumala Rao *et al.* (2014), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013), Mulugeta *et al.* (2012) and Akhtar *et al.* (2011).

High heritability (93.40%) accompanied with moderate genetic advance as per cent of mean (16.43) was observed for this trait indicating the predominance of both additive and non-additive gene action in the inheritance of this character. These findings were in line with the results obtained by Keya *et al.* (2015), Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Alam *et al.* (2014), Rahman *et al.* (2014), Paikhomba *et al.* (2013), Sathya and Jebaraj (2013) and Toshimenla and Sapu (2013).

4.3.2.2.4 Total Number of Tillers per Plant

The variation for this total number of tillers per plant ranged from 8.00 (MTU 1001 × MTU 7029) to 11.67 (MTU 1001 × MTU 1140) with a mean of 9.62. The estimate of PCV (11.89) was moderate and GCV (7.42) was low indicated moderate variation among the genotypes studied. These results were in broad agreement with the findings of Gokulakrishnan *et al.* (2014), Mamunur *et al.* (2014), Paikhomba *et al.* (2013) and Akinwale *et al.* (2011).

Moderate heritability (38.90%) combined with low genetic advance as per cent of mean (9.53) was observed for this trait indicating character is highly influenced by environmental effects and selection would be ineffective. These findings are in conformity with the results of Navin Kumar *et al.* (2015), Gokulakrishnan *et al.* (2014), Mamunur *et al.* (2014), Paikhomba *et al.* (2013) and Ravindra Babu *et al.* (2012).

4.3.2.2.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers

The range of variation for this character ranged from 57.14 (MTU 1001 × MTU 7029) to 86.97 (MTU 1121) with a mean of 65.78. The estimates of PCV (16.75) and GCV (11.37) were high indicating moderate variation among the genotypes studied.

Moderate heritability (46.10%) together with moderate genetic advance as per cent of mean (15.91) was observed for this trait indicating character is highly influenced by environmental effects and selection would be ineffective.

4.3.2.2.6 Number of Vegetative Buds after the Harvest of Main Crop

The trait, number of vegetative buds after the harvest of main crop ranged from 10.00 (MTU 1121 × MTU 1140) to 13.00 (MTU 1001 × MTU 1140) with a mean of 11.50. The estimates of PCV (8.80) and GCV (4.47) were high indicating low variation among the genotypes studied.

Low heritability (25.70%) combined with low genetic advance as per cent of mean (4.67) was noticed that the character is highly influenced by environmental effects and selection would be ineffective.

4.3.2.2.7 Number of Ear Bearing Tillers per Plant

There is a significant variation for number of ear bearing tillers per plant from 4.67 (BPT 3291 × MTU 7029) to 9.00 (MTU 1001 × MTU 1140) with a mean of 6.81. The estimates of PCV (18.02) and GCV (14.20) were high indicating moderate variation among the entries studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. The above results were in agreement with Keya *et al.* (2015), Navin Kumar *et al.* (2015), Gokulakrishnan *et al.* (2014), Mamunur *et al.* (2014), Ravindra Babu *et al.* (2012), Shiva Prasad *et al.* (2011), Sivaparthi *et al.* (2011) and Ullah *et al.* (2011).

High heritability (62.10%) supplemented with high genetic advance as per cent of mean (23.05) was observed for this trait indicating the predominance of additive gene action in the inheritance of this trait. Similar results were earlier reported by Allam *et al.* (2015), Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Arpita *et al.* (2014), Bornare *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Perera *et al.* (2014), Gangashetty *et al.* (2013), Sathya and Jebaraj (2013) and Ukaoma *et al.* (2013).

4.3.2.2.8 Number of Ratoon Ear bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

The range of variation for this character ranged from 41.18 cm (BPT 3291 × MCM 100) to 76.77 cm (MTU 1064) with a mean of 58.15 cm. The estimates of PCV (19.89) and GCV (13.86) were moderate indicating moderate variability. The magnitude of PCV was greater than GCV indicated that the expression of this trait.

Moderate heritability (48.60%) coupled with moderate genetic advance as per cent of mean (19.90) was observed for this trait revealing the preponderance of non-additive gene action in the inheritance of this trait.

4.3.2.2.9 Panicle Length (cm)

There is significant variation for panicle length per plant in the material studied which ranged from 23.56 (BPT 3291) to 33.14 (MCM 100 × MTU 1140) with a mean of 28.25. The estimates of PCV (9.62) and GCV (7.97) for this trait were low indicating less variation among the entries studied (Plate 4.11). These findings are corroborated by Navin Kumar *et al.* (2015), Sameera *et al.* (2015), Alam *et al.* (2014), Bornare *et al.* (2014), Thirumala Rao *et al.* (2014), Aditya Kumar *et al.* (2013), Atif and Khalid (2013), Paikhomba *et al.* (2013) and Sathya and Jebaraj (2013).

High heritability (68.70%) in conjunction with moderate genetic advance as per cent of mean (13.60) was recorded for this trait indicating the operation of both additive and non-additive gene actions in the inheritance of this trait. These results are in accordance with Sameera *et al.* (2015), Shajedur Hossain *et al.* (2015), Vijay Kumar *et al.* (2015), Lingaiah *et al.* (2014), Mamunur *et al.* (2014), Sandhya *et al.* (2014) and Singh *et al.* (2014).

4.3.2.2.10 Number of Grains per Panicle

The range of variation for this trait, varied from 108.69 (MTU 1001) to 222.28 (MCM 100 × MTU 1140) with a mean of 162.21. The estimates of PCV (16.19) and GCV (14.99) for this trait were moderate indicating moderate variation among the entries studied. The magnitude of PCV was greater than GCV indicated that the apparent variation is not only due to genotypes but also due to influence of environment. Selection for such traits sometimes may be misleading. These results are in consonance with findings of Keya *et al.* (2015), Bornare *et al.* (2014), Mamunur *et al.* (2014), Nitiprasad and Lotan Kumar (2014), Paikhomba *et al.* (2013) and Sathya and Jebaraj (2013).

High heritability (85.70%) coupled with high genetic advance as per cent of mean (28.58) was observed for this trait revealing the preponderance of additive gene action which may be exploited through simple selection procedures. These findings were in line with the results obtained by Allam *et al.* (2015), Sameera *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur Hossain *et al.* (2015), Gokulakrishnan *et al.* (2014), Lingaiah *et al.* (2014) and Nitiprasad and Lotan Kumar (2014).

4.3.2.2.11 Test Weight (g)

The range of variation observed for this varied from 16.81 (MTU 7029) to 23.78 (MTU 1001 × MCM 100) with a mean of 19.92. The estimates of PCV (8.76) and GCV (8.40) for this trait were low. These results were in broad agreement with the findings of Navin Kumar *et al.* (2015), Shajedur Hossain *et al.* (2015), Osekita *et al.* (2014), Rahman *et al.* (2014), Paikhomba *et al.* (2013), Mulugeta *et al.* (2012), Akhtar *et al.* (2011) and Satish (2000).

High heritability (92.00%) accompanied with moderate genetic advance as per cent of mean (16.60) was observed for this trait revealing the preponderance of both additive and non-additive gene action. These findings are in conformity with the results of Navin Kumar *et al.* (2015), Shajedur Hossain *et al.* (2015), Gokulakrishnan *et al.* (2014), Mulugeta *et al.* (2012), Ravindra Babu *et al.* (2012) and Seyed Mustafa Sadeghi (2011).

4.3.2.2.12 Leaf Area Index at Maximum Tillering Stage

This trait, possessed significant variation which was ranged from 1.19 (BPT 3291 × MTU 1121) to 2.82 (MTU 1001 × MTU 1140) with a mean of 1.81. The estimates of PCV (25.54) and GCV (24.57) were moderate. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. The above results were in agreement with Zulqarnain *et al.* (2012), Surender Raju (2002), Shivani and Sriramareddy (2000) and Niranjan Murthi *et al.* (1999).

Moderate heritability (92.50%) supplemented with moderate genetic advance as per cent of mean (48.69) indicated that this trait character was highly influenced by environmental effects and selection would be ineffective. Similar results were earlier reported by Satish *et al.* (2004) and Prasanthi (1993).

4.3.2.2.13 Grain Yield per Plant (g)

The range of variation for grain yield per plant varied from 11.71 g (MTU 1064 × MTU 7029) to 35.27 g (MTU 1001 × MTU 1140) with a mean of 20.29 g. The estimates of PCV (30.73) and GCV (29.96) for this trait were high respectively, showing high variability. The magnitude of PCV was greater than GCV indicated that the influence of environment on expression of this trait. These findings are corroborated by Allam *et al.* (2015), Keya *et al.* (2015), Tuhina-Khatun *et al.* (2015), Shajedur

Hossain *et al.* (Singh *et al.* (2014), Swati Sharma *et al.* (2014), Aditya Kumar *et al.* (2013), Gulzar *et al.* (2013), Shiva Prasad *et al.* (2013), Toshimenla and Sapu (2013) and Ukaoma *et al.* (2013).

High heritability (95.10%) coupled with high genetic advance as per cent of mean (60.18) was observed for this trait revealing the preponderance of additive gene action which may be exploited through simple selection procedures. These results are in accordance with Allam *et al.* (2015), Tuhina-Khatun *et al.* (2015), Navin Kumar *et al.* (2015), Nitiprasad and Lotan Kumar (2014) and Thirumala Rao *et al.* (2014).

4.3.2.2.14 Hulling Recovery (%)

The range of variation noted for hulling recovery varied from 75.70% (BPT 3291) to 81.02% (BPT 3291 $\times$ MTU 1064) with a mean of 78.97% the estimates of PCV (1.86) and GCV (1.56) were low revealing the influence of environment for expression of this trait (Plate 4.12). These results are in consonance with findings of Venkanna *et al.* (2014), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Umadevi *et al.* (2010b).

High heritability (70.30%) along with low genetic advance as per cent of mean (2.69) indicated role of non-additive gene action in governing the inheritance of this character heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. These findings were in line with the results obtained by Venkata Subbaiah *et al.* (2011), Satish Chandra *et al.* (2009) and Vanaja and Luckins (2006).

4.3.2.2.15 Milling Recovery (%)

The variation for milling recovery ranged from 70.35% (BPT 3291) to 76.89% (MTU 1001 $\times$ MTU 1140) with a mean of 72.64%. The estimates of PCV (2.79) and GCV (1.94) were low, exhibiting low variability (Plate 4.12). These results were in broad agreement with the findings of Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Satish Chandra *et al.* (2009).

High heritability (48.50%) accompanied with low genetic advance as per cent of mean (2.79) indicated role of non-additive gene action in governing the inheritance of this character. These findings are in conformity with the results of Venkata Subbaiah *et al.* (2011) Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009) and Krishna Naik (2004).

4.3.2.2.16 Head Rice Recovery (%)

There is significant variation for head rice recovery in the material studied which ranged from 65.60% (MTU 7029) to 72.35% (MTU 1001 × MTU 1140) with a mean of 69.54%. The low estimates of PCV (2.41) and GCV (2.06) indicated less variability (Plate 4.12). The above results were in agreement with Ravindra Babu *et al.* (2012), Venkata Subbaiah *et al.* (2011), Sivaparvathi *et al.* (2011), Rajeswari *et al.* (2010), Satish Chandra *et al.* (2009), Krishna Naik (2004) and Patil *et al.* (2003b).

High heritability (73.10%) coupled with low genetic advance as per cent of mean (3.63) indicated the role of non-additive gene action. Heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. Similar results were earlier reported by Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010) and Madhavalatha *et al.* (2005).

4.3.2.2.17 Kernel Length (mm)

The range of variation for this character ranged from 5.09 mm (MCM 100 × MTU 1140) to 5.97 mm (BPT 3291 × MTU 1140) with a mean of 5.45 mm. The estimates of PCV (3.43) and GCV (2.91) were low, reveals the influence of environment of this trait. These findings are corroborated by Tuhina-Khatun *et al.* (2015), Gokulakrishnan *et al.* (2014), Osekita *et al.* (2014), Venkanna *et al.* (2014), Aditya Kumar *et al.* (2013), Awaneet Kumar and Senapati (2013), Ravindra Babu *et al.* (2012) and Venkata Subbaiah *et al.* (2011).

High heritability (72.0%) together with low genetic advance as per cent of mean (5.08) indicated the role of non-additive gene action in governing the inheritance of this character. These results are in accordance with Seyed Mustafa Sadeghi (2011) and Prasad *et al.* (2009).

4.3.2.2.18 Kernel Breadth (mm)

The range of variation observed for this trait varied from 1.70 mm (MTU 1001 × MTU 1064) to 2.23 mm (MTU 1001 × MTU 7029) with a mean of 2.01 mm. The estimates of PCV (5.20) and GCV (4.79) were low, indicating low variability. These results are in consonance with findings of Allam *et al.* (2015), Venkanna *et al.* (2014), Aditya Kumar *et al.* (2013), Awaneet Kumar and Senapati (2013) and Ravindra Babu *et al.* (2012).

High heritability (84.60%) along with low genetic advance as per cent of mean (9.07) the role of non-additive gene action in governing the inheritance of this character selection for such traits may not be rewarded. These findings were in line with the results obtained by Ravindra Babu *et al.* (2012), Seyed Mustafa Sadeghi (2011), Venkata Subbaiah *et al.* (2011) and Prasad *et al.* (2009).

4.3.2.2.19 Kernel Length (L)/Breadth (B) Ratio

The variation for kernel length/breadth ratio was ranged from 2.50 (MTU 1001 × MTU 7029) to 3.15 (MTU 1001 × MTU 1064) with a mean of 2.72. The estimates of PCV (4.89) and GCV (4.06) were low, showing low variation. These results were in broad agreement with the findings of Venkanna *et al.* (2014) and Venkata Subbaiah *et al.* (2011).

High heritability (69.00%) accompanied with low genetic advance as per cent of mean (6.95) indicated the role of non-additive gene action in governing the trait. Heritability is being exhibited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarded. Similar results were earlier reported by Mohan Lal and Chauhan (2011), Singh *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Verma *et al.* (2011).

4.3.2.2.20 Kernel Length after Cooking (mm)

The variation for kernel length after cooking ranged from 8.54 (MTU 7029) to 9.88 (MTU 1061) with a mean of 9.33. The low estimates of PCV (4.11) and GCV (3.90) indicates less variability. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Venkata Subbaiah *et al.* (2011).

High heritability (90.10%) together with low genetic advance as per cent of mean (7.62) indicated the role of non-additive gene action in governing the inheritance of this character. The above results were in agreement with Venkata Subbaiah *et al.* (2011), Sarkar *et al.* (2007) and Krishna Naik (2004).

4.3.2.2.21 Kernel Breadth after Cooking

This variation for kernel breadth after cooking ranged from 2.60 (MTU 1001 × MTU 1064) to 3.29 (MCM 100 × MTU 1140) with a mean of 2.93. The estimates of PCV (8.10) and GCV (7.07) were low; the magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. These findings are in conformity with the results of Venkata Subbaiah *et al.* (2011).

High heritability (76.00%) coupled with moderate genetic advance as per cent of mean (12.69) indicated the role of additive and non-additive gene action in governing the inheritance of this character. Similar results were earlier reported by Venkata Subbaiah *et al.* (2011).

4.3.2.2.22 Kernel Elongation Ratio

The range of variation noted for this trait varied from 1.57 (BPT 3291 × MTU 1140) to 1.85 (MTU 1001 × MTU 1121) with a mean of 1.71. The estimates of PCV (4.22) and GCV (3.47) were low. The magnitude of PCV was higher than GCV revealing the influence of environment in inheritance of this trait. Similar results were earlier reported by Allam *et al.* (2015), Venkata Subbaiah *et al.* (2011), Sunayana *et al.* (2010), Vanaja and Luckins (2006) and Krishna Naik (2004).

High heritability (67.40%) along with low genetic advance as per cent of mean (5.87) indicated the role of non-additive gene action in governing the inheritance of this character and selection for such traits may not be rewarding. These findings are corroborated by Sunayana *et al.* (2010) and Madhaviatha *et al.* (2005).

4.3.2.2.23 Volume Expansion Ratio

Volume expansion ratio ranged from 3.88 (BPT 3291 × MTU 1140) to 5.00 (MTU 1061 × MTU 7029) with a mean of 4.51. The estimates of PCV (7.02) and GCV (6.22) were low. The magnitude of PCV was higher than GCV revealing the influence of environment on expression of this trait. These findings are in conformity with the results of Venkata Subbaiah *et al.* (2011).

High heritability (78.40%) coupled with low genetic advance as per cent of mean (11.34) indicated that the character is highly influenced by environmental effects and selection would be ineffective. Contrary, high heritability coupled with high genetic advance as per cent of mean was reported by Ravindra Babu *et al.* (2012), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006), this might be due to differences in breeding material studied under different environments.

4.3.2.2.24 Water Uptake (ml)

This character possessed significant variation which was ranged from 156.33 (BPT 3291) to 285.33 (MTU 1001 × MTU 1064) with a mean of 210.94. The estimates of PCV (13.06) and GCV (12.72) were moderate. The magnitude of PCV was higher

than GCV revealing the influence of environment on expression of this trait. These results are in accordance with Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Umadevi *et al.* (2010b) and Vanaja and Luckins (2006).

High heritability (94.80%) supplemented with high genetic advance as per cent of mean (25.52) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. These results are in consonance with findings of Sivaparvathi *et al.* (2011), Chakraborty *et al.* (2010), Umadevi *et al.* (2010b), Vanaja and Luckins (2006) and Yadav *et al.* (2002).

4.3.2.2.25 Gel Consistency (mm)

The variation for gel consistency ranged from 37.29 (MTU 1064 × MTU 1061) to 95.21 (MCM 100 × MTU 1061) with a mean of 66.42. The high estimates of PCV (29.77) and GCV (29.39) reveals high variability. These findings were in line with the results obtained by Sivaparvathi *et al.* (2011), Umadevi *et al.* (2010b) and Asish Binodh *et al.* (2007).

High heritability (97.50%) along with high genetic advance as per cent of mean (59.76) indicates that most likely the heritability is due to additive gene effects and selection may be effective. These results were in broad agreement with the findings of Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011) and Manonmani *et al.* (2010).

4.3.2.2.26 Alkali Spreading Value (mm)

The range of variation for alkali spreading value varied from 2.50 (MCM 100 × MTU 1121) to 6.22 (MTU 1001) with a mean of 4.34. The estimates of PCV (26.80) and GCV (26.33) were high, indicating high variation. These findings are in conformity with the results of Allam *et al.* (2015), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010), Sunayana *et al.* (2010) and Umadevi *et al.* (2010b).

High heritability (96.60%) supplemented with high genetic advance as per cent of mean (53.31) indicated the role of additive gene action in governing the inheritance of this character and offers the scope for improvement through simple selection. These findings are in conformity with the results of Allam *et al.* (2015), Ravindra Babu *et al.* (2012), Sivaparvathi *et al.* (2011), Venkata Subbaiah *et al.* (2011), Chakraborty *et al.* (2010), Rajeswari *et al.* (2010), Sunayana *et al.* (2010) and Umadevi *et al.* (2010b).

4.3.2.2.27 Amylose Content (%)

Amylose content possessed significant variation which was ranged from 18.13 (MCM 100 × MTU 1061) to 30.90 (MTU 1121 × MTU 7029) with a mean of 22.92. The estimates of PCV (13.97) and GCV (13.69) were moderate, exhibiting moderate variability. The above results were in agreement with Sunayana *et al.* (2010), Asish Binodh *et al.* (2007), Vanaja and Luckins (2006) and Patil *et al.* (2003b).

High heritability (96.00%) coupled with high genetic advance as per cent of mean (27.62) indicated that most likely the heritability is due to additive gene action and selection may be effective. These findings are corroborated by Venkata Subbaiah *et al.* (2011), Rajeswari *et al.* (2010), Sunayana *et al.* (2010), Umadevi *et al.* (2010b), Asish Binodh *et al.* (2007), Krishnaveni *et al.* (2006a), Vanaja and Luckins (2006) and Patil *et al.* (2003b).

Thus, in the present study of analysis of variance revealed that significant differences among the entries for all the traits studied indicating the existence of high degree of variability in the material. The magnitude of difference between PCV and GCV was relatively low for all the traits except total number of tillers per plant, number of ratoon tillers as percentage of main crop tillers, number of vegetative buds after harvest of main crop, total ear bearing tillers per plant, number of ear bearing tillers as percentage of main crop ear bearing tillers, panicle length, number of grain per panicle, LAI, grain yield per plant, kernel length, kernel length after cooking, kernel linear elongation ratio and volume expansion ratio revealed least influence of environment on these traits. The magnitude of PCV was higher than GCV for all the characters which revealed the influence of environment on expression of this trait.

High variability was observed in case of leaf area index, grain yield per plant, gel consistency and alkali spreading value which indicated their amenability towards directional selection. The traits number of ratoon tillers as percentage of main crop tillers, total ear bearing tillers per plant, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers, number of grains per panicle, water uptake and amylose content recorded moderate variability, while the remaining characters exhibited low variability.

The estimates of heritability and genetic advance as per cent of means were high for most of the characters viz., number of ear bearing tillers per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, water uptake, gel

consistency and alkali spreading value which suggested the predominance of additive gene action and hence, improvement for this character can be achieved by pure line selection, mass selection, progeny selection and hybridization & selection with pedigree breeding.

Moderate to high heritability coupled with moderate genetic advance as per cent of mean was observed for days to maturity, plant height, number of ratoon tillers as percentage of main crop tillers, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers per plant panicle length, test weight, kernel breadth after cooking and volume expansion ratio revealed the involvement of both additive and non-additive gene action in the inheritance of these traits. Improvement in these traits is possible by recombination breeding with postponement of selection at later generations and also population improvement methods viz., cyclic hybridization, bi-parental mating and diallel selective mating. Whereas, moderate to high heritability and low genetic advance as per cent of mean was observed for days to 50% flowering, total number of tillers per plant, hulling recovery, milling percentage, head rice recovery, kernel length, kernel breadth, L/B ratio, kernel length after cooking and elongation ratio indicated the role of non-additive gene action in governing the inheritance of this character. The heritability is being exhibited due to favourable influence of environment rather than genotype, where this trait can be improved by launching a heterosis breeding programme and recombination breeding with postponement of selection at later generations. While, low heritability coupled with low genetic advance as per cent of mean was observed for number of vegetative buds after the harvest of main crop indicated that the character is highly influenced by environmental effects and selection would be ineffective.

4.3.2.3 COMBINING ABILITY AND GENE ACTION

Knowledge on combining ability plays a significant role in crop improvement, since it helps the breeder to determine the nature and magnitude of gene action involved in the inheritance of the traits. Estimates of combining ability will be useful in selection of desirable parents based on the performance of the test cross progeny obtained by different mating designs.

The information on gene action and combining ability helps in identifying the best combiners which may be hybridized either to exploit heterosis or to produce the transgressive segregates in F_2 and subsequent generations. Exploitation of heterosis is primarily dependant on the screening and selection of lines in available germplasm that could produce better combinations of important characters.

The entire genetic variability observed for each trait was partitioned into its components *i.e.*, general and specific combining ability (Sprague and Tatum, 1942). General combining ability (*gca*) is used to designate the average performance of a line in hybrid combinations while specific combining ability (*sca*) define those crosses in which certain combinations do relatively better or worse than expected on the basis of the average performance of the lines involved. The general combining ability (*gca*) effects were due to the additive type of gene action whereas, specific combining ability (*sca*) effects are due to the genes which are non-additive *i.e.*, either dominant or epistatic in nature (Sprague and Tatum, 1942).

The relative importance of general and specific combining ability can be assessed by estimating the components of variance and expressed in the ratio $2\sigma^2 gca / 2\sigma^2 gca + \sigma^2 sca$ (Baker, 1978). The closer the ratio to unity, greater is the magnitude of additive gene action and *vice versa*. Further, the gene action can be confirmed by the estimates of narrow sense heritability. Higher values of narrow sense heritability indicate the presence of additive gene action.

In the present study, 28 F₁s and their 8 parents (ratoon crop) were evaluated during *summer*, 2016 to estimate the combining ability for yield and yield components. Analysis of variance for combining ability for different characters under study is presented in Table 4.29. The results revealed the existence of sufficient variability among the parents and cross combinations for all of the 27 characters studied in the present investigation. The character-wise estimates of *gca* effects of parents and *sca* effects of crosses are presented in Tables 4.30 and 4.31, respectively and estimates of genetic components of variance are presented in Table 4.32.

4.3.2.3.1 Days to 50% Flowering

Among eight parents involved, BPT 3291 (-2.267**), MTU 1001 (-1.633**) and MCM 100 (-1.367**) and MTU 7029 (-0.833**) recorded significant negative *gca* effects and these were identified as good general combiners for earliness. Whereas, the lines MTU 1140 (3.300**), MTU 1064 (1.500**), MTU 1061 (1.200**) and MTU 1121 (0.100) established significant positive *gca* effects and these were identified as good general combiners for late duration type. The cross, MTU 1001 × MTU 1061 (-6.011**), with high negative *gca* × high positive *gca* ($H^- gca \times H^+ gca$) parental combination showed highest significant *sca* effect followed by MTU 1001 × MTU 7029 (-3.644**) with high negative *gca* × high negative *gca* ($H^- gca \times H^- gca$) parental

combination and MTU 1001 $\times$ MTU 1064 (-3.378**) with high negative $gca \times$ high positive gca ($H^- gca \times H^+ gca$), MTU 1140 $\times$ MTU 1064 (3.089**) ($H^+ gca \times H^+ gca$), MTU 1061 $\times$ MTU 7029 (2.856**) ($H^+ gca \times H^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^- gca \times H^- gca$, $H^- gca \times H^+ gca$, $H^+ gca \times H^+ gca$ and $H^+ gca \times H^- gca$ combinations..

The gca component of variance (35.654**) was significantly greater than sca component of variance (5.690**). The ratio of gca component of variance to total genetic variance (0.926) was closer to unity. Further, the estimate of narrow sense heritability (54.70) was moderate (Table 4.32). These results revealed that role of both additive and non-additive gene action, for improvement of this trait breeding programmes recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization. The involvements of both the gene actions were earlier indicated by Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Satheeshkumar and Sravanan (2013), Utharasu and Anandakumar (2013) and Veerasha *et al.* (2013b).

4.3.2.3.2 Days to Maturity

Based on gca effects, BPT 3291 (-3.517**), MTU 1001 (-3.250**), MCM 100 (-2.017**), and MTU 7029 (-19.83**) which, exhibited significant gca effects in negative direction were found to be good general combiners for early maturity in hybridization programmes. The lines, MTU 1140 (5.383**), MTU 1064 (2.517**), MTU 1121 (1.483**) and MTU 1061 (1.383**), showed positive significant general combining ability effect, which can be used as good general combiners for late maturity. The cross combination, MTU 1001 $\times$ MTU 1061 (-6.011**) ($H^- gca \times H^+ gca$), showed highest significant sca effect followed by BPT 3291 $\times$ MTU 1064 (-4.537**) ($H^- gca \times H^+ gca$) and MTU 1001 $\times$ MTU 7029 (-4.304**) ($H^- gca \times H^- gca$) parental combination in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^- gca \times H^- gca$, and $H^+ gca \times H^+ gca$ combinations.

This trait had significant gca component of variance (100.511**) greater than sca component of variance (10.009**). The ratio of gca component of variance to total genetic variance (0.652) was closer to unity, had high narrow sense heritability (66.50).

These results revealed that role of additive in inheritance of this trait. Which can be improved by pure line selection, mass selection and progeny selection. The involvement of the gene actions were earlier indicated by Upadhyay and Jaiswal (2015), Zaazaa and Anis (2014), Koli et al (2013), Sanghera and Hussain (2013), Gulzar and Wassem (2012) and Sharma *et al.* (2012).

4.3.2.3.3 Plant Height (cm)

Out of eight parents evaluated, BPT 3291 (-5.628**), MCM 100 (-2.329**), MTU 1001 (-2.222**) and MTU 7029 (-2.041**) exhibited negative significant *gca* effects in desired direction, were identified as good general combiners for dwarfness in hybridization programme. Whereas, MTU 1140 (6.921**), MTU 1061 (3.155**) and MTU 1121 (2.079**) recorded positive significant *gca* effect, were found to be good general combiners for tallness in cross programme. The cross combination BPT 3291 $\times$ MTU 7029 (-13.795**) with high negative *gca* $\times$ high negative *gca* ($H^- gca \times H^- gca$) parental combination showed highest significant *sca* effect followed by MTU 1001 $\times$ MTU 7029 (-12.493**) with high negative *gca* $\times$ high negative *gca* ($H^- gca \times H^- gca$), MTU 1121 $\times$ MTU 1064 (-7.614**) ($H^+ gca \times L^+ gca$) and BPT 3291 $\times$ MTU 1064 (-4.958**) ($H^- gca \times L^+ gca$) in the desirable direction. The cross combination involving high $\times$ low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

The estimates of *gca* component of variance (154.839**) was significantly greater than *sca* components of variance (60.191**) indicated additive gene action. The ratio of *gca* component of variance to total genetic variance (0.231) was far away to unity, and the estimate of narrow sense heritability (33.70) was low (Table 4.32) indicated the greater in magnitude of non-additive gene action. Hence, the result conforms that this trait was under the control of both additive and non-additive gene action. These are in agreement with findings of Upadhyay and Jaiswal (2015), Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Patil and Mehta (2014) and Koli et al (2013). For improvement of this trait, the breeding methods involving selection, intermating among selected ones and reselection (or) heterosis breeding for development of hybrid variety can be employed for exploitation of both the gene actions.

4.3.2.3.4 Total Number of Tillers per Plant

The best general combiners identified for total number of tillers per plant based on positive significant *gca* effects were, MTU 1121 (0.442**) and MTU 1061 (0.308*). These parents may be utilized in breeding programmes for improvement of this trait. The cross combination, MTU 1001 $\times$ MTU 1140 (1.963**) with non-significant negative *gca* $\times$ non-significant positive *gca* ($L^- gca \times L^+ gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 7029 (1.663**) with high negative *gca* $\times$ high negative *gca* ($H^- gca \times H^- gca$) and BPT 3291 $\times$ MTU 1061 (13.96**) with non-significant positive *gca* $\times$ high positive *gca* ($L^+ gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times L^+ gca$, $H^- gca \times H^- gca$ and $L^+ gca \times H^+ gca$ combinations. These results indicate that crosses with high specific combining ability in desirable direction are resulted from the parents having both high and low *gca* effects. This indicates that one can include few low combiners along with high combiners in hybridization programme.

The estimated significant component of *gca* variance (0.913**) was significantly higher than *sca* components of variance (0.741**). The ratio of *gca* component of variance to total genetic variance (-3.161) was away from the unity, indicates the greater in magnitude of non-additive gene action and the estimate of narrow sense heritability (14.90) was low (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character. Similar results were earlier reported by Gulzar and Wassem (2012), Shyam *et al.* (2012), El-Namaky *et al.* (2010), Muhammad Yussouf *et al.* (2010). This trait can be improved by recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes.

4.3.2.3.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers

Among parents evaluated, BPT 3291 (1.204), MTU 1001 (0.892) and MTU 1121 (0.0664) exhibited non-significant *gca* effect in desired direction. The cross combination, MCM 100 $\times$ MTU 7029 (1.538) with non-significant positive *gca* $\times$ non-significant negative *gca* ($L^+ gca \times L^- gca$) showed highest low *sca* effect followed by MTU 1140 $\times$ MTU 7029 (0.508) with non-significant negative *gca* $\times$ low negative *gca*

($L^- gca \times L^- gca$) and MTU 1001 $\times$ MTU 1140 (0.431) with non-significant positive $gca \times$ non-significant negative gca ($L^+ gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from low $\times$ low general combinations. The superiority of the crosses having low gca parents may be due to high nicking ability/genetic diversity of those parents.

The estimated component of variance due to sca (93.501**) was significantly greater than gca components of variance (14.571). The ratio of gca component of variance to total genetic variance (-0.003) was away from the unity and the estimate of narrow sense heritability (-1.50) was low (Table 4.32). These results confirm the possible involvement of non-additive gene actions in the inheritance of this character. This trait can be improved by heterosis breeding or by recombination breeding with selection at later generations.

4.3.2.3.6 Number of Vegetative Buds after the Harvest of Main Crop

Based on gca effects, MTU 1001 (0.183), MTU 1121 (0.183), MTU 1061 (0.150) were found to good general combiners. These parents could be useful for improvement of this trait in hybridization programmes. The cross combination, MTU 1001 $\times$ MTU 1140 (1.333**) with non-significant positive $gca \times$ non-significant negative gca ($L^+ gca \times L^- gca$) followed by BPT 3291 $\times$ MTU 1061 (1.267**) with non-significant negative $gca \times$ non-significant negative gca ($L^- gca \times L^- gca$) and BPT-3921 $\times$ MTU 1121 (1.033*) with non-significant negative $\times$ non-significant positive ($L^- gca \times L^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times L^- gca$, $L^- gca \times L^-$ and $L^- gca \times L^+$ combinations. The cross between two low general combiners indicated that the superiority of the crosses having low gca parent may be due to high nicking ability of those parents. Thus, it can be recommended to include, some of the low combiners along with high combiners in hybridization programmes.

The estimated component of variance due to sca (0.560**) was significantly greater than gca components of variance (0.346). The ratio of gca component of variance to total genetic variance (-14.864) was away from the unity, and the estimate of narrow sense heritability (-3.20) was low (Table 4.32), indicating the operation of non-additive gene actions in the inheritance of this character. As this trait was governed by non-additive gene action, the breeding methods involving selection, intermating among selected ones and reselection (or) heterosis breeding for development of hybrid variety may help to improve this trait.

4.3.2.3.7 Number of Ear Bearing Tillers per Plant

The estimates of *gca* effects revealed that out of eight parents studied, MTU 1140 (0.700**), MTU 1064 (0.400**) and MTU 1121 (0.333*) exhibited significant positive *gca* effects, found to be good general combiners in desirable direction. The cross combination, MTU 1140 × MTU 7029 (1.752**) with high positive *gca* × high negative *gca* ($H^+ gca \times H^- gca$) parental combination showed the highest significant *sca* effects followed by MTU 1001 × MTU 1140 (1.452**) ($L^+ gca \times H^+ gca$) and BPT 3291 × MTU 1061 (1.252**) with high negative × non-significant positive ($H^- gca \times L^+ gca$) parental combination in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

This character showed significant *gca* (2.565**) and *sca* (0.767**) components of variance and noticed that *gca* was higher in magnitude than *sca*. The ratio of *gca* component of variance to total genetic variance (0.997) was near to unity, and the estimate of narrow sense heritability (38.20) was moderate. These results indicated that this trait was governed by both additive and non-additive gene action and hence, population improvement programme should be taken up for the development of superior lines with several desirable genes. These findings are corroborated by Premkumar *et al.* (2015), Upadhyay and Jaiswal (2015), Damodar *et al.* (2014) and Kolom *et al.* (2014).

4.3.2.3.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

The parents evaluated, MTU 1140 (3.926**) exhibited significant positive *gca* effects in desired direction, while MTU 7029 (-4.835**), MCM 100 (-0.467**) and BPT 3291 (-3.834**) recorded significant negative general combining ability effects. The cross combination, MTU 1140 × MTU 7029 (15.083**) with high positive *gca* × high negative *gca* ($H^+ gca \times H^- gca$) parental combination showed the highest significant *sca* effects followed by MTU 1001 × MTU 1140 (8.671) with non-significant positive *gca* × high positive *gca* ($L^- gca \times H^+ gca$) and BPT 3291 × MTU 1061 (7.388) with high negative × non-significant positive *gca* ($H^- gca \times L^+ gca$) parental combination in the desirable direction. These results indicated that the crosses

with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $L^- gca \times H^+ gca$ and $H^- gca \times L^+ gca$ combinations. Thus, revealing that the high specific combining ability in desirable direction is resulted from the parents having both high and low *gca* effects. This indicates that one can include few low combiners along with high combiners in hybridization programme.

Significant *gca* (126.076**) and *sca* (78.295**) components of variance was exhibited by this trait and *gca* variance was greater in magnitude than *sca* variance. The ratio of *gca* component of variance to total genetic variance (0.011) was away from unity. The estimate of narrow sense heritability (20.90) was low. Thus, these results showed that the inheritance of this trait was governed by both additive and non-additive gene actions. So, population improvement programme and recombination breeding with reselection at later generations was effective.

4.3.2.3.9 Panicle Length (cm)

Out of eight parents, MTU 1140 (1.260**), MTU 1064 (0.926**) and MTU 1121 (0.597**) recorded significant positive desirable general combining ability effects while lines MTU 1001 (-0.788**) and BPT 3291 (-2.052) possessed *gca* effects in negative direction.

The cross combination, MCM 100 $\times$ MTU 1140 (3.025**) with non-significant positive *gca* $\times$ high positive *gca* ($L^+ gca \times H^+ gca$) parental combination showed the highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1140 (2.840**) ($H^- gca \times H^+ gca$) and MTU 1064 $\times$ MTU 7029 (2.646**) ($H^+ gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times H^+ gca$, $H^- gca \times H^+ gca$ and $H^+ gca \times L^- gca$ combinations. The cross combination involving high $\times$ low and low $\times$ high general combiners general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners. The cross combinations involving high $\times$ high general combiner producing significant *sca* effect revealed additive and additive $\times$ additive genetic component of variance.

This trait had significant high *gca* (11.141**) than *sca* components of variance (4.513**). The ratio of *gca* component of variance to total genetic variance (0.022) was away from unity, and the estimate of narrow sense heritability (31.50) was low (Table

4.32). These results confirm the possible involvement of both additive and non-additive gene actions are of equal magnitude, population improvement programme should be taken up for the development of superior lines with several desirable genes. These results are in accordance with Premkumar *et al.* (2015), Damodar *et al.* (2014), Kolom *et al.* (2014), Gopikannan and Ganesh (2013), Sanghera and Hussain (2013) and Satheeshkumar and Sravanan (2013).

4.3.2.3.10 Number of Grains per Panicle (g)

The general combining ability studies revealed that the parents, MTU 1140 (19.839**), MTU 1121 (6.991**), MTU 1064 (4.998**) and MTU 1061 (4.113*) showed significant positive *gca* effects. This indicated that these parents are good general combiners for improvement of this trait. The cross combination MCM 100 × MTU 1140 (33.239**) with high negative × high positive *gca* ($H^- gca \times H^+ gca$) showed highest significant *sca* effect followed by MTU 1061 × MTU 7029 (29.099**) with high positive × high negative *gca* ($H^+ gca \times H^- gca$) and MCM 100 × MTU 1061 (25.568**) ($H^- gca \times H^+ gca$), in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^+ gca \times L^- gca$ and $H^- gca \times H^+ gca$ combinations.

High significant *gca* component of variance (1180.664**) was observed that *sca* components of variance (484.807**). The ratio of *gca* component of variance to total genetic variance (0.000) was away from unity and the estimate of narrow sense heritability (32.10) was low (Table 4.32). Which indicated that the character may be controlled by both additive and non-additive gene actions, where population improvement programme such as bi-parental mating, diallel selective mating systems or recombination breeding with selection at later generations should be taken up for the development of superior lines with several desirable genes. These results are in consonance with findings of Verica *et al.* (2013), Sharma *et al.* (2012), Tiwari *et al.* (2011) and Rahimi *et al.* (2010).

4.3.2.3.11 Test Weight (g)

The two parents, MTU 1001 (1.177**) and MTU 1140 (0.938**), exhibited significant positive *gca* effects for test weight in desirable direction. Hence, these are used as good general combiners for improvement of this trait in crossing programme. The cross combination, MTU 1001 × MCM 100 (2.772**) ($H^+ gca \times L^- gca$), parental

combination showed highest significant *sca* effect followed by MTU 1121 × MTU 1064 (2.069**) ($L^- gca \times H^- gca$) and BPT 3291 × MCM 100 (2.308**) ($L^- gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times L^- gca$, $L^- gca \times H^- gca$ and $L^- gca \times L^- gca$ combinations. The cross combination involving high x low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners. The cross between two low general combiners combiner producing significant *sca* effect revealed that the superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, it can be recommended to include, some of the low combiners along with high combiners in hybridization programmes.

This trait had significance of both *gca* (5.764**) and *sca* (2.161**) components of variance and *gca* variance was greater than *sca* variance. The ratio of *gca* component of variance to total genetic variance (-0.231) was away from unity and the estimate of narrow sense heritability (34.50) was low (Table 4.32). These results showed that this trait was governed by both additive and non-additive gene actions and can be improved either by population improvement methods viz., bi-parental mating, diallel selective mating systems and recombination breeding with selection at later generations. These findings were in line with the results obtained by Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gonya Nayak *et al.* (2012), Shyam *et al.* (2012) and Waghmode *et al.* (2011).

4.3.2.3.12 Leaf Area Index at Maximum Tillering Stage

Among eight parents involved, MTU 1140 (0.497**) and MTU 1001 (0.058**), MTU 1064 (0.058**), recorded significant positive general combining ability effects in desirable direction. The cross combination, MTU 1001 × BPT 3291 (0.807**) with high positive × high negative *gca* ($H^+ gca \times H^- gca$) showed highest significant *sca* effect followed by MCM 100 × MTU 1140 (0.507**) with high negative × high *gca* ($H^- gca \times H^+ gca$) and MTU 1001 × MTU 1140 (0.463**) ($H^+ gca \times H^+ gca$), in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^- gca \times H^+ gca$ and $H^+ gca \times H^+ gca$ combinations.

The estimated *gca* (0.541**) component of variance was significantly greater than *sca* (0.117**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.946) was near to unity and the estimate of narrow sense heritability (47.70) was moderate (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character and can be improved either by population improvement methods like bi-parental mating, diallel selective mating systems or even by recombination breeding and selection at later generations, these results are conformity with Sanjeev Kumar *et al.* (2009), Vanaja *et al.* (2003) and Sanjeev Kumar *et al.* (2008).

4.3.2.3.13 Grain Yield per Plant (g)

The estimate of *gca* effects were significant and positive for parents, MTU 1140 (6.431**), MTU 1001 (1.470**) and MTU 1121 (1.357**). These may be utilized in hybridization programmes for improving this important trait. The cross combination, MTU 1140 × MTU 7029 (7.434**) ($H^+ gca \times H^- gca$) showed highest significant *sca* effect followed by MTU 1001 × MTU 1140 (7.087**) ($H^+ gca \times H^+ gca$), MCM 100 × MTU 1140 (6.573**) ($H^- gca \times H^+ gca$) and MTU 1001 × MTU 1064 (5.532**) ($H^+ gca \times L^- gca$) in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability/genetic diversity of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

The *gca* component of variance (102.720**) was significantly higher than *sca* components of variance (21.292**). The ratio of *gca* component of variance to total genetic variance (0.906) was near to unity and the estimate of narrow sense heritability (48.90) was moderate (Table 4.32). Thus, showed that the inheritance of this trait was due to preponderance of both additive and non-additive gene action; reliance should be placed by recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes.. These results were in broad agreement with the findings of Premkumar *et al.* (2015), Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014), Damodar *et al.* (2014), Kolom *et al.* (2014), Malini *et al.* (2014), Patil and Mehta (2014), Zaazaa and Anis (2014) and Gopikannan and Ganesh (2013).

4.3.2.3.14 Hulling Recovery (%)

The parents, MTU 1121 (0.786**), MTU 1140 (0.575**), MTU 1064 (0.447**) and MTU 1061 (0.348**) recorded significant positive general combining ability effects while lines MTU 7029 (-0.922**), BPT 3291 (-0.477**), MCM 100 (-0.394**) and MTU 1001 (-0.362**) recorded significant negative general combining ability effects. The cross combinations MTU 1001 $\times$ BPT 3291 (2.092**) ($H^+ gca \times H^- gca$), showed highest significant *sca* effects followed by BPT 3291 $\times$ MTU 1064 (2.076**) ($H^- gca \times L^- gca$) and MTU 1064 $\times$ MTU 7029 (1.798**) ($L^- gca \times H^- gca$) parental combinations in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^- gca \times L^- gca$ and $L^- gca \times H^- gca$ combinations. The cross combinations involving high $\times$ high general combiner producing significant *sca* effect revealed additive. The cross combination involving high $\times$ low general combiners and low high general combiners producing significant *sca* effect might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

This trait showed significance for both *gca* (3.761**) and *sca* (1.221**) components of variance and *gca* variance was greater than *sca* variance. The ratio of general combining ability component of variance to total genetic variance (0.860) was near to unity. The estimate of narrow sense heritability (36.70) was also moderate (Table 4.32). These results confirm the possible involvement of additive and non-additive gene action; reliance should be placed recombination breeding with postponement of selection at later generation and population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken for the development of superior lines with desirable genes. The above results were in agreement with Gnanamalar and Vivekanandam (2013), Adilakshmi and Upendra (2014), Thakare *et al.* (2010) and Sreedhar (1999).

4.3.2.3.15 Milling Recovery (%)

The general combining ability studies revealed that, MTU 1001 (0.836**) recorded significant positive and desirable general combining ability effects while lines MCM 100 (-0.646*) possessed *gca* effects in significantly negative direction. The cross combination, MTU 1001 $\times$ MTU 1140 (3.241**), ($H^- gca \times H^+ gca$) showed highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1064 (2.715**) ($H^- gca \times H^+ gca$) and BPT 3291 $\times$ MTU 1140 (2.026**) ($H^- gca \times H^+ gca$), parental combinations in the

desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^- gca \times H^+ gca$, $H^- gca \times H^+ gca$ and $H^- gca \times H^+ gca$ combinations.

The *sca* component of variance (2.734**) was significantly greater than *gca* components of variance (2.559**). The ratio of *gca* component of variance to total genetic variance was away from unity (0.652) and the estimate of narrow sense heritability (11.90) was low (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character and can be improved either by population improvement methods population improvement methods viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization. These findings are in conformity with the results of Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Waghmode *et al.* (2011), Thakare *et al.* (2010) and Sreedhar (1999).

4.3.2.3.16 Head Rice Recovery

Out of eight parents, MTU 1140 (0.890**), MTU 1061 (0.450**) and MTU 1121 (0.354*) exhibited significant positive *gca* effect for head rice recovery in desirable direction while MTU 7029 (-1.491**) and MCM 100 (-0.680**) exhibited significant negative general combining ability effect. The cross combination, MTU 1064 $\times$ MTU 7029 (2.366**) with non-significant negative *gca* $\times$ high negative *gca* ($L^- gca \times L^- gca$) parental combination showed the highest significant *sca* effect followed by MTU 1001 $\times$ BPT 3291 (1.645**) ($H^+ gca \times L^+ gca$) and MTU 1001 $\times$ MTU 1064 (1.550**) ($H^+ gca \times L^- gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times L^- gca$, $H^+ gca \times L^+ gca$ and $H^+ gca \times L^- gca$ combinations. The cross combination involving high $\times$ low general combiners producing significant *sca* effect might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners. The cross between two low general combiners revealed, superiority of the crosses having low *gca* parents may be due to high nicking ability/ genetic diversity of their parents of those parents.

This trait exhibited significance and greater *gca* component of variance (5.643**) than *sca* components of variance (1.472**). The ratio of *gca* component of variance to total genetic variance (0.885) was near to unity and the estimate of narrow sense heritability (42.30) was moderate (Table 4.32). As this trait was governed by both

additive and non-additive gene actions are of equal magnitude, population improvement programme viz., bi-parental mating, diallel selective mating systems (or) cyclic hybridization should be taken up for the development of superior lines with several desirable genes improvement of this trait. The involvements of both the gene actions were earlier indicated by Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Asfaliza *et al.* (2012), Shyam *et al.* (2012) and Waghmode *et al.* (2011).

4.3.2.3.17 Kernel Length (mm)

Among the parents, MTU 1001 (0.065**), exhibited significant *gca* effects for number of kernel length in desirable direction, while MTU 1121 (-0.056**) exhibited significant negative general combining ability effects. The cross combination BPT 3291 $\times$ MTU 1140 (0.502**) ($L^+ gca \times H^+ gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1140 (-0.314**) ($L^- gca \times H^+ gca$) and MCM 100 $\times$ MTU 7029 (0.297**) ($L^- gca \times H^- gca$) parental combination in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times H^+ gca$, $L^- gca \times H^+ gca$ and $L^- gca \times H^- gca$ combinations. The cross combination involving high $\times$ low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

The estimated *sca* (0.032**) was significant and greater than *gca* (0.014**) components of variance. The ratio of *gca* component of variance to total genetic variance (0.465) was away from unity and the estimate of narrow sense heritability (6.20) was low (Table 4.32). These results showed that this trait was governed by both additive and non-additive gene actions in the inheritance of this character and can be improved either by recombination breeding with selection at later generations or even by heterosis breeding methods. Similar results were earlier reported by Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012) and Waghmode *et al.* (2011).

4.3.2.3.18 Kernel Breadth (mm)

The parents, MTU 1001 (0.030**) and MTU 7029 (0.020**), exhibited significant positive *gca* effects for kernel breadth in desirable direction while, MTU 1064 (-0.014**) and BPT 3291 (-0.017**) exhibited significant negative general

combining ability effect. For fine grain rice the cross combination bearing kernel breadth in negative direction would be desirable viz., MTU 1001 $\times$ MTU 1064 (-0.321**) with high positive $\times$ non-significant negative *gca* ($H^+ gca \times L^+ gca$) showed highest significant *sca* effect followed by MTU 1001 $\times$ MCM 100 (-0.083**) ($H^+ gca \times L^- gca$) and for bold varieties the cross combination MTU 1001 $\times$ MTU 7029 (0.178**) ($H^+ gca \times L^- gca$) and MCM 100 $\times$ MTU 7029 (0.127**) ($L^- gca \times L^- gca$) showed highest positive significant would be effective. Thus results indicated that the crosses with high specific combining ability in desirable direction are possible from $H^+ gca \times L^+ gca$, $H^+ gca \times L^- gca$, $H^+ gca \times L^- gca$ and $L^- gca \times L^- gca$ combinations. The cross combination involving high $\times$ low general combiners producing significant *sca* effect might be due to dominant $\times$ recessive type of interaction. The cross between two low general combiners combiner producing significant *sca* effect revealed indicated the presence of non additive gene action. The superiority of the crosses having low *gca* parents may be due to high nicking ability/ genetic diversity of those parents.

Significance of both *sca* (0.012**) and *gca* (0.003**) components of variance were observed for kernel breadth and the *sca* component of variance was greater than *gca* component of variance. The ratio of *gca* component of variance to total genetic variance (0.327) was far from unity and the estimate of narrow sense heritability (3.70) was low (Table 4.32). Thus, results showed that non-additive gene actions in the inheritance of this character and can be improved either by heterosis breeding methods and recombination breeding with selection at later generation. These findings are corroborated by Gnanamalar and Vivekanandam (2013), Damodar *et al.* (2012), Gulzar and Wassem (2012), Srivastava *et al.* (2012), Waghmode *et al.* (2011) and Thakare *et al.* (2010).

4.3.2.3.19 Kernel Length/Breadth Ratio

Among the eight parents tested for general combining ability, MTU 1064 (0.031**) and BPT 3291 (0.028**), recorded significant positive general combining ability effects while lines MTU 7029 (-0.041**) and MTU 1121 (-0.033**) possessed significant *gca* effects in negative direction. The cross combination, MTU 1001 $\times$ MTU 1064 (0.397**) with high positive *gca* $\times$ high negative *gca* ($H^+ gca \times H^- gca$) parental combination showed highest significant *sca* effect followed by BPT 3291 $\times$ MTU 1140 (0.200**) ($H^- gca \times L^- gca$), MTU 1001 $\times$ MTU 7029 (-0.180**) ($H^+ gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific

combining ability in desirable direction are possible from $H^+ gca \times H^- gca$, $H^- gca \times L^- gca$ and $H^+ gca \times H^+ gca$ combinations. The cross between high and low combiners with significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners, whereas the cross combination involving two high general combiners revealed additive component of variance.

This trait had significantly higher *gca* component of variance (0.016**) than *sca* components of variance (0.007**). The ratio of *gca* component of variance to total genetic variance (0.485) was away from unity and the estimate of narrow sense heritability (6.60) was low (Table 4.32). As this trait was governed by both additive and non-additive gene actions are of equal magnitude, population improvement programme and recombination breeding with selection at later generation was effective should be taken up for the development of superior lines with several desirable genes. These results are in accordance with Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014), Malini *et al.* (2014), Patil and Mehta (2014), Damodar *et al.* (2012), Gulzar and Wassem (2012) and Srivastava *et al.* (2012).

4.3.2.3.20 Kernel Length after Cooking (mm)

Out of eight parents, MTU 1001 (0.275**), MTU 1064 (0.161**), and MTU 1061 (0.093**), recorded significant positive general combining ability effects while, lines MTU 7029 (-0.277**), MTU 1121 (-0.187**) and MCM 100 (-0.081**) possessed significant *gca* effects in negative direction. The cross combination, BPT 3291 $\times$ MTU 1121 (0.546**) ($L^- gca \times H^- gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1061 (0.543**) ($H^- gca \times H^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times H^- gca$ and $H^- gca \times H^+ gca$ combinations. The crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

The estimated component of variance due to *gca* (0.328**) was significantly greater than *sca* components of variance (0.089**). The ratio of *gca* component of variance to total genetic variance (0.880) was closer to unity and the estimate of narrow

sense heritability (42.00) was moderate (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character. It can be improved either by population improvement methods or by recombination breeding with selection at later generations. These results are in consonance with findings of Upadhyay and Jaiswal (2015), Gnanamalar and Vivekanandam (2013) and Sreedhar (1999).

4.3.2.3.21 Kernel Breadth after Cooking (mm)

The parents, MTU 7029 (0.118**), BPT 3291 (0.083**), MTU 1121 (0.071**), recorded significant positive general combining ability effects while lines MCM 100 (-0.087**), MTU 1064 (-0.073**) and MTU 1001 (-0.054**) possessed in significant *gca* negative direction. The cross combination, MCM 100 $\times$ MTU 1140 (0.325**) ($H^- gca \times L^- gca$) showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1061 (0.286**) ($H^- gca \times H^- gca$) and BPT 3291 $\times$ MTU 1061 (0.283**) ($L^+ gca \times H^- gca$) in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

The component of variance due to *gca* (0.062**) showed significantly higher in magnitude than *sca* components of variance (0.044**). The ratio of *gca* component of variance to total genetic variance (0.740) was close to unity and the estimate of narrow sense heritability (20.90) was low (Table 4.32). These results showed that this trait was governed by both additive and non-additive gene actions in the inheritance of this character. These findings were in line with the results obtained by Li *et al.* (1999) and Sreedhar (1999). It can be improved either by population improvement methods or by recombination breeding with selection at later generations.

4.3.2.3.22 Kernel Linear Elongation Ratio

Among eight parents, MTU 1064 (0.023**) and MTU 1001 (0.031**) recorded significant positive general combining ability effects while lines MTU 7029 (-0.043**) and MTU 1121 (-0.079**) possessed significant negative *gca* effects. The cross combinations MTU 1001 $\times$ MTU 1121 (0.108**) ($H^- gca \times H^- gca$) showed highest

significant *sca* effects followed by MCM 100 × MTU 1061 (0.096**) ($H^- gca \times L^- gca$) in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

Significance of both *gca* (0.005*) and *sca* (0.004*) components of variance was observed for this trait. The ratio of general combining ability component of variance to total genetic variance (0.741) was near to unity. The estimate of narrow sense heritability (20.40) was also low (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character and can be improved either by population improvement methods or even by recombination breeding with post ponement of selection at later generations. These results were in broad agreement with the findings of Upadhyay and Jaiswal (2015), Adilakshmi and Upendra (2014) and Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013).

4.3.2.3.23 Volume Expansion Ratio

Based on *gca* effects, MTU 1061 (0.213**) recorded significant positive general combining ability effects while lines MTU 1121 (-0.079**) possessed significantly negative *gca* effects. The cross combination, MTU 1064 × MTU 7029 (0.357**) ($L^+ gca \times L^- gca$) showed highest significant *sca* effect followed by MTU 1001 × MTU 7029 (0.338**) ($L^- gca \times L^- gca$) and MTU 1061 × MTU 7029 (0.293**) with non-significant negative *gca* × high negative *gca* ($H^+ gca \times L^- gca$) parental combinations in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times L^- gca$, $L^- gca \times L^- gca$ and $H^+ gca \times L^- gca$. The cross combination involving two low general combiners revealed the superiority of the crosses having low *gca* parents may be due to high nicking ability of those parents. The cross combination involving high × low general combiners producing significant *sca* effects might be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners.

The *sca* component of variance (0.087**) was significantly higher than *gca* components of variance (0.082**). The ratio of *gca* component of variance to total genetic variance (0.653) was away from unity and the estimate of narrow sense

heritability (14.70) was low (Table 4.32). Thus, the results showed that inheritance of this trait was governed by non-additive gene actions, Heterosis breeding and recombination breeding with selection at later generations was effective; similar findings were reported by Adilakshmi and Upendra (2014), Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013) and Gonya Nayak *et al.* (2012).

4.3.2.3.24 Water Uptake (ml)

Out of eight parents, MTU 1001 (12.267**), MTU 1064 (6.867**), MTU 1140 (5.717**), MTU 1061 (4.183**) and MCM 100 (2.683**) recorded significant positive general combining ability effects while lines BPT 3291 (-17.783**) and MTU 1121 (-15.050**) possessed significant *gca* effects in negative direction. The cross combination, MTU 1001 × MTU 1064 (55.256**) with non-significant negative *gca* × non-significant positive *gca* ($L^- gca \times L^+ gca$) parental combinations showed highest significant *sca* effect followed by MTU 1001 × MCM 100 (-35.494**) ($L^- gca \times L^+ gca$) and MTU 1140 × MTU 1064 (-29.528**) ($L^- gca \times L^+ gca$) in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^- gca \times L^+ gca$, $L^- gca \times L^+ gca$ and $L^- gca \times L^+ gca$ combinations. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, it can be recommended to include, some of the low combiners along with high combiners in hybridization programmes.

Significance of both *gca* (1141.428**) and *sca* (631.099**) components of variance was noticed for this trait and *gca* component of variance was greater than *sca* variance. The ratio of *gca* component of variance to total genetic variance (0.783) was near to unity and the estimate of narrow sense heritability (26.30) was low (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions, where population improvement programme and recombination breeding with later selection at later generations should be taken up for the development of superior lines with several desirable genes. The above results were in agreement with Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013), Gonya Nayak *et al.* (2012) and Sharma and Mani (1998).

4.3.2.3.25 Gel Consistency (mm)

Among eight parents involved, MTU 1140 (5.372**) and MTU 1121 (2.331**) recorded significant positive general combining ability effects while, lines MTU 1064 (-9.330**) possessed significant *gca* effects in negative direction. The cross

combinations BPT 3291 $\times$ MTU 7029 (28.954**) ($H^- gca \times L^+ gca$) showed highest significant *sca* effects followed by MCM 100 $\times$ MTU 1061 (25.441**) ($H^+ gca \times H^+ gca$) in the desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are possible from the parents with high *gca* along with few low *gca* effects also. The superiority of the crosses having low *gca* parent may be due to high nicking ability of those parents. Thus, in practice, some of the low combiners can also be recommended along with high combiners in production of hybrids with good *sca* effect and heterosis.

This trait had significantly higher *sca* component of variance (435.886**) than *gca* components of variance (178.198**). The ratio of *gca* component of variance to total genetic variance (0.450) was away from unity and the estimate of narrow sense heritability (7.40) was low (Table 4.32). These results exhibited that this trait was governed by preponderance of non-additive gene actions in the inheritance of this character. For improvement of this trait breeding programmes breeding methods involving selection, intermating among selected ones and reselection (or) heterosis breeding for development of hybrid variety may help to improve this trait. These findings were in conformity with Malini *et al.* (2014), Gnanamalar and Vivekanandam (2013), Sreedhar (1999) and Kaw and Cruz (1990).

4.3.2.3.26 Alkali Spreading Value (mm)

The parents, MTU 1001 (0.742**), MTU 1061 (0.482**) and MTU 1064 (0.398**) recorded significant positive general combining ability effects while lines MTU 1121 (-0.819**), MTU 1140 (-0.442**) and MCM 100 (-0.419**) possessed significant negative *gca* effects. The cross combination, MCM 100 $\times$ MTU 1064 (1.466**) with non-significant positive *gca* $\times$ non-significant negative *gca* ($L^+ gca \times L^- gca$) showed highest significant *sca* effect followed by MTU 1061 $\times$ MTU 7029 (0.940**) with non-significant positive *gca* $\times$ non-significant positive *gca* ($L^+ gca \times L^+ gca$) and in the desirable direction. These results indicated that the crosses with high specific combining ability in desirable direction are possible from $L^+ gca \times L^- gca$ and $L^+ gca \times L^+ gca$ combinations. Thus, in practice, some of the low combiners can also be recommended along with high combiners in hybridization programme.

The *gca* component of variance (2.839**) was significantly higher than and *sca* components of variance (0.944**). The ratio of general combining ability component of variance to total genetic variance (0.857) was near to unity. The estimate of narrow

sense heritability (37.40) was also low (Table 4.32). These results confirm the possible involvement of both additive and non-additive gene actions in the inheritance of this character. Which can be improved by population improvement methods or by recombination breeding with selection selection at later generations. These results were in broad agreement with the findings of Adilakshmi and Upendra (2014), Gnanamalar and Vivekanandam (2013), Gonya Nayak *et al.* (2012), Lakshmi (2009) and Sreedhar (1999).

4.3.2.3.27 Amylose Content (%)

Based on *gca* effects, MCM 100 (1.065**), BPT 3291 (0.431**) and MTU 7029 (0.356**), recorded significant positive general combining ability effects while, parents MTU 1121 (-0.597**), MTU 1140 (-0.461**), MTU 1061 (-0.421**) and MTU 1001 (-0.227*) possessed significant *gca* effects in negative direction. For the rice grain which cook dry, are less tender and becomes hard upon cooling high amylose content was referable, thus the cross combination BPT 3291 $\times$ MTU 7029 (6.998**) ($L^- gca \times L^+ gca$), showed highest significant *sca* effect followed by MCM 100 $\times$ MTU 1121 (6.747**) ($H^- gca \times H^- gca$) and MTU 1121 $\times$ MTU 7029 (6.564**) ($H^- gca \times L^+ gca$), parental combinations are in desirable direction. For rice grain of cook moist and sticky upon cooling, low amylose content was preferable, thus the cross combination MCM 100 $\times$ MTU 1001 (-3.771**) with high positive $\times$ high negative *gca* ($H^+ gca \times H^- gca$), BPT 3291 $\times$ MTU 1064 (-3.430**) with non-significant negative $\times$ high positive *gca* ($L^- gca \times H^+ gca$) and MTU 1001 $\times$ MTU 7029 (-3.154**) with high positive $\times$ non-significant positive *gca* ($H^+ gca \times L^+ gca$) parental combination are in desirable direction. These results indicate that crosses with high specific combining ability in desirable direction are resulted from the parents having both high and low *gca* effects. This indicates that one can include few low combiners along with high combiners in hybridization programme.

This trait exhibited significant *sca* (11.661**) as well as *gca* (3.236**) components of variance and the magnitude of *sca* was higher than *gca* component of variance. The ratio of *gca* component of variance to total genetic variance (0.357) was away from unity and the estimate of narrow sense heritability (5.00) was low (Table 4.32). These results confirm the possible involvement non-additive gene actions in the inheritance of this character. For improvement of this trait breeding programmes like heterosis breeding and recombination breeding with selection at later generations. These

results are in consonance with findings of Adilakshmi and Upendra (2014), Malini *et al.* (2014), Patil and Mehta (2014), Gnanamalar and Vivekanandam (2013), Lakshmi (2009) and Sanjeev Kumar *et al.* (2005).

Among the eight lines tested for their general combining ability studies pertaining to 27 different characters (quantitative and qualitative), the line, MTU 1001 recorded significant *gca* effects in desirable direction for majority of the characters viz., days to 50% flowering, days to maturity, plant height (cm), test weight (g), leaf area index at maximum tillering stage, milling recovery (%), head rice recovery (%), kernel length (mm), kernel length after cooking (mm), kernel linear elongation ratio, alkali spreading value (mm) and grain yield per plant (g) and MTU 1140 recorded significant *gca* effects in desirable direction for total number of ear bearing tillers per plant, number of ratoon ear bearing tillers as per cent of main crop tillers, panicle length (cm), number of grains per panicle, test weight (g), hulling recovery (%), head rice recovery, gel consistency (mm) and grain yield per plant (g) followed by MTU 1064 recorded significant *gca* effects in desirable direction for total number of ear bearing tillers per plant, panicle length (cm), number of grains per panicle, leaf area index at maximum tillering stage, hulling recovery (%), kernel breadth (mm), L/B ratio, kernel length after cooking (mm), kernel linear elongation ratio and alkali spreading value and MTU 1061 recorded significant *gca* effects in desirable direction for number of tillers per plant, number of grains per panicle, hulling recovery (%), head rice recovery (%), kernel length after cooking (mm), volume expansion ratio and alkali spreading value (mm) and BPT 3291 recorded significant *gca* effects in desirable direction for days to 50% flowering, days to maturity, plant height (cm), kernel breadth (mm), L/B ratio, kernel breadth after cooking (mm), water uptake (ml) and amylose content (%), followed by MTU 7029 recorded significant *gca* effects in desirable direction for days to 50% flowering, days to maturity, plant height (cm), kernel breadth after cooking (mm) and amylose content (%), followed by MCM 100 recorded significant *gca* effects in desirable direction for days to 50% flowering, days to maturity, plant height (cm) and amylose content (%) (Table 4.33).

Further, the tested lines were given ranking based on the respective combining abilities of all the characters studied (Table 4.33). The line, MTU 1001 ranked first followed by MTU 1140, MTU 1064, BPT 3291, MTU 1061, MTU 7029 and MCM 100. Therefore these lines can be utilized in improvement of the respective traits in any breeding programme wherever hybridization is involved. Due to their good combining

ability these lines can also be utilized straightaway as parents for production of good hybrids by crossing with other divergent lines or can also be employed in the development of multiline variety or hybrid varieties.

The cross combinations involving high $\times$ high general combiners producing crosses with significant *sca* effects revealed the role of additive and additive genetic component of variance which could be easily improved through simple selection procedures such as pureline selection, mass selection, progeny selection and hybridization & selection with pedigree breeding. The crosses between high $\times$ high or low $\times$ high *gca* combiners resulted in superior cross combinations due to complementary gene action which has arisen out of both additive and non-additive gene action. These crosses may likely throw superior transgressive segregants. These components may be exploited by adopting breeding procedures like mass selection, population improvement methods like diallel selective mating systems, bi-parental mating and reciprocal recurrent selection and recombination breeding with selection at later generation. The crosses between low $\times$ low combiners producing crosses with significant *sca* effects revealed the role of non-additive interallelic interaction. This may be due to high nicking ability/genetic diversity of parents involved. This component may be exploited through breeding procedure such heterosis breeding and recombination breeding with postponement of selection at later generations should be carried out for improvement of the traits controlling these types of gene action.

The perusal of *sca* effects (Table 4.31) revealed that the crosses, MTU 1001 $\times$ MTU 1140, MTU 1140 $\times$ MTU 7029 and MCM 100 $\times$ MTU 1140 expressed high *sca* effects with high *per se* performance for grain yield per plant. These crosses did not express high *sca* effects for all the yield attributing traits. This study also revealed that there is no relationship between *per se* performance of hybrids and *gca* effects of parents. In majority of the crosses studied, the *per se* value of crosses were related to their corresponding *sca* effects. Thus, the study revealed the possibility for simultaneous improvement of grain yield and yield attributing traits by exploring these F_1 crosses.

4.3.2.4 HETEROSIS

The superiority of F_1 over the parents in terms of yield or some other related traits is commonly referred to as heterosis or hybrid vigour. Estimation of magnitude and nature of heterosis in diverse cross combinations would always be useful in choosing the best performing crosses for further exploitation. Exploitation of heterosis

is of direct interest for developing hybrids in cross pollinated crops but it is also of importance in self pollinated crops where such feasibility existed. The heterotic crosses may produce desirable transgressive segregants in the advanced generations. In the present study the estimates of heterosis for yield and yield components over mid parent (relative heterosis) and better parent (heterobeltiosis) for 28 cross combinations are presented in the Table 4.34 and are described character-wise hereunder.

4.3.2.4.1 Days to 50% Flowering

The range of relative heterosis for this character varied from -11.64** (MTU 1001 × MTU 1061) to 7.07** (MTU 1001 × MCM 100) with a mean of -1.42, heterobeltiosis ranged from -15.66** (MTU 1001 × MTU 1061) to 4.79 (MTU 1001 × MCM 100) with a mean of -4.30. Negative heterosis is a desirable feature for this character as it indicates the earliness of a genotype. High negative significant heterosis over mid parent was observed in the cross, MTU 1001 × MTU 1061 (-11.64**) followed by MTU 1001 × MTU 7029 (-7.69**) and MCM 100 × MTU 1064 (-6.70**), while high significantly negative heterosis over better parent was observed in the cross, MTU 1001 × MTU 1061 (-15.66**) followed by MTU 1001 × MTU 7029 (-11.06**) and MCM 100 × MTU 1064 (-9.05**),

Similar results of significant negative heterosis over mid parent and better parent was reported by for this trait were reported by Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Borah and Barman (2010). The cross, MTU 1001 × MTU 1061, recorded highest significant heterosis over mid parent and better parent in desired direction. The line, MTU 1001 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects. The line, MTU 1061 had better *per se* performance for this trait.

4.3.2.4.2 Days to Maturity

Relative heterosis for this character ranged from -8.86** (MTU 1001 × MTU 1061) to 5.32** (MTU 1001 × MCM 100) with a mean of -2.12; and heterobeltiosis ranged from -14.58** (MTU 1001 × MTU 1061) to 1.96 (MTU 1140 × MTU 1064) with a mean of -5.66. Negative heterosis is a desirable feature for this character as it indicates the earliness of a genotype. Highest negative significant heterosis over mid parent was observed in the cross, MTU 1001 × MTU 1061 (-8.86**) followed by BPT 3291 × MTU 7029 (-8.59**) and BPT 3291 × MTU 1064 (-8.13**), while highly

significant negative heterosis over better parent was observed in the cross, MTU 1001 $\times$ MTU 1061 (-14.58**) followed by BPT 3291 $\times$ MTU 1064 (-12.16**) and BPT 3291 $\times$ MTU 1061 (-10.51**). The cross, MTU 1001 $\times$ MTU 1061, recorded highest significant heterosis over mid parent and better parent in desired direction. The line, MTU 1001 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects. The line, MTU 1061 had better *per se* performance for this trait. The results are in agreement with the findings of Kumari *et al.* (2014), Sreedhar *et al.* (2012), Sanjeev kumar *et al.* (2010) and Akarsh and Pathak (2008).

4.3.2.4.3 Plant Height (cm)

The estimated mid-parent heterosis was ranged from -12.84** (BPT 3291 $\times$ MTU 7029) to 24.75** (BPT 3291 $\times$ MTU 1140) with a mean of 7.77, and heterobeltiosis ranged from -16.74** (BPT 3291 $\times$ MTU 7029) to 19.96** (MCM 100 $\times$ MTU 7029) with a mean of 4.89. Negative heterosis is a desirable feature for this character as it indicates the dwarfness of a genotype. High negatively significant heterosis over mid parent was observed in the cross, BPT 3291 $\times$ MTU 7029 (-12.84**) followed by MTU 1001 $\times$ MTU 7029 (-9.86**) and MTU 1121 $\times$ MTU 1064 (-4.79**) and over better parent heterosis it was observed for the crosses, BPT 3291 $\times$ MTU 7029 (-16.74**) followed by MTU 1001 $\times$ MTU 7029 (-12.13**) and BPT 3291 $\times$ MTU 1064 (-8.58**).

The results of significant negative heterosis for this trait were in agreement with those of Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Borah and Barman (2010), Gouri Shankar *et al.* (2010), Panwar and Mashiat Ali (2010) and Sanjeev Kumar *et al.* (2010). The cross, BPT 3291 $\times$ MTU 7029, recorded highest significant heterosis over mid parent and better parent in desired direction. The line, BPT 3291 and MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects.

4.3.2.4.4 Total Number of Tillers per Plant

The total number of tillers per plant, relative heterosis varied from -17.24* (MTU 1001 $\times$ MTU 7029) to 22.81** (MTU 1001 $\times$ MTU 1140) with a mean of 2.02; and heterobeltiosis ranged from -20.00** (MTU 1001 $\times$ MTU 7029) to 17.24* (BPT 3291 $\times$ MTU 1061) with a mean of -0.87. High significantly positive heterosis over mid parent was observed in the cross MTU 1001 $\times$ MTU 1140 (22.81**) followed by BPT

3291 × MTU 1061 (21.43**) and MCM 100 × MTU 7029 (17.24*) and high significantly positive heterosis over better parent was observed in the cross, BPT 3291 × MTU 1061 (17.24*) followed by MTU 1001 × MTU 1140 (16.67*). These findings for significant positive heterosis over mid parent are corroborated by Sreedhar *et al.* (2012) and Deo *et al.* (2007). The cross, MTU 1001 × MTU 1140, recorded highest significant heterosis over mid parent and BPT 3291 × MTU 1061 over better parent in desired direction. The line, MTU 1001 and BPT 3291 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and MTU 1061.

4.3.2.4.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers per Plant

The range of heterosis for mid-parent heterosis was from -33.03** (MTU 1001 × MTU 1121) to -13.31** (MTU 1140 × MTU 7029) with a mean of -23.79, and heterobeltiosis ranged from -34.32** (MTU 1001 × MTU 7029) to -13.97 (MTU 1140 × MTU 7029) with a mean of -27.02.

The cross, MTU 1140 × MTU 7029 (-13.31**), showed high negative significant heterosis over mid parent and also MCM 1001 × MTU 7029 (-19.17**) registered high negative heterosis over better parent. The cross, MTU 1140 × MTU 7029, recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140.

4.3.2.4.6 Number of Vegetative Buds after the Harvest of Main Crop

Relative heterosis for this trait ranged from -16.22** (MTU 1061 × MTU 7029) to 15.15** (BPT 3291 × MTU 1061) with a mean of -0.58; and heterobeltiosis ranged from -18.42** (MTU 1061 × MTU 7029) to 8.33 (MTU 1001 × MTU 1140) with a mean of -4.42.

High significant positive heterosis over mid parent was observed in the cross BPT 3291 × MTU 1061 (15.15**) followed by MTU 1001 × MTU 1140 (13.04*) and BPT 3291 × MTU 1121 (12.50*) and over better parent was observed in the cross, MTU 1001 × MTU 1140 (8.33) followed by BPT 3291 × MTU 1121 (5.88) and BPT 3291 × MTU 1064 (5.56). The cross, BPT 3291 × MTU 1061 recorded highest significant heterosis over mid parent and MTU 1001 × MTU 1140 over better parent in desired direction. The line had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and MTU 1061.

4.3.2.4.7 Total Number of Ear Bearing Tillers per Plant

This trait, exhibits mid-parent heterosis with range from -23.81** (MTU 1064 × MTU 7029) to 45.95** (MTU 1001 × MTU 1140) with a mean of 5.57, and heterobeltiosis ranged from -33.33** (MTU 1064 × MTU 7029) to 44.44** (MTU 1140 × MTU 7029) with a mean of -0.24. High significantly positive heterosis over mid parent was observed in the cross MTU 1001 × MTU 1140 (45.95**) followed by MTU 1140 × MTU 7029 (44.44**) and for better parent was observed in the cross, MTU 1140 × MTU 7029 (44.44**) followed by MTU 1001 × MTU 1140 (42.11**) and MCM 100 × MTU 1140 (19.05*).

These results for significant positive heterosis over mid parent and better parent are in accordance with Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Borah and Barman (2010). The cross, MTU 1001 × MTU 1140 recorded highest significant heterosis over mid parent and MTU 1140 × MTU 7029 over better parent in desired direction. The line had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140.

4.3.2.4.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

The magnitude of mid-parent heterosis varied from -40.20** (BPT 3291 × MCM 100) to 23.24* (MTU 1140 × MTU 7029) with a mean of -14.90; and heterobeltiosis ranged from -41.77** (BPT 3291 × MCM 100) to 18.56 (MTU 1140 × MTU 7029) with a mean of -19.28. The cross combination, MTU 1140 × MTU 7029 (23.24*) showed highest significant positive heterosis over mid parent and the crosses, MTU 1140 × MTU 7029 (18.56) and MTU 1001 × MTU 1140 (5.56), observed non-significant positive heterosis over better parent. The cross, recorded highest significant heterosis MTU 1140 × MTU 7029 over mid parent and over better parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and had better *per se* performance for this trait.

4.3.2.4.9 Panicle Length per Plant (cm)

The trait, registered relative heterosis from -0.26 (BPT 3291 × MTU 7029) to 32.10** (MCM 100 × MTU 1140) with a mean of 12.86; and heterobeltiosis varied from -4.73 (BPT 3291 × MTU 1064) to 31.65** (MCM 100 × MTU 1140) with a mean of 9.99.

High significantly positive heterosis over mid-parent parent was observed in the cross, MCM 100 $\times$ MTU 1140 (32.10**) followed by BPT 3291 $\times$ MTU 1140 (23.26**) and MTU 1140 $\times$ MTU 1061 (22.33**) and high positive and significant heterosis over better parent was observed for MCM 100 $\times$ MTU 1140 (31.65**) followed by BPT 3291 $\times$ MTU 1140 (20.39**) and MTU 1140 $\times$ MTU 7029 (19.54**). The cross, MCM 100 $\times$ MTU 1140 recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, MCM 100 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140. These results were in conformity with the findings Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Janardhanam *et al.* (2001), Vanisree *et al.* (2011) and Borah and Barman (2010) for relative heterosis and heterobeltiosis.

4.3.2.4.10 Number of Grains per Panicle

Heterosis over mid-parent for this character varied from -13.00** (MTU 1121 $\times$ MTU 1064) to 45.32** (MTU 1001 $\times$ BPT 3291) with a mean of 25.02; and heterobeltiosis ranged from -23.79** (MTU 1121 $\times$ MTU 1064) to 42.92** (MTU 1001 $\times$ BPT 3291) with a mean of 15.83.

High significant positive over mid parent heterosis was recorded for MTU 1001 $\times$ BPT 3291 (45.32**) followed by MCM 100 $\times$ MTU 1121 (43.27**) and BPT 3291 $\times$ MTU 7029 (41.55**) and significantly positive heterosis over better parent was observed in the cross, MTU 1001 $\times$ BPT 3291 (42.92**) followed by BPT 3291 $\times$ MTU 7029 (39.27**) and MCM 100 $\times$ MTU 1140 (30.53**). The cross, MTU 1001 $\times$ BPT 3291 recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, MTU 1001 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects. The line, BPT 3291 had better *per se* performance for this trait. These findings are corroborated by Kumari *et al.* (2014), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011), Borah and Barman (2010) and Panwar and Mashiat Ali (2010) for relative heterosis, and heterobeltiosis.

4.3.2.4.11 Test Weight (g)

Relative heterosis for this character ranged from -0.08 (MTU 1064 $\times$ MTU 1061) to 28.11** (MTU 1001 $\times$ MCM 100) with a mean of 11.21; heterobeltiosis ranged from -3.67 (MTU 1140 $\times$ MTU 7029) to 22.46** (BPT 3291 $\times$ MCM 100) with a mean of 7.22.

The crosses, MTU 1001 × MCM 100 (28.11**) followed by BPT 3291 × MCM 100 (25.50**) and BPT 3291 × MTU 1140 (20.26**) established highly significant positive heterosis over mid parent and the crosses, BPT 3291 × MCM 100 (22.46**) followed by MTU 1121 × MTU 1140 (19.08**) and MTU 1001 × MCM 100 (18.92**) recorded high significant positive heterosis over better parent. The cross, MTU 1001 × MCM 100 recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, MCM 100 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and had better *per se* performance for this trait. These results are in consonance with findings of Kumari *et al.* (2014), Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Panwar and Mashiat Ali (2010) for relative heterosis and heterobeltiosis.

4.3.2.4.12 Leaf Area Index at Maximum Tillering Stage

Leaf area index recorded relative heterosis varied from -31.32** (MCM 100 X MTU 7029) to 67.98** (BPT 3291 × MTU 1140) with mean of -1.29 and heterobeltiosis ranged from -39.33** (MCM 100 × MTU 7029) to 32.97** (MTU 1001 × MTU 1140), with mean -12.72.

Highest positive significant heterosis over mid parent BPT 3291 × MTU 1140 (67.98**) followed by MTU 1001 × BPT 3291 (57.55**) and BPT 3291 × MTU 1140 (67.98**) with a mean of -1.29 and high significant positive heterosis over better parent was observed in the cross, MTU 1001 × MTU 1140 (32.97**) followed by MTU 1001 × BPT 3291 (28.67**) and MCM 100 × MTU 1140 (28.26**) with a mean of -12.72. The cross, BPT 3291 × MTU 1140 recorded highest significant heterosis over mid parent and MTU 1001 × MTU 1140 over better parent in desired direction. The line, BPT 3291 and MTU 1140 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and had better *per se* performance for this trait.

4.3.2.4.13 Grain Yield per Plant (g)

The estimates of mid-parent heterosis for this trait ranged from -30.78** (MTU 1064 × MTU 7029) to 87.04** (MTU 1001 × MTU 1140) with a mean of 18.15; and heterobeltiosis ranged from -34.96** (MTU 1064 × MTU 7029) to 70.27** (MTU 1001 × MTU 1140) with a mean of 11.60.

The crosses, MTU 1001 $\times$ MTU 1140 (87.04**), MCM 100 $\times$ MTU 1140 (74.47**) and MTU 1140 $\times$ MTU 7029 (67.72**) showed positive significant heterosis over mid parent and positive significant heterosis over better parent was observed in MTU 1001 $\times$ MTU 1140 (70.27**) followed by MCM 100 $\times$ MTU 1140 (67.24**) and MTU 1140 $\times$ MTU 7029 (47.05**). The cross, MTU 1001 $\times$ MTU 1140 recorded highest significant heterosis over mid parent and MTU 1001 $\times$ MTU 1140 over better parent in desired direction. The line, MTU 1001 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and had better *per se* performance for this trait.

These findings were in line with the results obtained by Kumari *et al.* (2014), Gnanamalar and Vivekananda (2013), Chandra and Suresh (2012), Sreedhar *et al.* (2012), Vanisree *et al.* (2011) and Borah and Barman (2010) for relative heterosis and heterobeltiosis.

4.3.2.4.14 Hulling Recovery (%)

Relative heterosis for hulling recovery was from -1.51* (MTU 1121 $\times$ MTU 1140) to 5.08** (MTU 1001 $\times$ BPT 3291) with a mean of 1.36; and heterobeltiosis ranged from -3.24** (MTU 1140 $\times$ MTU 7029) to 4.19** (MTU 1001 $\times$ BPT 3291) with a mean of 0.08.

Mid-parent heterosis with significantly positive was recorded for the crosses, MTU 1001 $\times$ BPT 3291 (5.08**) followed by BPT 3291 $\times$ MTU 1064 (4.89**) and MTU 1064 $\times$ MTU 7029 (4.29**) and positive significant heterosis over over better parent was MTU 1001 $\times$ BPT 3291 (4.19**) followed by BPT 3291 $\times$ MTU 1064 (3.23**) and MTU 1064 $\times$ MTU 7029 (4.29**). The cross, MTU 1001 $\times$ BPT 3291 recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, BPT 3291 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and had better *per se* performance for this trait. The above results were in agreement with Gnanamalar and Vivekananda (2013), Chandra and suresh (2012), Pandya and Tripathi (2006) and Raju *et al.* (2003) for relative heterosis and heterobeltiosis.

4.3.2.4.15 Milling Recovery (%)

Milling recovery recorded relative heterosis from -0.98 (MTU 1140 $\times$ MTU 7029) to 8.38** (MTU 1001 $\times$ MTU 1140) with a mean of 2.99 and heterobeltiosis ranged from -1.88 (MTU 1140 $\times$ MTU 7029) to 7.35** (MTU 1001 $\times$ BPT 3291) with a mean of 2.14.

The estimates of highly significant positive heterosis over mid parent was recorded in MTU 1001 $\times$ MTU 1140 (8.38**) followed by MTU 1001 $\times$ BPT 3291 (7.62**) and BPT 3291 $\times$ MTU 1064 (7.09**) and highly significant positive over better parent was observed in the cross, MTU 1001 $\times$ BPT 3291 (7.35**) followed by MTU 1001 $\times$ MTU 1140 (6.96**) and BPT 3291 $\times$ MTU 1064 (6.44**). Similar results for significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013) and Chandra and suresh (2012). The cross, MTU 1001 $\times$ BPT 3291 recorded highest significant heterosis over mid parent and over better parent in desired direction. The line, BPT 3291 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and had better *per se* performance for this trait.

4.3.2.4.16 Head Rice Recovery (%)

The magnituded of heterosis for this character over mid-parent varied from -0.71 (MCM 100 $\times$ MTU 1121) to 5.55** (MTU 1064 $\times$ MTU 7029) with a mean of 2.33; and heterobeltiosis ranged from -3.20** (MCM 100 $\times$ MTU 7029) to 5.25** (MTU 1001 $\times$ BPT 3291) with a mean of 1.16.

Among the crosses, highest positive significant heterosis over mid parent was recorded for MTU 1001 $\times$ BPT 3291 (5.48**) followed by MTU 1064 $\times$ MTU 7029 (5.55**) and MTU 1001 $\times$ MTU 1140 (4.95**) and high significant heterosis over better parent was observed in the cross, MTU 1001 $\times$ BPT 3291 (5.25**) followed by BPT 3291 $\times$ MTU 1064 (4.60**) and MTU 1064 $\times$ MTU 7029 (3.69**). These findings are in conformity with the results of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis MTU 1064 $\times$ MTU 7029 over mid parent and MTU 1001 $\times$ BPT 3291 over better parent in desired direction. The line, MTU 7029 and BPT 3291 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and MTU 1064 and had better *per se* performance for this trait.

4.3.2.4.17 Kernel Length (mm)

Kernel length possessed the ranges for mid-parent heterosis from -8.36** (MTU 1121 $\times$ MTU 1140) to 13.40** (BPT 3291 $\times$ MTU 1140) with a mean of -0.20; and heterobeltiosis ranged from 12.00** (MTU 1121 $\times$ MTU 1140) to 10.68** (MCM 100 $\times$ MTU 7029) with a mean of -4.69.

Relative heterosis for this crosses, BPT 3291 $\times$ MTU 1140 (13.35**), MCM 100 $\times$ MTU 7029 (11.99**) and MTU 1061 $\times$ MTU 7029 (9.35**) recorded highest positive significant heterosis and heterobeltiosis highest positive significant was recorded the crosses, MCM 100 $\times$ MTU 7029 (10.68**) followed by MTU 1061 $\times$ MTU 7029 (8.07**) and BPT 3291 $\times$ MTU 1140 (8.03**). Similar results for significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013), Chandra and suresh (2012), Gouri Shankar *et al.* (2010) and Panwar and Mashiat Ali (2010). The cross, recorded highest significant heterosis BPT 3291 $\times$ MTU 1140 over mid parent and MCM 100 $\times$ MTU 7029 over better parent in desired direction. The line had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and MTU 7029 and had better *per se* performance for this trait.

4.3.2.4.18 Kernel Breadth (mm)

The estimates of relative heterosis for this character ranged from -14.93 (MTU 1001 $\times$ MTU 1064) to 15.22 (MTU 1001 $\times$ MTU 7029) with a mean of 3.09; and heterobeltiosis ranged from -15.00 (MTU 1001 $\times$ MTU 1064) to 11.67 (MTU 1001 $\times$ MTU 7029) with a mean of 1.10. Highest positive significant heterosis over mid parent MTU 1001 $\times$ MTU 7029 (15.22**) followed by MCM 100 $\times$ MTU 7029 (11.09**) and MTU 1001 $\times$ MTU 1061 (10.08**) and high positive significant over better parent was observed in MTU 1001 $\times$ MTU 7029 (11.67**) followed by MCM 100 $\times$ MTU 7029 (7.67**) and MTU 1001 $\times$ MTU 1064 (6.50**). The cross, recorded highest significant heterosis for MTU 1001 $\times$ MTU 7029 over mid parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and had better *per se* performance for this trait. These findings are corroborated by Gnanamalar and Vivekananda (2013), Chandra and suresh (2012) and Panwar and Mashiat Ali (2010).

4.3.2.4.19 Kernel Length/Breadth Ratio

Relative heterosis for this character ranged from -12.79 (MTU 1001 $\times$ MTU 7029) to 9.31 (MTU 1001 $\times$ MTU 1064) with a mean of -6.86; and heterobeltiosis ranged from -16.67 (MTU 1001 $\times$ MTU 7029) to 5.00 (MTU 1001 $\times$ MTU 1064) with a mean of -9.97.

The crosses, MTU 1001 $\times$ MTU 1064 (9.31**), BPT 3291 $\times$ MTU 1140 (2.72), registered, high significant positive heterosis over mid parent and high significant positive heterosis over better parent was observed in the cross MTU 1001 $\times$ MTU 1064 (5.00**) followed by BPT 3291 $\times$ MTU 1140 (-1.44). Similar results for significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013), Chandra and suresh (2012) and Panwar and Mashiat Ali (2010).

The cross, recorded highest significant heterosis MTU 1001 $\times$ MTU 7029 over mid parent and over better parent in desired direction. The line, MTU 1001 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 7029 and had better *per se* performance for this trait.

4.3.2.4.20 Kernel Length after Cooking (mm)

Relative heterosis for this character ranged from -7.04 (MTU 1140 $\times$ MTU 1061) to 7.40 (BPT 3291 $\times$ MTU 1121) with a mean of -0.87; and heterobeltiosis ranged from -11.03 (MTU 1140 $\times$ MTU 7029) to 6.19 (BPT 3291 $\times$ MTU 1121) with a mean of -4.31.

Highest positive significant heterosis over mid parent BPT 3291 $\times$ MTU 1121 (7.40**) followed by BPT 3291 $\times$ MTU 7029 (7.28**) and MTU 1121 $\times$ MTU 7029 (4.35**) and high positive significant heterosis over better parent was observed in BPT 3291 $\times$ MTU 1121 (6.19**) followed by BPT 3291 $\times$ MTU 7029 (4.52**). These results are in accordance with Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012).

The cross, recorded highest significant heterosis BPT 3291 $\times$ MTU 1121 over mid parent and over better parent in desired direction. The line, BPT 3291 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects.

4.3.2.4.21 Kernel Breadth after Cooking (mm)

Relative heterosis for this character ranged from -10.56 (MTU 1121 $\times$ MTU 1061) to 15.32 (MCM 100 $\times$ MTU 1140) with a mean of 2.39; and heterobeltiosis ranged from 13.44 (MTU 1001 $\times$ MTU 1064), (MTU 1121 $\times$ MTU 1061) to 9.56 (MCM 100 $\times$ MTU 1140) with a mean of -1.82.

Mid-parent heterosis for this trait showed highest positive significant heterosis over mid parent MCM 100 × MTU 1140 (15.32**) followed by BPT 3291 × MTU 1140 (13.80**) and BPT 3291 × MTU 1061 (12.63**) and high positive significant heterosis over better parent was observed in MCM 100 × MTU 1140 (9.56**) followed by BPT 3291 × MTU 1061 (9.00**) and MCM 100 × MTU 1061 (8.67**). These results are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis MCM 100 × MTU 1140 over mid parent and over better parent in desired direction. The line, MTU 1140 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects.

4.3.2.4.22 Kernel Elongation Ratio

The range of variation for relative heterosis was from -17.11 (BPT 3291 × MTU 7029) to 0.91 (MTU 1001 × MTU 1121) with a mean of -8.40; heterobeltiosis ranged from -21.67 (BPT 3291 × MTU 1140) to -7.67 (MTU 1001 × MTU 1121) with a mean of -14.52.

Heterosis for mid-parent was negative and significant for the cross, BPT 3291 × MTU 1121 (-3.46*) and high significant negative heterosis over better parent was observed in MTU 1001 × MTU 1121 (-0.767**) followed by MTU 1001 × MTU 1121 (-7.67**). Similar results for significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis MTU 1001 × MTU 1121 over mid parent and over better parent in desired direction. The line, MTU 1121 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1001 and had better *per se* performance for this trait.

4.3.2.4.23 Volume Expansion Ratio

The estimates of mid-parent heterosis for volume expansion varied from -19.35 (BPT 3291 × MTU 1140) to 21.91 (MTU 1064 × MTU 7029) with a mean of -1.28, and heterobeltiosis ranged from -22.47 (BPT 3291 × MTU 1140) to 21.25 (MTU 1064 × MTU 7029) with a mean of -6.96.

The crosses, MTU 1064 × MTU 7029 (21.91**), MTU 1064 × MTU 7029 (11.57**) and MCM 100 × MTU 7029 (9.09**) showed high positive significant heterosis over mid parent and the cross, MTU 1064 × MTU 7029 (21.25**), MCM 100

× MTU 7029 (8.50**) and MCM 100 × MTU 1064 (6.16*) showed high significant positive heterosis over better parent. These results are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis MTU 1064 × MTU 7029 over mid parent and over better parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1064 and had better *per se* performance for this trait.

4.3.2.4.24 Water Uptake (ml)

Relative heterosis for this character ranged from -15.50 (MTU 1001 × MCM 100) to 38.33 (MTU 1064 × MTU 1061) with a mean of 11.80; and heterobeltiosis ranged from -28.94 (MTU 1001 × MCM 100) to 34.67 (MTU 1064 × MTU 1061) with a mean of 2.43.

Highest positive significant heterosis over mid parent was observed in cross MTU 1064 × MTU 1061 (38.33) followed by MTU 1001 × MTU 1064 (37.07**), MCM 100 × MTU 1064 (32.61**) and highly significant positive heterosis over better parent was observed in MTU 1064 × MTU 1061 (34.67**) followed by MCM 100 × MTU 1064 (29.81**) and MTU 1064 × MTU 7029 (22.43**). These results are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis MTU 1064 × MTU 1061 over mid parent and over better parent in desired direction. The line, MTU 1064 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1064.

4.3.2.4.25 Gel Consistency (mm)

Mid-parent heterosis for this trait ranged from -43.15 (MTU 1064 × MTU 1061) to 98.17 (BPT 3291 × MTU 7029) with a mean of 25.02; and heterobeltiosis ranged from -43.66 (MTU 1064 × MTU 1061) to 86.20 (MTU 1140 × MTU 7029) with a mean of 15.83.

The estimates of highest positive significant heterosis over mid parent was found in the crosses, BPT 3291 × MTU 7029 (89.17**), MTU 1140 × MTU 7029 (86.77**) and BPT 3291 × MTU 1140 (83.21**) and highest positive significant heterosis better parent was observed in the cross, MTU 1140 × MTU 7029 (86.20**), BPT 3291 × MTU 7029 (78.98**) and BPT 3291 × MTU 1140 (72.09**). Similar results for

significant positive heterosis over mid parent were reported by Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis BPT 3291 $\times$ MTU 7029 over mid parent and MTU 1140 $\times$ MTU 7029 over better parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects of MTU 1140 and MTU 7029.

4.3.2.4.26 Alkali Spreading Value (mm)

The range of variation for relative heterosis for this character varied from -56.44 (MTU 1064 $\times$ MTU 1061) to 51.28 (MTU 1121 $\times$ MTU 7029) with a mean of -7.13, and heterobeltiosis ranged from -56.44 (MTU 1064 $\times$ MTU 1061) to 42.58 (MTU 1121 $\times$ MTU 7029) with a mean of -2.076.

The magnitude of highest positive significant heterosis over mid parent was observed in BPT 3291 $\times$ MTU 7029 (51.28**) followed by BPT 3291 $\times$ MTU 7029 (36.43**), MTU 1061 $\times$ MTU 7029 (24.25**) and high significantly positive heterosis over better parent was observed in cross, BPT 3291 $\times$ MTU 7029 (42.58**). These findings are in conformity with the results of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012). The cross, recorded highest significant heterosis BPT 3291 $\times$ MTU 7029 over mid parent and over better parent in desired direction. The line, MTU 7029 had low *per se* performance (Table 4.27) but produced high heterotic F₁ due to its high *gca* effects.

4.3.2.4.27 Amylose Content (%)

The estimates of relative heterosis for this character ranged from -17.67 (MCM 100 $\times$ MTU 1061) to 37.31 (MTU 1121 $\times$ MTU 7029) with a mean of -1.04; and heterobeltiosis ranged from -21.32 (MCM 100 $\times$ MTU 1061) to 34.36 (MTU 1121 $\times$ MTU 7029) with a mean of -4.14.

Highest positive significant heterosis over mid parent parent was observed in cross, MTU 1121 $\times$ MTU 7029 (37.31**) followed by MCM 100 $\times$ MTU 1121 (36.95**), BPT 3291 $\times$ MCM 100 (28.08**) and high positive significant heterosis over better parent was observed in cross, MTU 1121 $\times$ MTU 7029 (34.36**) followed by MCM 100 $\times$ MTU 1121 (30.98**) and BPT 3291 $\times$ MTU 1061 (29.87**). The cross, recorded highest significant heterosis MTU 1121 $\times$ MTU 7029 over mid parent and over better parent in desired direction. The line, MTU 7029, MTU 1001 had low *per se*

performance (Table 4.27) but produced high heterotic F_1 due to its high *gca* effects. These results are in consonance with findings of Gnanamalar and Vivekananda (2013) and Chandra and Suresh (2012).

The presence of parallelism between *per se* performance and high *sca* effects, relative heterosis and heterobeltiosis (Table 4.35), observed in the present investigation revealed that crosses MTU 1001 $\times$ MTU 1140 showed best heterotic combinations for traits viz., total of tillers per plant, number of vegetative buds after the harvest of F_1 main crop, total ear bearing tillers per plant milling percentage, head rice recovery and grain yield per plant; MTU 1140 $\times$ MTU 7029 for number of F_1 ratoon tillers as percentage of F_1 main crop ratoon tillers, number of ear bearing tillers, number ratoon ear bearing tillers as percentage of main crop ear bearing tillers, leaf area index at maximum tillering stage, gel consistency and grain yield per plant; MCM 100 $\times$ MTU 1140 for number of ear bearing tillers per plant, panicle length, number of grains per panicle, kernel breadth after cooking and grain yield per plant, suggested that the possibility of utilization of these F_1 s hybrids for commercial exploitation after testing these hybrids over large number of environments and seasons.

The cross combination MTU 1001 $\times$ MTU 1140 registered significant relative heterosis and heterobeltiosis for total number of tillers per plant, number of vegetative buds after the harvest of main crop, number of ear bearing tillers per plant, milling percentage, head rice recovery and grain yield per plant. It also recorded significant *sca* effects and better *per se* performance for all the 6 characters mentioned above. Thus among all the crosses, based on relative heterosis, heterobeltiosis, *sca* effects and *per se* performance, the cross MTU 1001 $\times$ MTU 1140 was identified as a promising hybrid for majority of characters studied (Table 4.35.).

4.3.2.5 CHARACTER ASSOCIATION

Correlation coefficient is one of the important biometric tools for formulating the selection index, as it provides information on the nature and magnitude of the association of different components characters with seed yield which is regarded as highly complex trait in which the breeder is ultimately interested in. Although understanding of the association of plant characters with yield and among themselves is essential for successful crop improvement programme.

In the present investigation, a number of yield attributes, grain quality their relationship with grain yield as well as among themselves were represented in Table 4.36 and Table 4.37. The results were discussed character wise hereunder. Genotypic correlations in general are higher than phenotypic correlations indicating that the apparent associations are largely due to genetic reasons.

4.3.2.5.1 Days to 50% Flowering

This character expressed positive significant association with days to maturity (0.869**, 0.968**), plant height (0.417**, 0.521**), total number of ear bearing tillers per plant (0.405**, 0.559**), number of ratoon productive tillers as percentage of main crop productive tillers (0.371**, 0.565**), panicle length (0.314**, 0.481**), number of grains per panicle (0.296**, 0.372**), leaf area index (0.489**, 0.609**), hulling recovery (0.224*, 0.305**), head rice recovery (0.201*, 0.233*), grain yield per plant (0.380**, 0.484**). Whereas, significant negative correlation with kernel breadth (-0.201*, -0.327**) and kernel breadth after cooking (-0.240*, -0.256**) at both phenotypic and genotypic levels.

It also showed positive significant association with L/B ratio (0.197*) at genotypic level and negative significant association with milling recovery (-0.211*) and kernel length (-0.233*) at genotypic level. Similar results were confined by Islam *et al.* (2015), Sathisha *et al.* (2015), Singh *et al.* (2015) and Shajedur Hossain *et al.* (2015).

4.3.2.5.2 Days to Maturity

Days to maturity was found to have significant positive correlation with plant height (0.507**, 0.564**), total number of ear bearing tillers per plant (0.425**, 0.594**), number of ratoon productive tillers as percentage of main crop productive tillers (0.364**, 0.563**), panicle length (0.379**, 0.508**), number of grains per panicle (0.368**, 0.430**), leaf area index (0.480**, 0.552**), hulling recovery (0.287**, 0.329**), head rice recovery (0.207*, 0.261**), grain yield per plant (0.380**, 0.484**) and negative significant correlation with kernel breadth (-0.338**, -0.257**), kernel breadth after cooking (-0.198*, -0.237**) at both phenotypic and genotypic levels.

It also exhibited positive significant association with total number of tillers per plant (0.246*) and L/B ratio (0.225*) at genotypic level. Whereas, significant negative association was observed with kernel length (-0.222*), milling recovery (-0.199*) at phenotypic level. Similar kind of relation was reported by Golam Sarwar *et al.* (2015), Islam *et al.* (2015), Kundu Sritama *et al.* (2015) and Nabedita Mohanty *et al.* (2015).

4.3.2.5.3 Plant Height (cm)

Plant height recorded significant positive correlation with total number of tillers per plant (0.356**, 0.603**), total number of ear bearing tillers per plant (0.498**, 0.673**), panicle length (0.697**, 0.871**), number of grains per panicle (0.562**, 0.627**), test weight (0.424**, 0.435**), leaf area index (0.474**, 0.514**), hulling recovery (0.409**, 0.477**), head rice recovery (0.381**, 0.471**), gel consistency (0.306**, 0.328**) and grain yield per plant (0.640**, 0.676**). Whereas, significant negative association with number of ratoon tillers as percentage of main crop tillers per plant (-0.218*, -0.345**), volume expansion ratio (-0.195*, -0.233*), alkali spreading value (-0.333**, -0.349**) at both phenotypic and genotypic levels.

It also had positive significant correlation with number of ratoon productive tillers as percentage of main crop productive tillers (0.245**) at genotypic level and milling recovery (0.260**) at genotypic level. Whereas, significant negative association with kernel linear elongation ratio (-0.215*) at genotypic level. These results are in consonance with findings of Anis *et al.* (2016), Islam *et al.* (2015), Sathisha *et al.* (2015) and Singh *et al.* (2015).

4.3.2.5.4 Total Number of Tillers per plant

At both phenotypic and genotypic levels, this trait exhibited significant positive correlation with number of vegetative buds after the harvest of main crop (0.555**, 0.910**), total number of ear bearing tillers per plant (0.410**, 0.826**), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.295**, 0.452**), number of grains per panicle (0.26**, 0.453**), hulling recovery (0.265**, 0.390**) and grain yield per plant (0.381**, 0.596**).

It showed positive significant association with number of ratoon tillers as percentage of main crop tillers per plant (0.387**) at phenotypic level and panicle length (0.380**), leaf area index (0.310**), milling recovery (0.292**), head rice recovery (0.297**), gel consistency (0.273**) at genotypic level, while significant negative association with number of ratoon tillers as percentage of main crop tillers per plant (-0.217*), alkali spreading value (-0.286*) at phenotypic level. These results are in accordance with Golam Sarwar *et al.* (2015), Kundu sritama *et al.* (2015), Sathisha *et al.* (2015) and Vijay Kumar *et al.* (2015).

4.3.2.5.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers per Plant

Number of ratoon tillers as percentage of main crop tillers per plant recorded significant positive correlation with number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.391**, 0.727**), kernel breadth (-0.230*, -0.320**), L/B ratio (0.333**, 0.419**) and exhibited negative significant association with panicle length (-0.385**, -0.614**), number of grains per panicle (-0.279**, -0.531**), test weight (-0.357**, -0.496**), milling recovery (-0.279**, -0.651**), head rice recovery (-0.278**, -0.523**), kernel breadth (-0.230*, -0.320**), kernel breadth after cooking (-0.260**, -0.550**) and water uptake (-0.272**, -0.382**) both phenotypic and genotypic levels, respectively.

It had positive significant association with number of vegetative buds after the harvest of main crop (0.208*) at phenotypic level and significant negative correlation with hulling recovery (-0.370**) at genotypic level.

4.3.2.5.6 Number of Vegetative Buds after the Harvest of Main Crop

This character expressed significant positive association with total number of ear bearing tillers per plant (0.231*, 0.612**), kernel breadth (0.442**), kernel breadth after cooking (0.190*, 0.300**) at both genotypic and phenotypic levels. This traits also exhibited positive significant association with number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.326**), grain yield per plant (0.357**) and significant negative association with L/B ratio (-0.553**) and alkali spreading value (-0.237**) at genotypic level.

4.3.2.5.7 Total Number of Ear Bearing Tillers per Plant

At both phenotypic and genotypic correlations indicated that this trait had significant positive association with number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers number of ear bearing tillers per plant (0.749**, 0.751**), panicle length (0.376**, 0.622**), number of grains per panicle (0.414**, 0.579**), leaf area index (0.456**, 0.598**), hulling recovery (0.268**, 0.371**), head rice recovery (0.304**, 0.499**) and grain yield per plant (0.711**, 0.935**). It also exhibited significant positive association with test weight (0.196*), gel consistency (0.235*) at genotypic level and it also recorded significant negative correlation with amylose content (-0.191*) at genotypic level. Similar kind of association was earlier reported by Golam Sarwar *et al.* (2015), Keya *et al.* (2015), Kundu Sritama *et al.* (2015) and Marzieh Moosavi *et al.* (2015).

4.3.2.5.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers recorded significant positive association with leaf area index (0.316**, 0.442**), L/B ratio (0.265**, 0.387**), grain yield per plant (0.439**, 0.635**) and it exerts significant negative correlation with milling recovery (-0.278**), kernel breadth (-0.260**, -0.414**) and kernel breadth after cooking (-0.0194*, -0.342**) at both phenotypic and genotypic levels. This trait, had positive significant correlation with kernel linear elongation ratio (0.318**) and significant negative association with test weight (-0.230*) at genotypic level.

4.3.2.5.9 Panicle Length per Plant (cm)

This trait, established significant positive association with number of grains per panicle (0.435**, 0.620**), test weight (0.337**, 0.433**), leaf area index (0.297**, 0.359**), hulling recovery (0.303**, 0.440**), head rice recovery (0.328**, 0.461**), water uptake (0.325**, 0.381**) and grain yield per plant (0.478**, 0.597**). Whereas, significant negative association with alkali spreading value (-0.287**, -0.332**) at both phenotypic and genotypic levels. It also showed positive significant and negative significant correlation with gel consistency (0.189*) and kernel length after cooking (-0.192*) at genotypic levels, respectively. These findings are corroborated by Kundu Sritama *et al.* (2015), Marzieh Moosavi *et al.* (2015) and Sathisha *et al.* (2015).

4.3.2.5.10 Number of Grains per Panicle

This character possessed significant positive correlation with test weight (0.310**, 0.355**), leaf area index (0.497**, 0.567**), hulling recovery (0.500**, 0.623**), milling recovery (0.274**, 0.467**), head rice recovery (0.479**, 0.588**), kernel breadth after cooking (0.266**, 0.364**), gel consistency (0.313**, 0.351**), grain yield per plant (0.633**, 0.688**) and significant negative association with amylose content (-0.201*, -0.221*) at both phenotypic and genotypic levels, respectively. These results were in agreement with the findings Islam *et al.* (2015), Kundu Sritama *et al.* (2015) and Sandhyarani Das (2015).

4.3.2.5.11 Test Weight (g)

Test weight exhibited significant positive association with leaf area index (0.478**, 0.514**), hulling recovery (0.293**, 0.336**), milling recovery (0.386**, 0.558**), head rice recovery (0.477**, 0.617**), gel consistency (0.265**, 0.286**), grain yield per plant (0.439**, 0.469**) and possessed negative significant association with volume expansion ratio (-0.211*, -0.276**) both at phenotypic and genotypic levels, respectively. Similar results were confined by Kundu Sritama *et al.* (2015), Nabedita Mohanty *et al.* (2015), Sarafraz *et al.* (2015) and Sathisha *et al.* (2015).

4.3.2.5.12 Leaf Area Index at Maximum Tillering Stage

At both phenotypic and genotypic level this trait, possessed significant positive association with hulling recovery (0.332**, 0.431**), milling recovery (0.196*, 0.283*), grain yield per plant (0.688**, 0.720**), head rice recovery (0.490**, 0.581**) and showed negative significant association with volume expansion ratio (-0.254**, -0.305**). The above results were in agreement with Keya *et al.* (2015), Ganghua *et al.* (2014) and Hashem and Peyman (2011).

4.3.2.5.13 Hulling Recovery (%)

This trait had significant positive correlation with milling recovery (0.348**, 0.612**), head rice recovery (0.571**, 0.753**), kernel breadth (0.194*, 0.258**), grain yield per plant (0.287**, 0.367**) at both phenotypic and genotypic levels and this trait showed significant negative association with L/B ratio (-0.198*). Similar results were confined by Tushara *et al.* (2013) and Prem Kumar *et al.* (2010).

4.3.2.5.14 Milling Recovery (%)

Milling percentage possessed significant positive association with head rice recovery (0.541**, 0.751**), kernel length (0.155, 0.252*), kernel breadth (0.275**, 0.301**), kernel length after cooking (0.219*, 0.285**), kernel breadth after cooking (0.164, 0.340**), gel consistency (0.335**, 0.490**), grain yield per plant (0.223*, 0.349**) and showed significant negative association with volume expansion ratio (-0.243*, -0.342**) both at phenotypic and genotypic levels. It also had significant negative association with L/B ratio (-0.192*) at genotypic level. Similar kind of relation was reported by Nagaraju *et al.* (2013), Ruth Elizabeth Ekka *et al.* (2011) and Prem Kumar *et al.* (2010).

4.3.2.5.15 Head Rice Recovery (%)

The trait, head rice recovery expressed significant positive association with kernel length after cooking (0.252**, 0.320**), kernel linear elongation ratio (0.209*, 0.284**), grain yield per plant (0.477**, 0.604**) and negative significant association was observed with amylose content (-0.222*, -0.268**) at both phenotypic and genotypic levels, respectively. Similar results were confined by Krishna Veni *et al.* (2013) and Prem Kumar *et al.* (2010).

4.3.2.5.16 Kernel Length (mm)

At both phenotypic and genotypic correlations indicated that this trait had significant positive association with kernel breadth (0.490**, 0.601**), kernel length after cooking (0.364**, 0.483**) and also negative significant association with kernel linear elongation ratio (-0.444**, -0.0276**). These results are in consonance with findings of Islam *et al.* (2015), Singh *et al.* (2014) and Gulzar *et al.* (2013).

4.3.2.5.17 Kernel Breadth (mm)

Kernel breadth was found to have significant positive association with kernel breadth after cooking (0.250**, 0.345**) and while significant negative association with L/B ratio (-0.771**, -0.798**), kernel linear elongation ratio (-0.222*, -0.255**), at both phenotypic and genotypic levels, respectively. These results are in accordance with Nitiprasad and Lotan Kumar (2014), Aditya and Anuradha Bhartiya (2013) and Awaneet Kumar and Senapathi (2013).

4.3.2.5.18 Kernel Length/Breadth Ratio

This character, possessed negative significant association with kernel breadth after cooking (-0.269**, -0.453**) and non-significant negative association with kernel linear elongation ratio (-0.059) and volume expansion ratio (-0.057, -0.115) at both phenotypic and genotypic levels, respectively. Sathisha *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014) and Venkata Lakshmi *et al.* (2014) also reported similar association

4.3.2.5.19 Kernel Length after Cooking (mm)

Kernel length after cooking exhibited significant positive association with kernel linear elongation ratio (0.672**, 0.708**), water uptake (0.0189*, 0.216*), alkali spreading value (0.277**, 0.289**) both at phenotypic and genotypic levels, respectively. Similar results were confined by Dhurai *et al.* (2014) and Prem Kumar *et al.* (2010).

4.3.2.5.20 Kernel Breadth after Cooking (mm)

The trait, kernel breadth after cooking recorded non-significant positive correlation with volume expansion ratio (0.025), water uptake (0.005), gel consistency (0.026, 0.037), amylose content (0.115, 0.134) and negative non-significant association with kernel linear elongation ratio (-0.150, -0.134), volume expansion ratio (-0.002, 0.025), water uptake (0.005, -0.017), alkali spreading value (-0.156, -0.182) and grain yield per plant (-0.007, 0.007) at both phenotypic and genotypic levels, respectively. Similar results were confined by Arulmozhi and Muthuswamy (2013).

4.3.2.5.21 Kernel Elongation Ratio

At both phenotypic and genotypic levels, this trait, possessed significant positive association with spreading value (0.214*), non-significant positive association with volume expansion ratio (0.003, 0.045), water uptake (0.066, 0.092), spreading value (0.180), grain yield per plant (0.068, 0.128) and negative low association with gel consistency (-0.005, -0.027), alkali amylose content (-0.076, -0.098). Similar kind of association was earlier reported by Nabedita Mohanty *et al.* (2015), Dhurai *et al.* (2014), Krishna Veni *et al.* (2013) and Chaudhary and Motiramani (2003).

4.3.2.5.22 Volume Expansion Ratio

Volume expansion established significant positive correlation with water uptake (0.204*, 0.218*), alkali spreading value (0.231*, 0.274**) and negative significant association was observed with gel consistency (-0.202*, -0.211*) and grain yield per plant (-0.222*, -0.280**) at both phenotypic and genotypic levels, respectively. These findings are corroborated by Malini *et al.* (2011).

4.3.2.5.23 Water Uptake (ml)

This character showed non-significant positive association with alkali spreading value (0.165, 0.169), amylose content (0.039, 0.038) and grain yield per plant (0.112, 0.120) and negative non-significant correlation with gel consistency (-0.070, -0.072) at both phenotypic and genotypic levels, respectively. These results were in agreement with the findings Krishna Veni *et al.* (2013) and Malini *et al.* (2011).

4.3.2.5.24 Gel Consistency (mm)

At both phenotypic and genotypic correlations indicated that this trait had significant positive correlation with grain yield per plant (0.314**, 0.328**) and non-significant negative association with alkali spreading value (-0.057, -0.061) and amylose content (-0.026, -0.027). Contrary, positive non-significant correlation was reported Malini *et al.* (2011) and Nagajyothi (2001), this might be due to differences in breeding material studied under different environments.

4.3.2.5.25 Alkali Spreading Value (mm)

Alkali spreading value expressed positive non-significant association with amylose content (0.129, 0.131) and grain yield per plant (-0.125, -0.123) at both phenotypic and genotypic levels, respectively. The above results were in agreement with Manonmani *et al.* (2010).

4.3.2.5.26 Amylose Content (%)

The trait, amylose content recorded significant negative correlation with grain yield per plant (-0.272**, -0.283**) at both phenotypic and genotypic levels, respectively, Contrary, negative non-significant association was reported by Patel *et al.* (2014) and Krishna Veni *et al.* (2013), this might be due to differences in breeding material studied under different environments.

Thus, in the present investigation, the genotypic correlations in general are higher than phenotypic correlations and thus suggested that the observed relationships among the characters were due to genetic causes. The traits, which showed highly significant positive correlation with grain yield per plant were days to 50% flowering, days to maturity, plant height, total number of tillers per plant, total number of ear bearing tillers per plant, number of ear bearing tillers as percentage of main crop ear bearing tillers, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, hulling percentage, milling percentage, head rice recovery and gel consistency at both genotypic and phenotypic levels. The characters, volume expansion ratio and amylose content, were found to possess significant negative correlation with grain yield per plant at both genotypic and phenotypic levels. So, while making simultaneous selections for improvement of grain yield with good grain quality and good ratoonability a compromise had to be stuck at level of improvement with regard to the traits having negative association in desirable direction with grain yield per plant.

4.3.2.6 PATH COEFFICIENT ANALYSIS

Yield being a complex character, is composed of several components some of which affect yield directly while others contribute towards it indirectly. Correlation studies provide an opportunity to study the magnitude and direction of association of yield with its components and also among various components. To accumulate optimum combination of yield contributing characters in a single genotype, it is essential to know the amplification of interrelationship of various characters with standard partial correlation or regression.

In the present study, path analysis was used to work out the direct and indirect effects of yield contributing characters and quality traits on grain yield in 28 F₁s and 8 parents of ratoon crop results are presented (Table 4.38) character wise hereunder. The path diagrams were given in Figures 4.4.

4.3.2.6.1 Days to 50% Flowering

This character expressed significant positive association (0.484**) and negative direct effect (-1.463) on grain yield per plant at genotypic level. It also exhibited positive indirect effect *via* days to maturity (1.595), total number of ratoon tillers as percentage of main crop tillers per plant (0.019), number of vegetative buds after harvest of main crop (0.023), total number of ear bearing tillers per plant (0.221), panicle length (0.053), number of grains per panicle (0.044), test weight (0.033), leaf area index (0.190), head rice recovery (0.107), L/B ratio (0.000), kernel length after cooking (0.143), kernel linear elongation ratio (0.314), volume expansion ratio (0.012); while exhibited negative indirect effect mainly through plant height (-0.099), number of tillers per plant (-0.006), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.002), hulling recovery (-0.144), milling recovery (-0.030), kernel length (-0.423), kernel breadth (-0.015), kernel breadth after cooking (-0.037), water uptake (-0.014), gel consistency (-0.024), alkali spreading value (-0.011) and amylose content (-0.001). Similar results were confined by Islam *et al.* (2015), Shajedur *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Imad *et al.* (2014), Khare *et al.* (2014), Thirumala Rao (2014) and Awaneet and Senapati (2013).

4.3.2.6.2 Days to Maturity

Days to maturity showed negative significant correlation (0.495**) and positive direct effect (1.648) on grain yield per plant at genotypic level. It also expressed positive indirect effects mainly through number of ratoon tillers as percentage of main

crop tillers per plant (0.025), number of vegetative buds after harvest of main crop (0.023), total number of ear bearing tillers per plant (0.235), panicle length (0.056), number of grains per panicle (0.050), test weight (0.022), leaf area index (0.172), head rice recovery (0.120), L/B ratio (0.000), kernel length after cooking (0.015), kernel linear elongation ratio (0.396) and amylose content (0.001). It also possessed negative indirect effect *via* days to 50% flowering (-1.416), plant height (-0.107), total number of tillers per plant (-0.007), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.002), kernel length (-0.403), kernel breadth (-0.015), hulling recovery (-0.155), milling recovery (-0.029), kernel breadth after cooking (-0.034), volume expansion ratio (-0.012), water uptake (-0.012), gel consistency (-0.032), alkali spreading value (-0.040). These findings are in conformity with the results of Golam *et al.* (2015), Islam *et al.* (2015), Singh *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Khare *et al.* (2014), Awaneet and Senapati (2013), Bineeta *et al.* (2012), Mulugeta *et al.* (2012) and Nandan *et al.* (2010).

4.3.2.6.3 Plant Height (cm)

At genotypic level, this trait showed positive direct effect (-0.190) and positive significant association (0.676**) on grain yield per plant. This trait also expressed positive indirect effects *via* number of vegetative buds after harvest of main crop (0.020), total number of ear bearing tillers per plant (0.266), panicle length (0.095), number of grains per panicle (0.073), test weight (0.088), leaf area index (0.160), milling recovery (0.037), head rice recovery (0.216), kernel length (0.261), kernel breadth (0.000), L/B ratio (0.000), kernel length after cooking (0.295), kernel breadth after cooking (0.003), water uptake (0.033), gel consistency (0.092), and amylose content (0.001); where it exhibited negative indirect effect *via* days to 50% flowering (-0.762), days to maturity (0.929), total number of tillers per plant (-0.016), number of ratoon tillers as percentage of main crop tillers per plant (-0.111), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), hulling recovery (-0.225), kernel linear elongation ratio (-0.469), volume expansion ratio (-0.053) and alkali spreading value (-0.067). These findings are corroborated by Golam *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Patel *et al.* (2014) and Awaneet and Senapati (2013).

4.3.2.6.4 Total Number of Tillers per Plant

Direct effects of this trait on grain yield was positive direct effect (-0.027) and significant positive association (0.596**) was observed at genotypic level and exerts positive indirect effects mainly through days to maturity (0.405), number of vegetative

buds after harvest of main crop (0.130), total number of ear bearing tillers per plant (0.327), panicle length (0.042), number of grains per panicle (0.053), test weight (0.025), leaf area index (0.097), milling recovery (0.042), head rice recovery (0.136), kernel length (0.049), kernel breadth (0.008), L/B ratio (0.000), kernel length after cooking (0.153), kernel breadth after cooking (0.023), water uptake (0.018), gel consistency (0.077) and amylose content (-0.002). It also had negative indirect effect *via* days to 50% flowering (-0.322), plant height (-0.115), number of ratoon tillers as percentage of main crop tillers per plant (-0.070), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.002), hulling recovery (-0.184), kernel linear elongation ratio (-0.186), volume expansion ratio (-0.026) and alkali spreading value (-0.055). These results are in accordance with Alam *et al.* (2014), Mohammad and Kayvan (2014), Nitiprasad and Lotan (2014), Patel *et al.* (2014) and Krishnamurthy *et al.* (2013).

4.3.2.6.5 Number of Ratoon Tillers as Percentage of Main Crop Tillers per Plant

This trait had significant positive association (-0.165) on grain yield per plant and showed positive direct effect (0.321) at genotypic level. It showed positive indirect effects mainly through days to maturity (0.127), plant height (0.066), total number of tillers per plant (0.006), number of vegetative buds after harvest of main crop (0.011), total number of ear bearing tillers per plant (0.022), leaf area index (0.005), hulling recovery (0.175), kernel length (0.083), L/B ratio (0.000), kernel linear elongation ratio (0.124), volume expansion ratio (0.028) and alkali spreading value (0.031). This trait also exhibited negative indirect effect *via* days to 50% flowering (-0.086), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.003), panicle length (-0.067), number of grains per panicle (-0.062), test weight (-0.100), milling recovery (-0.093), head rice recovery (-0.240), kernel breadth (-0.105), kernel length after cooking (-0.286), kernel breadth after cooking (-0.079), water uptake (-0.079), gel consistency (-0.051) and amylose content (-0.003).

4.3.2.6.6 Number of Vegetative Buds after the Harvest of Main Crop

The trait, number of vegetative buds after the harvest of main crop had positive direct effect (0.143) and significant positive association (0.357**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to maturity (0.259), number of ratoon tillers as percentage of main crop tillers per plant (0.024), total number of ear bearing tillers per plant (0.242), panicle length (0.003), number of grains per panicle (0.012), leaf area index (0.049), milling recovery (0.024), head rice

recovery (0.000), kernel breadth (0.020), L/B ratio (0.000), kernel breadth after cooking (0.043), kernel linear elongation ratio (0.062) and amylose content (0.001), whereas negative indirect effect through days to 50% flowering (-0.233), plant height (-0.026), total number of tillers per plant (-0.024), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), test weight (-0.010), hulling recovery (-0.016), kernel length (-0.008), kernel length after cooking (-0.099), volume expansion ratio (-0.034), water uptake (-0.003), gel consistency (-0.026) and alkali spreading value (-0.045).

4.3.2.6.7 Total Number of Ear Bearing Tillers per Plant

Total number of ear bearing tillers per plant expressed negative direct effect (0.395) and significant positive association (0.935**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to maturity (0.978), number of ratoon tillers as percentage of main crop tillers per plant (0.018), number of vegetative buds after harvest of main crop (0.088), panicle length (0.068), number of grains per panicle (0.068), test weight (0.039), leaf area index (0.187), milling recovery (0.023), head rice recovery (0.229), L/B ratio (0.000), kernel linear elongation ratio (0.348), water uptake (0.026), gel consistency (0.066) and amylose content (0.004); while showed negative indirect effect *via* days to 50% flowering (-0.818), plant height (-0.128), total number of tillers per plant (-0.022), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.003), hulling recovery (-0.175), kernel length (-0.076), kernel breadth (-0.006), kernel length after cooking (-0.292), kernel breadth after cooking (-0.014), volume expansion ratio (-0.058), alkali spreading value (-0.008). These results are in consonance with findings of Pradhan *et al.* (2015), (2014), Dhurai *et al.* (2014), Imad *et al.* (2014), Patel *et al.* (2014), Thirumala Rao (2014), Krishna Veni *et al.* (2013) and Ravindra Babu *et al.* (2012).

4.3.2.6.8 Number of Ratoon Ear Bearing Tillers as Percentage of Main Crop Ear Bearing Tillers

This trait, had negative direct effect (-0.004) and significant positive association (0.635**) on grain yield per plant at genotypic level. It also recorded positive indirect effects mainly through days to maturity (0.928), plant height (-0.047), number of ratoon tillers as percentage of main crop tillers per plant (0.233), number of vegetative buds after harvest of main crop (0.047), total number of ear bearing tillers per plant (0.297), panicle length (0.011), number of grains per panicle (0.018), leaf area index (0.138),

hulling recovery (0.000), head rice recovery (0.068), kernel linear elongation ratio (0.695), gel consistency (0.005), alkali spreading value (0.036) and amylose content (0.004); and negative indirect effect through days to 50% flowering (-0.826), total number of tillers per plant (-0.012), test weight (-0.046), milling recovery (-0.040), kernel length (-0.289), kernel breadth (-0.019), L/B ratio (0.000), kernel length after cooking (-0.475), kernel breadth after cooking (-0.049), volume expansion ratio (-0.006) and water uptake (-0.030).

4.3.2.6.9 Panicle Length per Plant

Panicle length per plant possessed significant positive association (0.597**) and negative direct effect (0.110) with grain yield per plant at genotypic level and recorded positive indirect effects *via* days to maturity (0.838), number of vegetative buds after harvest of main crop (0.003), total number of ear bearing tillers per plant (0.246), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.000), number of grains per panicle (0.073), test weight (0.087), leaf area index (0.112), milling recovery (0.027), head rice recovery (0.211), L/B ratio (0.000), kernel length after cooking (0.548), kernel breadth after cooking (0.010), water uptake (0.079), gel consistency (0.053) and amylose content (0.002). It also exhibited negative indirect effect *via* days to 50% flowering (-0.703), plant height (-0.166), total number of tillers per plant (-0.010), number of ratoon tillers as percentage of main crop tillers per plant (-0.197), hulling recovery (-0.207), kernel length (-0.098), kernel breadth (-0.002), kernel linear elongation ratio (-0.328), volume expansion ratio (-0.024) and alkali spreading value (-0.064). These results are in consonance with findings of Golam *et al.* (2015), Pradhan *et al.* (2015), Alam *et al.* (2014), Dhurai *et al.* (2014), Patel *et al.* (2014), Rahman *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013) and Krishna Veni *et al.* (2013).

4.3.2.6.10 Number of Grains per Panicle

At genotypic level, the trait number of grains per panicle had positive direct effect (0.117) and significant positive association (0.688**) on grain yield per plant. This trait exhibited positive indirect effect through days to maturity (0.709), n number of vegetative buds after harvest of main crop (0.015), total number of ear bearing tillers per plant (0.229), panicle length (0.068), test weight (0.071), leaf area index (0.177), milling recovery (0.067), head rice recovery (0.270), kernel breadth (0.005), L/B ratio (0.000), kernel breadth after cooking (0.052), kernel linear elongation ratio (0.368),

water uptake (0.030), gel consistency (0.098) and amylose content (0.005); while exhibited negative indirect effect *via* days to 50% flowering (-0.544), plant height (-0.119), total number of tillers per plant (-0.012), number of ratoon tillers as percentage of main crop tillers per plant (-0.171), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), kernel length (-0.020), hulling recovery (-0.294), kernel length after cooking (-0.384), alkali spreading value (-0.038) and volume expansion ratio (-0.010). These results were in broad agreement with the findings of Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Gulzar *et al.* (2013) and Nagaraju *et al.* (2013).

4.3.2.6.11 Test Weight (g)

This character expressed positive direct effect (0.201) and significant positive association (0.469**) with grain yield per plant at genotypic level and exhibited positive indirect effect through days to maturity (0.181), total number of ear bearing tillers per plant (0.077), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), panicle length (0.047), number of grains per panicle (0.042), leaf area index (0.160), milling recovery (0.080), head rice recovery (0.283), kernel length (0.214), kernel breadth (0.005), L/B ratio (0.000), kernel linear elongation ratio (0.039), water uptake (0.012), gel consistency (0.080) and amylose content (0.000). It also exhibited negative indirect effect *via* days to 50% flowering (-0.241), plant height (-0.083), total number of tillers per plant (-0.003), number of ratoon tillers as percentage of main crop tillers per plant (-0.159), number of vegetative buds after harvest of main crop (-0.007), hulling recovery (-0.159), kernel length after cooking (-0.215), kernel breadth after cooking (-0.014), volume expansion ratio (-0.063) and alkali spreading value (-0.010). The above results were in agreement with Pradhan *et al.* (2015), Dhurai *et al.* (2014), Imad *et al.* (2014), Thirumala Rao (2014), Awaneet and Senapati (2013) and Bhabendra *et al.* (2012).

4.3.2.6.12 Leaf area Index at Maximum Tillering Stage

Direct effects of this trait on grain yield was negative (0.312) and showed significant positive association (0.720**) with grain yield per plant at genotypic level and exerts positive indirect effect through days to maturity (0.909), number of ratoon tillers as percentage of main crop tillers per plant (0.005), number of vegetative buds after harvest of main crop (0.023), total number of ear bearing tillers per plant (0.236), panicle length (0.039), number of grains per panicle (0.066), test weight (0.103), milling

recovery (0.041), head rice recovery (0.266), L/B ratio (0.000), water uptake (0.019), gel consistency (0.029) and amylose content (0.003). Whereas this trait showed negative indirect effect *via* days to 50% flowering (-0.891), plant height (-0.098), total number of tillers per plant (-0.008), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.002), hulling recovery (-0.204), kernel length (-0.065), kernel breadth (-0.008), kernel length after cooking (-0.233), kernel breadth after cooking (-0.015), kernel linear elongation ratio (0.304), volume expansion ratio (-0.069) and alkali spreading value (-0.005). These findings are in conformity with the results of Zulqarnain *et al.* (2012) and Ullah *et al.* (2011).

4.3.2.6.13 Hulling Recovery (%)

Hulling recovery recorded positive direct effect (-0.472) and significant positive association (0.367**) with grain yield per plant at genotypic level and this trait exhibited positive indirect effects *via* days to maturity (0.543), , number of vegetative buds after harvest of main crop (0.005), total number of ear bearing tillers per plant (0.147), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.000), panicle length (0.048), number of grains per panicle (0.073), test weight (0.068), leaf area index (0.135), milling recovery (0.088), head rice recovery (0.345), kernel length (0.336), kernel breadth (0.012), L/B ratio (0.000), kernel breadth after cooking (0.027), volume expansion ratio (0.018), water uptake (0.021), gel consistency (0.029) and amylose content (0.000); while negative indirect effect was recorded through days to 50% flowering (-0.446), plant height (-0.091), total number of tillers per plant (-0.011), number of ratoon tillers as percentage of main crop tillers per plant (-0.119), kernel length after cooking (-0.309), kernel linear elongation ratio (-0.047) and alkali spreading value (-0.030). These results are in accordance with Mahalingam *et al.* (2013), Nandan *et al.* (2010), Parvathi (2010), Praveen *et al.* (2010), Prem Kumar *et al.* (2010) and Nagajyothi (2001).

4.3.2.6.14 Milling Recovery (%)

The trait, expressed negative direct effect (0.144) and significant positive association (0.349**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to 50% flowering (0.309), number of vegetative buds after harvest of main crop (0.024), total number of ear bearing tillers per plant (0.063), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), panicle length (0.021), number of grains per panicle (0.055), test weight

(0.112), leaf area index (0.088), head rice recovery (0.345), kernel length (0.457), kernel breadth (0.014), L/B ratio (0.000), kernel breadth after cooking (0.049), kernel linear elongation ratio (0.292), water uptake (0.022), gel consistency (0.137) and amylose content (0.003). This trait showed negative indirect effect *via* days to maturity (-0.327), plant height (-0.049), total number of tillers per plant (-0.008), number of ratoon tillers as percentage of main crop tillers per plant (-0.209), hulling recovery (-0.289), kernel length after cooking (-0.812), volume expansion ratio (-0.078) and alkali spreading value (-0.015). These findings are corroborated by Madhusoodanan (2013), Nagaraju *et al.* (2013), Ruth *et al.* (2011), Parvathi (2010) and Ruth *et al.* (2011).

4.3.2.6.15 Head Rice Recovery (%)

Head rice recovery possessed positive direct effect (0.459) and significant positive association (0.604**) on grain yield per plant at genotypic level. It also had positive indirect effects through days to maturity (0.431), number of vegetative buds after harvest of main crop (0.000), total number of ear bearing tillers per plant (0.197), panicle length (0.051), number of grains per panicle (0.069), test weight (0.124), leaf area index (0.181), milling recovery (0.108), kernel length (0.195), kernel breadth (0.009), L/B ratio (0.000), kernel breadth after cooking (0.017), kernel linear elongation ratio (0.621), water uptake (0.016), gel consistency (0.030) and amylose content (0.006); while it showed negative indirect effect *via* days to 50% flowering (-0.341), plant height (-0.090), number of ratoon tillers as percentage of main crop tillers per plant (-0.168), total number of tillers per plant (-0.008), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), hulling recovery (-0.356), kernel length after cooking (-0.911), volume expansion ratio (-0.022) and alkali spreading value (-0.013). These results are in accordance with Krishna Veni *et al.* (2013), Ruth *et al.* (2011), Praveen *et al.* (2010) and Nayak *et al.* (2005).

4.3.2.6.16 Kernel Length (mm)

At genotypic level, kernel length exhibited significant positive correlation (-0.079) and positive direct effect (1.813) on grain yield per plant and also showed positive indirect effects through days to 50% flowering (0.341), number of ratoon tillers as percentage of main crop tillers per plant (0.015), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), test weight (0.024), milling recovery (0.036), head rice recovery (0.049), kernel breadth (0.027), L/B ratio (0.000), volume expansion ratio (0.001), water uptake (0.038), gel consistency (0.049), alkali

spreading value (0.024) and amylose content (0.002); while it exhibited negative indirect effect *via* days to maturity (-0.366), plant height (-0.027), total number of tillers per plant (-0.001), number of vegetative buds after harvest of main crop (-0.001), total number of ear bearing tillers per plant (-0.017), panicle length (-0.006), number of grains per panicle (-0.001), leaf area index (-0.011), hulling recovery (-0.087), kernel length after cooking (-1.377), kernel breadth after cooking (-0.002) and kernel linear elongation ratio (-0.602). These results are in consonance with findings of Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Krishna Veni *et al.* (2013) and Ruth *et al.* (2011).

4.3.2.6.17 Kernel Breadth (mm)

Kernel breadth had non-significant positive association (-0.121) and negative direct effect (0.046) on grain yield per plant at genotypic level. It also showed positive indirect effects *via* days to 50% flowering (0.478), plant height (0.002), number of vegetative buds after harvest of main crop (0.063), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.002), number of grains per panicle (0.012), test weight (0.023), milling recovery (0.043), head rice recovery (0.088), kernel length (1.089), L/B ratio (0.000), kernel breadth after cooking (0.049), volume expansion ratio (0.021), water uptake (0.013), gel consistency (0.023) and amylose content (0.003), whereas negative indirect effect *via* days to maturity (-0.557), number of ratoon tillers as percentage of main crop tillers per plant (-0.103), total number of tillers per plant (-0.005), total number of ear bearing tillers per plant (-0.056), panicle length (-0.005), leaf area index (-0.051), hulling recovery (-0.122), kernel linear elongation ratio (-0.558), kernel length after cooking (-0.616) and alkali spreading value (-0.005). These results are in consonance with findings of Islam *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013) and Krishna Veni *et al.* (2013), Ruth *et al.* (2011) and Nandan *et al.* (2010).

4.3.2.6.18 Kernel Length/Breadth Ratio

At genotypic level, the trait number of L/B ratio had negative direct effect (-0.001) and non-significant positive association (0.090) on grain yield per plant. This trait exhibited positive indirect effect *via* days to maturity (0.371), total number of tillers per plant (0.006), number of ratoon tillers as percentage of main crop tillers per plant (0.135), total number of ear bearing tillers per plant (0.057), panicle length (0.000), leaf area index (0.049), hulling recovery (0.094), kernel linear elongation ratio (0.276),

water uptake (0.017), gel consistency (0.008) and alkali spreading value (0.025), whereas negative indirect effect *via* days to 50% flowering (-0.288), plant height (-0.018), number of vegetative buds after harvest of main crop (-0.079), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.002), number of grains per panicle (-0.017), test weight (-0.011), milling recovery (-0.025), head rice recovery (-0.076), kernel length (-0.006), L/B ratio (-0.001), kernel length after cooking (-0.295), kernel breadth after cooking (-0.065), volume expansion ratio (-0.026) and amylose content (-0.002). These results were in broad agreement with the findings of Shathisha *et al.* (2015), Dhurai *et al.* (2014), Patel *et al.* (2014), Awaneet and Senapati (2013), Gulzar *et al.* (2013), Krishna Veni *et al.* (2013), Awaneet and Senapati (2013), Nagaraju *et al.* (2013) and Khatu *et al.* (2010).

4.3.2.6.19 Kernel Length after Cooking (mm)

Kernel length after cooking expressed negative direct effect (-2.849) and significant positive association (0.041) on grain yield per plant and exhibited positive indirect effect mainly through days to 50% flowering (0.074), plant height (0.020), total number of tillers per plant (0.001), number of ratoon tillers as percentage of main crop tillers per plant (0.032), number of vegetative buds after harvest of main crop (0.005), total number of ear bearing tillers per plant (0.041), number of grains per panicle (0.016), test weight (0.015), leaf area index (0.025), milling recovery (0.041), head rice recovery (0.147), kernel length (0.876), kernel breadth (0.010), L/B ratio (0.000), kernel linear elongation ratio (1.547), volume expansion ratio (0.012), water uptake (0.045), gel consistency (0.025), alkali spreading value (0.055) and amylose content (0.004). Whereas this trait exhibited negative indirect effect *via* days to maturity (-0.009), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), panicle length (-0.021), hulling recovery (-0.051) and kernel breadth after cooking (-0.019). The above results were in agreement with Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Prem Kumar *et al.* (2010) and Nandan *et al.* (2010).

4.3.2.6.20 Kernel Breadth after Cooking (mm)

This character recorded positive direct effect (0.144) and non-significant positive association (0.007) on grain yield per plant at genotypic level and exhibited positive indirect effect *via* days to 50% flowering (0.374), number of vegetative buds after harvest of main crop (0.043), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), panicle length (0.008), number of grains per

panicle (0.043), milling recovery (0.049), head rice recovery (0.054), kernel breadth (0.016), L/B ratio (0.000), kernel length after cooking (0.371), volume expansion ratio (0.006) and gel consistency (0.010); while this trait exhibited negative indirect effect *via* days to maturity (-0.391), plant height (-0.004), total number of tillers per plant (-0.004), number of ratoon tillers as percentage of main crop tillers per plant (-0.177), total number of ear bearing tillers per plant (-0.037), test weight (-0.019), leaf area index (-0.033), hulling recovery (-0.090), kernel length (-0.020), kernel linear elongation ratio (-0.293), water uptake (-0.004), alkali spreading value (-0.035) and amylose content (-0.003). These findings are in conformity with the results of Nandan *et al.* (2010) and Prem Kumar *et al.* (2010).

4.3.2.6.21 Kernel Linear Elongation Ratio

This trait had non-significant positive association (0.128) and negative direct effect (2.186) on grain yield per plant at genotypic level and showed positive indirect effect *via* days to maturity (0.299), plant height (0.041), total number of tillers per plant (0.002), number of ratoon tillers as percentage of main crop tillers per plant (0.018), number of vegetative buds after harvest of main crop (0.004), total number of ear bearing tillers per plant (0.063), number of grains per panicle (0.020), test weight (0.004), leaf area index (0.043), hulling recovery (0.010), milling recovery (0.019), head rice recovery (0.019), kernel length (0.130), L/B ratio (0.000), volume expansion ratio (0.010), water uptake (0.019), alkali spreading value (0.041) and amylose content (0.002). It also exhibited negative indirect effect through days to 50% flowering (-0.210), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), panicle length (-0.016), kernel breadth (-0.012), kernel length after cooking (-2.017), kernel breadth after cooking (-0.019) and gel consistency (-0.008). Similar results were earlier reported by Dhurai *et al.* (2014), Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Parvathi (2010), Prem Kumar *et al.* (2010) and Krishna *et al.* (2009a).

4.3.2.6.22 Volume Expansion Ratio

Volume expansion ratio recorded positive direct effect (0.227) and non-significant positive association (-0.280**) on grain yield per plant at genotypic level, with positive indirect effects through plant height (0.044), total number of tillers per plant (0.003), number of ratoon tillers as percentage of main crop tillers per plant (0.040), number of ratoon ear bearing tillers as percentage of main crop ear bearing

tillers (0.000), kernel length (0.004), kernel breadth (0.004), L/B ratio (0.000), kernel breadth after cooking (0.004), kernel linear elongation ratio (0.098), water uptake (0.045) and alkali spreading value (0.052); while negative indirect effect through days to 50% flowering (-0.075), days to maturity (-0.090), number of vegetative buds after harvest of main crop (-0.021), total number of ear bearing tillers per plant (-0.102), panicle length (-0.012), number of grains per panicle (-0.005), test weight (-0.056), leaf area index (-0.095), hulling recovery (-0.037), milling recovery (-0.049), head rice recovery (-0.045), kernel length after cooking (-0.154), gel consistency (-0.052) and amylose content (-0.003). Similar results were confirmed by Krishna Veni *et al.* (2013), Nandan *et al.* (2010), Praveen *et al.* (2010) and Satyavathi *et al.* (2001)

4.3.2.6.23 Water Uptake (ml)

At genotypic level, water uptake exhibited non-significant positive correlation (0.120) and positive direct effect (0.207) on grain yield per plant. It also showed positive indirect effects *via* days to 50% flowering (0.096), total number of ear bearing tillers per plant (0.050), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), panicle length (0.042), number of grains per panicle (0.017), test weight (0.011), milling recovery (0.015), head rice recovery (0.036), kernel length (0.329), kernel breadth (0.003), L/B ratio (0.000), kernel linear elongation ratio (0.202), volume expansion ratio (0.049) and alkali spreading value (0.032) and showed negative indirect effect *via* days to maturity (-0.098), plant height (-0.031), total number of tillers per plant (-0.002), number of ratoon tillers as percentage of main crop tillers per plant (-0.123), number of vegetative buds after harvest of main crop (-0.002), leaf area index (-0.029), hulling recovery (-0.047), kernel length after cooking (-0.614), kernel breadth after cooking (-0.003), gel consistency (-0.020) and amylose content (-0.001).

4.3.2.6.24 Gel Consistency (mm)

Gel consistency showed significant positive association (0.328**) and negative direct effect (0.280) on grain yield per plant at genotypic level. It also showed positive indirect effects through days to 50% flowering (0.127), total number of ear bearing tillers per plant (0.093), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.000), panicle length (0.021), number of grains per panicle (0.041), test weight (0.058), leaf area index (0.032), milling recovery (0.070), head rice recovery (0.049), kernel length (0.318), kernel breadth (0.004), L/B ratio (0.000), kernel breadth

after cooking (0.005) and amylose content (0.001) and recorded negative indirect effect *via* days to maturity (-0.190), plant height (-0.062), total number of tillers per plant (-0.007), number of ratoon tillers as percentage of main crop tillers per plant (-0.059), number of vegetative buds after harvest of main crop (-0.014), hulling recovery (-0.048), kernel length after cooking (-0.256), kernel linear elongation ratio (-0.059), volume expansion ratio (-0.048), water uptake (-0.015) and alkali spreading value (-0.012).

4.3.2.6.25 Alkali Spreading Value (mm)

At genotypic level, the trait alkali spreading value recorded significant positive association (-0.123) and positive direct effect (0.191) on grain yield per plant and exhibited positive indirect effect *via* days to 50% flowering (0.087), plant height (0.066), total number of tillers per plant (0.008), number of ratoon tillers as percentage of main crop tillers per plant (0.053), hulling recovery (0.075), kernel length (0.223), L/B ratio (0.000), kernel linear elongation ratio (0.467), volume expansion ratio (0.062) and water uptake (0.035); while negative indirect effect were observed mainly through days to maturity (-0.348), number of vegetative buds after harvest of main crop (-0.034), total number of ear bearing tillers per plant (-0.016), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (-0.001), panicle length (-0.036), number of grains per panicle (-0.023), test weight (-0.011), leaf area index (-0.008), milling recovery (-0.011), head rice recovery (-0.030), kernel breadth (-0.001), kernel length after cooking (-0.823), kernel breadth after cooking (-0.026), gel consistency (-0.017) and amylose content (-0.003).

4.3.2.6.26 Amylose Content (%)

Amylose content exerts positive direct effect (-0.023) and significant positive association (-0.283**) on grain yield per plant at genotypic level and established positive indirect effect through plant height (0.010), number of ratoon tillers as percentage of main crop tillers per plant (0.038), number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers (0.001), test weight (0.001), L/B ratio (0.000), kernel length after cooking (0.469), kernel breadth after cooking (0.019), volume expansion ratio (0.028), water uptake (0.008) and alkali spreading value (0.025). Whereas negative indirect effect were observed through days to 50% flowering (-0.076), days to maturity (-0.052), total number of tillers per plant (-0.003), number of vegetative buds after harvest of main crop (-0.006), total number of ear bearing tillers per plant (-0.075), panicle length (-0.008), number of grains per panicle (-0.026), leaf area index (-0.036), hulling recovery (-0.008), milling recovery (-0.021), head rice

recovery (-0.123), kernel length (-0.195), kernel breadth (-0.007), kernel linear elongation ratio (-0.215) and gel consistency (-0.008). These findings are corroborated by Patel *et al.* (2014), Krishna Veni *et al.* (2013) and Garg *et al.* (2010).

In plant breeding it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield *i.e.*, residual effect measures the role of the possible independent variables which were not included in the study on the dependent variable. In the present study, the residual effect at genotypic level was 0.0401 indicating that the characters included in the present investigation are contributing more than 95 per cent of variability pertaining the dependent variable *i.e.*, yield. Less than five per cent of contribution is from the few other characters which were not included in the present study.

Path analysis revealed the true relationship of days to maturity, total number of ear bearing tillers per plant, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, milling percentage, head rice recovery, and gel consistency by establishing significant positive association and positive direct effect on grain yield per plant. Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that simultaneous improvement of grain yield per plant is possible through manifestation of days to maturity, total number of ear bearing tillers per plant, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, milling percentage, head rice recovery and gel consistency

The present study, combining ability analysis using diallel analysis (without reciprocals) has identified the lines/varieties lines, MTU 1001, MTU 1140 and MTU 1064, as the good general combiners and the crosses, MTU 1140 $\times$ MTU 7029, MTU 1001 $\times$ MTU 1140, MCM 100 $\times$ MTU 1140 and MTU 1001 $\times$ MTU 1064 as the good specific combiners for grain yield per plant. Thus, the identified lines/varieties and hybrids can be used in future breeding programme as follows.

The lines/varieties having good *gca* effects (MTU 1001, MTU 1140 and MTU 1064) can be used in the heterosis breeding programme for the exploitation of the traits to improve the yield potential.

The crosses, MTU 1140 $\times$ MTU 7029, MTU 1001 $\times$ MTU 1140, MCM 100 $\times$ MTU 1140 and MTU 1001 $\times$ MTU 1064 can be evaluated over environments to confirm their superiority.

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation entitled "Heterosis and combining ability studies of ratooning in rice (*Oryza sativa* L.)" was carried out to assess the combining ability of eight parents viz., MTU 1001, BPT 3291, MCM 100, MTU 1140, MTU 1121 MTU 1061, MTU 1064 and MTU 7029, selected based on ratoonability performance along with grain yield, yield attributing parameters coupled with grain quality traits, during *kharif*, 2014 as main crop and its ratoon crop, in *rabi*, 2014-15. Further, gene action and heterosis studies were carried out for 28 F₁s using Griffing's diallel, Model II, Method 2 during *rabi*, 2015-16 as F₁ main crop and its ratoon crop in *summer*, 2016, at Andhra Pradesh Rice Research Institute (APRRI) and Regional Agricultural Research Station (RARS), Maruteru, W.G., A.P., India.

Twenty four characters of both main crop and ratoon crop were considered for present study consisting of 10 yield attributing characters viz., days to 50% flowering, days to maturity, plant height (cm), total number of tillers per plant, number of ear bearing tillers per plant, panicle length (cm), number of grains per panicle, test weight (gm), leaf area index at maximum tillering stage, grain yield per plant; 6 physical quality traits such as hulling per cent, milling per cent, head rice recovery per cent, kernel length (mm), kernel breadth (mm), kernel L/B ratio; and 8 cooking quality traits such as kernel length after cooking (mm), kernel breadth after cooking (mm), kernel elongation ratio, volume expansion ratio, water uptake value (ml), gel consistency (mm), alkali digestion value and amylose content (%). Further, in ratoon crop along with number of tillers per plant, number of ear bearing tillers per plant and ratooning related traits such as number of ratoon tillers as percentage of main crop tiller, number of vegetative buds after the harvest of main crop, number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers, were also recorded.

Twenty popular varieties/cultivars, were evaluated in Randomised Complete Block Design during *kharif*, 2014 as main crop, and screened for ratoonability of ratoon crop after the harvest of main crop during *rabi*, 2014-15. Analysis of variance revealed highly significant differences among varieties for all the characters studied. The studies on genetic parameters, showed high PCV and GCV for alkali spreading value for both main crop and ratoon crop and the traits viz., number of ear bearing tillers per plant, number ratoon ear bearing tillers as percentage of main crop ear bearing tillers, grain yield per

plant in ratoon crop showed high variability. While, number of grains per panicle, test weight, leaf area index at maximum tillering stage, kernel breadth after cooking, water uptake, gel consistency recorded moderate variability (*i.e.*, moderate PCV and GCV), in both main and ratoon crop; and number of vegetative buds after the harvest of main crop, showed moderate variability in ratoon crop. The traits, number of tillers per plant and number of tillers as percentage of main crop tillers also shows moderate variability in ratoon crop with high PCV coupled with moderate GCV and the remaining characters exhibited low variability.

The estimates of heritability and genetic advance as per cent of mean were high for the characters *viz.*, number of ear bearing tillers per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, water uptake, gel consistency and alkali spreading value in both main crop and ratoon crop, whereas the traits *viz.*, total number tillers per plant, grain yield per plant, kernel breadth after cooking, showed high heritability and genetic advance as percent of mean in ratoon crop, indicating the role of additive gene action. This in turn suggests feasibility of simple selection procedures for improving these traits. The traits, such as days to 50% flowering, days to maturity, plant height, panicle length, head rice recovery, kernel breadth, kernel length after cooking and kernel linear elongation ratio showed high heritability in conjunction with moderate genetic advance as per cent of mean, revealed the role of both additive and non-additive gene action, in inheritance of these traits. Moderate heritability and moderate genetic advance as per cent of mean was observed for grain yield in main crop and the traits such as number of ratoon tillers as percentage of main crop tillers, vegetative buds after the harvest of main crop were observed in ratoon crop indicating the preponderance of non-additive gene action in inheritance of these traits.

Closer scrutiny of character association studies and path analysis in main crop revealed that plant height, total number of tillers per plant, test weight and amylose content, showed significant positive association and positive direct effect on grain yield per plant. Hence, simultaneous improvement of grain yield per plant and good cooking quality traits is possible through manifestation of these characters.

Character association and path analysis studies of ratoon crop, revealed that days to 50% flowering, days to maturity, number of vegetative buds after harvest of main crop, number of ear bearing tillers as percentage main crop ear bearing tillers, kernel length, kernel length after cooking and gel consistency showed significant association in desirable

direction and positive direct effect of these traits on grain yield per plant. Thus, the present study indicated that due weightage should be given for these traits to get higher grain yield per plant coupled with good quality traits.

Analysis of variance (ANOVA) studies in main crop, revealed that significant amount of variability among parents, F_1 s and their interaction for most of the characters except, plant height, panicle length, hulling per cent, grain yield per plant in parent; panicle length in F_1 s; and leaf area index at maximum tillering stage, kernel length and kernel length after cooking in F_1 s vs. parents.

ANCOVA for F_1 ratoon crop revealed that significant amount of variability among parents, crosses and their interaction for most of the characters, except total number of total number of tillers per plant, number of ratoon tillers as per cent of main crop tillers, number of vegetative buds after the harvest of main crop, number of ratoon ear bearing tillers as per cent of main crop ear bearing tillers, panicle length, milling per cent in parents; total number of tillers per plant, number of ratoon tillers as per cent of main crop tillers for F_1 s; and days to 50% flowering, total number of tillers per plant, number of vegetative buds after the harvest of main crop, number of ear bearing tillers per plant, kernel length, kernel linear elongation ratio and volume expansion ratio for interactions (F_1 s vs parents).

High PCV coupled with GCV was recorded for gel consistency and alkali spreading value both in F_1 and its ratoon crop and leaf area index at maximum tillering stage in F_1 ratoon, reveals wider variability for these traits. Further, moderate PCV and GCV was observed for traits viz., total number of tillers per plant, number of grains per panicle, LAI at maximum tillering stage, volume expansion ratio, water uptake, amylose content and grain yield per plant in main crop; and number ratoon tillers as percentage of main crop tillers, total number of ear bearing tillers per plant, number of ratoon ear bearing tillers as percentage of ear bearing tillers per plant, number of grains per panicle, water uptake and amylose content in ratoon crop, indicating the moderate variability for these characters under study.

Estimates of high heritability and high genetic advance as per cent of means for the characters viz., total number of tillers per plant, number of grains per panicle, leaf area index at maximum tillering stage, water uptake, gel consistency, alkali spreading value, amylose content and grain yield per plant, revealed the role of additive gene action. This in turn suggests the feasibility of simple selection procedures for improving these traits.

High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, test weight, kernel breadth after cooking and volume expansion ratio were observed for both in F₁ main crop and its ratoon crop, revealed that importance of both additive and non-additive gene actions. Moderate heritability coupled with moderate genetic advance as per cent of mean was observed for number of ear bearing tillers per plant in F₁ main crop; and traits viz., number of ratoon tillers as percentage of main crop tillers and number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers was observed in F₁ ratoon crop, indicates the preponderance of non-additive gene action in inheritance of these traits.

General combining ability studies in F₁ main crop, revealed that, among the eight parents tested, MTU 1001 and MTU 1121 found to be best general combiners. MTU 1001 recorded significant general combining ability effects in desirable direction for days to 50% flowering, days to maturity, plant height (cm), test weight (g), leaf area index at maximum tillering stage, head rice recovery (%), kernel length (mm), kernel linear elongation ratio, alkali spreading value (mm), amylose content (%) and grain yield per plant (g) and MTU 1121 recorded significant general combining effects for days to 50% flowering, days to maturity, total number of tillers per plant, number of grains per panicle, head rice recovery, L/B ratio, kernel breadth after cooking (mm), volume expansion, water uptake (ml), gel consistency (mm) and amylose content (%) in desirable direction

In F₁ ratoon crop, general combining ability studies revealed that out of the eight parents tested, MTU 1001 ranks first for recording significant general combining ability effects in desirable direction for traits 12 traits viz., days to 50% flowering, days to maturity, plant height (cm), test weight (g), leaf area index at maximum tillering stage, milling per cent (%), head rice recovery (%), kernel length (mm), kernel length after cooking (mm), kernel linear elongation ratio, alkali spreading value (mm) and grain yield per plant (g) and MTU 1140 ranks second best general combiner for 9 traits viz., total number of ear bearing tillers per plant, number of ratoon ear bearing tillers as per cent of main crop tillers, panicle length (cm), number of grains per panicle, test weight (g), hulling per cent (%), head rice recovery, gel consistency (mm) and grain yield per plant (g).

However, the general combining ability for ratoonability related traits revealed that the parent MTU 1121 and MTU 1061 recorded as a best general combiner for total number of tillers per plant; MTU 1121, MTU 1140 and MTU 1064 for number of ear bearing tillers per plant and MTU 1140 for number of ratoon ear bearing tillers as

percentage of main crop ear bearing tillers. Whereas MTU 1001, MTU 1121 and BPT 3291 as good general combiners for number of vegetative buds and total number of tillers as percentage of main crop tillers.

The perusal of *sca* effects revealed that the crosses, MTU 1001 $\times$ MTU 1061, MTU 1001 $\times$ MTU 1140, MCM 100 $\times$ MTU 1064 and MCM 100 $\times$ MTU 1140 in F₁ main crop; and MTU 1001 $\times$ MTU 1140, MCM 100 $\times$ MTU 1140 and MTU 1140 $\times$ MTU 7029 in F₁ ratoon crop expressed high *sca* effects with high *per se* performance for grain yield per plant. These crosses did not express high *sca* effects for all the yield attributing traits, revealing that there is no relationship between *per se* performance of hybrids and *gca* effects of parents. In majority of the crosses studied, the *per se* value of crosses were related to their corresponding *sca* effects. Thus, the study revealed the possibility for simultaneous improvement of grain yield and yield attributing traits by exploring these F₁s as basic material in breeding programmes.

Studies on specific combining ability effects for the ratoonability related traits disclosed that, crosses MTU 1001 $\times$ MTU 1140, BPT 3291 $\times$ MTU 1061 and MCM 100 $\times$ MTU 7029 exhibited high *sca* effects for total number of tillers per plant; and MTU 1140 $\times$ MTU 7029, MCM 100 $\times$ MTU 7029 and MTU 1001 $\times$ MTU 1140 for total number of tillers as percentage of main crop tillers; the crosses MTU 1001 $\times$ MTU 1140, BPT 3291 $\times$ MTU 1121 for the trait total number of vegetative buds after the harvest of main crop; and the trait, total number of ear bearing tillers per plant showed high *sca* effects for BPT 3291 $\times$ MTU 1061; MTU 1001 $\times$ MTU 1140, BPT 3291 $\times$ MTU 1061. The crosses MTU 1140 $\times$ MTU 7029 showed high *sca* for number of ear bearing tillers as percentage of main crop ear bearing tillers.

Heterosis studies, in F₁ main crop revealed that 25 out of 28 cross combinations registered significant positive heterosis over both mid and better parents for grain yield per plant. The best heterotic combination identified were MTU 1001 $\times$ MTU 1140 for total of tillers per plant, leaf area index at maximum tillering stage, milling percentage, head rice recovery, L/B ratio, gel consistency and grain yield per plant. MTU 1001 $\times$ MTU 1061 for days to flowering, days to maturity, kernel breadth, L/B ratio, and grain yield per plant; MCM 100 $\times$ MTU 1140 for kernel breadth after cooking, kernel linear elongation ratio and grain yield per plant; MCM 100 $\times$ MTU 1064 for days to 50% flowering, days to maturity, water uptake and grain yield per plant.

Close scrutiny of relative heterosis, heterobeltiosis, *sca* effects and *per se* performance, the cross MTU 1001 × MTU 1140 recognized as hopeful hybrids by exhibiting significant relative heterosis, heterobeltiosis, *sca* effects and better *per se* performance for the traits *viz.*, total number of tillers per plant, number of vegetative buds after the harvest of main crop and total ear bearing tillers per plant. The cross MTU 1140 × MTU 7029 for number of tillers as percentage of main crop tillers and number of ear bearing tillers as percentage of main crop ear bearing tillers.

F₁ ratoon crop, heterosis revealed that 14 out of 28 cross combinations registered significant positive heterosis over both mid and better parents for grain yield per plant. MTU 1001 × MTU 1140 showed best heterotic combinations for traits *viz.*, total of tillers per plant, number of vegetative buds after the harvest of F₁ main crop, total ear bearing tillers per plant milling percentage, head rice recovery and grain yield per plant; MTU 1140 × MTU 7029 for number of ratoon tillers as percentage of main crop ratoon tillers, number of ear bearing tillers, number ratoon ear bearing tillers as percentage of main crop ear bearing tillers, leaf area index at maximum tillering stage, gel consistency and grain yield per plant; and MCM 100 × MTU 1140 for number of ear bearing tillers per plant, panicle length, number of grains per panicle, kernel breadth after cooking and grain yield per plant, suggested that the possibility of utilization of these F₁ hybrids for commercial exploitation after testing these hybrids over large number of environments and seasons.

Perusal of relative heterosis, heterobeltiosis, *sca* effects and *per se* performance, the cross MTU 1001 × MTU 1140 was identified as a promising hybrid by registering significant relative heterosis, heterobeltiosis, *sca* effects and better *per se* performance for the traits total number of tillers per plant, leaf area index at maximum tillering stage, milling per cent, head rice recovery, L/B ratio, gel consistency and grain yield per plant, in F₁ main crop; and number of tillers per plant, number of vegetative buds after the harvest of main crop, number of ear bearing tillers per plant, milling per cent, head rice recovery, and grain yield in F₁ ratoon crop for majority of characters studied.

The studies of relative heterosis, heterobeltiosis, *sca* effects and *per se* performance of the traits related to ratoonability revealed that the crosses MTU 1001 × MTU 1140 was identified as a promising hybrid by registering significant relative heterosis, heterobeltiosis, *sca* effects and better *per se* performance for the traits total number of tillers per plant; MCM 100 × MTU 7029 for number of ratoon tillers as percentage of main crop tillers; MTU 1001 × MTU 1140 for number of vegetative buds

after the harvest of main crop; MTU 1001 $\times$ MTU 1140 for number of ear bearing tillers per plant and MTU 1140 $\times$ MTU 7029 for number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers.

Gene action studies in F_1 main crop revealed that the estimates of variance due to *gca* and *sca* was significant for most of the traits under study indicated that days to 50% flowering was governed by additive gene action, where simple selection methods such as pureline selection, mass selection, progeny selection, hybridization & selection with pedigree breeding, heterosis breeding and inter-crossing and selection at later generation may be used for improvement of this trait. Whereas, both additive and non-additive gene action plays a role in inheritance of most of the traits under study. These components may be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes, except for the traits viz., total number of tillers, total ear bearing tillers, panicle length, grain yield, milling per cent, kernel length, kernel breadth, L/B ratio, kernel breadth after cooking, kernel elongation ratio, volume expansion ratio and amylose content, where component of variance due to *sca* was high and significant while the component of *gca* variance was low and non-significant, indicating the role of non-additive gene action in the inheritance of these characters. These results are further confirmed by the low values of narrow sense heritability. Hence, these 12 characters can be improved by employing heterosis breeding methods and recombination breeding with postponement of selection at later generations.

In F_1 ratoon crop, revealed that days to maturity showed it was controlled by additive gene action and rest of the traits exhibited significant *gca* and *sca* variance indicating the role of both additive and non-additive gene action in the inheritance of these characters, which can be improved by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes, except for six traits i.e., number of ratoon tillers as percentage of main crop tillers and number of vegetative buds after the harvest of F_1 main crop, kernel breadth, volume expansion, gel consistency and amylose content, where the component of variance due to *sca* was high and significant and *gca* variance was low and non-significant, indicating the role of non-additive gene action in the inheritance of these characters. These results are further confirmed by the low values of narrow sense

heritability. Hence, breeding methods such as heterosis breeding, and recombination breeding with postponement of selection at later generations were effective for improvement of these traits.

Gene action studies for the ratoonability related traits disclosed the preponderance of both additive and non-additive gene action in the inheritance of total number of tillers per plant, total number of ear bearing tillers per plant and number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers. Which can be exploited by adopting breeding procedures like cyclic hybridization, bi-parental mating and diallel selective mating systems or by recombination breeding with postponement of selection at later generations for the development of superior lines with desirable genes, while the other two traits, number of ratoon tillers as percentage of main crop tillers and number of vegetative buds after the harvest of F₁ main crop were controlled by non-additive gene action, where heterosis breeding and recombination breeding with postponement of selection at later generations was effective.

Combined perusal of character association and path analysis studies both in F₁ main crop and its ratoon crop showed that days to 50% flowering, days to maturity, total number of tillers per plant, total number of ear bearing tillers per plant, panicle length per plant, number of grains per panicle, test weight, leaf area index at maximum tillering stage, milling percentage, head rice recovery, and gel consistency showed significant association in desirable direction and positive direct effect on grain yield per plant. Thus, the present study indicated that simultaneous improvement of grain yield per plant and good cooking quality traits was possible through manifestation of these characters.

From the present study on "Heterosis and combining ability studies of ratooning in rice (*Oryza sativa* L.)", it is concluded that cultivars MTU 1064, MTU 1140 and MTU 1001 had shown good ratoon performance and these varieties may be suggested for the areas where resources are limited for raising second crop. Further ratoonability traits are mostly under control of both additive and non-additive gene action and improvement of these traits will be possible by adopting breeding procedures like bi-parental mating and diallel selective mating and recombination breeding. The character association studies revealed significant positive association for yield and quality traits in ratoon crop, which is very important in development of varieties or selection of progenies with good ratoonability, yield and grain quality.

The cultivar MTU 1121, MTU 1140 and MTU 1064 showed as good combiners for total ear bearing tillers in ratoon crop and MTU 1140 was found to be a good general combiner for the trait number of ratoon ear bearing tillers as percentage of main crop ratoon ear bearing tillers and cross combination MTU 1140 × MTU 7029 found as specific combiners for ratoonability trait.

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*** Original not seen**

Note: The pattern of Literature Cited presented above is in accordance with the guidelines for thesis presentation, Acharya N. G. Ranga Agricultural University, Guntur, Andhra Pradesh.

Table 4.37. Genotypic (rg) correlation among grain yield, yield contributing and quality characters of F₁ ratoon in rice (*Oryza sativa* L.)

S.No	Characters	DFD	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TPTP	NRTPM CPT	PL (cm)	NGPP	TW (g)	LAI	HP	MP	HRR	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)	
1	DFD	r _g	1.000	0.968**	0.521**	0.220	0.059	0.159	0.559**	0.565**	0.481**	0.372**	0.165	0.609**	0.305**	-0.211*	0.233*	-0.233*	-0.327**	0.197*	-0.050	-0.256**	0.144	0.052	-0.065	-0.087	-0.059	0.052	0.484**
2	DM	r _g		1.000	0.564**	0.246*	0.077	0.157	0.594**	0.563**	0.508**	0.430**	0.110	0.552**	0.329**	-0.199*	0.261**	-0.222*	-0.338**	0.225*	-0.005	-0.237**	0.181	-0.055	-0.060	-0.116	-0.211	-0.032	0.495**
3	PH	r _g			1.000	0.603**	-0.345**	0.138	0.673**	0.245**	0.871**	0.627**	0.435**	0.514**	0.477**	0.260**	0.471**	0.144	-0.009	0.095	-0.104	0.020	-0.215*	-0.233*	0.161	0.328**	-0.349**	-0.051	0.676**
4	TNTP	r _g				1.000	-0.217*	0.910**	0.826**	0.452**	0.380**	0.453**	0.125	0.310**	0.390**	0.292**	0.297**	0.027	0.177	-0.213	-0.054	0.158	-0.085	-0.113	0.086	0.273**	-0.286*	0.104	0.596**
5	NRTPMCPT	r _g					1.000	0.073	0.056	0.727**	-0.614**	-0.531**	-0.496**	0.016	-0.370**	-0.651**	-0.523**	0.046	-0.320**	0.419**	0.100	-0.550**	0.057	0.123	-0.382**	-0.182	0.164	0.117	-0.165
6	NVGBAHMC	r _g						1.000	0.612**	0.326**	0.024	0.106	-0.048	0.157	0.033	0.167	0.000	-0.004	0.442**	-0.553**	0.035	0.300**	0.028	-0.149	-0.015	-0.094	-0.237**	-0.045	0.357**
7	TEBTP	r _g							1.000	0.751**	0.622**	0.579**	0.196*	0.598**	0.371**	0.159	0.499**	-0.042	-0.141	0.143	0.103	-0.095	0.159	-0.257	0.126	0.235*	-0.042	-0.191*	0.935**
8	NRTPMCT	r _g								1.000	0.098	0.150	-0.230*	0.442**	-0.001	-0.278**	0.147	-0.159	-0.414**	0.387**	0.167	-0.342**	0.318**	-0.025	-0.147	0.017	0.187	-0.163	0.635**
9	PL	r _g									1.000	0.620**	0.433**	0.359**	0.440**	0.190*	0.461**	-0.054	-0.045	-0.001	-0.192*	0.070	-0.150	-0.107	0.381**	0.189*	-0.332**	-0.073	0.597**
10	NGPP	r _g										1.000	0.355**	0.567**	0.623**	0.467**	0.588**	-0.011	0.105	-0.141	0.135	0.364**	0.168	-0.044	0.143	0.351**	-0.200*	-0.221*	0.688**
11	TW	r _g											1.000	0.514**	0.336**	0.558**	0.617**	0.118	0.112	-0.053	0.075	-0.094	0.018	-0.276**	0.056	0.286**	-0.053	0.007	0.469**
12	LAI	r _g												1.000	0.431**	0.283*	0.581**	-0.036	-0.164	0.158	0.082	-0.107	0.139	-0.305**	-0.092	0.102	-0.025	-0.116	0.720**
13	HP	r _g													1.000	0.612**	0.753**	0.185	0.258**	-0.198*	0.108	0.190	-0.022	0.077	0.099	0.102	-0.158	0.016	0.367**
14	MP	r _g														1.000	0.751**	0.252*	0.301**	-0.171	0.285**	0.340**	0.133	-0.342**	0.108	0.490**	-0.079	-0.149	0.349**
15	HRR	r _g															1.000	0.108	0.192*	-0.167	0.320**	0.118	0.284**	-0.098	0.079	0.106	-0.066	-0.268**	0.604**
16	KL	r _g																1.000	0.601**	-0.003	0.483**	-0.011	-0.276**	0.002	0.181	0.175	0.123	-0.108	-0.079
17	KB	r _g																	1.000	-0.798**	0.216*	0.345**	-0.255**	0.091	0.064	0.081	-0.026	-0.146	-0.121
18	L/B ratio	r _g																		1.000	0.104	-0.453**	0.126	-0.115	0.083	0.029	0.128	0.086	0.090
19	KLAC	r _g																			1.000	-0.130	0.708**	0.054	0.216*	0.090	0.289**	-0.165	0.041
20	KBAC	r _g																				1.000	-0.134	0.025	-0.017	0.037	-0.182	0.134	0.007
21	KLER	r _g																					1.000	0.045	0.092	-0.027	0.214*	-0.098	0.128
22	VER	r _g																						1.000	0.218*	-0.211*	0.274**	0.122	-0.280**
23	WU	r _g																							1.000	-0.072	0.169	0.038	0.120
24	GC	r _g																								1.000	-0.061	-0.027	0.328**
25	ASV	r _g																									1.000	0.131	-0.123
26	AC	r _g																										1.000	-0.283**
27	GYPP	r _g																											1.000

* Significant at 5% level

** Significant at 1% level

G: Genotypic level

DFD: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCET: Number of ratoon productive tillers as percentage of main crop productive tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.5. Phenotypic correlations among grain yield, yield contributing and quality characters in rice (*Oryza sativa* L.)

Characters		DDF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DDF	r _p	1.000	0.957**	0.333**	0.142	-0.263*	0.168	0.369**	-0.683**	0.107	0.244	0.214	0.227	-0.435**	-0.272*	-0.017	-0.318*	-0.397**	0.143	-0.372**	-0.099	0.110	-0.315*	0.069	-0.313*
DM	r _p		1.000	0.336**	0.148	-0.237	0.170	0.344**	-0.677**	0.146	0.231	0.193	0.228	-0.372**	-0.234	-0.019	-0.299*	-0.343**	0.125	-0.407**	-0.098	0.122	-0.319*	0.089	-0.294*
PH	r _p			1.000	0.378**	0.072	0.592**	0.239	-0.021	0.114	-0.005	-0.010	0.302*	-0.008	0.012	-0.053	0.233	-0.213	0.160	-0.033	0.440**	0.333**	0.031	0.442**	0.213
TNTP	r _p				1.000	0.236	0.165	0.478**	-0.236	0.392 **	0.146	0.146	0.264*	0.116	-0.229	0.400**	0.185	-0.303*	0.273*	-0.005	0.097	0.165	-0.013	0.180	0.304*
EBTP	r _p					1.000	0.161	0.206	0.187	0.411**	0.145	0.282*	0.568**	0.289*	0.157	0.018	0.512**	0.253	0.314*	0.233	0.205	0.388**	0.373**	-0.239	0.488**
PL	r _p						1.000	0.165	0.178	0.130	-0.093	0.008	0.222	0.277*	0.308*	-0.205	0.102	-0.129	-0.074	0.052	0.179	0.233	0.131	0.017	0.263*
NGPP	r _p							1.000	-0.531**	0.472**	0.487**	0.324*	0.228	-0.205	-0.695**	0.761**	0.085	-0.634**	0.568**	-0.032	-0.211	0.335**	-0.238	0.149	0.203
TW	r _p								1.000	-0.153	-0.466**	-0.274*	-0.154	0.528**	0.598**	-0.361**	0.529**	0.503**	-0.223	0.317*	0.343**	-0.069	0.635**	-0.061	0.411**
LAI	r _p									1.000	0.191	0.373 **	0.380**	0.212	-0.165	0.390**	0.376**	-0.108	0.350**	0.070	-0.335**	0.069	0.077	0.031	0.501**
HP	r _p										1.000	0.316 *	0.204	-0.378**	-0.506**	0.370**	-0.150	-0.367**	0.137	-0.107	-0.141	0.350**	-0.260*	0.021	-0.077
MP	r _p											1.000	0.548**	-0.011	-0.199	0.260 *	0.207	-0.376**	0.341**	0.137	-0.304*	-0.084	0.031	-0.269*	-0.046
HRR	r _p												1.000	0.080	0.069	-0.047	0.362**	-0.095	0.372**	0.096	0.061	0.332**	0.112	-0.176	0.101
KL	r _p													1.000	0.679**	-0.104	0.252	0.289*	-0.348**	-0.098	0.144	0.192	0.246	-0.128	0.420**
KB	r _p														1.000	-0.799**	0.073	0.612**	-0.562**	0.022	0.313*	0.023	0.338**	-0.221	0.116
L/B	r _p															1.000	0.117	-0.586**	0.476**	-0.074	-0.315*	0.090	-0.242	0.189	0.182
KLAC	r _p																1.000	0.070	0.550**	0.427**	0.193	0.022	0.673**	0.062	0.479**
KBAC	r _p																	1.000	-0.284*	0.095	0.245	-0.126	0.361**	-0.221	0.186
KLER	r _p																		1.000	0.377**	-0.124	-0.008	0.245	0.058	0.152
VER	r _p																			1.000	-0.055	-0.384**	0.266*	-0.193	0.173
WU	r _p																				1.000	0.239	0.351**	0.296*	0.134
GC	r _p																					1.000	0.004	0.185	0.197
ASV	r _p																						1.000	-0.003	0.369**
AC	r _p																							1.000	0.094
GYPP	r _p																								1.000

* Significant at 5% level

** Significant at 1% level

r_p: Phenotypic level

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.4. Genotypic (rg) correlation among grain yield, yield contributing and quality characters in rice (Oryza sativa L.)

Characters		DFF	DM	PH (cm)	TNTP	EBTP	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DFF	r _g	1.000	0.983**	0.377**	0.270*	-0.260*	0.205	0.412**	-0.735**	0.129	0.334**	0.259*	0.238	-0.457**	-0.295*	-0.008	-0.338**	-0.458**	0.153	-0.476**	-0.125	0.108	-0.341**	0.130	-0.370**
DM	r _g		1.000	0.418**	0.255*	-0.277*	0.234	0.414**	-0.728**	0.158	0.300*	0.279*	0.254*	-0.410**	-0.281*	0.008	-0.353**	-0.468**	0.122	-0.540**	-0.109	0.131	-0.348**	0.140	-0.356**
PH	r _g			1.000	0.479**	0.061	0.663**	0.267*	-0.02	0.141	0.060	-0.078	0.388**	0.015	0.019	-0.048	0.257*	-0.332**	0.156	-0.078	0.488**	0.365**	0.028	0.504**	0.272*
TNTP	r _g				1.000	0.238	0.235	0.615**	-0.287*	0.481**	0.189	0.192	0.361**	0.121	-0.286*	0.490**	0.269*	-0.389**	0.425**	0.041	0.096	0.194	-0.013	0.152	0.527**
EBTP	r _g					1.000	0.141	0.218	0.235	0.461**	0.241	0.477**	0.737**	0.363**	0.201	0.023	0.611**	0.205	0.382**	0.354**	0.217	0.469**	0.459**	-0.300	0.657
PL	r _g						1.000	0.189	0.212	0.163	-0.031	0.138	0.211	0.346**	0.358**	-0.224	0.135	-0.215	-0.102	0.072	0.176	0.279*	0.156	0.049	0.425**
NGPP	r _g							1.000	-0.583**	0.500*	0.701**	0.491**	0.248	-0.219	-0.735**	0.811**	0.100	-0.841**	0.628**	-0.037	-0.244	0.343**	-0.252	0.189	0.238
TW	r _g								1.000	-0.159	-0.602**	-0.353**	-0.169	0.543**	0.623**	-0.383**	0.565**	0.621**	-0.224	0.382**	0.347**	-0.077	0.651**	-0.041	0.523**
LAI	r _g									1.000	0.254*	0.498**	0.412**	0.217	-0.168	0.402**	0.388**	-0.135	0.366**	0.091	-0.347**	0.075	0.077	0.020	0.671**
HP	r _g										1.000	0.318*	0.247	-0.508**	-0.632**	0.436**	-0.196	-0.627**	0.213	-0.078	-0.175	0.485**	-0.306*	0.066	-0.174
MP	r _g											1.000	0.714**	-0.005	-0.215	0.301*	0.312*	-0.445**	0.487**	0.243	-0.416**	-0.106	0.039	-0.498**	-0.097
HRR	r _g												1.000	0.085	0.074	-0.053	0.410**	-0.088	0.425**	0.134	0.058	0.350**	0.122	-0.258*	0.236
KL	r _g													1.000	0.690**	-0.117	0.264**	0.379**	-0.346**	-0.122	0.146	0.193	0.250	-0.144	0.591**
KB	r _g														1.000	-0.798**	0.072	0.718**	-0.595**	-0.035	0.325*	0.015	0.342**	-0.269*	0.195
L/B	r _g															1.000	0.130	-0.672**	0.525**	-0.018	-0.331**	0.102	-0.247	0.240	0.220
KLAC	r _g																1.000	0.095	0.536**	0.513**	0.220	0.025	0.693**	0.042	0.733**
KBAC	r _g																	1.000	-0.372**	0.080	0.335**	-0.153	0.468**	-0.301*	0.252*
KLER	r _g																		1.000	0.458**	-0.112	-0.008	0.256*	0.033	0.276*
VER	r _g																			1.000	-0.060	-0.471**	0.296*	-0.263*	0.252*
WU	r _g																				1.000	0.237	0.363**	0.371**	0.168
GC	r _g																					1.000	0.005	0.222	0.312*
ASV	r _g																						1.000	-0.014	0.510**
AC	r _g																							1.000	0.278*
GYPP	r _g																								1.000

* Significant at 5% level

** Significant at 1% level

r_g: Genotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.6. Genotypic (G) direct and indirect effects of different traits on grain yield in rice (*Oryza sativa* L.)

Characters	DDF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DDF	4.041	-0.342	0.588	0.005	-0.124	-0.580	0.487	-3.154	-0.247	1.228	-0.289	0.376	-9.191	7.592	0.135	0.925	-0.302	-0.021	-0.974	0.224	-0.315	-0.597	0.164	-0.370**
DM	4.100	-0.337	0.653	0.004	-0.132	-0.661	0.489	-3.123	-0.303	1.104	-0.311	0.401	-8.235	7.216	-0.140	0.967	-0.308	-0.017	-1.103	0.196	-0.382	-0.610	0.177	-0.356**
PH	1.523	-0.141	1.561	0.008	0.029	-1.874	0.315	-0.086	-0.271	0.222	0.087	0.613	0.302	-0.499	0.842	-0.704	-0.218	-0.021	-0.160	-0.874	-1.068	0.049	0.638	0.272*
TNT	1.092	-0.086	0.747	0.017	0.113	-0.664	0.726	-1.230	-0.921	0.695	-0.214	0.571	2.429	7.355	-8.564	-0.736	-0.256	-0.059	0.083	-0.172	-0.568	-0.023	0.192	0.527**
EBT	-1.051	0.093	0.096	0.004	0.475	-0.399	0.258	1.007	-0.883	0.886	-0.531	1.164	7.293	-5.163	-0.394	-1.671	0.135	-0.053	0.724	-0.389	-1.369	0.805	-0.380	0.657**
PL	0.829	-0.079	1.035	0.004	0.067	-2.827	0.223	0.908	-0.313	-0.115	-0.153	0.333	6.943	-9.195	3.909	-0.369	-0.142	0.014	0.147	-0.315	-0.814	0.273	0.063	0.425**
NGP	1.665	-0.139	0.416	0.011	0.104	-0.534	1.181	-2.501	-0.958	2.581	-0.547	0.391	-4.394	18.892	-14.171	-0.274	-0.554	-0.086	-0.076	0.437	-1.003	-0.442	0.238	0.238
TW	-2.969	0.245	-0.031	-0.005	0.111	-0.598	-0.688	4.292	0.305	-2.218	0.393	-0.267	10.918	-16.022	6.694	-1.547	0.409	0.031	0.780	-0.622	0.224	1.141	-0.052	0.523**
LAI	0.521	-0.053	0.221	0.008	0.219	-0.462	0.590	-0.682	-1.917	0.935	-0.555	0.651	4.362	4.319	-7.033	-1.063	-0.089	-0.050	0.186	0.622	-0.218	0.134	0.026	0.671**
HP	1.348	-0.101	0.094	0.003	0.114	0.089	0.828	-2.585	-0.486	3.684	-0.354	0.390	-10.207	16.260	-7.628	0.536	-0.413	-0.029	-0.160	0.313	-1.418	-0.536	0.083	-0.174
MP	1.046	-0.094	-0.121	0.003	0.226	-0.389	0.580	-1.513	-0.955	1.169	-1.115	1.128	-0.105	5.525	-5.262	-0.853	-0.293	-0.067	0.496	0.747	0.311	0.067	-0.630	-0.097
HRR	0.963	-0.086	0.606	0.006	0.350	-0.597	0.293	-0.725	-0.790	0.910	-0.796	1.579	1.701	-1.905	0.931	-1.122	-0.058	-0.058	0.273	-0.105	-1.022	0.214	-0.326	0.236
KL	-1.848	0.138	0.023	0.002	0.172	-0.977	-0.258	2.332	-0.416	-1.871	0.006	0.134	20.096	-17.749	2.053	-0.722	0.249	0.048	-0.250	-0.262	-0.565	0.437	-0.182	0.591**
KB	-1.193	0.095	0.030	-0.005	0.095	-1.011	-0.868	2.674	0.322	-2.329	0.239	0.117	13.869	-25.717	13.957	-0.197	0.472	0.082	-0.072	-0.583	-0.044	0.600	-0.340	0.195
L/B	-0.031	-0.003	-0.075	0.009	0.011	0.632	0.957	-1.644	-0.771	1.607	-0.336	-0.084	-2.360	20.532	-17.482	-0.356	-0.442	-0.072	-0.038	0.593	-0.299	-0.433	0.304	0.220
KLAC	-1.366	0.119	0.401	0.005	0.290	-0.381	0.118	2.427	-0.744	-0.722	-0.347	0.647	5.302	-1.848	-2.272	-2.737	0.063	-0.074	1.050	-0.394	-0.074	1.215	0.053	0.733**
KBAC	-1.852	0.158	-0.518	-0.007	0.097	0.608	-0.993	2.664	0.259	-2.311	0.496	-0.139	7.611	-18.457	11.741	-0.260	0.658	0.051	0.163	-0.601	0.447	0.820	-0.381	0.252*
ER	0.618	-0.041	0.243	0.007	0.181	0.287	0.742	-0.960	-0.701	0.786	-0.542	0.671	-6.946	15.310	-9.182	-1.466	-0.245	-0.138	0.936	0.201	0.022	0.449	0.042	0.276*
VER	-1.924	0.182	-0.122	0.001	0.168	-0.204	-0.044	1.638	-0.174	-0.287	-0.271	0.211	-2.452	0.910	0.322	-1.405	0.052	-0.063	2.045	0.107	1.375	0.519	-0.333	0.252*
WU	-0.506	0.037	0.761	0.002	0.103	-0.497	-0.288	1.489	0.665	-0.644	0.464	0.092	2.938	-8.365	5.784	-0.601	0.221	0.015	-0.122	-1.793	-0.692	0.636	0.469	0.168
GC	0.436	-0.044	0.570	0.003	0.223	-0.788	0.405	-0.329	-0.143	1.788	0.119	0.553	3.887	-0.388	-1.789	-0.069	-0.101	0.001	-0.963	-0.425	-2.921	0.008	0.280	0.312*
ASV	-1.377	0.117	0.043	0.000	0.218	-0.440	-0.298	2.794	-0.147	-1.127	-0.043	0.193	5.013	-8.806	4.318	-1.897	0.308	-0.035	0.605	-0.651	-0.013	1.753	-0.018	0.510**
AC	0.524	-0.047	0.787	0.003	-0.143	-0.140	0.223	-0.177	-0.039	0.243	0.555	-0.407	-2.886	6.905	-4.195	-0.115	-0.198	-0.005	-0.538	-0.665	-0.647	-0.024	1.265	0.278*

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.2792

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNT: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g)

Table 4.10. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of ratoon crop in rice (*Oryza sativa* L.)

S.No.	Characters		DFE	DM	PH (cm)	TNTP	NRTPMC T	NVBAHM C	TPTP	NRTPM CPT	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_p	1.000	0.921**	0.422**	0.279*	0.072	0.211	0.537**	0.440**	0.378**	0.538**	-0.314*	0.191	-0.115	0.316*	0.350**	-0.129	-0.404**	0.326*	0.326*	-0.023	0.475**	0.177	-0.037	0.189	0.053	-0.058	0.527**
2	DM	r_p		1.000	0.388**	0.330**	0.123	0.272*	0.470**	0.372**	0.357**	0.565**	-0.401**	0.228	-0.124	0.402**	0.372**	-0.233	-0.415**	0.250	0.258*	-0.070	0.495**	0.186	-0.117	0.251	0.050	-0.028	0.452**
3	PH	r_p			1.000	0.355**	0.174	0.298*	0.286*	0.307*	0.584**	0.157	-0.023	0.233	-0.009	0.188	0.333**	0.147	-0.124	0.254	0.283*	0.005	0.187	0.331*	0.296*	0.448**	0.236	0.245	0.296*
4	TNTP	r_p				1.000	0.845**	0.859**	0.536**	0.596**	0.200	0.274*	-0.079	-0.006	-0.105	0.265*	0.507**	0.156	-0.081	0.211	0.541**	-0.061	0.471**	0.182	0.085	0.306*	0.174	0.193	0.485**
5	NRTPMCPT	r_p					1.000	0.746**	0.482**	0.589**	0.098	0.081	0.026	-0.126	-0.040	0.307*	0.519**	0.163	0.109	0.013	0.392**	0.041	0.288*	0.150	0.067	0.200	0.143	0.145	0.470**
6	NVGBAHMC	r_p						1.000	0.434**	0.441**	0.113	0.122	-0.025	-0.090	-0.010	0.208	0.489**	0.259*	-0.012	0.228	0.505**	-0.125	0.342**	0.145	0.072	0.249	0.292*	0.141	0.399**
7	TEBTP	r_p							1.000	0.872**	0.277*	0.292*	0.184	-0.013	-0.013	0.291*	0.559**	0.284*	0.031	0.185	0.556**	0.173	0.363**	0.087	0.037	0.378**	0.288*	-0.118	0.860**
8	NRTPMCCT	r_p								1.000	0.314*	0.290*	0.138	-0.029	-0.010	0.252	0.508**	0.174	0.024	0.102	0.487**	0.129	0.382**	0.149	0.099	0.293*	0.201	0.125	0.754**
9	PL	r_p									1.000	0.053	-0.226	-0.133	-0.108	0.165	0.374**	-0.072	-0.146	0.096	-0.122	0.167	-0.090	0.318*	-0.103	0.617**	-0.165	0.190	0.266*
10	NGPP	r_p										1.000	-0.494**	0.157	-0.208	0.491**	0.320*	-0.361**	-0.636**	0.368**	0.230*	-0.459**	0.665**	0.007	0.039	0.074	-0.116	-0.054	0.275*
11	TW (g)	r_p											1.000	-0.149	0.217	-0.433**	-0.181	0.739**	0.676**	-0.114	0.330**	0.416**	-0.282*	-0.067	0.349**	-0.122	0.375**	-0.107	0.293*
12	LAI	r_p												1.000	0.257*	0.223	0.079	-0.170	-0.062	-0.089	-0.085	0.034	0.071	0.010	0.012	-0.234	0.272*	-0.114	-0.024
13	HL%	r_p													1.000	-0.102	0.079	0.119	0.075	0.006	0.006	0.096	-0.098	0.007	-0.095	-0.162	0.344**	-0.021	-0.063
14	ML%	r_p														1.000	0.698**	-0.299*	-0.309*	0.070	0.002	-0.248	0.259*	-0.016	-0.315*	0.192	-0.127	-0.121	0.302*
15	HRR%	r_p															1.000	0.093	-0.225	0.297*	0.320*	-0.064	0.262*	0.081	-0.261*	0.417**	-0.030	-0.018	0.519**
16	KL (mm)	r_p																1.000	0.452**	0.338**	0.539**	0.322*	-0.277*	-0.041	0.375**	0.057	0.383**	-0.165	0.396**
17	KB (mm)	r_p																	1.000	-0.685**	-0.060	0.595**	-0.479**	-0.131	0.170	-0.237	0.279*	-0.019	0.150
18	L/B ratio	r_p																		1.000	0.505**	-0.361**	0.281*	0.100	0.127	0.289*	0.010	-0.112	0.154
19	KLAC (mm)	r_p																			1.000	-0.022	0.659**	-0.047	0.305*	0.100	0.242	-0.042	0.590**
20	KBAC (mm)	r_p																				1.000	-0.322*	-0.134	-0.055	-0.080	0.005	-0.242	0.201
21	KLER	r_p																					1.000	-0.014	0.017	0.054	-0.058	0.089	0.300*
22	VER	r_p																						1.000	-0.009	0.164	-0.009	0.158	0.067
23	WU (ml)	r_p																							1.000	-0.150	0.583**	0.239	0.171
24	GC (mm)	r_p																								1.000	-0.113	0.090	0.297*
25	ASV (mm)	r_p																									1.000	0.035	0.257*
26	AC (%)	r_p																										1.000	-0.079
27	GYPP (g)	r_p																											1.000

r_p : Phenotypic level

* Significant at 5% level

** Significant at 1% level

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth; L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.11. Genotypic (r_g) correlation among grain yield, yield contributing and quality characters of ratoon crop in rice (*Oryza sativa* L.)

S. No	Characters		DFF	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TPTP	NRTPM CPT	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_g	1.000	0.998**	0.478**	0.416**	0.149	0.376**	0.600**	0.568**	0.413**	0.619**	-0.351**	0.288*	-0.165	0.400**	0.416**	-0.175	-0.441**	0.406**	0.346**	0.001	0.580**	0.305*	-0.056	0.199	0.050	-0.060	0.547**
2	DM	r_g		1.000	0.492**	0.456**	0.170	0.407**	0.591**	0.579**	0.451**	0.651**	-0.480**	0.383**	-0.124	0.467**	0.455**	-0.242	-0.531**	0.458**	0.309*	-0.055	0.593**	0.146	-0.127	0.285*	0.068	-0.092	0.500**
3	PH	r_g			1.000	0.477**	0.215	0.441**	0.352**	0.446**	0.658**	0.205	-0.022	0.261	-0.001	0.225	0.399**	0.177	-0.162	0.355**	0.316*	0.002	0.247	0.713**	0.330**	0.489**	0.258*	0.360**	0.326*
4	TNTP	r_g				1.000	0.864**	0.999**	0.699**	0.828**	0.307*	0.446**	-0.080	0.065	-0.047	0.322*	0.672**	0.302*	-0.165	0.469**	0.733**	-0.125	0.666**	0.184	0.154	0.416**	0.235	0.297*	0.633**
5	NRTPMCPT	r_g					1.000	0.860**	0.763**	0.949**	0.228*	0.278*	0.084	-0.171	0.095	0.439**	0.787**	0.387**	0.078	0.224	0.620**	0.036	0.436**	-0.013	0.140	0.321*	0.256*	0.349**	0.709**
6	NVGBAHMC	r_g						1.000	0.749**	0.833**	0.187	0.298*	0.040	0.113	0.035	0.295*	0.654**	0.406**	-0.115	0.489**	0.798**	-0.229	0.665**	0.190	0.181	0.420**	0.445**	0.341**	0.631**
7	TEBTP	r_g							1.000	0.917**	0.378**	0.341**	0.178	-0.126	0.081	0.377**	0.684**	0.385**	0.051	0.267*	0.609**	0.193	0.426**	0.195	0.058	0.441**	0.315*	-0.161	0.948**
8	NRTPMCT	r_g								1.000	0.496**	0.407**	0.124	-0.206	0.031	0.394**	0.661**	0.280*	0.069	0.151	0.591**	0.163	0.491**	0.383**	0.147	0.400**	0.249	0.175	0.937**
9	PL	r_g									1.000	0.088	-0.243	-0.057	-0.226	0.229	0.368**	-0.147	-0.192	0.107	-0.123	0.172	-0.047	0.808**	-0.126	0.695**	-0.188	0.236	0.292*
10	NGPP	r_g										1.000	-0.549**	0.182	-0.341**	0.556**	0.405	-0.402**	-0.745**	0.581**	0.320*	-0.511**	0.752**	-0.010	0.044	0.058	-0.131	-0.061	0.284*
11	TW	r_g											1.000	-0.251	0.305*	-0.480**	-0.185	0.936**	0.739**	-0.112	0.343**	0.446**	-0.362**	-0.101	0.369**	-0.122	0.386**	-0.191	0.301*
12	LAI	r_g												1.000	0.444**	0.281*	0.134	-0.136	-0.038	-0.079	-0.135	0.028	-0.046	0.131	0.025	-0.331*	0.363**	-0.226	-0.038
13	HL	r_g													1.000	-0.137	0.046	0.071	0.136	-0.122	-0.030	0.145	-0.088	0.823**	-0.172	-0.255*	0.510	-0.170	-0.130
14	ML	r_g														1.000	0.789**	-0.332*	-0.360**	0.143	0.007	-0.286*	0.278*	-0.003	-0.335**	0.204	-0.120	-0.190	0.349**
15	HRR	r_g															1.000	0.088	-0.254*	0.374**	0.344**	-0.082	0.342**	0.342**	-0.278*	0.474**	-0.032	-0.048	0.567**
16	KL	r_g																1.000	0.615**	0.098	0.626**	0.375**	-0.060	-0.155	0.457**	0.079	0.454**	-0.144	0.488**
17	KB	r_g																	1.000	-0.724**	-0.069	0.642**	-0.621**	-0.260*	0.191	-0.245	0.306*	-0.021	0.170
18	L/B	r_g																		1.000	0.643**	-0.475**	0.744**	0.185	0.161	0.374**	0.005	-0.094	0.206
19	KLAC	r_g																			1.000	-0.015	0.741**	0.033	0.308*	0.105	0.246	-0.050	0.607**
20	KBAC	r_g																				1.000	-0.355**	-0.281*	-0.047	-0.083	0.006	-0.287	0.215
21	KLER	r_g																					1.000	0.152	0.006	0.054	-0.065	0.050	0.336**
22	VER	r_g																						1.000	0.050	0.258*	0.010	0.641**	0.142
23	WU	r_g																							1.000	-0.157	0.597**	0.294**	0.186
24	GC	r_g																								1.000	-0.118	0.141	0.305*
25	ASV	r_g																									1.000	0.051	0.260*
26	AC	r_g																										1.000	-0.113
27	GYPP	r_g																											1.000

** Significant at 1% level

* Significant at 5% level

rg: Genotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.12. Genotypic (G) direct and indirect effects of different traits on grain yield of ratoon crop in rice (Oryza sativa L.)

S.N o	Character	DFE	DM	PH	TNTP	NRTMCT	NVBAHMC	TPTP	NRTPMCT	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP
1	DF	0.298	0.801	-0.150	-0.143	-0.010	0.139	-0.535	0.600	-0.131	-0.215	0.129	-0.033	-0.047	-0.027	-0.004	-0.935	5.322	-4.245	2.042	0.000	-2.434	0.039	-0.048	0.124	-0.034	0.042	0.547**
2	DM	0.298	0.802	-0.155	-0.157	-0.011	0.151	-0.528	0.611	-0.143	-0.226	0.176	-0.043	-0.035	-0.032	-0.004	-1.293	6.408	-4.782	1.823	0.022	-2.489	0.019	-0.110	0.177	-0.046	0.064	0.500**
3	PH (cm)	0.143	0.395	-0.314	-0.164	-0.014	0.163	-0.314	0.471	-0.208	-0.071	0.008	-0.030	0.000	-0.015	-0.004	0.947	1.950	-3.702	1.869	-0.001	-1.036	0.090	0.284	0.304	-0.175	-0.250	0.326*
4	TNTP	0.124	0.365	-0.150	-0.344	-0.058	0.370	-0.624	0.873	-0.097	-0.155	0.029	-0.007	-0.013	-0.022	-0.006	1.618	1.989	-4.894	4.330	0.051	-2.798	0.023	0.133	0.259	-0.159	-0.206	0.633**
5	NRTMCT	0.045	0.136	-0.068	-0.297	-0.067	0.319	-0.681	1.002	-0.072	-0.096	-0.031	0.019	0.027	-0.030	-0.007	2.069	-0.937	-2.341	3.660	-0.014	-1.829	-0.002	0.121	0.200	-0.173	-0.243	0.709**
6	NVBAHMC	0.112	0.327	-0.138	-0.344	-0.057	0.371	-0.669	0.879	-0.059	-0.103	-0.015	-0.013	0.010	-0.020	-0.006	2.171	1.384	-5.112	4.711	0.092	-2.794	0.024	0.156	0.262	-0.302	-0.237	0.631**
7	TPTP	0.179	0.474	-0.110	-0.240	-0.051	0.278	-0.893	0.968	-0.119	-0.118	-0.065	0.014	0.023	-0.026	-0.006	2.062	-0.615	-2.784	3.597	-0.078	-1.790	0.025	0.050	0.275	-0.214	0.112	0.948**
8	NRTPMCT	0.169	0.464	-0.140	-0.285	-0.063	0.309	-0.819	1.055	-0.157	-0.141	-0.046	0.023	0.009	-0.027	-0.006	1.497	-0.831	-1.572	3.489	-0.066	-2.061	0.048	0.126	0.249	-0.169	-0.122	0.937**
9	PL (cm)	0.123	0.362	-0.207	-0.105	-0.015	0.069	-0.337	0.523	-0.316	-0.031	0.089	0.006	-0.064	-0.016	-0.003	-0.785	2.321	-1.115	-0.727	-0.069	0.198	0.102	-0.108	0.433	0.127	-0.164	0.292*
10	NGPP	0.185	0.522	-0.065	-0.154	-0.019	0.110	-0.304	0.430	-0.028	-0.347	0.202	-0.021	-0.097	-0.038	-0.004	-2.151	8.978	-6.063	1.892	0.206	-3.158	-0.001	0.038	0.036	0.089	0.042	0.284*
11	TW (g)	-0.105	-0.385	0.007	0.028	-0.006	0.015	-0.159	0.131	0.077	0.191	-0.367	0.028	0.087	0.033	0.002	5.007	-8.914	1.166	2.028	-0.180	1.519	-0.013	0.317	-0.076	-0.262	0.133	0.301*
12	LAI	0.086	0.307	-0.082	-0.023	0.011	0.042	0.113	-0.217	0.018	-0.063	0.092	-0.113	0.126	-0.019	-0.001	-0.730	0.459	0.829	-0.799	-0.011	0.192	0.017	0.022	-0.206	-0.246	0.158	-0.038
13	HP (%)	-0.049	-0.100	0.000	0.016	-0.006	0.013	-0.072	0.033	0.072	0.118	-0.112	-0.050	0.284	0.009	0.000	0.381	-1.642	1.273	-0.176	-0.059	0.369	0.104	-0.148	-0.159	-0.346	0.118	-0.130
14	MP (%)	0.119	0.374	-0.071	-0.111	-0.029	0.109	-0.336	0.416	-0.072	-0.193	0.176	-0.032	-0.039	-0.068	-0.007	-1.773	4.341	-1.495	0.039	0.116	-1.167	0.000	-0.289	0.127	0.081	0.132	0.349*
15	HRR (%)	0.124	0.365	-0.125	-0.231	-0.052	0.243	-0.610	0.698	-0.116	-0.141	0.068	-0.015	0.013	-0.054	-0.009	0.469	3.066	-3.907	2.030	0.033	-1.436	0.043	-0.240	0.295	0.022	0.034	0.567**
16	KL (mm)	-0.052	-0.194	-0.056	-0.104	-0.026	0.150	-0.344	0.295	0.046	0.140	-0.344	0.015	0.020	0.023	-0.001	5.349	-7.418	-1.022	3.695	-0.151	0.250	-0.020	0.393	0.049	-0.308	0.100	0.488**
17	KB (mm)	-0.132	-0.426	0.051	0.057	-0.005	-0.043	-0.046	0.073	0.061	0.258	-0.271	0.004	0.039	0.024	0.002	3.290	-12.059	7.566	-0.408	-0.259	2.608	-0.033	0.164	-0.153	-0.207	0.014	0.170
18	L/B ratio	0.121	0.367	-0.111	-0.161	-0.015	0.181	-0.238	0.159	-0.034	-0.202	0.041	0.009	-0.035	-0.010	-0.004	0.524	8.735	-10.445	3.797	0.192	-3.124	0.023	0.138	0.233	-0.004	0.065	0.206
19	KLAC (mm)	0.103	0.248	-0.099	-0.252	-0.041	0.296	-0.544	0.623	0.039	-0.111	-0.126	0.015	-0.009	0.000	-0.003	3.346	0.834	-6.714	5.906	0.006	-3.112	0.004	0.265	0.065	-0.167	0.035	0.607**
20	KBAC (mm)	0.000	-0.044	-0.001	0.043	-0.002	-0.085	-0.172	0.172	-0.054	0.177	-0.164	-0.003	0.041	0.019	0.001	2.006	-7.747	4.960	-0.089	-0.404	1.492	-0.035	-0.040	-0.051	-0.004	0.200	0.215
21	KLER	0.173	0.475	-0.078	-0.229	-0.029	0.247	-0.381	0.518	0.015	-0.261	0.133	0.005	-0.025	-0.019	-0.003	-0.319	7.491	-7.770	4.378	0.143	-4.199	0.019	0.005	0.034	0.044	-0.035	0.336**
22	VER	0.091	0.117	-0.224	-0.063	0.001	0.070	-0.174	0.404	-0.256	0.004	0.037	-0.015	0.234	0.000	-0.003	-0.827	3.130	-1.929	0.192	0.113	-0.638	0.126	0.043	0.161	-0.007	-0.446	0.142
23	WU (ml)	-0.017	-0.102	-0.104	-0.053	-0.009	0.067	-0.052	0.155	0.040	-0.015	-0.135	-0.003	-0.049	0.023	0.003	2.444	-2.299	-1.677	1.816	0.019	-0.026	0.006	0.861	-0.098	-0.404	-0.205	0.186
24	GC (mm)	0.059	0.229	-0.153	-0.143	-0.021	0.156	-0.394	0.422	-0.220	-0.020	0.045	0.037	-0.072	-0.014	-0.004	0.424	2.956	-3.908	0.620	0.033	-0.228	0.033	-0.135	0.623	0.080	-0.098	0.305*
25	ASV (mm)	0.015	0.055	-0.081	-0.081	-0.017	0.165	-0.281	0.263	0.059	0.045	-0.142	-0.041	0.145	0.008	0.000	2.431	-3.683	-0.054	1.455	-0.002	0.273	0.001	0.514	-0.074	-0.678	-0.036	0.260*
26	AC (%)	-0.018	-0.074	-0.113	-0.102	-0.023	0.126	0.144	0.185	-0.075	0.021	0.070	0.026	-0.048	0.013	0.001	-0.772	0.248	0.979	-0.297	0.116	-0.210	0.081	0.253	0.088	-0.035	-0.696	-0.113

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.1420

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEPT: Total number of Ear Bearing Tillers per Plant; NRTMCT: Number of ratoon tillers as percentage of main crop tillers; NREPTMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.23. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of F₁s in rice (*Oryza sativa* L.)

Characters	DFE	DM	PH	TNTP	TEBTP	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP	
DFE	r _p	1.000	0.975**	0.048	-0.290**	-0.271**	-0.288**	0.070	-0.420**	0.039	-0.169	-0.252**	-0.338**	-0.156	-0.248**	0.171	-0.082	-0.095	0.030	-0.097	0.217*	-0.273**	0.133	-0.078	-0.250**
DM	r _p		1.000	0.057	-0.322**	-0.283**	-0.288**	0.070	-0.375**	0.063	-0.168	-0.245*	-0.323**	-0.185	-0.284**	0.189*	-0.079	-0.121	0.056	-0.091	0.233*	-0.292**	0.154	-0.078	-0.264**
PH	r _p			1.000	0.427**	0.395**	0.272**	0.489**	0.412**	0.448**	0.167	0.288**	0.479**	0.098	0.028	0.025	-0.101	-0.027	-0.166	-0.250**	0.125	0.272**	-0.229*	0.046	0.498**
TNTP	r _p				1.000	0.623**	0.619**	0.461**	0.283**	0.132	0.278**	0.523**	0.356**	0.004	0.355**	-0.389**	-0.115	0.390**	-0.111	-0.108	-0.001	0.288**	-0.171	0.079	0.662**
TEBTP	r _p					1.000	0.442**	0.417**	0.345**	0.122	0.241*	0.431**	0.394**	0.186	0.308**	-0.209*	-0.051	0.241*	-0.186	-0.015	-0.061	0.240*	-0.169	0.026	0.404**
PL	r _p						1.000	0.451**	0.380**	0.057	0.142	0.443**	0.292**	0.228*	0.395**	-0.273**	0.004	0.338**	-0.162	-0.044	-0.176	0.302**	-0.107	0.073	0.406**
NGPP	r _p							1.000	0.174	0.316**	0.109	0.389**	0.341**	0.110	0.155	-0.101	0.076	0.238*	-0.004	-0.068	-0.124	0.245*	-0.107	-0.202*	0.409**
TW	r _p								1.000	0.419**	0.063	0.302**	0.499**	0.188	0.223*	-0.122	0.154	-0.104	0.023	-0.162	-0.048	0.234*	-0.103	0.138	0.322**
LAI	r _p									1.000	0.171	0.229*	0.554**	-0.033	-0.155	0.142	0.017	-0.068	0.048	-0.425**	-0.036	0.070	-0.112	-0.116	0.281**
HP	r _p										1.000	0.464**	0.414**	0.048	0.109	-0.096	0.057	0.060	0.032	-0.107	-0.132	0.145	0.010	0.034	0.198*
MP	r _p											1.000	0.645**	0.120	0.270**	-0.202*	0.201*	0.150	0.128	-0.066	-0.159	0.512**	0.086	-0.060	0.499**
HRR	r _p												1.000	0.008	0.154	-0.156	0.125	-0.023	0.133	-0.332**	-0.258**	0.434**	-0.125	-0.199*	0.459**
KL	r _p													1.000	0.464**	0.156	0.387**	0.021	-0.358**	0.171	0.156	0.102	0.058	-0.102	0.002
KB	r _p														1.000	-0.799**	0.088	0.291**	-0.262**	0.273**	-0.141	0.127	-0.024	-0.047	0.088
L/B	r _p															1.000	0.178	-0.323**	0.066	-0.175	0.278**	-0.067	0.080	-0.030	-0.093
KLAC	r _p																1.000	-0.151	0.721**	-0.002	-0.236*	0.048	0.292**	-0.176	0.138
KBAC	r _p																	1.000	-0.169	-0.013	-0.136	0.088	-0.104	0.133	0.241*
KLER	r _p																		1.000	-0.136	0.119	-0.021	0.246*	-0.105	0.145
VER	r _p																			1.000	0.150	-0.157	0.199*	0.019	-0.179
WU	r _p																				1.000	-0.255**	0.246**	0.052	0.122
GC	r _p																					1.000	-0.002	0.029	0.320**
ASV	r _p																						1.000	0.084	-0.006
AC	r _p																							1.000	-0.152
GYPP	r _p																								1.000

* Significant at 5% level

** Significant at 1% level

rg: Genotypic level

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.24. Genotypic (rg) correlation among grain yield, yield contributing and quality characters of F₁s in rice (*Oryza sativa* L.)

Characters		DFF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DFF	r _g	1.000	0.999*	0.056	-0.323**	-0.350**	-0.389**	0.094	-0.451**	0.053	-0.299**	-0.299**	-0.387**	-0.197*	-0.264**	0.171	-0.093	-0.127	0.051	-0.102	0.237*	-0.284**	0.146	-0.070	-0.271**
DM	r _g		1.000	0.049	-0.344**	-0.388**	-0.381**	0.075	-0.407**	0.085	-0.326**	-0.307**	-0.379**	-0.226*	-0.287**	0.181	-0.080	-0.147	0.086	-0.101	0.243*	-0.307**	0.165	-0.075	-0.278**
PH	r _g			1.000	0.492**	0.513**	0.358**	0.546**	0.442**	0.479**	0.302**	0.341**	0.543**	0.131	0.039	0.027	-0.088	-0.061	-0.193*	-0.271**	0.127	0.281**	-0.241*	0.044	0.544**
TNTP	r _g				1.000	0.942**	0.846**	0.597**	0.338**	0.136	0.424**	0.660**	0.485**	0.048	0.422**	-0.442**	-0.138	0.492**	-0.184	-0.111	-0.014	0.325**	-0.185	0.068	0.752**
TEBTP	r _g					1.000	0.947**	0.526**	0.467**	0.170	0.614**	0.710**	0.571**	0.223*	0.486**	-0.387**	-0.015	0.268**	-0.181	-0.079	-0.113	0.349**	-0.223*	0.074	0.615**
PL	r _g						1.000	0.716**	0.562**	0.090	0.449**	0.750**	0.481**	0.369**	0.531**	-0.365**	0.093	0.477**	-0.182	-0.001	-0.231*	0.395**	-0.125	0.069	0.556**
NGPP	r _g							1.000	0.213*	0.361**	0.134	0.486**	0.394**	0.081	0.214*	-0.187	0.065	0.292**	0.015	-0.124	-0.164	0.280**	-0.110	-0.227*	0.481**
TW	r _g								1.000	0.450**	0.157	0.361**	0.588**	0.237*	0.239*	-0.123	0.151	-0.123	-0.011	-0.183	-0.041	0.245*	-0.015	0.145	0.327**
LAI	r _g									1.000	0.253*	0.281**	0.623**	-0.004	-0.165	0.176	0.005	-0.102	0.021	-0.453**	-0.046	0.071	-0.121	-0.138	0.291**
HP	r _g										1.000	0.954**	0.708**	0.176	0.243*	-0.169	0.095	0.235*	-0.010	-0.158	-0.339**	0.312**	0.010	0.004	0.390**
MP	r _g											1.000	0.757**	0.207*	0.300**	-0.191*	0.283**	0.241*	0.173	-0.117	-0.185	0.584**	0.113	-0.100	0.605**
HRR	r _g												1.000	0.001	0.145	-0.154	0.187	-0.011	0.230*	-0.396**	-0.317**	0.495**	-0.148	-0.243*	0.549**
KL	r _g													1.000	0.487**	0.088	0.494**	0.006	-0.248**	0.185	0.177	0.129	0.079	-0.103	-0.003
KB	r _g														1.000	-0.825**	0.101	0.348**	-0.283**	0.304**	-0.157	0.140	-0.025	-0.062	0.077
L/B	r _g															1.000	0.218*	-0.409**	0.181	-0.210*	0.306**	-0.072	0.093	-0.013	-0.086
KLAC	r _g																1.000	-0.181	0.720**	-0.009	0.276**	0.071	0.335**	-0.197*	0.127
KBAC	r _g																	1.000	-0.204*	-0.030	-0.171	0.091	-0.107	0.151	0.271**
KLER	r _g																		1.000	-0.166	0.159	-0.016	0.302**	-0.143	0.154
VER	r _g																			1.000	0.162	-0.175	0.219*	0.018	-0.209*
WU	r _g																				1.000	-0.264**	0.255**	0.047	0.131
GC	r _g																					1.000	-0.003	0.026	0.346**
ASV	r _g																						1.000	0.082	-0.001
AC	r _g																							1.000	-0.154
GYPP	r _g																								1.000

* Significant at 5% level

** Significant at 1% level

r_p: Phenotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

rg: Genotypic level

Table 4.25. Genotypic (G) direct and indirect effects of different traits on grain yield of F₁s in rice (*Oryza sativa* L.)

Characters		DF	DM	PH	TNTP	TEBTP	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC
DF	G	-0.490	-0.489	-0.028	0.159	0.171	0.191	-0.046	0.221	-0.026	0.147	0.147	0.189	0.097	0.129	-0.084	0.046	0.062	-0.025	0.050	-0.116	0.139	-0.072	0.034
DM	G	0.609	0.610	0.030	-0.210	-0.237	-0.232	0.046	-0.248	0.052	-0.199	-0.187	-0.231	-0.138	-0.175	0.110	-0.049	-0.090	0.053	-0.062	0.148	-0.187	0.100	-0.046
PH	G	-0.008	-0.007	-0.147	-0.072	-0.075	-0.053	-0.080	-0.065	-0.070	-0.044	-0.050	-0.080	-0.019	-0.006	-0.004	0.013	0.009	0.028	0.040	-0.019	-0.041	0.035	-0.007
TNTP	G	-0.231	-0.246	0.352	0.715	0.673	0.605	0.427	0.241	0.097	0.303	0.472	0.347	0.034	0.301	-0.316	-0.099	0.351	-0.132	-0.080	-0.010	0.232	-0.132	0.049
TEBTP	G	-0.051	-0.056	0.074	0.137	0.145	0.137	0.076	0.068	0.025	0.089	0.103	0.083	0.032	0.070	-0.056	-0.002	0.039	-0.026	-0.011	-0.016	0.051	-0.032	0.011
PL	G	-0.232	-0.228	0.214	0.505	0.566	0.597	0.428	0.335	0.054	0.268	0.448	0.287	0.221	0.317	-0.218	0.055	0.285	-0.109	-0.001	-0.138	0.236	-0.075	0.041
NGPP	G	-0.019	-0.015	-0.110	-0.120	-0.106	-0.144	-0.201	-0.043	-0.073	-0.027	-0.098	-0.079	-0.016	-0.043	0.038	-0.013	-0.059	-0.003	0.025	0.033	-0.056	0.022	0.046
TW	G	0.234	0.212	-0.230	-0.175	-0.243	-0.292	-0.111	-0.520	-0.234	-0.082	-0.187	-0.306	-0.123	-0.124	0.064	-0.079	0.064	0.006	0.095	0.021	-0.127	0.008	-0.075
LAI	G	-0.008	-0.013	-0.073	-0.021	-0.026	-0.014	-0.055	-0.069	-0.152	-0.039	-0.043	-0.095	0.001	0.025	-0.027	-0.001	0.016	-0.003	0.069	0.007	-0.011	0.018	0.021
HP	G	0.036	0.040	-0.037	-0.052	-0.075	-0.055	-0.016	-0.019	-0.031	-0.122	-0.116	-0.086	-0.021	-0.030	0.021	-0.012	-0.029	0.001	0.019	0.041	-0.038	-0.001	-0.001
MP	G	0.199	0.205	-0.228	-0.440	-0.473	-0.500	-0.324	-0.240	-0.187	-0.636	-0.667	-0.505	-0.138	-0.200	0.127	-0.189	-0.161	-0.115	0.078	0.123	-0.389	-0.075	0.066
HRR	G	-0.519	-0.509	0.728	0.651	0.766	0.645	0.528	0.789	0.836	0.950	1.015	1.342	0.001	0.194	-0.206	0.251	-0.015	0.309	-0.532	-0.425	0.664	-0.199	-0.325
KL	G	-0.605	-0.691	0.402	0.147	0.682	1.131	0.250	0.725	-0.013	0.538	0.634	0.003	3.063	1.492	0.269	1.512	0.018	-0.759	0.568	0.543	0.394	0.243	-0.314
KB	G	2.007	2.186	-0.294	-3.211	-3.700	-4.044	-1.626	-1.823	1.258	-1.853	-2.282	-1.103	-3.710	-7.616	6.285	-0.769	-2.650	2.158	-2.315	1.196	-1.063	0.188	0.468
L/B ratio	G	-1.076	-1.136	-0.171	2.779	2.432	2.295	1.173	0.773	-1.104	1.062	1.199	0.965	-0.552	5.184	-6.282	-1.367	2.570	-1.139	1.322	-1.925	0.454	-0.586	0.083
KLAC	G	-0.146	-0.126	-0.138	-0.217	-0.024	0.146	0.103	0.238	0.008	0.149	0.445	0.294	0.775	0.159	0.342	1.570	-0.285	1.131	-0.015	0.434	0.112	0.526	-0.309
KBAC	G	0.002	0.003	0.001	-0.009	-0.005	-0.008	-0.005	0.002	0.002	-0.004	-0.004	0.000	0.000	-0.006	0.007	0.003	-0.018	0.004	0.001	0.003	-0.002	0.002	-0.003
KLER	G	-0.069	-0.117	0.262	0.251	0.246	0.247	-0.021	0.015	-0.028	0.013	-0.235	-0.314	0.337	0.386	-0.247	-0.980	0.277	-1.361	0.226	-0.216	0.021	-0.410	0.194
VER	G	-0.021	-0.021	-0.056	-0.023	-0.016	0.000	-0.025	-0.038	-0.093	-0.032	-0.024	-0.081	0.038	0.062	-0.043	-0.002	-0.006	-0.034	0.205	0.033	-0.036	0.045	0.004
WU	G	0.086	0.088	0.046	-0.005	-0.041	-0.084	-0.060	-0.015	-0.017	-0.123	-0.067	-0.115	0.064	-0.057	0.111	0.100	-0.062	0.058	0.059	0.364	-0.096	0.093	0.017
GC	G	-0.026	-0.028	0.026	0.030	0.032	0.037	0.026	0.023	0.007	0.029	0.054	0.046	0.012	0.013	-0.007	0.007	0.008	-0.001	-0.016	-0.025	0.093	0.000	0.002
ASV	G	0.046	0.051	-0.075	-0.058	-0.070	-0.039	-0.035	-0.005	-0.038	0.003	0.035	-0.046	0.025	-0.008	0.029	0.105	-0.033	0.094	0.069	0.080	-0.001	0.313	0.026
AC	G	0.010	0.010	-0.006	-0.009	-0.010	-0.009	0.031	-0.020	0.019	-0.001	0.014	0.033	0.014	0.008	0.002	0.027	-0.021	0.019	-0.002	-0.006	-0.004	-0.011	-0.136
GYPP	G	-0.271**	-0.278**	0.544**	0.752**	0.615**	0.556**	0.481**	0.327**	0.291**	0.390**	0.605**	0.549**	-0.003	0.077	-0.086	0.127	0.271**	0.154	-0.209*	0.131	0.346**	-0.001	-0.154

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

G: Genotypic level

Residual effect at genotypic level = 0.447

DF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GYPP: Grain Yield per plant (g).

Table 4.36. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of F₁ ratoon in rice (*Oryza sativa* L.)

S. No.	Characters		DFE	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TETP	NRETP MCET	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_p	1.000	0.869**	0.417**	0.109	0.038	0.032	0.405**	0.371**	0.314**	0.296**	0.119	0.489**	0.224*	-0.096	0.201*	-0.171	-0.204*	0.077	-0.039	-0.240*	0.100	0.027	-0.064	-0.076	-0.052	0.041	0.380**
2	DM	r_p		1.000	0.507**	0.145	0.084	0.028	0.425**	0.364**	0.379**	0.368**	0.095	0.480**	0.287**	-0.086	0.207*	-0.184	-0.257**	0.134	-0.012	-0.198*	0.138	-0.044	-0.061	-0.108	-0.179	-0.027	0.447**
3	PH	r_p			1.000	0.356**	-0.218*	0.128	0.498**	0.159	0.697**	0.562**	0.424**	0.474**	0.409**	0.171	0.381**	0.094	-0.015	0.067	-0.098	0.018	-0.154	-0.195*	0.154	0.306**	-0.333**	-0.051	0.640**
4	TNTP	r_p				1.000	0.387**	0.555**	0.410**	0.295**	0.160	0.296**	0.027	0.173	0.265**	0.138	0.183	0.113	0.043	0.029	-0.022	0.172	-0.106	-0.097	0.049	0.174	-0.158	0.048	0.381**
5	NRTPMCPT	r_p					1.000	0.208*	-0.012	0.391**	-0.385**	-0.279*	-0.357**	0.004	-0.168	-0.279**	-0.278**	0.110	-0.230*	0.333**	0.078	-0.260**	-0.015	0.077	-0.272**	-0.117	0.150	0.063	-0.089
6	NVGBAHMC	r_p						1.000	0.231*	0.153	0.037	0.062	-0.048	0.030	0.097	-0.065	0.032	0.071	0.180	-0.150	0.003	0.190*	-0.055	-0.040	-0.009	-0.075	-0.124	0.003	0.188
7	TEBTP	r_p							1.000	0.749**	0.376**	0.414**	0.146	0.456**	0.268**	0.081	0.304**	0.024	-0.087	0.113	0.054	-0.050	0.035	-0.157	0.132	0.174	-0.008	-0.141	0.711**
8	NRTPMCT	r_p								1.000	0.040	0.103	-0.158	0.316**	0.049	-0.140	0.076	-0.025	-0.260 **	0.265**	0.075	-0.194*	0.088	-0.020	-0.043	0.022	0.162	-0.091	0.439**
9	PL	r_p									1.000	0.436**	0.337**	0.297**	0.303**	0.120	0.328**	-0.026	-0.027	0.002	-0.170	0.029	-0.132	-0.027	0.325**	0.161	-0.287**	-0.069	0.478**
10	NGPP	r_p										1.000	0.310**	0.497**	0.500**	0.274**	0.479**	-0.021	0.063	-0.085	0.104	0.266**	0.124	-0.048	0.127	0.313**	-0.180	-0.201*	0.633**
11	TW	r_p											1.000	0.478**	0.293 **	0.386**	0.477**	0.101	0.104	-0.044	0.054	-0.101	-0.005	-0.211*	0.059	0.265**	-0.051	0.004	0.439**
12	LAI	r_p												1.000	0.332**	0.196*	0.490**	-0.014	-0.154	0.143	0.076	-0.115	0.098	-0.254**	-0.099	0.103	-0.035	-0.112	0.688**
13	HL	r_p													1.000	0.348**	0.571**	0.102	0.194*	-0.148	0.054	0.155	-0.021	0.110	0.104	0.069	-0.119	0.028	0.287**
14	ML	r_p														1.000	0.541**	0.155	0.275**	-0.192*	0.219*	0.164	0.097	-0.243*	0.070	0.335**	-0.031	-0.092	0.223*
15	HRR	r_p															1.000	0.057	0.131	-0.113	0.252**	0.071	0.209*	-0.076	0.059	0.101	-0.055	-0.222*	0.477**
16	KL	r_p																1.000	0.490**	0.171	0.364**	0.031	-0.444**	0.018	0.147	0.145	0.101	-0.097	-0.027
17	KB	r_p																	1.000	-0.771**	0.178	0.250**	-0.222*	0.066	0.041	0.065	-0.011	-0.112	-0.115
18	L/B	r_p																		1.000	0.075	-0.269**	-0.059	-0.057	0.086	0.031	0.092	0.039	0.109
19	KLAC	r_p																			1.000	-0.131	0.672**	0.029	0.189*	0.101	0.277**	-0.156	0.033
20	KBAC	r_p																				1.000	-0.150	-0.002	0.005	0.026	-0.156	0.115	-0.007
21	KLER	r_p																					1.000	0.003	0.066	-0.005	0.180	-0.076	0.068
22	VER	r_p																						1.000	0.204*	-0.202*	0.231*	0.116	-0.222*
23	WU	r_p																							1.000	-0.070	0.165	0.039	0.112
24	GC	r_p																								1.000	-0.057	-0.026	0.314**
25	ASV)	r_p																									1.000	0.129	-0.125
26	AC	r_p																										1.000	-0.272**
27	GYPP	r_p																											1.000

r_g : Genotypic level

* Significant at 5% level

** Significant at 1% level

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.38. Genotypic (G) direct and indirect effects of different traits on grain yield F₁ ratoon in rice (*Oryza sativa* L.)

S.N o	Character	DFE	DM	PH	TNTP	NRTPMCT	NVBAHMC	TPTP	NRTPMCPT	PL	NGPP	TW	LAI	HL	ML	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP
1	DF	-1.463	1.595	-0.099	-0.006	0.019	0.023	0.221	-0.002	0.053	0.044	0.033	0.190	-0.144	-0.030	0.107	-0.423	-0.015	0.000	0.143	-0.037	0.314	0.012	-0.014	-0.024	-0.011	-0.001	0.484**
2	DM	-1.416	1.648	-0.107	-0.007	0.025	0.023	0.235	-0.002	0.056	0.050	0.022	0.172	-0.155	-0.029	0.120	-0.403	-0.015	0.000	0.015	-0.034	0.396	-0.012	-0.012	-0.032	-0.040	0.001	0.495**
3	PH (cm)	-0.762	0.929	-0.190	-0.016	-0.111	0.020	0.266	-0.001	0.095	0.073	0.088	0.160	-0.225	0.037	0.216	0.261	0.000	0.000	0.295	0.003	-0.469	-0.053	0.033	0.092	-0.067	0.001	0.676**
4	TNTP	-0.322	0.405	-0.115	-0.027	-0.070	0.130	0.327	-0.002	0.042	0.053	0.025	0.097	-0.184	0.042	0.136	0.049	0.008	0.000	0.153	0.023	-0.186	-0.026	0.018	0.077	-0.055	-0.002	0.596**
5	NRTPMCT	-0.086	0.127	0.066	0.006	0.321	0.011	0.022	-0.003	-0.067	-0.062	-0.100	0.005	0.175	-0.093	-0.240	0.083	-0.015	0.000	-0.286	-0.079	0.124	0.028	-0.079	-0.051	0.031	-0.003	-0.165
6	NVBAHMC	-0.233	0.259	-0.026	-0.024	0.024	0.143	0.242	-0.001	0.003	0.012	-0.010	0.049	-0.016	0.024	0.000	-0.008	0.020	0.000	-0.099	0.043	0.062	-0.034	-0.003	-0.026	-0.045	0.001	0.357**
7	TPTP	-0.818	0.978	-0.128	-0.022	0.018	0.088	0.395	-0.003	0.068	0.068	0.039	0.187	-0.175	0.023	0.229	-0.076	-0.006	0.000	-0.292	-0.014	0.348	-0.058	0.026	0.066	-0.008	0.004	0.935**
8	NRTPMCPT	-0.826	0.928	-0.047	-0.012	0.233	0.047	0.297	-0.004	0.011	0.018	-0.046	0.138	0.000	-0.040	0.068	-0.289	-0.019	0.000	-0.475	-0.049	0.695	-0.006	-0.030	0.005	0.036	0.004	0.635**
9	PL (cm)	-0.703	0.838	-0.166	-0.010	-0.197	0.003	0.246	0.000	0.110	0.073	0.087	0.112	-0.207	0.027	0.211	-0.098	-0.002	0.000	0.548	0.010	-0.328	-0.024	0.079	0.053	-0.064	0.002	0.597**
10	NGPP	-0.544	0.709	-0.119	-0.012	-0.171	0.015	0.229	-0.001	0.068	0.117	0.071	0.177	-0.294	0.067	0.270	-0.020	0.005	0.000	-0.384	0.052	0.368	-0.010	0.030	0.098	-0.038	0.005	0.688**
11	TW (g)	-0.241	0.181	-0.083	-0.003	-0.159	-0.007	0.077	0.001	0.047	0.042	0.201	0.160	-0.159	0.080	0.283	0.214	0.005	0.000	-0.215	-0.014	0.039	-0.063	0.012	0.080	-0.010	0.000	0.469**
12	LAI	-0.891	0.909	-0.098	-0.008	0.005	0.023	0.236	-0.002	0.039	0.066	0.103	0.312	-0.204	0.041	0.266	-0.065	-0.008	0.000	-0.233	-0.015	0.304	-0.069	-0.019	0.029	-0.005	0.003	0.72
13	HL (%)	-0.446	0.543	-0.091	-0.011	-0.119	0.005	0.147	0.000	0.048	0.073	0.068	0.135	-0.472	0.088	0.345	0.336	0.012	0.000	-0.309	0.027	-0.047	0.018	0.021	0.029	-0.030	0.000	0.367
14	ML (%)	0.309	-0.327	-0.049	-0.008	-0.209	0.024	0.063	0.001	0.021	0.055	0.112	0.088	-0.289	0.144	0.345	0.457	0.014	0.000	-0.812	0.049	0.292	-0.078	0.022	0.137	-0.015	0.003	0.349
15	HRR (%)	-0.341	0.431	-0.090	-0.008	-0.168	0.000	0.197	-0.001	0.051	0.069	0.124	0.181	-0.356	0.108	0.459	0.195	0.009	0.000	-0.911	0.017	0.621	-0.022	0.016	0.030	-0.013	0.006	0.604
16	KL (mm)	0.341	-0.366	-0.027	-0.001	0.015	-0.001	-0.017	0.001	-0.006	-0.001	0.024	-0.011	-0.087	0.036	0.049	1.813	0.027	0.000	-1.377	-0.002	-0.602	0.001	0.038	0.049	0.024	0.002	-0.079
17	KB (mm)	0.478	-0.557	0.002	-0.005	-0.103	0.063	-0.056	0.002	-0.005	0.012	0.023	-0.051	-0.122	0.043	0.088	1.089	0.046	0.000	-0.616	0.049	-0.558	0.021	0.013	0.023	-0.005	0.003	-0.121
18	L/B ratio	-0.288	0.371	-0.018	0.006	0.135	-0.079	0.057	-0.002	0.000	-0.017	-0.011	0.049	0.094	-0.025	-0.076	-0.006	-0.036	-0.001	-0.295	-0.065	0.276	-0.026	0.017	0.008	0.025	-0.002	0.09
19	KLAC (mm)	0.074	-0.009	0.020	0.001	0.032	0.005	0.041	-0.001	-0.021	0.016	0.015	0.025	-0.051	0.041	0.147	0.876	0.010	0.000	-2.849	-0.019	1.547	0.012	0.045	0.025	0.055	0.004	0.041
20	KBAC (mm)	0.374	-0.391	-0.004	-0.004	-0.177	0.043	-0.037	0.001	0.008	0.043	-0.019	-0.033	-0.090	0.049	0.054	-0.020	0.016	0.000	0.371	0.144	-0.293	0.006	-0.004	0.010	-0.035	-0.003	0.007
21	KLER	-0.210	0.299	0.041	0.002	0.018	0.004	0.063	-0.001	-0.016	0.020	0.004	0.043	0.010	0.019	0.130	-0.500	-0.012	0.000	-2.017	-0.019	2.186	0.010	0.019	-0.008	0.041	0.002	0.128
22	VER	-0.075	-0.090	0.044	0.003	0.040	-0.021	-0.102	0.000	-0.012	-0.005	-0.056	-0.095	-0.037	-0.049	-0.045	0.004	0.004	0.000	-0.154	0.004	0.098	0.227	0.045	-0.059	0.052	-0.003	-0.280**
23	WU (ml)	0.096	-0.098	-0.031	-0.002	-0.123	-0.002	0.050	0.001	0.042	0.017	0.011	-0.029	-0.047	0.015	0.036	0.329	0.003	0.000	-0.614	-0.003	0.202	0.049	0.207	-0.020	0.032	-0.001	0.120
24	GC (mm)	0.127	-0.190	-0.062	-0.007	-0.059	-0.014	0.093	0.000	0.021	0.041	0.058	0.032	-0.048	0.070	0.049	0.318	0.004	0.000	-0.256	0.005	-0.059	-0.048	-0.015	0.280	-0.012	0.001	0.328**
25	ASV (mm)	0.087	-0.348	0.066	0.008	0.053	-0.034	-0.016	-0.001	-0.036	-0.023	-0.011	-0.008	0.075	-0.011	-0.030	0.223	-0.001	0.000	-0.823	-0.026	0.467	0.062	0.035	-0.017	0.191	-0.003	-0.123
26	AC (%)	-0.076	-0.052	0.010	-0.003	0.038	-0.006	-0.075	0.001	-0.008	-0.026	0.001	-0.036	-0.008	-0.021	-0.123	-0.195	-0.007	0.000	0.469	0.019	-0.215	0.028	0.008	-0.008	0.025	-0.023	-0.283**

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.0401

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NRETPMCET: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Appendix A: Meterological data during the crop period (21-07-2014 to 30-08-2016)

Standard week	Date and month weekly	Mean Temperature ($^{\circ}\text{C}$)		Mean Relative Humidity (%)		Mean Rainfall (mm)	Number of rainy days	Mean evaporation mm(d $^{-1}$)
		Max	Min	A.M	P.M			
29	16 Jul - 22 Jul, 2014	30.71	28.29	78.14	78.86	0.00	0.00	3.74
30	23 Jul - 29 Jul, 2014	30.79	26.71	84.29	80.00	20.56	3.00	4.37
31	30 Jul - 05 Aug, 2014	31.14	27.86	82.14	79.00	0.60	1.00	1.00
32	06 Aug - 12 Aug, 2014	32.86	26.71	86.29	74.57	24.07	2.00	6.34
33	13 Aug - 19 Aug, 2014	33.00	26.57	85.00	72.86	2.13	1.00	4.17
34	20 Aug - 26 Aug, 2014	32.71	27.43	85.00	73.86	10.40	3.00	4.86
35	27 Aug - 02 Sep, 2014	29.00	25.71	87.71	78.29	0.00	3.00	1.00
36	03 Sep - 09 Sep, 2014	30.00	25.71	92.29	76.14	8.68	4.00	3.31
37	10 Sep - 16 Sep, 2014	31.00	27.14	84.14	75.71	11.67	2.00	4.66
38	17 Sep - 23 Sep, 2014	29.57	26.29	88.86	77.86	19.15	2.00	3.63
39	24 Sep - 30 Sep, 2014	32.00	26.57	87.57	72.43	11.75	3.00	3.94
40	01 Oct - 07 Oct, 2014	33.00	26.71	86.57	73.71	17.30	2.00	3.77
41	08 Oct - 14 Oct, 2014	30.71	26.00	83.57	77.86	15.50	2.00	2.57
42	15 Oct - 21 Oct, 2014	30.71	25.14	85.29	76.00	16.40	1.00	3.29
43	22 Oct - 28-Oct, 2014	29.29	24.43	89.00	72.14	6.80	3.00	3.00
44	29 Oct - 04 Nov, 2014	28.71	22.86	89.00	72.14	0.00	0.00	0.00
45	05 Nov - 11 Nov, 2014	29.86	21.71	91.43	72.57	5.50	2.00	2.31
46	12 Nov - 18 Nov, 2014	30.43	23.57	91.43	74.57	4.40	2.00	2.74
47	19 Nov - 25 Nov, 2014	29.57	21.43	88.14	74.43	0.00	0.00	2.43
48	26 Nov - 01 Dec, 2014	29.57	18.43	90.14	70.71	0.00	0.00	0.00
49	03 Dec - 10 Dec, 2014	30.19	19.75	87.75	71.00	0.00	0.00	2.53
50	11 Dec - 17 Dec, 2014	29.71	22.00	86.43	71.43	0.00	0.00	2.26

51	18 Dec - 24 Dec, 2014	27.71	18.29	84.57	74.00	0.00	0.00	2.66
52	25 Dec - 31 Dec, 2014	26.14	19.71	81.57	76.57	3.50	1.00	2.51
1	01 Jan, - 07 Jan, 2015	29.57	23.14	89.43	72.00	0.00	0.00	2.57
2	08 Jan, - 14 Jan, 2015	28.29	18.57	85.14	71.57	0.00	0.00	2.26
3	15 Jan, - 21 Jan, 2015	27.86	19.29	84.71	69.00	0.00	0.00	2.57
4	23 Jan, - 28 Jan, 2015	27.29	19.14	86.57	71.14	0.00	0.00	3.00
5	29 Jan, - 04 Feb, 2015	27.14	20.43	87.86	74.43	0.00	0.00	0.00
6	05 Feb, -11 Feb, 2015	28.57	19.71	87.71	72.00	0.00	0.00	3.31
7	12 Feb, - 18 Feb, 2015	29.57	20.43	90.71	72.71	0.00	0.00	3.57
8	19 Feb, - 25 Feb, 2015	30.14	20.86	87.57	68.14	0.00	0.00	3.63
9	26 Feb, - 04 Mar, 2015	29.43	21.29	85.71	72.14	0.00	0.00	0.00
10	05 Mar, - 11 Mar, 2015	31.43	23.00	90.14	72.43	0.00	0.00	4.09
11	12 Mar, -18 Mar, 2015	31.71	20.71	87.86	71.29	0.00	0.00	4.46
12	19 Mar, -25 Mar, 2015	32.14	22.86	90.43	73.43	0.00	0.00	4.74
13	26 Mar, - 01 Apr, 2015	31.79	24.00	89.00	73.14	0.00	0.00	0.00
14	02 Apr, - 08 Apr, 2015	31.00	25.43	88.57	72.14	0.00	0.00	4.66
15	09 Apr, - 15 Apr, 2015	29.71	24.71	87.00	77.00	6.90	2.00	3.77
16	16 Apr, - 22 Apr, 2015	32.57	25.14	85.14	67.57	18.20	1.00	4.51
17	23 Apr, - 29 Apr, 2015	32.57	26.00	85.29	72.00	0.00	0.00	4.71
18	30 Apr, - 06 May, 2015	33.29	26.71	88.29	74.14	3.40	1.00	1.00
19	07 May, - 13 May, 2015	33.71	26.86	87.57	72.14	0.00	0.00	5.77
20	14 May, - 20 May, 2015	34.00	27.57	86.00	73.86	12.50	2.00	4.34
21	21 May, - 27 May, 2015	39.14	30.29	81.00	68.57	0.00	0.00	7.14
22	28 May, - 03 Jun, 2015	35.71	29.00	84.43	73.43	0.00	1.00	1.00
23	04 Jun, - 10 Jun, 2015	37.43	26.57	84.14	78.71	16.58	4.00	3.67
24	11 Jun, -17 Jun, 2015	35.00	26.71	86.29	74.29	30.45	2.00	3.75

25	18 Jun, -24 Jun, 2015	30.86	26.43	80.00	80.29	43.38	4.00	5.50
26	25 Jun, -01 Jul, 2015	34.43	29.43	80.00	74.29	0.00	0.00	0.00
27	02 Jul, -08 Jul, 2015	34.86	28.71	77.00	71.71	1.50	1.00	5.63
28	09 Jul, - 15 Jul, 2015	34.57	28.29	83.71	73.57	10.00	1.00	5.86
29	16 Jul, - 22 Jul, 2015	33.57	26.57	85.14	73.71	18.32	3.00	5.14
30	23 Jul, - 29 Jul, 2015	31.71	27.57	83.57	75.57	8.00	1.00	4.66
31	30 Jul, -05 Aug, 2015	32.43	27.29	85.29	72.86	0.00	3.00	1.00
32	06 Aug, - 12 Aug, 2015	31.71	27.14	86.14	78.86	7.50	4.00	4.51
33	13 Aug, - 19 Aug, 2015	30.71	26.86	85.43	76.29	35.93	3.00	3.11
34	20 Aug, - 26 Aug, 2015	31.71	27.14	85.14	74.86	26.47	3.00	4.57
35	27 Aug, - 02 Sep, 2015	30.29	27.00	83.86	77.14	0.00	4.00	1.00
36	03 Sep, - 09 Sep, 2015	31.00	26.86	86.14	75.14	3.30	1.00	3.60
37	10 Sep, - 16 Sep, 2015	29.86	26.00	84.57	72.57	26.96	4.00	3.57
38	17 Sep, - 23 Sep, 2015	30.86	26.29	88.29	76.86	19.67	3.00	3.06
39	24 Sep, - 30 Sep, 2015	32.71	26.86	89.00	77.71	17.00	1.00	3.57
40	01 Oct, - 07 Oct, 2015	31.43	26.00	91.57	78.14	33.30	4.00	2.90
41	08 Oct, - 14 Oct, 2015	32.29	27.14	89.57	74.86	0.00	0.00	3.94
42	15 Oct, - 21 Oct, 2015	32.14	26.57	87.14	74.43	2.30	1.00	3.51
43	22 Oct, - 28 Oct, 2015	31.14	25.29	87.00	74.43	13.60	1.00	3.49
44	29 Oct, - 04 Nov, 2015	29.71	24.00	88.00	75.86	0.00	0.00	0.00
45	05 Nov, - 11 Nov, 2015	29.86	23.43	85.71	77.86	13.60	1.00	3.20
46	12 Nov, - 18 Nov, 2015	28.00	20.43	84.00	77.57	28.93	3.00	2.69
47	19 Nov, - 25 Nov, 2015	28.43	22.43	84.57	73.43	24.00	1.00	3.09
48	26 Nov, - 02 Dec, 2015	29.00	21.86	87.29	74.57	0.00	1.00	1.00
49	03 Dec, - 09 Dec, 2015	29.29	21.29	85.14	71.43	0.00	0.00	3.29
50	10 Dec, - 16 Dec, 2015	30.00	21.00	89.71	71.86	0.00	0.00	2.97

51	17 Dec, - 23 Dec, 2015	29.29	21.43	90.29	73.29	0.00	0.00	2.63
52	24 Dec, - 31 Dec, 2015	29.14	21.00	85.71	71.71	2.20	0.00	2.34
1	01 Jan - 07 Jan, 2016	29.29	20.71	91.71	72.71	0.00	0.00	2.37
2	08 Jan, -14 Jan, 2016	29.14	20.29	87.86	74.00	0.00	0.00	2.66
3	15 Jan, - 21 Jan, 2016	29.14	20.14	87.14	72.43	0.00	0.00	2.51
4	22 Jan, - 28 Jan, 2016	28.29	20.57	87.86	73.71	0.00	0.00	2.40
5	29 Jan, -04 Feb, 2016	30.07	21.86	90.57	72.57	0.00	0.00	0.00
6	05 Feb, - 11 Feb, 2016	29.71	22.43	86.57	73.43	0.00	0.00	2.89
7	12 Feb, - 18 Feb, 2016	29.86	21.14	89.29	70.43	0.00	0.00	3.46
8	19 Feb, - 25 Feb, 2016	31.14	21.86	90.00	71.71	0.00	0.00	3.63
9	26 Feb, - 03 Mar, 2016	31.14	23.71	87.57	75.00	0.00	0.00	0.00
10	04 Mar, - 10 Mar, 2016	32.00	21.57	88.71	72.57	0.00	0.00	4.00
11	11 Mar, - 17 Mar, 2016	31.64	23.43	89.00	73.57	0.00	0.00	3.66
12	18 Mar, - 24 Mar, 2016	33.07	25.14	87.14	73.57	0.00	0.00	4.09
13	25 Mar, - 31 Mar, 2016	32.00	24.00	88.00	73.86	0.00	0.00	3.89
14	01 Apr, - 07 Apr, 2016	32.57	24.57	89.14	73.29	0.00	0.00	4.54
15	08 Apr, - 14 Apr, 2016	33.57	24.43	88.43	73.29	0.00	0.00	4.83
16	15 Apr, - 21 Apr, 2016	33.86	25.57	87.14	74.14	0.00	0.00	5.46
17	24 Apr, - 28 Apr, 2016	35.00	27.57	87.86	73.86	0.00	0.00	5.43
18	29 Apr, - 05 May, 2016	35.29	27.00	86.43	73.71	0.00	0.00	0.00
19	06 May, - 12 May, 2016	35.71	27.00	80.57	70.71	2.80	1.00	5.83
20	13 May, -19 May, 2016	34.29	27.14	86.00	77.43	75.40	1.00	6.00
21	20 May, - 26 May, 2016	36.00	28.43	82.29	69.14	42.40	1.00	6.00
22	27 May, - 02 Jun, 2016	38.14	27.14	81.86	73.43	0.00	3.00	1.00
23	03 Jun, - 09 Jun, 2016	30.43	26.14	87.71	78.14	13.37	3.00	3.00
24	10 Jun, -16 Jun, 2016	34.29	28.14	80.86	73.00	0.60	0.00	5.29

25	25 Jun, - 23 Jun, 2016	31.86	27.14	84.43	78.29	16.20	4.00	4.34
26	24 Jun, - 30 Jun, 2016	29.43	25.71	87.29	80.71	28.24	4.00	3.30
27	01 Jul, - 07 Jul, 2016	30.86	27.57	77.71	73.14	2.53	2.00	4.14
28	08 Jul, - 14 Jul, 2016	32.00	28.29	79.29	77.14	7.20	1.00	4.40
29	15 Jul, - 21 Jul, 2016	32.07	27.29	82.43	76.43	22.33	3.00	4.89
30	22 Jul, - 28 Jul, 2016	30.43	27.00	85.29	78.71	15.48	4.00	3.94
31	29 Jul, - 04 Aug, 2016	30.00	27.00	82.29	75.00	0.00	1.00	1.00
32	05 Aug, - 11 Aug, 2016	31.29	27.00	82.43	72.57	3.40	1.00	5.80
33	12 Aug, - 18 Aug, 2016	31.86	27.29	79.71	72.00	0.00	0.00	6.34
34	19 Aug, - 25 Aug, 2016	32.57	27.57	86.57	72.14	22.70	2.00	5.80
35	26 Aug, - 01 Sep, 2016	30.43	27.14	85.71	71.14	21.10	3.00	4.31

Appendix B. Measurement of varietal differences for ratooning rate (RR) under field conditions or within cultivars, as suggested by Samson (1980)

S. No.	Varieties	Ratooning vigor rating	Missing hills/plot				Total hills/plot				Total number of tillers/hill				Samson (1980) $RR = (1.0 - 0.1 \text{ ratooning vigor rating}) \times (1.0 - \text{Missing hills/plot} / \text{Total hills/plot}) \times (\text{Total tillers/hill} / 16)$				
			Varieties	R1	R2	R3	Varieties	R1	R2	R3	Varieties	R1	R2	R3	Varieties	R1	R2	R3	Mean
1	MTU 1121	1.00	MTU 1121	23.00	19.13	24.75	MTU 1121	37.00	40.88	35.25	MTU 1121	8.00	9.00	10.00	MTU 1121	0.17	0.27	0.17	0.20
2	MTU 1001	1.00	MTU 1001	15.00	15.75	12.75	MTU 1001	45.00	44.25	47.25	MTU 1001	11.00	13.00	11.00	MTU 1001	0.41	0.47	0.45	0.45
3	MTU 1075	1.00	MTU 1075	26.00	24.00	20.00	MTU 1075	34.00	36.00	40.00	MTU 1075	11.00	10.00	9.00	MTU 1075	0.15	0.19	0.25	0.20
4	MTU 3626	9.00	MTU 3626	37.00	35.00	31.13	MTU 3626	23.00	25.00	28.88	MTU 3626	6.00	4.00	3.00	MTU 3626	-0.02	-0.01	0.00	-0.01
5	MTU 7029	1.00	MTU 7029	24.00	18.00	19.00	MTU 7029	36.00	42.00	41.00	MTU 7029	8.00	9.00	10.00	MTU 7029	0.15	0.29	0.30	0.25
6	MTU 1061	1.00	MTU 1061	19.50	17.00	8.50	MTU 1061	40.50	43.00	51.50	MTU 1061	11.00	8.00	10.00	MTU 1061	0.32	0.27	0.47	0.35
7	MTU 1064	1.00	MTU 1064	17.50	23.25	15.75	MTU 1064	42.50	36.75	44.25	MTU 1064	9.00	12.00	10.00	MTU 1064	0.30	0.25	0.36	0.30
8	MTU 2077	9.00	MTU 2077	34.00	31.00	30.00	MTU 2077	26.00	29.00	30.00	MTU 2077	4.00	5.00	6.00	MTU 2077	-0.01	0.00	0.00	0.00
9	MTU 2716	5.00	MTU 2716	25.50	21.50	24.75	MTU 2716	34.50	38.50	35.25	MTU 2716	6.00	7.00	9.00	MTU 2716	0.05	0.10	0.08	0.08
10	MTU 1140	1.00	MTU 1140	18.00	15.50	11.63	MTU 1140	42.00	44.50	48.38	MTU 1140	10.00	7.00	9.00	MTU 1140	0.32	0.26	0.38	0.32
11	MTU 1112	1.00	MTU 1112	32.63	34.50	27.00	MTU 1112	27.38	25.50	33.00	MTU 1112	10.00	8.00	9.00	MTU 1112	-0.11	-0.16	0.09	-0.06
12	MTU 4870	1.00	MTU 4870	28.88	30.00	24.37	MTU 4870	31.13	30.00	35.63	MTU 4870	8.00	10.00	11.00	MTU 4870	0.03	0.00	0.20	0.08
13	BPT 3291	1.00	BPT 3291	21.00	25.00	14.00	BPT 3291	39.00	35.00	46.00	BPT 3291	9.00	10.00	9.00	BPT 3291	0.23	0.16	0.35	0.25
14	BPT 5204	1.00	BPT 5204	38.63	25.50	25.88	BPT 5204	21.38	34.50	34.13	BPT 5204	9.00	8.00	10.00	BPT 5204	-0.41	0.12	0.14	-0.05
15	PLA 1100	5.00	PLA 1100	25.50	24.50	24.75	PLA 1100	34.50	38.50	35.25	PLA 1100	7.00	8.00	6.00	PLA 1100	0.06	0.09	0.06	0.07
16	MTU 1166	1.00	MTU 1166	27.00	25.00	26.50	MTU 1166	33.00	35.00	33.50	MTU 1166	10.00	9.00	10.00	MTU 1166	0.10	0.14	0.12	0.12
17	MTU 1078	5.00	MTU 1078	22.00	25.50	23.00	MTU 1078	38.00	34.50	37.00	MTU 1078	8.00	8.00	9.00	MTU 1078	0.11	0.07	0.11	0.09
18	MTU 2067	5.00	MTU 2067	33.75	35.50	26.25	MTU 2067	26.25	24.50	33.75	MTU 2067	8.00	9.00	10.00	MTU 2067	-0.07	-0.13	0.07	-0.04
19	MCM 100	1.00	MCM 100	21.50	24.00	15.00	MCM 100	38.50	36.00	45.00	MCM 100	11.00	9.00	8.00	MCM 100	0.27	0.17	0.30	0.25
20	MTU 1071	5.00	MTU 1071	28.88	23.00	25.13	MTU 1071	31.13	37.00	34.88	MTU 1071	9.00	10.00	8.00	MTU 1071	0.02	0.12	0.07	0.07

Appendix C. Measurement of varietal differences for ratooning ability (RA) under field conditions, within cultivars, as suggested by Chauhan *et al.*(1989)

S. No.	Main crop productive tillers					Ratoon productive tillers					Ratoonability - Chauhan <i>et al.</i> (1989) Ratooning ability (RA) = Ratoon crop productive tillers /Main crop productive tillers				
	Varieties	R1	R2	R3	Mean	Varieties	R1	R2	R3	Mean	Varieties	R1	R2	R3	Mean
1	MTU 1121	10.00	9.00	9.00	9.33	MTU 1121	7.00	6.00	8.00	7.00	MTU 1121	0.70	0.67	0.89	0.75
2	MTU 1001	8.00	8.00	8.00	8.00	MTU 1001	8.00	5.00	6.00	6.33	MTU 1001	1.00	0.63	0.75	0.79
3	MTU 1075	9.00	8.00	8.00	8.33	MTU 1075	5.00	6.00	6.00	5.67	MTU 1075	0.56	0.75	0.75	0.69
4	MTU 3626	7.00	7.00	9.00	7.67	MTU 3626	2.00	3.00	2.00	2.33	MTU 3626	0.29	0.43	0.22	0.31
5	MTU 7029	8.00	9.00	8.00	8.33	MTU 7029	6.00	6.00	6.00	6.00	MTU 7029	0.75	0.67	0.75	0.72
6	MTU 1061	10.00	12.00	12.00	11.33	MTU 1061	9.00	8.00	9.00	8.67	MTU 1061	0.90	0.67	0.75	0.77
7	MTU 1064	10.00	9.00	9.00	9.33	MTU 1064	9.00	9.00	7.00	8.33	MTU 1064	0.90	1.00	0.78	0.89
8	MTU 2077	6.00	5.00	6.00	5.67	MTU 2077	3.00	2.00	3.00	2.67	MTU 2077	0.50	0.40	0.50	0.47
9	MTU 2716	9.00	8.00	9.00	8.67	MTU 2716	3.00	3.00	4.00	3.33	MTU 2716	0.33	0.38	0.44	0.38
10	MTU 1140	8.00	9.00	9.00	8.67	MTU 1140	7.00	7.00	8.00	7.33	MTU 1140	0.88	0.78	0.89	0.85
11	MTU 1112	7.00	7.00	6.00	6.67	MTU 1112	4.00	5.00	4.00	4.33	MTU 1112	0.57	0.71	0.67	0.65
12	MTU 4870	7.00	6.00	6.00	6.33	MTU 4870	4.00	4.00	3.00	3.67	MTU 4870	0.57	0.67	0.50	0.58
13	BPT 3291	8.00	6.00	7.00	7.00	BPT 3291	6.00	5.00	6.00	5.67	BPT 3291	0.75	0.83	0.86	0.81
14	BPT 5204	7.00	8.00	8.00	7.67	BPT 5204	4.00	4.00	4.00	4.00	BPT 5204	0.57	0.50	0.50	0.52
15	PLA 1100	8.00	8.00	7.00	7.67	PLA 1100	5.00	4.00	5.00	4.67	PLA 1100	0.63	0.50	0.71	0.61
16	MTU 1166	8.00	6.00	8.00	7.33	MTU 1166	5.00	4.00	4.00	4.33	MTU 1166	0.63	0.67	0.50	0.60
17	MTU 1078	7.00	8.00	7.00	7.33	MTU 1078	3.00	4.00	3.00	3.33	MTU 1078	0.43	0.50	0.43	0.45
18	MTU 2067	6.00	8.00	6.00	6.67	MTU 2067	3.00	4.00	5.00	4.00	MTU 2067	0.50	0.50	0.83	0.61
19	MCM 100	10.00	9.00	10.00	9.67	MCM 100	8.00	7.00	6.00	7.00	MCM 100	0.80	0.78	0.60	0.73
20	MTU 1071	7.00	8.00	8.00	7.67	MTU 1071	5.00	6.00	5.00	5.33	MTU 1071	0.71	0.75	0.63	0.70

Table 4.2. Mean performance of 20 varieties in rice (*Oryza sativa* L.)

S.No	Varieties	DFF	DM	PH	TNTP	EBTP	PL	NGPP	TW	LAI	GYPP	HP
1	MTU 1121	101.67	133.33	108.79	11.67	9.33	25.51	216.67	19.91	3.43	23.76	80.74
2	MTU 1001	101.67	132.00	115.05	11.67	8.00	24.54	172.00	23.01	2.34	22.2	78.86
3	MTU 1075	105.33	136.00	114.02	14.00	8.33	25.95	228.00	22.05	3.46	25.66	80.99
4	MTU 3626	96.33	126.00	94.88	10.00	7.67	26.49	158.00	25.54	2.41	22.49	78.55
5	MTU 7029	114.33	144.33	105.16	11.67	8.33	23.64	180.67	18.42	2.94	22.8	80.04
6	MTU 1061	113.00	144.67	115.14	12.67	11.33	26.01	223.67	19.93	3.27	24.01	81.57
7	MTU 1064	117.33	147.33	114.98	12.00	9.33	27.11	208.33	19.61	3.16	23.75	80.88
8	MTU 2077	115.67	147.00	115.34	8.67	5.67	26.44	172.67	18.63	2.3	18.12	81.33
9	MTU 2716	114.67	145.00	111.2	11.00	8.67	25.27	209.67	19.69	2.55	20.71	79.2
10	MTU 1140	113.33	143.67	115.27	11.33	8.67	25.78	184.67	21.39	3.47	23.66	78.77
11	MTU 1112	120.67	150.67	119.34	13.00	6.67	24.83	236.67	16.8	2.8	19.82	81.54
12	MTU 4870	114.00	145.67	117.21	13.00	6.33	26.04	164.67	20.4	2.82	20.82	77.46
13	BPT 3291	104.67	135.33	98.15	10.00	7.00	21.34	184.67	20.07	2.36	20.35	79.76
14	BPT 5204	112.00	140.67	95.3	12.33	7.67	22.62	238.00	15.49	3.01	20.33	82.10
15	PLA 1100	122.00	152.00	100.62	10.33	7.67	24.29	182.00	18.93	2.76	18.54	81.02
16	MTU 1166	121.33	152.00	115.35	13.00	7.33	26.02	236.00	15.68	3.07	20.88	82.24
17	MTU 1078	116.00	148.00	98.89	11.67	7.33	23.76	204.67	15.07	3.25	19.70	79.70
18	MTU 2067	117.33	147.67	108.73	12.67	6.67	24.08	174.00	18.71	2.55	21.28	79.72
19	MCM 100	103.67	133.00	107.83	12.33	9.67	24.23	169.00	19.24	2.42	19.45	81.20
20	MTU 1071	122.33	152.33	118.37	13.33	7.67	28.14	242.00	16.58	2.54	21.77	80.09
Mean		112.37	142.83	109.48	11.82	7.97	25.1	199.30	19.26	2.84	21.51	80.29
CV		2.18	1.89	3.07	7.75	9.52	3.54	4.95	2.4	1.84	7.74	1.17
SEm		1.41	1.56	1.94	0.53	0.44	0.51	5.69	0.27	0.03	0.96	0.54
CD at 5%		4.04	4.46	5.55	1.51	1.25	1.47	16.3	0.76	0.09	2.75	1.55

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; GY: Grain Yield per plant (g); HP: Hulling percentage.

Table 4.2. (Cont.)

Table 4.2. Mean performance of 20 varieties in rice (*Oryza sativa* L.)

S.No	Varieties	MP	HRR	KL	KB	L/B	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC
1	MTU 1121	72.74	67.41	5.79	1.98	2.92	9.52	2.78	1.73	4.68	185.00	62.89	3.11	24.03
2	MTU 1001	70.32	62.95	5.93	2.23	2.66	10.07	3.01	1.70	4.61	285.00	56.64	6.00	26.86
3	MTU 1075	72.25	63.55	6.11	2.03	3.01	10.31	2.65	1.69	4.34	185.00	63.37	4.50	23.99
4	MTU 3626	72.44	57.78	5.97	2.30	2.6	9.36	3.19	1.57	5.06	185.00	43.4	5.94	21.55
5	MTU 7029	70.74	64.95	5.38	2.07	2.61	8.85	3.47	1.71	4.63	210.67	48.37	3.44	22.98
6	MTU 1061	76.21	70.56	5.80	2.06	2.82	10.21	2.97	1.76	4.2	259.67	67.5	6.67	23.21
7	MTU 1064	73.98	69.85	5.53	2.1	2.63	10.07	2.81	1.82	4.46	176.67	68.08	6.72	24.55
8	MTU 2077	70.51	59.91	5.28	2.08	2.53	7.91	2.74	1.50	4.00	212.67	58.59	2.83	24.79
9	MTU 2716	73.54	65.68	5.6	2.04	2.75	10.16	2.71	1.81	4.52	206.33	57.74	4.06	22.08
10	MTU 1140	74.92	67.32	5.68	2.19	2.6	10.45	2.86	1.72	4.95	186.67	46.51	4.72	24.76
11	MTU 1112	73.37	63.54	4.98	1.69	2.94	9.35	2.39	1.88	4.88	192.67	53.18	3.78	24.71
12	MTU 4870	73.67	66.46	5.67	2.14	2.65	9.72	2.91	1.71	4.42	212.33	40.23	5.3	23.30
13	BPT 3291	72.91	63.25	5.43	1.84	2.96	9.37	2.79	1.73	4.12	175.00	56.44	3.89	24.53
14	BPT 5204	74.67	61.49	4.99	1.64	3.04	9.25	2.37	1.86	4.80	170.00	45.20	4.33	23.80
15	PLA 1100	75.44	68.38	5.53	2.17	2.54	9.19	2.85	1.66	4.24	187.67	55.36	4.44	21.79
16	MTU 1166	76.6	67.27	5.5	1.86	2.95	9.11	2.15	1.66	4.27	188.33	53.64	2.06	24.98
17	MTU 1078	75.43	63.79	6.01	2.11	2.85	8.14	2.81	1.65	3.93	145.00	52.98	2.72	22.67
18	MTU 2067	68.09	59.30	5.58	2.13	2.62	8.38	2.99	1.50	3.70	224.00	62.97	3.61	25.31
19	MCM 100	74.80	71.03	5.61	2.2	2.55	9.19	2.91	1.64	4.92	205.00	59.42	3.50	21.34
20	MTU 1071	73.27	66.56	5.68	2.02	2.82	8.4	2.32	1.72	4.25	208.33	64.26	2.50	24.10
Mean		73.29	65.05	5.60	2.04	2.75	9.35	2.78	1.70	4.45	200.05	55.84	4.21	23.77
CV		2.24	2.07	0.84	1.45	1.38	1.83	7.19	1.84	4.46	3.56	2.58	4.12	3.29
SEm		0.95	0.78	0.03	0.02	0.02	0.1	0.12	0.02	0.11	4.11	0.83	0.1	0.45
CD at 5%		2.71	2.22	0.08	0.05	0.06	0.28	0.33	0.05	0.33	11.76	2.38	0.29	1.29

ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%).

Table 4.3. Estimates of variability, heritability and genetic advance as per cent of mean for grain yield, yield components and quality traits of 20 varieties in rice (*Oryza sativa* L.)

S.No.	Characters	Mean	Range		Coefficient of variation		Heritability (broad sense)	Genetic Advancement	Genetic advance as per cent of mean
			Minimum	Maximum	PCV (%)	GCV (%)			
1	Days to 50% flowering	112.37	96.33	122.33	6.997	6.649	90.30	14.628	13.018
2	Days to maturity	142.83	126.00	152.33	5.596	5.268	88.60	14.590	10.215
3	Plant height (cm)	109.48	94.88	119.34	7.709	7.072	84.20	14.633	13.365
4	Total number of tillers plant ⁻¹	11.82	8.67	14.00	12.822	10.215	63.50	1.981	16.764
5	Number of ear bearing tillers plant ⁻¹	7.97	5.67	11.33	18.198	15.508	72.60	2.169	27.224
6	Panicle length per plant (cm)	25.10	21.34	28.14	6.958	5.991	74.10	2.668	10.626
7	Number of grains per panicle	199.30	158.00	242.00	14.663	13.803	88.60	53.342	26.765
8	Test weight (g)	19.26	15.07	25.54	13.635	13.422	96.90	5.241	27.216
9	LAI at max tillering tillering stage	2.84	2.30	3.47	14.242	14.123	98.30	0.821	28.848
10	Grain yield plant ⁻¹ (g)	21.51	18.12	25.66	11.261	8.181	52.80	2.633	12.245
11	Hulling (%)	80.29	77.46	82.24	1.863	1.453	60.80	1.875	2.335
12	Milling (%)	73.29	68.09	76.60	3.467	2.648	58.30	3.053	4.166
13	Head rice recovery (%)	65.05	57.78	71.03	5.925	5.553	87.80	6.975	10.722
14	Kernel length (mm)	5.60	4.98	6.11	5.421	5.355	97.60	0.611	10.899
15	Kernel breadth (mm)	2.04	1.64	2.30	8.439	8.313	97.00	0.345	16.869
16	Length/Breadth Ratio	2.75	2.53	3.04	6.341	6.188	95.30	0.342	12.442
17	Kernel length after cooking (mm)	9.35	7.91	10.45	8.081	7.87	94.90	1.477	15.79
18	Kernel breadth after cooking (mm)	2.78	2.15	3.47	12.488	10.208	66.80	0.478	17.19
19	Kernel Elongation Ratio	1.70	1.50	1.88	6.167	5.885	91.10	0.197	11.57
20	Volume expansion ratio	4.45	3.70	5.06	9.079	7.906	75.80	0.631	14.183
21	Water uptake (ml)	200.05	145.00	285.00	15.746	15.339	94.90	61.578	30.781
22	Gel consistency (mm)	55.84	40.23	68.08	14.467	14.236	96.80	16.113	28.856
23	Alkali spreading value (mm)	4.21	2.06	6.72	32.342	32.079	98.40	2.757	65.544
24	Amylose content (%)	23.77	21.34	26.86	6.501	5.607	74.40	2.368	9.964

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

Table 4.8. Mean performance of ratoon crop of 20 varieties in rice (*Oryza sativa* L.) for yield, yield components and quality traits

S. No	Varieties	DFF	DM	PH (cm)	TNTP	NRTPM CT	NVBAHMC	TEBTP	NRPTP MCPT	PL (cm)	NGPP	TW (g)	LAI	GYPP (g)
1	MTU 1121	51.67	81.67	104.64	9.00	77.02	11.00	7.00	75.19	24.82	162.20	18.34	1.69	19.51
2	MTU 1001	45.33	71.67	110.87	11.67	100.00	13.00	6.33	79.17	21.64	125.53	21.20	1.70	18.98
3	MTU 1075	55.00	86.67	110.60	10.00	71.33	11.33	5.67	68.52	23.33	166.50	18.92	1.78	22.22
4	MTU 3626	43.67	68.00	90.55	4.33	43.00	7.67	2.33	31.22	18.37	109.50	22.62	1.97	5.68
5	MTU 7029	51.00	81.33	98.65	9.00	77.27	10.00	6.00	72.22	22.91	135.06	18.04	2.34	18.25
6	MTU 1061	55.00	88.00	111.74	9.67	76.71	12.00	8.67	77.22	23.32	153.67	18.61	2.41	21.89
7	MTU 1064	52.33	86.33	110.56	10.33	86.25	12.67	8.20	87.93	23.66	143.50	18.38	2.29	26.07
8	MTU 2077	47.67	75.67	108.06	5.00	57.87	6.67	2.67	46.67	25.05	123.10	16.96	1.83	5.87
9	MTU 2716	45.00	73.00	107.38	7.33	66.21	9.33	3.33	38.42	21.23	129.23	19.41	2.40	9.36
10	MTU 1140	53.33	81.00	111.42	8.67	77.78	10.33	7.33	84.72	22.02	153.63	21.10	2.15	24.01
11	MTU 1112	56.00	91.00	116.06	9.00	69.29	11.00	4.33	65.08	22.24	181.10	15.48	2.48	9.68
12	MTU 4870	48.67	78.33	112.79	9.67	75.03	11.33	3.67	57.94	22.36	144.80	19.52	3.03	12.24
13	BPT 3291	45.33	73.00	93.87	9.33	93.33	11.33	5.67	81.35	21.17	158.49	19.76	1.72	17.63
14	BPT 5204	49.00	79.33	90.36	9.00	72.86	10.00	4.00	52.38	20.25	181.50	15.39	2.11	6.71
15	PLA 1100	50.33	81.33	96.59	7.00	67.88	8.33	4.67	61.31	21.52	152.10	17.46	2.23	14.98
16	MTU 1166	49.00	79.00	111.17	9.67	74.66	11.67	4.33	59.72	22.75	167.12	15.21	1.91	8.30
17	MTU 1078	48.67	77.67	94.32	8.33	72.74	11.00	3.33	45.24	20.92	136.47	14.96	2.31	9.28
18	MTU 2067	46.67	75.00	108.00	9.00	71.31	11.00	4.00	61.11	24.68	99.18	19.56	1.83	7.05
19	MCM 100	51.00	82.00	104.71	9.33	75.43	10.67	7.00	72.59	22.09	167.00	18.96	2.00	18.49
20	MTU 1071	50.00	80.33	115.04	9.00	67.40	9.67	5.33	69.64	24.31	186.60	16.51	2.45	16.46
Overall Mean		49.73	79.52	105.37	8.72	73.67	10.50	5.19	64.38	22.43	148.81	18.32	2.13	14.63
C.V.		2.07	3.45	3.03	13.78	14.75	13.48	14.40	16.11	3.03	6.07	2.65	12.33	8.14
S.Em		0.59	1.58	1.84	0.69	6.27	0.82	0.43	5.99	0.39	5.21	0.28	0.15	0.69
C.D. 5%		1.70	4.53	5.28	1.98	17.96	2.34	1.24	17.14	1.12	14.93	0.80	0.43	1.97

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NRPTPMCPT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant

Table 4.8. (Cont.)

Table 4.8. Mean performance of ratoon crop of 20 varieties in rice (*Oryza sativa* L.) for yield, yield components and quality traits

S. No.	Varieties	HP	MP	HRR%	KL (mm)	KB (mm)	L/B ratio	KLA C (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)
1	MTU 1121	77.85	73.10	70.48	5.42	1.95	2.79	9.36	2.50	1.73	5.20	170.83	55.91	3.06	21.37
2	MTU 1001	77.82	68.48	66.72	5.83	2.32	2.52	10.13	2.80	1.74	4.84	264.17	54.76	5.89	25.26
3	MTU 1075	75.18	69.29	65.02	5.54	1.88	2.96	10.04	2.55	1.82	4.74	222.50	60.00	2.89	24.07
4	MTU 3626	79.04	62.80	54.84	5.55	2.27	2.44	8.80	2.62	1.58	4.54	231.83	39.92	5.89	22.23
5	MTU 7029	78.98	68.29	65.24	5.22	2.16	2.42	9.29	3.34	1.78	4.73	170.83	45.58	3.00	22.76
6	MTU 1061	79.89	71.59	70.82	5.45	1.93	2.83	9.42	2.80	1.73	4.88	215.17	62.78	6.94	21.05
7	MTU 1064	79.39	73.97	69.50	5.33	2.14	2.49	9.15	2.48	1.72	4.89	184.17	62.15	6.83	24.92
8	MTU 2077	77.46	70.51	63.36	4.91	2.07	2.37	7.05	2.88	1.44	4.83	207.50	55.53	3.50	25.04
9	MTU 2716	79.93	73.18	70.36	5.54	1.98	2.81	9.20	2.62	1.66	4.73	160.17	57.14	3.00	21.65
10	MTU 1140	80.48	72.50	69.83	5.39	2.13	2.54	9.57	2.70	1.77	5.34	200.83	45.29	4.67	24.62
11	MTU 1112	78.69	72.20	67.00	4.95	1.82	2.72	9.53	2.46	1.93	4.89	199.17	48.90	4.39	24.91
12	MTU 4870	79.76	71.79	65.57	5.44	2.15	2.53	8.71	2.70	1.60	4.92	233.00	42.13	6.78	23.01
13	BPT 3291	78.62	72.91	69.53	5.32	2.03	2.62	9.21	2.51	1.73	4.56	202.50	52.69	4.00	24.20
14	BPT 5204	79.44	69.90	65.13	4.84	1.78	2.72	8.66	2.25	1.79	4.74	170.83	48.07	3.73	23.58
15	PLA 1100	78.79	73.95	63.71	4.89	2.05	2.39	8.34	2.73	1.71	4.79	170.00	49.10	3.11	20.49
16	MTU 1166	78.63	72.74	65.71	4.82	1.73	2.79	9.32	2.17	1.93	5.02	196.83	55.14	4.22	24.55
17	MTU 1078	76.65	74.42	68.29	4.90	2.06	2.37	8.07	2.38	1.65	4.76	159.67	47.98	2.89	24.27
18	MTU 2067	80.00	66.46	64.89	5.23	2.14	2.44	8.37	2.82	1.60	5.26	140.50	63.83	2.89	25.00
19	MCM 100	76.69	74.80	69.08	5.28	2.16	2.45	9.28	2.92	1.76	4.22	157.50	56.00	3.47	21.06
20	MTU 1071	77.03	71.76	66.70	4.95	1.93	2.56	8.68	2.36	1.76	5.14	220.17	60.88	3.11	24.48
Overall Mean		78.52	71.23	66.59	5.24	2.03	2.59	9.01	2.63	1.72	4.85	193.91	53.19	4.21	23.42
C.V.		1.66	1.54	1.94	3.33	2.90	5.02	1.39	2.24	3.45	6.48	3.41	2.73	3.49	4.37
S.Em		0.75	0.63	0.74	0.10	0.03	0.08	0.07	0.03	0.03	0.18	3.81	0.84	0.08	0.59
C.D. 5%		2.15	1.82	2.13	0.29	0.10	0.21	0.21	0.10	0.10	0.52	10.92	2.40	0.24	1.69

HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLA C: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.14. Mean performance of parents and F₁s in rice (*Oryza sativa* L.)

S.No.	Lines and F ₁ s	DDF	DM	PH	TNTP	TEBTP	PL	NGPP	TW	LAI	GYPP	HP
1	MTU 1001	89.33	119.67	113.05	11.33	9.33	26.51	160.56	23.42	2.43	23.04	78.35
2	BPT 3291	95.33	125.33	106.44	10.67	8.67	24.47	141.23	19.43	2.17	20.21	79.08
3	MCM 100	100.33	129.67	105.02	12.00	10.33	26.63	195.13	18.43	2.49	20.39	80.38
4	MTU 1121	92.00	122.00	106.39	10.33	9.67	26.57	181.76	19.70	3.23	22.27	78.69
5	MTU 1140	105.67	134.67	115.67	12.33	10.33	26.41	225.50	21.03	3.28	22.98	80.14
6	MTU 1064	104.67	132.67	113.06	12.00	10.67	26.64	232.50	19.56	2.35	23.32	79.97
7	MTU 1061	107.00	136.67	114.84	12.33	11.00	26.97	214.77	19.85	3.02	23.02	79.02
8	MTU 7029	105.67	135.00	109.84	13.00	10.67	25.03	171.96	18.20	2.43	23.12	78.79
9	MTU 1001 × BPT 3291	83.67	114.00	109.66	14.67	12.00	29.20	211.09	23.42	3.47	24.79	81.26
10	MTU 1001 × MCM 100	95.67	126.67	117.43	15.67	11.67	29.71	213.49	24.33	2.86	35.20	80.20
11	MTU 1001 × MTU 1121	83.00	113.00	113.11	14.33	12.33	29.01	193.77	23.06	2.47	34.72	79.47
12	MTU 1001 × MTU 1140	90.67	121.00	125.40	17.67	12.67	29.27	214.69	22.46	3.72	36.55	80.67
13	MTU 1001 × MTU 1064	92.67	122.67	116.23	15.33	12.67	28.87	208.05	21.44	2.78	36.14	79.72
14	MTU 1001 × MTU 1061	82.33	111.33	118.46	16.67	13.33	28.58	222.60	21.87	2.50	38.03	79.60
15	MTU 1001 × MTU 7029	96.67	124.33	96.00	14.00	12.00	29.54	191.86	20.52	2.13	25.98	79.11
16	BPT 3291 × MCM 100	68.67	97.67	113.10	16.00	13.00	30.59	225.98	23.19	2.54	26.27	80.45
17	BPT 3291 × MTU 1121	95.67	123.33	108.53	16.00	13.33	29.52	211.90	19.78	2.09	26.92	78.98
18	BPT 3291 × MTU 1140	96.67	125.00	129.83	16.00	13.33	31.11	230.48	23.36	3.52	34.30	81.67
19	BPT 3291 × MTU 1064	86.00	117.00	103.90	16.00	12.67	29.59	216.85	19.85	2.45	29.11	82.24
20	BPT 3291 × MTU 1061	92.67	120.67	112.53	17.33	12.00	29.33	228.24	20.92	2.79	33.59	79.40
21	BPT 3291 × MTU 7029	92.67	120.00	92.90	15.00	10.67	28.97	212.60	19.35	2.17	26.71	79.36
22	MCM 100 × MTU 1121	87.67	118.00	116.98	16.67	12.00	30.36	205.97	21.62	2.36	25.47	78.67
23	MCM 100 × MTU 1140	98.67	128.33	123.12	17.33	13.00	28.28	257.28	21.73	3.62	35.31	79.73
24	MCM 100 × MTU 1064	82.67	111.00	122.29	16.00	12.33	28.94	215.40	20.06	2.56	35.93	81.12
25	MCM 100 × MTU 1061	92.00	122.00	115.11	16.00	10.67	30.65	248.88	19.98	2.45	32.76	79.52
26	MCM 100 × MTU 7029	91.33	118.33	130.18	17.33	14.00	29.61	225.94	21.37	2.11	29.29	80.68
27	MTU 1121 × MTU 1140	91.33	120.67	123.36	14.67	12.00	29.14	227.67	21.96	3.07	36.18	80.67
28	MTU 1121 × MTU 1064	96.67	128.00	107.31	14.33	12.33	29.06	186.82	22.64	2.57	24.40	78.97
29	MTU 1121 × MTU 1061	90.67	120.33	113.61	16.00	12.33	29.47	185.59	22.14	2.63	25.78	80.22
30	MTU 1121 × MTU 7029	98.33	127.33	112.09	14.67	13.00	28.65	190.59	20.00	2.16	23.75	80.98
31	MTU 1140 × MTU 1064	96.00	126.33	123.02	15.67	13.67	31.20	270.89	22.85	3.17	26.55	79.19
32	MTU 1140 × MTU 1061	99.33	128.33	129.10	15.67	12.67	29.58	249.50	23.33	3.04	27.85	79.65
33	MTU 1140 × MTU 7029	102.00	129.00	121.27	16.00	12.00	27.97	214.84	20.14	3.12	32.34	79.54
34	MTU 1064 × MTU 1061	100.33	129.33	121.44	17.33	12.00	29.09	236.17	19.88	2.49	35.68	80.15
35	MTU 1064 × MTU 7029	108.00	138.00	116.70	14.67	11.33	29.66	205.34	19.76	2.34	28.24	81.14
36	MTU 1061 × MTU 7029	104.67	135.67	119.28	14.33	11.00	30.20	270.11	20.71	2.49	28.91	77.82
	Overall Mean	94.35	123.69	114.90	14.87	11.85	28.73	213.78	21.15	2.70	79.85	72.65
	C.V.	2.04	1.84	1.77	6.49	8.64	4.41	5.28	2.05	4.68	1.43	1.66
	S.Em	1.11	1.32	1.17	0.56	0.59	0.73	6.51	0.25	0.07	0.66	0.70
	C.D. 5%	3.14	3.71	3.31	1.57	1.67	2.06	18.37	0.71	0.21	1.86	1.96

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant; NGPP: Number of Grains per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage.

Table 4.14. Mean performance of lines and F₁s in rice (*Oryza sativa* L.)

S.No.	Lines and F ₁ s	MP	HRR	KL	KB	L/B	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC
1	MTU 1001	67.87	63.91	5.93	2.31	2.57	10.05	2.81	1.69	4.91	256.67	52.27	5.50	25.45
2	BPT 3291	69.50	64.12	5.43	2.03	2.67	9.28	2.59	1.71	5.15	165.00	53.34	3.67	24.53
3	MCM 100	71.56	66.55	5.56	2.22	2.50	9.06	2.71	1.63	5.11	150.00	57.95	3.39	20.23
4	MTU 1121	69.50	64.52	5.78	2.09	2.76	9.40	2.58	1.63	4.80	171.67	57.27	2.94	22.21
5	MTU 1140	70.52	66.00	5.69	2.24	2.54	10.03	2.66	1.76	4.67	225.00	49.04	4.06	25.08
6	MTU 1064	72.36	65.80	5.66	2.11	2.69	9.98	2.61	1.76	4.47	156.67	62.88	6.11	24.22
7	MTU 1061	71.55	66.98	5.78	2.04	2.83	10.09	2.77	1.75	4.66	208.33	62.86	6.17	21.05
8	MTU 7029	67.20	62.67	5.31	2.13	2.49	8.73	3.07	1.64	3.92	185.00	46.12	3.11	22.48
9	MTU 1001 × BPT 3291	74.19	69.82	5.85	2.31	2.54	9.56	2.83	1.64	4.41	151.67	45.97	5.17	21.68
10	MTU 1001 × MCM 100	73.98	69.18	5.53	2.18	2.53	9.55	2.80	1.73	4.24	153.33	69.23	5.17	22.78
11	MTU 1001 × MTU 1121	73.13	70.23	5.65	2.23	2.54	10.00	2.72	1.77	4.05	165.00	86.70	4.28	23.89
12	MTU 1001 × MTU 1140	77.92	74.98	5.61	2.32	2.42	9.78	2.99	1.74	4.21	190.00	94.08	5.06	26.51
13	MTU 1001 × MTU 1064	73.99	67.73	5.60	1.93	2.90	9.77	2.56	1.75	4.44	255.00	76.36	4.94	22.70
14	MTU 1001 × MTU 1061	74.89	66.04	5.84	2.36	2.47	9.85	2.84	1.69	5.80	211.67	87.36	5.72	21.56
15	MTU 1001 × MTU 7029	72.83	65.42	5.84	2.46	2.37	9.81	3.08	1.68	5.82	170.00	50.75	4.28	20.86
16	BPT 3291 × MCM 100	74.10	70.46	5.57	2.27	2.46	9.38	3.10	1.68	4.62	121.67	91.37	2.56	28.73
17	BPT 3291 × MTU 1121	71.45	64.96	5.77	2.34	2.47	9.97	3.09	1.73	4.09	185.00	44.47	3.33	23.50
18	BPT 3291 × MTU 1140	76.51	70.54	6.06	2.25	2.69	9.55	3.20	1.58	3.79	166.67	94.10	2.78	23.61
19	BPT 3291 × MTU 1064	76.24	68.97	5.71	2.34	2.44	9.88	3.06	1.73	4.74	165.00	78.37	5.17	19.84
20	BPT 3291 × MTU 1061	70.69	63.60	5.51	2.16	2.55	9.05	3.23	1.64	4.71	185.00	43.04	4.67	31.04
21	BPT 3291 × MTU 7029	74.05	64.63	5.64	2.23	2.53	9.56	3.11	1.70	4.78	185.00	97.96	5.89	22.64
22	MCM 100 × MTU 1121	70.88	64.13	5.74	2.23	2.58	9.15	2.99	1.59	4.78	190.00	70.41	2.50	30.80
23	MCM 100 × MTU 1140	73.79	70.69	5.36	2.15	2.49	9.06	3.25	1.69	4.53	193.33	56.57	2.61	20.16
24	MCM 100 × MTU 1064	72.51	68.60	5.76	2.26	2.55	9.50	3.05	1.65	5.44	193.33	42.03	5.22	22.40
25	MCM 100 × MTU 1061	73.58	67.61	5.65	2.26	2.50	9.87	3.22	1.75	4.76	163.33	97.92	3.44	18.86
26	MCM 100 × MTU 7029	73.87	69.45	5.88	2.38	2.47	9.08	2.86	1.55	5.05	190.00	92.18	2.61	21.75
27	MTU 1121 × MTU 1140	73.39	71.51	5.49	2.15	2.55	9.54	2.79	1.74	4.40	163.33	87.11	3.56	21.94
28	MTU 1121 × MTU 1064	70.14	65.07	5.57	2.25	2.48	9.43	2.77	1.69	5.41	190.00	45.14	5.28	25.39
29	MTU 1121 × MTU 1061	73.00	67.33	5.61	2.27	2.47	9.09	2.56	1.62	4.70	200.00	55.87	4.78	22.67
30	MTU 1121 × MTU 7029	72.97	63.22	5.71	2.25	2.54	9.34	3.03	1.63	5.48	181.67	88.72	5.00	32.53
31	MTU 1140 × MTU 1064	71.96	68.54	5.73	2.27	2.53	9.62	2.76	1.68	4.91	163.33	55.14	2.56	21.17
32	MTU 1140 × MTU 1061	75.37	70.60	5.60	2.30	2.43	9.43	2.56	1.69	4.69	171.67	98.27	4.56	25.36
33	MTU 1140 × MTU 7029	70.44	67.38	5.67	2.27	2.50	9.17	2.75	1.62	4.06	163.33	87.85	4.44	23.26
34	MTU 1064 × MTU 1061	73.56	65.11	5.75	2.25	2.55	9.87	2.73	1.72	4.81	223.33	41.66	2.61	20.99
35	MTU 1064 × MTU 7029	74.62	65.32	5.55	2.22	2.51	9.47	3.10	1.71	4.79	205.00	48.03	5.67	29.36
36	MTU 1061 × MTU 7029	71.28	63.48	5.73	2.30	2.50	9.11	3.08	1.59	5.10	183.33	68.56	5.94	21.95
	Overall Mean	67.09	5.67	2.23	2.54	9.53	2.89	1.68	4.73	183.29	67.69	4.30	23.70	28.75
	C.V.	2.01	1.46	1.59	1.69	1.74	3.80	2.27	3.27	3.78	4.18	4.11	2.92	5.55
	S.Em	0.78	0.05	0.02	0.02	0.10	0.06	0.02	0.09	4.00	1.63	0.10	0.40	0.92
	C.D. 5%	2.20	0.13	0.06	0.07	0.27	0.18	0.06	0.25	11.29	4.60	0.29	1.13	2.60

HP%: Hulling percentage; MP%: Milling percentage; HRR%: Head Rice Recovery; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking; KBAC: Kernel Breadth After Cooking; KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake; GC: Gel Consistency; ASV: Alkali Spreading Value; AC: Amylose Content.

Table 4.15. Estimates of variability, heritability and genetic advance as per cent of mean for grain yield and yield components of F₁s in rice (*Oryza sativa* L.)

S.No.	Characters	Mean	Range		Coefficient of variation		Heritability (broad sense)	Genetic Advancement	Genetic advance as per cent of mean
			Min.	Max.	PCV (%)	GCV (%)			
1	Days to 50% flowering	94.35	68.67	107.00	8.96	8.73	94.80	16.51	17.50
2	Days to maturity	123.69	97.67	138.00	6.88	6.63	92.80	16.28	13.16
3	Plant height (cm)	114.90	92.90	130.18	7.56	7.35	94.50	16.91	14.72
4	Total number of tillers plant ⁻¹	14.87	10.33	17.67	14.29	12.73	79.40	3.47	23.36
5	Number of ear bearing tillers plant ⁻¹	11.85	8.67	14.00	12.75	9.38	54.10	1.68	14.21
6	Panicle length per plant (cm)	28.73	24.47	31.20	6.66	4.99	56.10	2.21	7.69
7	Number of grains per panicle	213.78	141.23	270.89	13.74	12.69	85.20	51.59	24.13
8	Test weight (g)	21.15	18.20	24.33	7.72	7.44	92.90	3.13	14.77
9	LAI at max tillering stage	2.70	2.09	3.72	17.49	16.85	92.80	0.90	33.45
10	Grain yield plant ⁻¹ (g)	28.75	20.21	38.03	19.24	18.42	91.70	10.45	36.33
11	Hulling (%)	79.85	77.82	82.24	1.69	0.91	28.90	0.81	1.01
12	Milling (%)	72.65	67.20	77.92	3.47	3.05	77.20	4.01	5.52
13	Head rice recovery (%)	67.09	62.67	74.98	4.59	4.12	80.70	5.12	7.63
14	Kernel length (mm)	5.67	5.31	6.06	2.99	2.61	76.20	0.27	4.69
15	Kernel breadth (mm)	2.23	1.93	2.46	4.89	4.62	89.40	0.20	9.01
16	Length/Breadth Ratio	2.54	2.37	2.90	4.62	4.30	86.60	0.21	8.24
17	Kernel length after cooking (mm)	9.53	8.73	10.09	4.00	3.60	81.10	0.64	6.68
18	Kernel breadth after cooking (mm)	2.89	2.56	3.25	8.14	7.20	78.20	0.38	13.12
19	Kernel Elongation Ratio	1.68	1.55	1.77	3.92	3.19	66.40	0.09	5.35
20	Volume expansion ratio	4.73	3.79	5.82	10.63	10.12	90.60	0.94	19.83
21	Water uptake (ml)	183.29	121.67	256.67	15.54	15.08	94.10	55.21	30.12
22	Gel consistency (mm)	67.69	41.66	98.27	29.28	28.98	98.00	39.99	59.08
23	Alkali spreading value (mm)	4.30	2.50	6.17	28.08	27.77	97.90	2.43	56.60
24	Amylose content (%)	23.70	18.86	32.53	14.09	13.78	95.70	6.58	27.78

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

Table 4.21. Relative heterosis, heterobeltiosis and standard heterosis for yield and yield contributing characters of F₁s in rice (*Oryza sativa* L.)

Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		Total number of tillers per plant	
	Relative heterosis	Hetero-beltiosis	Relative heterosis	Hetero-beltiosis	Relative heterosis	Hetero-beltiosis	Relative heterosis	Hetero-beltiosis
MTU 1001 × BPT 3291	-9.22 **	-12.24 **	-7.07 **	-9.04 **	-0.06	-2.96 *	35.38 **	33.33 **
MTU 1001 × MCM 100	1.06	-4.65 **	1.47	-2.31	7.73 **	3.92 **	36.23 **	30.56 **
MTU 1001 × MTU 1121	-8.29 **	-9.78 **	-6.61 **	-7.38 **	3.11 *	0.1	34.38 **	30.30 **
MTU 1001 × MTU 1140	-6.85 **	-14.20 **	-4.97 **	-10.15 **	9.68 **	8.41 **	51.43 **	43.24 **
MTU 1001 × MTU 1064	-4.30 **	-11.46 **	-2.90 *	-7.54 **	2.83 *	2.81	33.33 **	27.78 **
MTU 1001 × MTU 1061	-15.99 **	-23.05 **	-13.25 **	-18.54 **	3.99 **	3.16 *	42.86 **	35.14 **
MTU 1001 × MTU 7029	-0.68	-8.52 **	-2.48	-7.90 **	-13.84 **	-15.04 **	16.67 **	7.69
BPT 3291 × MCM 100	-29.69 **	-31.56 **	-23.30 **	-24.68 **	7.20 **	6.70 **	39.13 **	33.33 **
BPT 3291 × MTU 1121	2.32	0.7	-0.13	-1.33	2.2	2.01	50.00 **	45.45 **
BPT 3291 × MTU 1140	-3.65 **	-8.52 **	-3.72 **	-7.18 **	17.14 **	12.24 **	37.14 **	29.73 **
BPT 3291 × MTU 1064	-13.86 **	-17.83 **	-9.19 **	-11.81 **	-5.14 **	-8.10 **	39.13 **	33.33 **
BPT 3291 × MTU 1061	-8.25 **	-13.40 **	-7.77 **	-11.71 **	1.91	-2.01	48.57 **	40.54 **
BPT 3291 × MTU 7029	-7.64 **	-12.30 **	-7.69 **	-11.11 **	-13.92 **	-15.43 **	25.00 **	15.38 *
MCM 100 × MTU 1121	-8.68 **	-12.33 **	-6.35 **	-9.23 **	10.68 **	9.96 **	49.25 **	38.89 **
MCM 100 × MTU 1140	-4.05 **	-6.62 **	-3.02 *	-4.70 **	11.59 **	6.44 **	42.47 **	40.54 **
MCM 100 × MTU 1064	-19.22 **	-21.02 **	-15.48 **	-16.33 **	12.17 **	8.17 **	33.33 **	33.33 **
MCM 100 × MTU 1061	-11.11 **	-14.02 **	-8.50 **	-10.73 **	4.72 **	0.24	31.51 **	29.73 **
MCM 100 × MTU 7029	-11.18 **	-13.56 **	-10.69 **	-12.35 **	21.19 **	18.52 **	38.67 **	33.33 **
MTU 1121 × MTU 1140	-7.59 **	-13.56 **	-5.97 **	-10.40 **	11.30 **	6.65 **	31.34 **	18.92 **
MTU 1121 × MTU 1064	-1.69	-7.64 **	0.52	-3.52 *	-2.03	-5.09 **	30.30 **	19.44 **
MTU 1121 × MTU 1061	-8.88 **	-15.26 **	-6.96 **	-11.95 **	2.89 *	-1.07	43.28 **	29.73 **
MTU 1121 × MTU 7029	-0.51	-6.94 **	-0.91	-5.68 **	3.86 **	2.05	27.54 **	12.82 *
MTU 1140 × MTU 1064	-8.86 **	-9.43 **	-5.60 **	-6.42 **	7.42 **	6.05 **	30.56 **	30.56 **
MTU 1140 × MTU 1061	-6.73 **	-7.17 **	-5.52 **	-6.10 **	11.86 **	11.30 **	28.77 **	27.03 **
MTU 1140 × MTU 7029	-3.62 **	-3.77 *	-4.44 **	-4.44 **	7.40 **	4.55 **	28.00 **	23.08 **
MTU 1064 × MTU 1061	-5.35 **	-6.23 **	-4.08 **	-5.37 **	6.60 **	5.75 **	42.47 **	40.54 **
MTU 1064 × MTU 7029	2.53	2.21	2.99 *	2.22	4.74 **	3.27 *	17.33 **	12.82 *
MTU 1061 × MTU 7029	-1.57	-2.18	-0.25	-0.97	6.11 **	3.72 *	14.67 **	10.26
Mean	-7.20	-10.87	-5.78	-8.45	5.12	2.73	34.96	28.82
Range	-29.69 to 2.53	-31.56 to 2.21	-23.30 to 2.99	-24.68 to 2.22	-13.92 to 21.19	-15.43 to 18.52	14.67 to 51.43	7.69 to 45.45

Table 4.21. (Cont)

Crosses	No. of ear bearing tillers per plant		Panicle length per plant (cm)		Number of grains per panicle		Test weight (g)	
	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
MTU 1001 × BPT 3291	35.85 **	33.33 **	13.48 **	8.16 *	39.69 **	31.11 **	10.40 **	1.84
MTU 1001 × MCM 100	20.69 **	12.90	10.80 **	10.04 *	19.90 **	9.41	17.43 **	5.77 **
MTU 1001 × MTU 1121	32.14 **	27.59 **	8.31 *	7.44	13.06 **	6.61	8.02 **	0.28
MTU 1001 × MTU 1140	31.03 **	22.58 **	9.60 **	8.41 *	11.10 **	-4.79	2.02	-2.35
MTU 1001 × MTU 1064	28.81 **	18.75 *	7.64 *	6.93	5.75	-10.51 **	0.77	-6.77 **
MTU 1001 × MTU 1061	33.33 **	21.21 **	5.92	5.86	18.47 **	3.64	2.08	-4.90 **
MTU 1001 × MTU 7029	22.03 **	12.50	13.53 **	9.40 *	15.24 **	11.57 *	-0.36	-10.77 **
BPT 3291 × MCM 100	34.48 **	25.81 **	20.85 **	14.88 **	34.46 **	15.81 **	23.90 **	22.05 **
BPT 3291 × MTU 1121	42.86 **	37.93 **	16.74 **	11.10 **	31.30 **	16.58 **	2.20	0.39
BPT 3291 × MTU 1140	37.93 **	29.03 **	23.42 **	17.78 **	25.77 **	2.21	16.70 **	11.06 **
BPT 3291 × MTU 1064	28.81 **	18.75 *	16.86 **	11.07 **	16.12 **	-6.73	2.96	1.48
BPT 3291 × MTU 1061	20.00 **	9.09	15.08 **	8.74 *	28.30 **	6.27	7.67 **	5.36 **
BPT 3291 × MTU 7029	8.47	0.00	18.16 **	15.73 **	35.87 **	23.64 **	4.04 *	1.84
MCM 100 × MTU 1121	22.03 **	20.00 *	13.37 **	12.46 **	9.34 *	5.63	14.71 **	9.76 **
MCM 100 × MTU 1140	27.87 **	25.81 **	5.88	4.73	22.37 **	14.09 **	11.37 **	3.34
MCM 100 × MTU 1064	19.35 **	15.62 *	7.92 *	7.20	0.77	-7.35	6.83 **	2.57
MCM 100 × MTU 1061	1.59	-3.03	13.57 **	13.52 **	21.47 **	15.88 **	5.58 **	0.65
MCM 100 × MTU 7029	35.48 **	31.25 **	13.81 **	9.67 *	23.14 **	15.86 **	18.08 **	17.44 **
MTU 1121 × MTU 1140	18.03 *	16.13 *	9.10 **	7.91 *	11.74 **	0.96	7.04 **	4.42 *
MTU 1121 × MTU 1064	19.35 **	15.62 *	8.36 *	7.64 *	-9.86 *	-19.65 **	14.48 **	13.22 **
MTU 1121 × MTU 1061	17.46 *	12.12	9.20 **	9.15 *	-6.45	-13.59 **	11.12 **	10.72 **
MTU 1121 × MTU 7029	25.81 **	21.88 **	10.12 **	6.11	7.69	4.72	4.70 **	-0.02
MTU 1140 × MTU 1064	32.26 **	28.13 **	18.53 **	17.10 **	18.17 **	16.51 **	12.66 **	8.79 **
MTU 1140 × MTU 1061	20.63 **	15.15 *	11.67 **	9.65 *	13.21 **	10.40 *	14.23 **	11.11 **
MTU 1140 × MTU 7029	16.13 *	12.50	9.61 **	7.58	7.97	-4.94	2.78	-4.08 *
MTU 1064 × MTU 1061	9.09	9.09	7.79 *	7.74 *	5.72	1.80	-0.23	-0.60
MTU 1064 × MTU 7029	4.62	3.03	13.99 **	9.84 *	1.67	-11.49 **	3.45 *	-1.22
MTU 1061 × MTU 7029	1.54	0.00	16.07 **	11.84 **	39.61 **	25.63 **	8.44 **	3.55 *
Mean	23.13	17.60	12.48	9.92	16.49	5.69	8.32	3.75
Range	1.54 to 42.86	-3.03 to 37.93	5.88 to 23.42	4.73 to 17.78	-9.86 to 39.69	-19.65 to 31.11	-0.36 to 23.90	-10.77 to 22.05

Table 4.21. (Cont)

Crosses	LAI at max tillering stage		Hulling (%)		Milling (%)		Head rice recovery (%)	
	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
MTU 1001 × BPT 3291	66.72 **	60.31 **	3.47 **	2.76 *	7.92 **	6.75 **	8.99 **	8.88 **
MTU 1001 × MCM 100	27.15 **	14.57 **	1.28	-0.22	6.02 **	3.38 *	5.99 **	3.96 *
MTU 1001 × MTU 1121	-5.61	-23.55 **	1.44	0.99	6.37 **	5.22 **	9.29 **	8.84 **
MTU 1001 × MTU 1140	40.95 **	13.40 **	2.02	0.66	12.51 **	10.50 **	15.35 **	13.60 **
MTU 1001 × MTU 1064	28.07 **	18.61 **	0.93	-0.32	5.43 **	2.26	4.36 **	2.93
MTU 1001 × MTU 1061	-0.60	-17.42 **	1.39	0.74	7.33 **	4.66 **	0.84	-1.40
MTU 1001 × MTU 7029	-3.91	-12.47 **	0.91	0.40	7.74 **	7.10 **	3.30 *	2.22
BPT 3291 × MCM 100	13.20 **	2.01	0.95	0.08	4.69 **	3.54 *	7.95 **	5.89 **
BPT 3291 × MTU 1121	-20.03 **	-35.23 **	0.16	-0.03	2.43	2.07	1.09	0.68
BPT 3291 × MTU 1140	33.38 **	7.31 *	2.64 *	1.91	8.89 **	8.49 **	8.53 **	6.88 **
BPT 3291 × MTU 1064	12.88 **	4.55	3.46 **	2.83 *	7.11 **	5.37 **	6.27 **	4.82 **
BPT 3291 × MTU 1061	11.21 **	-7.61 *	0.50	0.49	-0.12	-1.21	-2.89	-5.05 **
BPT 3291 × MTU 7029	-2.26	-10.96 *	0.59	0.45	7.94 **	5.78 **	2.05	0.99
MCM 100 × MTU 1121	-9.57 **	-26.76 **	-0.85	-1.66	0.18	-1.56	-2.49	-4.29 *
MCM 100 × MTU 1140	37.16 **	10.36 **	-0.42	-0.51	3.55 **	2.49	6.30 **	5.50 **
MCM 100 × MTU 1064	17.64 **	8.95 *	1.42	1.40	0.45	0.20	3.32 *	2.39
MCM 100 × MTU 1061	-2.46	-18.96 **	0.02	-0.60	2.52 *	2.20	0.93	0.91
MCM 100 × MTU 7029	-4.66	-13.15 **	1.61	0.85	6.14 **	2.60	7.13 **	3.66 *
MTU 1121 × MTU 1140	-2.18	-6.40 *	1.39	0.67	4.46 **	4.07 **	9.17 **	8.34 **
MTU 1121 × MTU 1064	-3.87	-14.33 **	-0.65	-1.25	-1.46	-3.06 *	-0.50	-1.11
MTU 1121 × MTU 1061	-12.78 **	-13.12 **	1.54	1.53	3.15 *	2.03	2.03	0.53
MTU 1121 × MTU 7029	-20.49 **	-28.00 **	2.65 *	2.51 *	6.37 **	4.24 **	-0.96	-2.73
MTU 1140 × MTU 1064	18.45 **	5.56	-0.99	-1.01	0.39	-0.56	4.01 **	3.85 *
MTU 1140 × MTU 1061	0.94	0.55	0.18	-0.43	5.75 **	5.34 **	6.18 **	5.40 **
MTU 1140 × MTU 7029	14.85 **	4.00	0.19	-0.57	1.93	-0.79	4.73 **	2.09
MTU 1064 × MTU 1061	-0.86	-17.64 **	0.81	0.19	2.48 *	2.17	-2.07	-2.79
MTU 1064 × MTU 7029	5.71	-3.70	2.20 *	1.43	7.22 **	3.64 **	1.53	-1.04
MTU 1061 × MTU 7029	-8.47 *	-17.11 **	-1.36	-1.49	2.42	-1.00	-2.09	-5.26 **
Mean	8.23	-4.15	0.98	0.74	4.64	3.07	3.87	2.45
Range	-20.49 to 66.72	-35.23 to 60.31	-1.36 to 3.47	-1.66 to 2.83	-1.46 to 12.51	-3.06 to 10.50	-2.89 to 15.35	-5.26 to 13.60

Table 4.21. (Cont)

Crosses	Kernel length (mm)		Kernel breadth (mm)		Length/Breadth Ratio		Kernel length after cooking (mm)	
	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
MTU 1001 × BPT 3291	2.30 *	-2.56 *	14.38 **	13.44 **	-10.52 **	-15.44 **	-0.85	-4.43 **
MTU 1001 × MCM 100	-4.30 **	-7.83 **	3.39 **	-1.80	-7.88 **	-15.56 **	0.24	-4.47 **
MTU 1001 × MTU 1121	-4.02 **	-5.78 **	8.96 **	6.53 **	-11.92 **	-15.44 **	3.11 *	0.00
MTU 1001 × MTU 1140	-4.05 **	-6.56 **	9.52 **	3.73 **	-12.81 **	-19.44 **	-2.36 *	-2.49
MTU 1001 × MTU 1064	-4.03 **	-6.72 **	-6.01 **	-8.39 **	2.05	-3.22 **	-2.24	-2.33
MTU 1001 × MTU 1061	-0.88	-2.72 *	16.83 **	15.69 **	-15.31 **	-17.67 **	-1.96	-2.41
MTU 1001 × MTU 7029	3.36 **	-2.61 *	19.29 **	15.65 **	-13.66 **	-21.00 **	4.77 **	-1.90
BPT 3291 × MCM 100	5.59 **	0.30	7.34 **	1.95	-10.55 **	-18.00 **	3.91 **	3.57 *
BPT 3291 × MTU 1121	7.11 **	-0.12	14.33 **	11.78 **	-14.35 **	-17.78 **	8.35 **	6.07 **
BPT 3291 × MTU 1140	13.35 **	6.51 **	6.22 **	0.60	-2.95 **	-10.33 **	0.35	-4.79 **
BPT 3291 × MTU 1064	7.03 **	0.77	14.12 **	11.23 **	-14.35 **	-18.78 **	4.11 **	-1.00
BPT 3291 × MTU 1061	2.26 *	-4.62 **	7.10 **	6.05 **	-12.69 **	-15.11 **	-5.24 **	-10.37 **
BPT 3291 × MTU 7029	9.44 **	6.28 **	7.83 **	4.54 **	-7.71 **	-15.56 **	7.90 **	6.26 **
MCM 100 × MTU 1121	-2.55 *	-4.33 **	8.79 **	6.37 **	8.26 **	-6.64 **	-0.49	-2.59
MCM 100 × MTU 1140	-8.27 **	-10.67 **	1.65	-3.73 **	9.61 **	-2.10	-4.77 **	-9.64 **
MCM 100 × MTU 1064	-1.29	-4.06 **	9.90 **	7.12 **	8.74 **	-5.20 **	0.07	-4.84 **
MCM 100 × MTU 1061	-4.05 **	-5.83 **	11.88 **	10.78 **	3.31 *	-11.88 **	3.39 **	-2.21
MCM 100 × MTU 7029	4.01 **	-2.00	15.42 **	11.89 **	10.02 **	-0.80	2.48	0.93
MTU 1121 × MTU 1140	-6.10 **	-8.56 **	1.34	-4.02 **	-7.88 **	-14.89 **	0.25	-4.89 **
MTU 1121 × MTU 1064	-4.54 **	-7.22 **	9.58 **	6.80 **	-12.95 **	-17.44 **	-0.63	-5.51 **
MTU 1121 × MTU 1061	-4.73 **	-6.50 **	12.21 **	11.11 **	-15.20 **	-17.56 **	-4.82 **	-9.97 **
MTU 1121 × MTU 7029	1.06	-4.78 **	8.80 **	5.48 **	-7.47 **	-15.33 **	5.38 **	3.78 *
MTU 1140 × MTU 1064	-1.74	-4.50 **	10.55 **	7.75 **	-11.19 **	-15.78 **	-3.74 **	-3.83 **
MTU 1140 × MTU 1061	-4.90 **	-6.67 **	14.03 **	12.91 **	-16.57 **	-18.89 **	-6.14 **	-6.57 **
MTU 1140 × MTU 7029	0.29	-5.50 **	9.93 **	6.57 **	-9.05 **	-16.78 **	-2.10	-8.33 **
MTU 1064 × MTU 1061	-2.35 *	-4.17 **	11.55 **	10.46 **	-12.46 **	-14.89 **	-1.76	-2.21
MTU 1064 × MTU 7029	-1.77	-7.44 **	7.34 **	4.07 **	-8.68 **	-16.44 **	1.10	-5.33 **
MTU 1061 × MTU 7029	1.30	-4.56 **	11.22 **	7.82 **	-9.05 **	-16.78 **	-2.74 *	-8.93 **
Mean	-0.09	-4.02	9.55	6.51	-7.26	-14.16	0.20	-3.16
Range	-8.27 to 13.55	-10.67 to 6.51	-6.01 to 19.29	-8.39 to 15.69	-16.57 to 10.02	-21.00 to -0.80	-6.14 to 8.35	-10.37 to 6.26

Table 4.21. (Cont)

Crosses	Kernel breadth after cooking (mm)		Kernel Elongation Ratio		Volume expansion ratio		Water uptake (ml)	
	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
MTU 1001 × BPT 3291	1.31	-5.56	-11.77 **	-18.17 **	-13.20 **	-14.49 **	-28.12 **	-40.99 **
MTU 1001 × MCM 100	-1.87	-6.67 *	-4.87 **	-13.67 **	-16.15 **	-17.08 **	-24.65 **	-40.34 **
MTU 1001 × MTU 1121	-2.63	-9.44 **	-2.57	-11.67 **	-17.32 **	-19.00 **	-23.02 **	-35.80 **
MTU 1001 × MTU 1140	5.65 *	-0.33	-7.27 **	-12.83 **	-12.89 **	-15.73 **	-21.16 **	-26.07 **
MTU 1001 × MTU 1064	-8.91 **	-14.78 **	-7.17 **	-12.67 **	-6.16 **	-11.13 **	23.29 **	-0.78
MTU 1001 × MTU 1061	-1.50	-5.33	-9.96 **	-15.67 **	20.06 **	15.93 **	-9.03 **	-17.64 **
MTU 1001 × MTU 7029	1.48	0.33	-7.78 **	-16.00 **	30.44 **	16.40 **	-23.08 **	-33.85 **
BPT 3291 × MCM 100	8.53 **	3.22	-7.25 **	-15.83 **	-8.70 **	-9.71 **	-22.75 **	-26.26 **
BPT 3291 × MTU 1121	10.63 **	2.89	-4.78 **	-13.67 **	-16.43 **	-18.13 **	9.90 **	7.77 *
BPT 3291 × MTU 1140	13.19 **	6.78 *	-16.13 **	-21.17 **	-21.64 **	-24.20 **	-14.53 **	-25.93 **
BPT 3291 × MTU 1064	9.14 **	2.11	-7.88 **	-13.33 **	0.04	-5.27 *	2.59	0.00
BPT 3291 × MTU 1061	12.02 **	7.67 *	-12.28 **	-17.83 **	-2.52	-5.87 *	-0.89	-11.20 **
BPT 3291 × MTU 7029	2.58	1.41	-6.86 **	-15.17 **	7.21 **	-4.33	5.71 *	0.00
MCM 100 × MTU 1121	7.29 *	-0.22	-12.13 **	-20.33 **	-2.35	-4.33	18.13 **	10.68 **
MCM 100 × MTU 1140	14.72 **	8.22 **	-9.93 **	-15.33 **	-6.41 **	-9.47 **	3.11	-14.07 **
MCM 100 × MTU 1064	8.55 **	1.56	-12.31 **	-17.50 **	14.89 **	8.80 **	26.09 **	23.40 **
MCM 100 × MTU 1061	11.68 **	7.33 *	-6.76 **	-12.67 **	-1.35	-4.73	-8.84 **	-21.60 **
MCM 100 × MTU 7029	-5.66 *	-6.73 *	-15.10 **	-22.67 **	13.11 **	0.93	13.43 **	2.70
MTU 1121 × MTU 1140	-1.30	-6.89 *	-7.62 **	-13.17 **	-8.96 **	-11.93 **	-17.72 **	-27.41 **
MTU 1121 × MTU 1064	-1.43	-7.78 *	-10.01 **	-15.33 **	14.33 **	8.27 **	15.62 **	10.47 **
MTU 1121 × MTU 1061	-11.33 **	-14.78 **	-13.52 **	-19.00 **	-2.59	-5.93 *	5.17 *	-4.00
MTU 1121 × MTU 7029	-0.27	-1.41	-10.34 **	-18.33 **	22.82 **	9.60 **	1.77	-1.80
MTU 1140 × MTU 1064	-1.78	-8.11 **	-10.72 **	-16.00 **	3.63	-1.87	-14.41 **	-27.41 **
MTU 1140 × MTU 1061	-11.21 **	-14.67 **	-9.96 **	-15.67 **	-2.87	-6.20 *	-20.77 **	-23.70 **
MTU 1140 × MTU 7029	-9.28 **	-10.31 **	-11.25 **	-19.17 **	-9.00 **	-18.80 **	-20.33 **	-27.41 **
MTU 1064 × MTU 1061	-5.20	-8.89 **	-8.36 **	-14.17 **	11.13 **	3.29	22.26 **	7.20 **
MTU 1064 × MTU 7029	2.03	0.87	-6.31 **	-14.67 **	20.82 **	19.67 **	19.88 **	10.81 **
MTU 1061 × MTU 7029	1.37	0.22	-12.90 **	-20.67 **	14.31 **	2.00	-6.70 **	-11.86 **
Mean	1.71	-2.83	-9.42	-16.16	0.87	-4.40	-3.18	-12.32
Range	-11.33 to 14.72	-14.78 to 8.22	-15.10 to -2.57	-22.67 to -11.67	-21.64 to 30.44	-24.20 to 19.67	-28.12 to 26.09	-40.99 to 23.40

Table 4.21. (Cont)

Crosses	Gel consistency (mm)		Alkali spreading value (mm)		Amylose content (%)		Grain yield per plant (g)	
	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
MTU 1001 × BPT 3291	-12.72 **	-13.82 **	6.90 **	-13.89 **	-12.46 **	-13.29 **	14.74 **	7.78
MTU 1001 × MCM 100	25.93 **	19.47 **	10.05 **	-13.89 **	0.75	-8.87 **	62.24 **	53.04 **
MTU 1001 × MTU 1121	58.69 **	51.40 **	-4.36	-28.72 **	1.23	-4.43	53.39 **	50.97 **
MTU 1001 × MTU 1140	86.23 **	80.93 **	0.56	-15.72 **	5.87 **	5.70 *	58.97 **	58.91 **
MTU 1001 × MTU 1064	32.94 **	21.44 **	-18.36 **	-19.09 **	-7.75 **	-9.19 **	56.02 **	54.94 **
MTU 1001 × MTU 1061	52.12 **	38.97 **	-5.92 **	-7.19 **	-6.37 **	-13.77 **	65.27 **	65.21 **
MTU 1001 × MTU 7029	3.43	-2.41	-6.11 *	-28.72 **	-12.15 **	-16.57 **	12.67 *	12.39 *
BPT 3291 × MCM 100	64.71 **	57.68 **	-30.81 **	-36.08 **	27.05 **	14.92 **	30.07 **	28.82 **
BPT 3291 × MTU 1121	-19.34 **	-22.35 **	-3.98	-16.67 **	-0.45	-6.01 **	27.35 **	20.85 **
BPT 3291 × MTU 1140	84.44 **	77.55 **	-31.07 **	-31.55 **	-5.72 **	-5.87 *	59.60 **	49.24 **
BPT 3291 × MTU 1064	35.25 **	24.63 **	2.21	-15.44 **	-19.38 **	-20.64 **	34.38 **	24.81 **
BPT 3291 × MTU 1061	-25.70 **	-31.53 **	-8.13 **	-24.27 **	34.83 **	24.17 **	56.17 **	45.94 **
BPT 3291 × MTU 7029	97.66 **	84.84 **	65.59 **	47.17 **	-4.63 *	-9.43 **	23.91 **	15.56 **
MCM 100 × MTU 1121	22.17 **	21.40 **	-15.87 **	-16.67 **	45.93 **	38.68 **	20.52 **	14.37 *
MCM 100 × MTU 1140	5.70	-2.47	-25.93 **	-35.58 **	-10.56 **	-19.62 **	64.28 **	53.62 **
MCM 100 × MTU 1064	-30.46 **	-33.16 **	14.67 **	-14.51 **	1.30	-7.53 **	65.85 **	54.04 **
MCM 100 × MTU 1061	62.03 **	55.77 **	-24.87 **	-44.16 **	-8.09 **	-10.37 **	52.31 **	42.33 **
MCM 100 × MTU 7029	77.07 **	58.94 **	-14.46 **	-15.97 **	2.41	-3.25	35.86 **	26.71 **
MTU 1121 × MTU 1140	64.29 **	52.82 **	0.80	-12.33 **	-6.78 **	-12.51 **	60.86 **	57.42 **
MTU 1121 × MTU 1064	-24.69 **	-28.21 **	15.84 **	-13.64 **	9.87 **	4.83 *	7.69	4.63
MTU 1121 × MTU 1061	-6.78 *	-11.13 **	4.22	-22.54 **	5.34 *	3.06	14.54 **	12.01 *
MTU 1121 × MTU 7029	72.07 **	55.65 **	63.67 **	60.77 **	46.24 **	44.67 **	5.28	2.74
MTU 1140 × MTU 1064	-1.44	-12.31 **	-49.42 **	-58.16 **	-13.96 **	-15.31 **	14.61 **	13.82 *
MTU 1140 × MTU 1061	75.70 **	56.32 **	-10.36 **	-26.11 **	10.15 **	1.44	21.06 **	21.01 **
MTU 1140 × MTU 7029	84.70 **	79.28 **	24.99 **	11.08 **	-2.03	-6.96 **	40.24 **	39.88 **
MTU 1064 × MTU 1061	-33.81 **	-33.88 **	-57.04 **	-57.62 **	-6.82 **	-12.56 **	55.09 **	55.03 **
MTU 1064 × MTU 7029	-11.98 **	-23.77 **	24.41 **	-5.56 *	26.34 **	22.35 **	22.46 **	22.15 **
MTU 1061 × MTU 7029	25.66 **	8.83 *	30.48 **	-0.94	0.94	-2.39	25.36 **	25.05 **
Mean	30.85	22.53	-1.51	-16.29	3.61	-1.38	37.89	33.33
Range	-33.81 to 97.66	-33.88 to 84.84	-57.04 to 65.59	-57.62 to 60.77	-19.38 to 46.24	-20.64 to 44.67	5.28 to 65.85	4.63 to 65.21

* Significant at 5% level

** Significant at 1% level

Table 4.22. The best heterotic combinations identified for yield, yield contributing characters and quality traits of F₁s in rice (*Oryza sativa* L.) based on overall performance

S. No.	Characters	Crosses combinations	Per se performance	sca effects	Relative heterosis	Hetero-beltiosis
1	Days to 50% flowering	MTU 1001 × MTU 1061	82.33	-10.119**	-15.99 **	-23.05 **
		BPT 3291 × MCM 100	68.67	-18.252**	-29.69 **	-31.56 **
		MCM 100 × MTU 1064	82.67	-10.752**	-19.22 **	-21.02 **
2	Days to maturity	MTU 1001 × MTU 1061	111.33	-11.044**	-13.25 **	-18.54 **
		BPT 3291 × MCM 100	97.67	-18.344**	-23.30 **	-24.68 **
		MCM 100 × MTU 1064	111.00	-11.944**	-15.48 **	-16.33 **
3	Plant height (cm)	MTU 1001 × MTU 7029	96.00	-15.132**	-13.84 **	-15.04 **
		BPT 3291 × MTU 1064	103.90	-6.217**	-5.14 **	-8.10 **
		BPT 3291 × MTU 7029	92.90	-14.330**	-13.92 **	-15.43 **
4	Total number of tillers per plant	MTU 1001 × MTU 1140	17.67	2.696**	51.43 **	43.24 **
		BPT 3291 × MTU 1121	16.00	1.930**	50.00 **	45.45 **
		BPT 3291 × MTU 1061	17.33	2.196**	48.57 **	40.54 **
		MCM 100 × MTU 1121	16.67	1.930**	49.25 **	38.89 **
5	Number of ear bearing tillers per plant	MTU 1001 × BPT 3291	12.00	0.515	35.85 **	33.33 **
		BPT 3291 × MTU 1121	13.33	1.715	42.86 **	37.93 **
		MCM 100 × MTU 7029	14.00	2.215**	35.48 **	31.25 **
6	Panicle length per plant (cm)	BPT 3291 × MCM 100	30.59	1.712**	20.85 **	14.88 **
		BPT 3291 × MTU 1140	31.11	2.435**	23.42 **	17.78 **
		MTU 1140 × MTU 1064	31.20	2.277**	18.53 **	17.10 **
7	Number of grains per panicle	MTU 1001 × BPT 3291	211.09	22.485**	39.69 **	31.11 **
		BPT 3291 × MCM 100	225.98	16.720**	34.46 **	15.81 **
		BPT 3291 × MTU 7029	212.60	16.147**	35.87 **	23.64 **
8	Test weight (g)	MTU 1001 × MCM 100	24.33	1.934**	17.43 **	5.77 **
		BPT 3291 × MCM 100	23.19	2.321**	23.90 **	22.05 **
		BPT 3291 × MTU 1140	23.36	0.360**	16.70 **	11.06 **
		MCM 100 × MTU 7029	21.37	1.549**	18.08 **	17.44 **
9	Leaf area index at max tillering stage	MTU 1001 × BPT 3291	3.47	0.814**	66.72 **	60.31 **
		MTU 1001 × MCM 100	2.86	0.185**	27.15 **	14.57 **
		MTU 1001 × MTU 1140	3.72	0.418**	40.95 **	13.40 **
		MTU 1001 × MTU 1064	2.78	0.156*	28.07 **	18.61 **
10	Hulling (%)	MTU 1001 × BPT 3291	81.26	1.318*	3.47 **	2.76 *
		BPT 3291 × MTU 1064	82.24	1.721**	3.46 **	2.83 *
11	Milling (%)	MTU 1001 × BPT 3291	74.19	1.022	7.92 **	6.75 **
		MTU 1001 × MTU 1140	77.92	4.333**	12.51 **	10.50 **
		BPT 3291 × MTU 1140	76.51	2.962**	8.89 **	8.49 **
12	Head rice recovery (%)	MTU 1001 × BPT 3291	69.82	2.242**	8.99 **	8.88 **
		MTU 1001 × MTU 1140	74.98	4.901**	15.35 **	13.60 **
		MTU 1121 × MTU 1140	71.51	3.004**	9.17 **	8.34 **
13	Kernel length (mm)	BPT 3291 × MTU 1140	6.06	0.407**	13.35 **	6.51 **
		BPT 3291 × MTU 7029	5.64	0.015	9.44 **	6.28 **
14	Kernel breadth (mm)	MTU 1001 × MTU 1061	2.36	0.106**	16.83 **	15.69 **
		MTU 1001 × MTU 7029	2.46	0.171**	19.29 **	15.65 **
		MCM 100 × MTU 7029	2.38	0.115**	15.42 **	11.89 **
15	Length/Breadth Ratio	MTU 1001 × MTU 1140	2.42	-0.107**	-12.81 **	-19.44 **
		MTU 1001 × MTU 1061	2.47	-0.098**	-15.31 **	-17.67 **
		BPT 3291 × MTU 1064	2.44	-0.0162**	-14.35 **	-18.78 **
		MTU 1121 × MTU 1061	2.47	-0.119**	-15.20 **	-17.56 **
		MTU 1140 × MTU 1061	2.43	-0.114**	-16.57 **	-18.89 **
16	Kernel length after cooking (mm)	BPT 3291 × MTU 1121	9.97	0.509**	8.35 **	6.07 **
		BPT 3291 × MTU 7029	9.56	0.337**	7.90 **	6.26 **
		MTU 1121 × MTU 7029	9.34	0.133	5.38 **	3.78 *

Table 4.22. (Cont.)

17	Kernel breadth after cooking (mm)	BPT 3291 × MTU 1140	3.20	0.268**	13.19 **	6.78 *
		BPT 3291 × MTU 1061	3.23	0.282**	12.02 **	7.67 *
		MCM 100 × MTU 1140	3.25	0.325**	14.72 **	8.22 **
18	Volume expansion ratio	MTU 1001 × MTU 7029	5.82	1.033**	30.44 **	16.40 **
		MTU 1064 × MTU 7029	4.79	-0.069	20.82 **	19.67 **
19	Water uptake (ml)	MCM 100 × MTU 1064	193.33	18.630**	26.09 **	23.40 **
20	Gel consistency (mm)	MTU 1001 × MTU 1140	94.08	19.618**	86.23 **	80.93 **
		BPT 3291 × MTU 7029	97.96	29.291**	97.66 **	84.84 **
		MTU 1140 × MTU 7029	87.85	-21.037**	84.70 **	79.28 **
21	Alkali spreading value (mm)	BPT 3291 × MTU 7029	5.89	1.631**	65.59 **	47.17 **
		MTU 1121 × MTU 7029	5.00	0.973**	63.67 **	60.77 **
22	Amylose content (%) (for sticky rice)	BPT 3291 × MTU 1064	19.84	-4.239**	-19.38 **	-20.64 **
	Amylose content (%) (for non-sticky rice)	MTU 1121 × MTU 7029	32.53	7.241**	46.24 **	44.67 **
23	Grain yield per plant (g)	MTU 1001 × MTU 1140	36.55	4.300**	58.97 **	58.91 **
		MTU 1001 × MTU 1061	38.03	6.417**	65.27 **	65.21 **
		MCM 100 × MTU 1140	35.31	4.703**	64.28 **	53.62 **
		MCM 100 × MTU 1064	35.93	6.558**	65.85 **	54.04 **
		MTU 1121 × MTU 1140	36.18	7.501**	60.86 **	57.42 **

Table 4.27. Mean performance of parents and F₁ ratoon in rice (*Oryza sativa* L.)

S.N	Lines, F ₁ s and Checks	DDF	DM	PH	TNTP	NRTPMCT	NVBAHMC	TEBT	NRTPMCPT	PL	NGPP	TW	LAI	GYPP
1	MTU 1001	60.00	86.33	96.89	9.67	86.71	12.00	6.33	68.15	24.94	108.69	20.04	1.53	16.87
2	BPT 3291	60.33	90.33	93.35	9.00	84.55	10.33	5.67	66.67	23.56	112.71	18.17	1.27	16.06
3	MCM 100	62.67	95.67	98.26	9.67	80.69	11.67	7.33	70.71	25.38	139.92	17.13	1.59	18.70
4	MTU 1121	58.67	86.67	98.33	9.00	86.97	11.33	6.00	62.59	27.32	136.10	18.23	1.82	16.23
5	MTU 1140	67.00	101.67	102.76	9.00	72.86	11.00	6.33	61.21	25.17	170.29	19.56	2.12	20.72
6	MTU 1064	66.33	98.67	105.00	10.00	83.94	11.67	8.00	76.77	27.06	180.83	18.10	2.38	18.37
7	MTU 1061	66.00	98.33	107.10	9.67	78.42	12.00	7.00	64.24	26.40	156.30	18.65	2.12	17.95
8	MTU 7029	61.33	92.33	102.14	9.33	71.89	12.67	6.00	56.36	25.79	116.75	16.81	1.53	15.82
9	MTU 1001 × BPT 3291	58.33	84.33	101.66	8.67	59.21	10.33	5.00	41.86	25.06	161.09	22.37	2.57	16.85
10	MTU 1001 × MCM 100	65.67	95.67	109.50	9.67	61.81	12.00	7.67	65.91	29.57	163.49	23.78	1.96	25.52
11	MTU 1001 × MTU 1121	59.67	87.67	105.20	8.33	58.25	11.00	6.33	51.52	27.87	143.77	21.80	1.70	20.39
12	MTU 1001 × MTU 1140	66.00	97.67	117.43	11.67	66.12	13.00	9.00	71.78	29.46	194.69	21.86	2.82	35.27
13	MTU 1001 × MTU 1064	61.33	92.67	108.38	9.33	60.97	10.67	8.00	63.49	30.40	178.05	20.88	1.88	26.90
14	MTU 1001 × MTU 1061	55.67	84.00	110.67	10.67	63.97	12.33	7.33	55.16	28.78	182.60	20.88	1.60	26.06
15	MTU 1001 × MTU 7029	56.00	82.67	89.75	8.00	57.14	12.00	5.67	47.67	25.40	141.86	19.38	1.23	12.54
16	BPT 3291 × MCM 100	59.33	89.67	105.10	9.67	60.70	11.33	5.33	41.18	27.45	167.98	22.04	1.64	16.22
17	BPT 3291 × MTU 1121	57.00	89.00	100.71	10.00	62.79	12.00	6.33	47.95	27.04	161.23	18.61	1.19	15.43
18	BPT 3291 × MTU 1140	61.67	93.00	122.11	10.00	62.80	11.33	7.33	55.16	30.30	180.48	22.58	2.62	26.55
19	BPT 3291 × MTU 1064	59.00	86.67	95.99	10.00	63.62	11.67	7.33	57.91	25.78	166.85	18.71	1.55	19.21
20	BPT 3291 × MTU 1061	62.00	88.00	105.01	11.33	65.47	12.67	7.67	63.73	26.19	171.57	19.32	1.89	21.12
21	BPT 3291 × MTU 7029	58.33	83.33	85.05	9.00	60.34	11.00	4.67	43.85	24.83	162.60	18.29	1.27	12.09
22	MCM 100 × MTU 1121	62.67	93.67	108.92	10.67	64.09	11.67	6.33	53.01	29.89	155.97	20.09	1.46	14.66
23	MCM 100 × MTU 1140	65.67	99.67	115.30	10.33	59.87	12.00	8.33	64.56	33.14	222.28	20.89	2.72	34.65
24	MCM 100 × MTU 1064	60.33	93.33	112.02	10.00	62.80	11.33	8.33	67.74	31.14	165.40	19.13	1.66	25.58
25	MCM 100 × MTU 1061	61.67	92.33	109.50	10.00	62.50	11.33	7.33	69.09	28.18	198.88	18.33	1.55	22.84
26	MCM 100 × MTU 7029	59.33	89.00	122.53	11.33	65.47	12.33	6.67	47.95	30.14	175.94	19.90	1.21	19.27
27	MTU 1121 × MTU 1140	62.67	94.00	118.32	8.67	59.21	10.00	7.00	58.82	30.66	192.67	20.90	2.17	24.14
28	MTU 1121 × MTU 1064	62.67	92.00	96.63	8.33	58.25	11.00	6.00	48.51	28.92	137.82	21.56	1.67	14.69
29	MTU 1121 × MTU 1061	62.00	90.67	104.85	10.00	62.52	11.67	6.33	51.28	29.00	135.59	20.87	1.73	14.86
30	MTU 1121 × MTU 7029	61.33	89.33	104.00	8.67	59.21	10.67	6.33	48.93	27.84	140.59	18.85	1.26	13.66
31	MTU 1140 × MTU 1064	70.00	104.00	115.03	9.67	61.81	12.33	7.33	54.05	30.72	196.56	21.88	2.27	27.40
32	MTU 1140 × MTU 1061	66.00	98.33	120.95	10.00	63.89	11.00	8.00	63.46	31.44	166.17	22.14	2.14	26.56
33	MTU 1140 × MTU 7029	66.00	93.67	113.15	10.00	62.80	11.67	8.67	72.32	30.83	164.84	19.27	2.22	30.88
34	MTU 1064 × MTU 1061	66.33	97.67	113.38	10.00	58.10	11.67	7.00	58.14	30.95	148.17	18.31	1.59	16.43
35	MTU 1064 × MTU 7029	61.67	91.33	107.83	8.67	59.21	11.00	5.33	47.22	31.52	155.34	18.40	1.44	11.71
36	MTU 1061 × MTU 7029	65.33	96.00	111.59	8.33	58.97	10.33	6.00	54.29	29.06	185.44	19.30	1.59	18.07
Overall Mean		62.11	92.20	106.51	9.62	65.78	11.50	6.81	58.15	28.25	162.21	19.92	1.81	20.29
C.V.		3.17	2.17	2.20	9.30	12.29	7.59	11.09	14.26	5.38	6.12	2.48	6.98	6.82
S.Em		1.14	1.15	1.35	0.52	4.67	0.50	0.44	4.79	0.88	5.74	0.28	0.07	0.80
C.D. 5%		3.21	3.26	3.81	1.46	13.17	1.42	1.23	13.50	2.48	16.18	0.80	0.21	2.25

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBT: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NRTPMCPT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant.

S.N	Lines, F1s and Checks	HP	MP	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC (%)
1	MTU 1001	77.13	70.44	67.53	5.77	2.08	2.77	9.86	2.85	1.71	4.88	242.67	54.38	6.22	25.32
2	BPT 3291	75.70	70.35	67.70	5.24	1.79	2.92	9.07	2.63	1.73	4.79	156.33	52.83	4.75	23.09
3	MCM 100	80.07	72.81	69.82	5.37	1.97	2.73	8.88	2.75	1.66	4.28	165.67	57.23	3.33	20.54
4	MTU 1121	78.68	71.05	68.03	5.54	1.95	2.85	9.21	2.62	1.66	4.78	200.67	61.12	3.06	23.01
5	MTU 1140	80.30	71.88	69.87	5.52	2.01	2.76	9.84	2.70	1.78	4.61	244.00	46.57	4.55	24.11
6	MTU 1064	78.48	70.86	67.88	5.51	2.00	2.76	9.79	2.65	1.77	4.22	173.33	65.32	5.94	24.20
7	MTU 1061	78.91	70.38	69.30	5.46	1.87	2.92	9.88	2.81	1.81	4.81	182.67	66.20	6.00	23.04
8	MTU 7029	75.98	70.69	65.60	5.12	1.88	2.73	8.54	3.11	1.67	3.96	191.67	47.29	3.39	22.01
9	MTU 1001 × BPT 3291	80.23	75.52	71.57	5.50	2.08	2.65	9.37	2.87	1.71	4.14	186.00	44.42	5.11	20.96
10	MTU 1001 × MCM 100	78.83	74.97	71.39	5.37	1.95	2.75	9.34	2.84	1.74	4.25	172.67	65.28	4.94	21.73
11	MTU 1001 × MTU 1121	78.24	73.69	70.50	5.31	2.00	2.65	9.81	2.76	1.85	3.99	212.83	85.69	4.39	21.84
12	MTU 1001 × MTU 1140	80.43	76.89	72.35	5.41	2.09	2.59	9.65	3.03	1.79	4.31	220.67	91.23	4.83	25.79
13	MTU 1001 × MTU 1064	78.58	73.61	69.27	5.35	1.70	3.15	9.59	2.60	1.79	4.21	285.33	73.62	4.94	22.62
14	MTU 1001 × MTU 1061	79.04	74.15	70.53	5.66	2.13	2.66	9.66	2.88	1.71	4.73	246.33	91.31	5.56	20.51
15	MTU 1001 × MTU 7029	77.54	72.46	68.89	5.59	2.23	2.50	9.59	3.12	1.72	4.78	212.00	47.49	4.28	19.89
16	BPT 3291 × MCM 100	79.91	73.67	70.04	5.42	2.04	2.66	9.19	3.14	1.70	4.44	157.33	90.12	2.61	27.88
17	BPT 3291 × MTU 1121	76.92	72.16	69.07	5.52	2.11	2.61	9.78	3.13	1.77	4.11	219.00	42.07	3.39	22.42
18	BPT 3291 × MTU 1140	79.75	75.20	71.33	5.97	2.02	2.96	9.36	3.24	1.57	3.88	199.50	91.21	2.78	21.85
19	BPT 3291 × MTU 1064	81.02	75.42	71.13	5.53	2.11	2.62	9.69	3.10	1.75	4.74	211.50	78.55	5.00	19.77
20	BPT 3291 × MTU 1061	79.92	71.18	69.90	5.28	1.93	2.73	8.86	3.27	1.68	4.81	216.33	40.55	4.83	29.93
21	BPT 3291 × MTU 7029	76.86	73.57	67.53	5.42	2.00	2.71	9.41	3.15	1.74	4.71	218.33	94.86	5.72	21.59
22	MCM 100 × MTU 1121	79.25	72.12	68.52	5.26	2.00	2.63	8.96	3.03	1.71	4.55	221.33	69.64	2.50	30.13
23	MCM 100 × MTU 1140	79.96	72.72	71.09	5.09	1.92	2.65	8.88	3.29	1.75	4.63	224.67	53.38	2.61	19.11
24	MCM 100 × MTU 1064	80.23	71.64	70.22	5.55	2.03	2.74	9.31	3.09	1.68	4.48	225.00	42.17	5.39	21.15
25	MCM 100 × MTU 1061	80.51	73.69	70.73	5.42	2.03	2.67	9.78	3.26	1.80	4.57	195.33	95.21	3.56	18.13
26	MCM 100 × MTU 7029	79.79	72.84	67.76	5.67	2.15	2.63	8.89	2.90	1.57	4.34	220.33	90.87	2.61	21.09
27	MTU 1121 × MTU 1140	78.45	71.33	69.94	5.28	1.92	2.76	9.20	2.83	1.74	4.65	208.50	88.08	3.50	20.89
28	MTU 1121 × MTU 1064	78.97	70.81	69.32	5.36	2.02	2.65	8.94	2.81	1.67	4.46	224.00	46.43	5.22	24.01
29	MTU 1121 × MTU 1061	79.10	72.33	69.24	5.41	2.04	2.66	8.91	2.60	1.65	4.77	224.33	59.20	4.94	20.71
30	MTU 1121 × MTU 7029	78.54	72.79	66.42	5.53	2.02	2.74	9.15	3.07	1.66	4.59	214.00	85.79	4.83	30.90
31	MTU 1140 × MTU 1064	80.19	71.38	69.69	5.46	2.04	2.68	9.43	2.80	1.73	4.72	194.00	52.70	2.78	20.61
32	MTU 1140 × MTU 1061	79.72	73.52	71.21	5.45	1.97	2.76	9.24	2.60	1.70	4.52	220.00	93.73	4.56	23.98
33	MTU 1140 × MTU 7029	77.41	70.65	69.41	5.45	2.04	2.67	8.90	2.79	1.63	4.21	200.33	88.05	4.50	21.21
34	MTU 1064 × MTU 1061	78.98	73.04	70.92	5.59	2.02	2.76	9.78	2.77	1.75	4.75	246.00	37.29	2.61	19.93
35	MTU 1064 × MTU 7029	80.30	73.17	70.51	5.38	1.99	2.71	9.28	3.14	1.72	4.85	234.67	43.10	5.22	28.31
36	MTU 1061 × MTU 7029	79.15	72.22	69.22	5.53	2.07	2.68	8.92	3.12	1.61	5.00	226.67	58.28	5.83	22.80
Overall Mean		78.97	72.64	69.54	5.45	2.01	2.72	9.33	2.93	1.71	4.51	210.94	66.42	4.34	22.92
C.V.		1.01	2.00	1.25	1.81	2.04	2.72	1.29	3.97	2.41	3.26	2.96	4.75	4.97	2.80
S.Em		0.46	0.84	0.50	0.06	0.02	0.04	0.07	0.07	0.02	0.09	3.61	1.82	0.12	0.37
C.D. 5%		1.30	2.37	1.42	0.16	0.07	0.12	0.20	0.19	0.07	0.24	10.18	5.14	0.35	1.04

HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.28. Estimates of variability, heritability and genetic advance as per cent of mean for grain yield and yield components of F₁ ratoon crop in rice (*Oryza sativa* L.)

S. No.	Character	Mean	Range		Coefficient of variation (%)		Heritability in broad sense (h^2_b)	Genetic advance (GA) (%)	Genetic advance as per cent of mean (GAM)
			Min	Max	Phenotypic (PCV)	Genotypic (GCV)			
1	DFF	62.11	55.67	70.00	6.08	5.19	72.80	5.67	9.12
2	DM	92.20	82.67	104.00	6.02	5.61	87.00	9.94	10.78
3	PH (cm)	106.51	85.05	122.53	8.54	8.25	93.40	17.50	16.43
4	TNTP	9.62	8.00	11.67	11.89	7.42	38.90	0.92	9.53
5	NRTPMCT	65.78	57.14	86.97	16.75	11.37	46.10	10.47	15.91
6	NVBAHMC	11.50	10.00	13.00	8.80	4.47	25.70	0.54	4.67
7	TEBTP	6.81	4.67	9.00	18.02	14.20	62.10	1.57	23.05
8	NRPTMCPT	58.15	41.18	76.77	19.89	13.86	48.60	11.57	19.90
9	PL (cm)	28.25	23.56	33.14	9.62	7.97	68.70	3.84	13.60
10	NGPP	162.21	108.69	222.28	16.19	14.99	85.70	46.36	28.58
11	TW (g)	19.92	16.81	23.78	8.76	8.40	92.00	3.31	16.60
12	LAI	1.81	1.19	2.82	25.54	24.57	92.50	0.88	48.69
13	GYPP (g)	20.29	11.71	35.27	30.73	29.96	95.10	12.21	60.18
14	HP	78.97	75.70	81.02	1.86	1.56	70.30	2.13	2.69
15	MP	72.64	70.35	76.89	2.79	1.94	48.50	2.03	2.79
16	HRR (%)	69.54	65.60	72.35	2.41	2.06	73.10	2.52	3.63
17	KL (mm)	5.45	5.09	5.97	3.43	2.91	72.00	0.28	5.08
18	KB (mm)	2.01	1.70	2.23	5.20	4.79	84.60	0.18	9.07
19	L/B ratio	2.72	2.50	3.15	4.89	4.06	69.00	0.19	6.95
20	KLAC (mm)	9.33	8.54	9.88	4.11	3.90	90.10	0.71	7.62
21	KBAC (mm)	2.93	2.60	3.29	8.10	7.07	76.00	0.37	12.69
22	KLER	1.71	1.57	1.85	4.22	3.47	67.40	0.10	5.87
23	VER	4.51	3.88	5.00	7.02	6.22	78.40	0.51	11.34
24	WU (ml)	210.94	156.33	285.33	13.06	12.72	94.80	53.84	25.52
25	GC (mm)	66.42	37.29	95.21	29.77	29.39	97.50	39.70	59.76
26	ASV (mm)	4.34	2.50	6.22	26.80	26.33	96.60	2.31	53.31
27	AC (%)	22.92	18.13	30.90	13.97	13.69	96.00	6.33	27.62

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NRPTMCPT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.34. Relative heterosis, heterobeltiosis and standard heterosis for yield and yield contributing characters of F₁ ratoon in rice (*Oryza sativa* L.)

S.No.	Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		Total number of tillers per plant	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	-3.05	-3.31	-4.35 **	-6.64 **	6.81 **	4.80 *	-8.77	-13.33
2	MTU 1001 × MCM 100	7.07 **	4.79	5.32 **	0.00	12.16 **	11.44 **	-1.69	-3.33
3	MTU 1001 × MTU 1121	0.56	-0.56	1.54	1.15	7.72 **	6.99 **	-12.28	-16.67 *
4	MTU 1001 × MTU 1140	3.94	-1.49	4.09 **	-3.93 *	17.57 **	14.28 **	22.81 **	16.67 *
5	MTU 1001 × MTU 1064	-2.90	-7.54 **	0.36	-6.08 **	7.31 **	3.22	-6.67	-6.67
6	MTU 1001 × MTU 1061	-11.64 **	-15.66 **	-8.86 **	-14.58 **	8.45 **	3.33	8.47	6.67
7	MTU 1001 × MTU 7029	-7.69 **	-8.70 **	-7.29 **	-10.47 **	-9.86 **	-12.13 **	-17.24 *	-20.00 **
8	BPT 3291 × MCM 100	-3.26	-5.32 *	-3.41 *	-6.27 **	9.91 **	6.97 **	3.57	0.00
9	BPT 3291 × MTU 1121	-3.93	-5.00	0.75	-1.11	5.28 **	2.42	11.11	11.11
10	BPT 3291 × MTU 1140	-2.89	-7.96 **	-2.96 *	-8.52 **	24.75 **	18.83 **	11.11	11.11
11	BPT 3291 × MTU 1064	-6.60 **	-11.06 **	-8.13 **	-12.16 **	-3.04	-8.58 **	5.26	0.00
12	BPT 3291 × MTU 1061	-1.59	-6.06 *	-6.55 **	-10.51 **	4.95 **	-1.95	21.43 **	17.24 *
13	BPT 3291 × MTU 7029	-3.85	-4.89	-8.59 **	-9.75 **	-12.84 **	-16.74 **	-1.82	-3.57
14	MCM 100 × MTU 1121	3.01	-0.53	2.55	-2.43	10.96 **	10.77 **	12.28	6.67
15	MCM 100 × MTU 1140	1.03	-1.99	0.84	-1.97	14.87 **	12.21 **	8.77	3.33
16	MCM 100 × MTU 1064	-6.70 **	-9.05 **	-4.11 **	-5.41 **	10.37 **	6.69 **	0.00	0.00
17	MCM 100 × MTU 1061	-4.39 *	-6.57 **	-4.97 **	-6.10 **	6.78 **	2.24	1.69	0.00
18	MCM 100 × MTU 7029	-4.56 *	-5.82 *	-5.49 **	-7.29 **	22.44 **	19.96 **	17.24 *	13.33
19	MTU 1121 × MTU 1140	-0.53	-6.47 **	-0.35	-7.54 **	17.88 **	15.15 **	-3.70	-3.70
20	MTU 1121 × MTU 1064	0.00	-5.53 *	-0.90	-6.76 **	-4.79 **	-7.97 **	-12.28	-16.67 *
21	MTU 1121 × MTU 1061	-0.80	-6.06 *	-2.16	-7.80 **	2.25	-2.10	7.14	3.45
22	MTU 1121 × MTU 7029	1.94	0.00	-0.37	-3.25	3.93 *	1.82	-5.45	-7.14
23	MTU 1140 × MTU 1064	5.00 *	4.48	3.65 *	1.96	10.60 **	9.55 **	1.75	-3.33
24	MTU 1140 × MTU 1061	-0.75	-1.49	-1.83	-3.59 *	15.14 **	12.93 **	7.14	3.45
25	MTU 1140 × MTU 7029	2.86	-1.49	-3.60 *	-8.17 **	10.31 **	9.85 **	9.09	7.14
26	MTU 1064 × MTU 1061	0.51	0.51	-1.01	-1.35	6.91 **	5.86 **	1.69	0.00
27	MTU 1064 × MTU 7029	-3.14	-6.57 **	-4.53 **	-7.74 **	4.11 *	2.69	-10.34	-13.33
28	MTU 1061 × MTU 7029	2.62	-1.01	0.88	-2.04	6.71 **	4.29 *	-13.79 *	-16.67 *
	Mean	-1.42	-4.30	-2.12	-5.66	7.77	4.89	2.02	-0.87
	Range	-11.64 to 7.07	-15.66 to 4.79	-8.86 to 5.32	-14.58 to 1.96	-12.84 to 24.75	-16.74 to 19.96	-17.24 to 22.81	-20.00 to 17.24

Table 4.34. (Cont.)

S. No.	Crosses	Number of ratoon tillers as percentage of main crop tillers		Number of vegetative buds after the harvest of main crop		Number of ear tillers per plant		Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	-30.97 **	-31.95 **	-7.46	-13.89 *	-14.29	-16.67	-37.83 **	-38.44 **
2	MTU 1001 × MCM 100	-26.28 **	-28.96 **	1.41	0.00	15.00	4.55	-4.97	-6.79
3	MTU 1001 × MTU 1121	-33.03 **	-33.04 **	-5.71	-8.33	5.56	5.56	-21.10 *	-24.24 *
4	MTU 1001 × MTU 1140	-17.28 *	-24.00 **	13.04 *	8.33	45.95 **	42.11 **	11.10	5.56
5	MTU 1001 × MTU 1064	-28.66 **	-29.92 **	-9.86	-11.11	14.29	0.00	-12.28	-17.29
6	MTU 1001 × MTU 1061	-22.65 **	-26.47 **	2.78	2.78	12.82	4.76	-16.58	-18.89
7	MTU 1001 × MTU 7029	-28.07 **	-34.32 **	-2.70	-5.26	-5.56	-5.56	-23.34 *	-29.90 **
8	BPT 3291 × MCM 100	-26.73 **	-28.58 **	4.62	-2.86	-20.00 *	-27.27 **	-40.20 **	-41.77 **
9	BPT 3291 × MTU 1121	-26.98 **	-27.81 **	12.50 *	5.88	5.56	5.56	-26.00 **	-28.43 **
10	BPT 3291 × MTU 1140	-20.44 **	-26.12 **	7.94	3.03	18.92 *	15.79	-13.96	-17.68
11	BPT 3291 × MTU 1064	-24.68 **	-25.15 **	7.69	0.00	4.76	-8.33	-19.45 *	-24.57 **
12	BPT 3291 × MTU 1061	-19.88 **	-22.98 **	15.15 **	5.56	17.95 *	9.52	-2.88	-4.88
13	BPT 3291 × MTU 7029	-23.08 **	-29.02 **	-2.94	-13.16 *	-22.22 *	-22.22 *	-28.90 **	-34.55 **
14	MCM 100 × MTU 1121	-23.68 **	-26.30 **	0.00	-2.78	-2.56	-9.52	-20.64 *	-25.34 **
15	MCM 100 × MTU 1140	-22.18 **	-26.09 **	4.35	0.00	25.00 **	19.05 *	-2.34	-9.07
16	MCM 100 × MTU 1064	-23.85 **	-25.18 **	-4.23	-5.56	11.11	4.17	-8.32	-11.77
17	MCM 100 × MTU 1061	-21.59 **	-22.84 **	-5.56	-5.56	4.76	4.76	2.18	-2.69
18	MCM 100 × MTU 7029	-14.35	-19.17 *	0.00	-2.63	2.56	-4.76	-24.70 **	-32.46 **
19	MTU 1121 × MTU 1140	-25.93 **	-31.95 **	-9.09	-9.09	13.51	10.53	-5.29	-6.63
20	MTU 1121 × MTU 1064	-31.84 **	-33.04 **	-2.94	-5.71	-14.29	-25.00 **	-30.59 **	-36.82 **
21	MTU 1121 × MTU 1061	-24.41 **	-28.13 **	1.45	-2.78	-2.56	-9.52	-19.39 *	-20.17
22	MTU 1121 × MTU 7029	-25.47 **	-31.95 **	-9.86	-15.79 **	5.56	5.56	-18.02	-22.33 *
23	MTU 1140 × MTU 1064	-21.23 **	-26.37 **	8.82	5.71	4.76	-8.33	-21.54 *	-29.60 **
24	MTU 1140 × MTU 1061	-15.61 *	-18.53 *	-4.35	-8.33	23.08 **	14.29	1.34	-1.21
25	MTU 1140 × MTU 7029	-13.31	-13.97	-1.41	-7.89	44.44 **	44.44 **	23.24 *	18.56
26	MTU 1064 × MTU 1061	-28.45 **	-30.83 **	-2.78	-2.78	-6.67	-12.50	-17.67 *	-24.49 **
27	MTU 1064 × MTU 7029	-24.04 **	-29.52 **	-10.81 *	-13.16 *	-23.81 **	-33.33 **	-29.18 **	-38.67 **
28	MTU 1061 × MTU 7029	-21.31 **	-24.39 **	-16.22 **	-18.42 **	-7.69	-14.29	-9.78	-15.17
	Mean	-23.79	-27.02	-0.58	-4.42	5.57	-0.24	-14.90	-19.28
	Range	-33.03 to -13.31	-34.32 to -13.97	-16.22 to 15.15	-18.42 to 8.33	-23.81 to 45.95	-33.33 to 44.44	-40.20 to 23.24	-41.77 to 18.56

Table 4.34. (Cont.)

S. No.	Crosses	Panicle length per plant (cm)		Number of grains per panicle		Test weight (gm)		LAI at max tillering stage	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	3.23	0.25	45.32 **	42.92 **	17.20 **	11.83 **	57.55 **	28.67 **
2	MTU 1001 × MCM 100	17.38 **	16.49 **	31.36 **	16.84 **	28.11 **	18.92 **	8.91	-2.17
3	MTU 1001 × MTU 1121	6.53	2.00	17.32 **	5.64	14.05 **	9.00 **	-10.99 *	-15.00 **
4	MTU 1001 × MTU 1140	17.45 **	17.06 **	39.42 **	14.33 **	10.52 **	9.30 **	36.94 **	32.97 **
5	MTU 1001 × MTU 1064	16.77 **	12.32 **	22.87 **	-1.54	9.60 **	4.40 *	-14.07 **	-20.98 **
6	MTU 1001 × MTU 1061	11.98 **	9.02	37.65 **	16.83 **	8.05 **	4.40 *	-22.55 **	-24.80 **
7	MTU 1001 × MTU 7029	0.01	-1.53	25.68 **	21.50 **	5.28 **	-3.12	-30.38 **	-38.50 **
8	BPT 3291 × MCM 100	11.17 *	8.14	32.83 **	20.05 **	25.50 **	22.46 **	26.74 **	3.14
9	BPT 3291 × MTU 1121	5.38	-1.02	29.45 **	18.47 **	2.71	2.07	-15.60 *	-34.62 **
10	BPT 3291 × MTU 1140	23.26 **	20.39 **	27.41 **	5.98	20.26 **	15.48 **	67.98 **	23.55 **
11	BPT 3291 × MTU 1064	0.99	-4.73	13.57 **	-7.73	3.65	3.35	-8.18	-34.83 **
12	BPT 3291 × MTU 1061	3.94	-0.78	27.42 **	9.77	5.43 **	3.59	21.24 **	-10.83 *
13	BPT 3291 × MTU 7029	-0.26	-3.72	41.55 **	39.27 **	5.10 *	1.63	0.00	-17.39 *
14	MCM 100 × MTU 1121	14.25 **	9.39 *	12.98 *	11.41	14.05 **	10.20 **	-23.39 **	-26.83 **
15	MCM 100 × MTU 1140	32.10 **	31.65 **	43.27 **	30.53 **	14.31 **	6.83 **	32.09 **	28.26 **
16	MCM 100 × MTU 1064	19.61 **	15.05 **	3.11	-8.53	8.99 **	5.67 *	-24.41 **	-30.49 **
17	MCM 100 × MTU 1061	9.64 *	6.74	34.24 **	27.25 **	2.81	-1.73	-24.82 **	-27.00 **
18	MCM 100 × MTU 7029	18.67 **	16.85 **	37.05 **	25.67 **	17.70 **	17.04 **	-31.32 **	-39.33 **
19	MTU 1121 × MTU 1140	17.55 **	13.57 **	25.81 **	13.14 **	11.30 **	6.87 **	5.42	2.35
20	MTU 1121 × MTU 1064	7.00	6.87	-13.00 **	-23.79 **	19.42 **	19.08 **	-23.80 **	-29.93 **
21	MTU 1121 × MTU 1061	8.61 *	7.40	-7.23	-13.25 *	13.91 **	11.92 **	-16.25 **	-18.68 **
22	MTU 1121 × MTU 7029	5.49	3.12	11.25 *	3.37	8.30 **	4.72 *	-28.68 **	-37.00 **
23	MTU 1140 × MTU 1064	18.02 **	13.52 **	12.05 **	8.70	14.83 **	9.38 **	3.42	-4.90
24	MTU 1140 × MTU 1061	22.33 **	19.09 **	1.85	-2.25	14.55 **	10.68 **	3.80	0.78
25	MTU 1140 × MTU 7029	21.40 **	19.54 **	14.97 **	-3.04	4.68 *	-3.67	25.66 **	11.00 *
26	MTU 1064 × MTU 1061	15.92 **	14.63 **	-12.14 **	-18.14 **	-0.08	-1.82	-22.88 **	-25.12 **
27	MTU 1064 × MTU 7029	19.40 **	16.73 **	4.34	-14.17 **	5.74 **	2.24	-18.30 **	-27.83 **
28	MTU 1061 × MTU 7029	12.21 **	11.76 *	35.98 **	18.87 **	7.77 **	1.56	-10.19 *	-20.67 **
	Mean	12.86	9.99	21.30	9.22	11.21	7.32	-1.29	-12.72
	Range	-0.26 to 32.10	-4.73 to 31.65	-13.00 to 45.32	-23.79 to 42.92	-0.08 to 28.11	-3.67 to 22.46	-31.32 to 67.98	-39.33 to 32.97

Table 4.34. (Cont.)

S. No.	Crosses	Hulling percentage		Milling percentage		Head rice recovery		Kernel length (mm)	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	5.08 **	4.19 **	7.62 **	7.35 **	5.48 **	5.25 **	-2.05	-8.28 **
2	MTU 1001 × MCM 100	0.38	-1.54	4.99 **	2.96	3.60 **	2.25 *	-5.51 **	-10.50 **
3	MTU 1001 × MTU 1121	0.51	-0.56	4.48 **	3.71 *	3.66 **	3.64 **	-8.00 **	-11.50 **
4	MTU 1001 × MTU 1140	2.26 **	0.16	8.38 **	6.96 **	4.95 **	3.55 **	-6.10 **	-9.83 **
5	MTU 1001 × MTU 1064	1.07	0.12	4.51 **	3.88 *	1.95 *	1.86	-7.12 **	-10.89 **
6	MTU 1001 × MTU 1061	1.40	0.17	5.64 **	5.36 **	2.74 **	1.77	-1.25	-5.72 **
7	MTU 1001 × MTU 7029	1.37	0.70	3.00 *	2.50	3.12 **	1.30	0.48	-6.89 **
8	BPT 3291 × MCM 100	2.40 **	-0.20	3.17 *	1.18	1.63	0.31	4.57 **	0.99
9	BPT 3291 × MTU 1121	-0.54	-2.23 **	2.32	1.57	1.55	1.53	4.77 **	-0.36
10	BPT 3291 × MTU 1140	2.05 **	-0.68	6.00 **	4.61 **	3.48 **	2.09 *	13.40 **	8.03 **
11	BPT 3291 × MTU 1064	4.89 **	3.23 **	7.09 **	6.44 **	4.69 **	4.60 **	5.26 **	0.36
12	BPT 3291 × MTU 1061	3.18 **	1.28	1.41	1.13	1.82 *	0.87	0.99	-3.24 *
13	BPT 3291 × MTU 7029	1.15	1.14	4.59 **	4.08 *	1.10	-0.69	7.05 **	5.79 **
14	MCM 100 × MTU 1121	-0.11	-0.93	0.13	-1.21	-0.71	-2.11 *	-0.28	-5.17 **
15	MCM 100 × MTU 1140	-0.23	-0.42	0.39	-0.38	1.65	1.55	-3.26 *	-7.85 **
16	MCM 100 × MTU 1064	1.25	0.29	-0.40	-1.86	1.86 *	0.31	5.58 **	0.67
17	MCM 100 × MTU 1061	1.33	0.64	2.79	0.95	1.55	1.04	3.73 **	-0.61
18	MCM 100 × MTU 7029	2.31 **	-0.26	1.38	-0.22	-0.05	-3.20 **	11.99 **	10.68 **
19	MTU 1121 × MTU 1140	-1.51 *	-2.30 **	-0.16	-0.77	1.45	0.10	-8.36 **	-12.00 **
20	MTU 1121 × MTU 1064	0.29	-0.03	-0.16	-0.26	2.03 *	1.94	-6.95 **	-10.72 **
21	MTU 1121 × MTU 1061	0.19	0.13	2.32	1.88	0.85	-0.09	-5.56 **	-9.83 **
22	MTU 1121 × MTU 7029	1.35	-0.59	2.75	2.53	-0.57	-2.32 *	-0.54	-7.83 **
23	MTU 1140 × MTU 1064	1.20	0.24	-0.07	-0.87	1.08	-0.45	-5.15 **	-9.00 **
24	MTU 1140 × MTU 1061	0.34	-0.35	3.28 *	2.12	2.24 *	1.73	-4.92 **	-9.22 **
25	MTU 1140 × MTU 7029	-0.75	-3.24 **	-0.98	-1.88	2.37 *	-0.84	-1.98	-9.17 **
26	MTU 1064 × MTU 1061	0.66	0.08	3.32 *	2.87	3.31 **	2.34 *	-2.47 *	-6.89 **
27	MTU 1064 × MTU 7029	4.29 **	2.94 **	3.29 *	3.06	5.55 **	3.69 **	-3.24 *	-10.33 **
28	MTU 1061 × MTU 7029	2.15 **	0.19	2.67	2.17	2.86 **	0.32	9.35 **	8.07 **
	Mean	1.36	0.08	2.99	2.14	2.33	1.16	-0.20	-4.69
	Range	-1.51 to 5.08	-3.24 to 4.19	-0.98 to 8.38	-1.88 to 7.35	-0.71 to 5.55	-3.20 to 5.25	-8.36 to 13.40	-12.00 to 10.68

Table 4.34. (Cont.)

S. No.	Crosses	Kernel breadth (mm)		Kernel L/B ratio		Kernel length after cooking (mm)		Kernel breadth after cooking (mm)	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	9.49 **	3.83 *	-10.52 **	-11.67 **	-1.68	-6.27 **	2.07	-4.22
2	MTU 1001 × MCM 100	-1.60	-2.33	-4.13 *	-8.44 **	-1.04	-6.60 **	-1.16	-5.33
3	MTU 1001 × MTU 1121	1.35	0.00	-9.34 **	-11.56 **	2.15 *	-1.90	-1.90	-8.11 *
4	MTU 1001 × MTU 1140	4.33 **	4.15 *	-10.13 **	-13.78 **	-2.67 **	-3.47 **	6.32 *	1.00
5	MTU 1001 × MTU 1064	-14.93 **	-15.00 **	9.31 **	5.00 *	-3.12 **	-4.13 **	-8.14 **	-13.44 **
6	MTU 1001 × MTU 1061	10.08 **	6.50 **	-10.20 **	-11.44 **	-2.82 **	-3.40 **	-0.80	-4.00
7	MTU 1001 × MTU 7029	15.22 **	11.67 **	-12.79 **	-16.67 **	3.43 **	-4.13 **	2.13	0.32
8	BPT 3291 × MCM 100	2.60	1.83	-7.04 **	-11.22 **	2.85 **	2.15	9.16 **	4.56
9	BPT 3291 × MTU 1121	6.93 **	5.50 **	-10.71 **	-12.89 **	7.40 **	6.19 **	11.27 **	4.22
10	BPT 3291 × MTU 1140	0.83	0.66	2.72	-1.44	-0.65	-4.88 **	13.80 **	8.11 *
11	BPT 3291 × MTU 1064	5.75 **	5.67 **	-9.08 **	-12.67 **	3.14 **	-1.02	9.79 **	3.44
12	BPT 3291 × MTU 1061	-0.09	-3.33	-7.61 **	-8.89 **	-6.18 **	-10.36 **	12.63 **	9.00 **
13	BPT 3291 × MTU 7029	3.01 *	-0.17	-5.35 **	-9.56 **	7.28 **	4.52 **	3.22	1.39
14	MCM 100 × MTU 1121	1.18	-0.17	-10.02 **	-12.22 **	-1.54	-2.64 *	7.95 **	1.11
15	MCM 100 × MTU 1140	-3.99 **	-4.15 *	-8.05 **	-11.78 **	-5.72 **	-9.73 **	15.32 **	9.56 **
16	MCM 100 × MTU 1064	1.42	1.33	-4.92 **	-8.67 **	-0.94	-4.94 **	9.20 **	2.89
17	MCM 100 × MTU 1061	4.91 **	1.50	-9.75 **	-11.00 **	3.60 **	-1.01	12.28 **	8.67 **
18	MCM 100 × MTU 7029	11.09 **	7.67 **	-8.14 **	-12.22 **	1.43	-1.19	-4.96	-6.65 *
19	MTU 1121 × MTU 1140	-4.33 **	-4.49 **	-4.23 *	-8.11 **	-2.32 *	-6.47 **	-0.58	-5.56
20	MTU 1121 × MTU 1064	1.08	1.00	-7.92 **	-11.56 **	-4.81 **	-8.65 **	-0.71	-6.44 *
21	MTU 1121 × MTU 1061	5.25 **	1.83	-10.20 **	-11.44 **	-5.58 **	-9.78 **	-10.56 **	-13.44 **
22	MTU 1121 × MTU 7029	4.04 **	0.83	-4.42 *	-8.67 **	4.35 **	1.67	0.38	-1.39
23	MTU 1140 × MTU 1064	2.09	2.00	-7.11 **	-10.78 **	-4.73 **	-5.73 **	-1.06	-6.78 *
24	MTU 1140 × MTU 1061	1.98	-1.33	-6.70 **	-8.00 **	-7.04 **	-7.60 **	-10.45 **	-13.33 **
25	MTU 1140 × MTU 7029	5.25 **	2.00	-6.86 **	-11.00 **	-4.01 **	-11.03 **	-8.57 **	-10.18 **
26	MTU 1064 × MTU 1061	4.57 **	1.17	-6.70 **	-8.00 **	-1.64	-2.23 *	-4.48	-7.56 *
27	MTU 1064 × MTU 7029	2.49	-0.67	-5.58 **	-9.78 **	0.09	-7.23 **	2.67	0.86
28	MTU 1061 × MTU 7029	6.62 **	3.33	-6.63 **	-10.78 **	-3.72 **	-10.77 **	2.02	0.21
	Mean	3.09	1.10	-6.86	-9.97	-0.87	-4.31	2.39	-1.82
	Range	-14.93 to 15.22	-15.00 to 11.67	-12.79 to 9.31	-16.67 to 5.00	-7.04 to 7.40	-11.03 to 6.19	-10.56 to 15.32	-13.44 to 9.56

Table 4.34. (Cont.)

S. No.	Crosses	Kernel elongation ratio		Volume expansion ratio		Water uptake (ml)		Gel consistency (mm)	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	-8.49 **	-14.67 **	-15.45 **	-17.20 **	-6.84 **	-23.46 **	-16.84 **	-17.75 **
2	MTU 1001 × MCM 100	-4.65 **	-12.83 **	-8.51 **	-15.07 **	-15.50 **	-28.94 **	17.37 **	14.06 **
3	MTU 1001 × MTU 1121	0.91	-7.67 **	-18.43 **	-20.20 **	-4.06 *	-12.41 **	48.87 **	40.20 **
4	MTU 1001 × MTU 1140	-5.47 **	-10.67 **	-10.40 **	-13.87 **	-9.38 **	-9.56 **	81.43 **	68.95 **
5	MTU 1001 × MTU 1064	-4.95 **	-10.33 **	-8.78 **	-15.87 **	37.07 **	17.42 **	23.40 **	12.71 **
6	MTU 1001 × MTU 1061	-10.41 **	-14.67 **	-3.47	-5.33 *	15.74 **	1.37	51.93 **	37.94 **
7	MTU 1001 × MTU 7029	-6.36 **	-14.17 **	6.81 **	-4.33	-2.45	-12.76 **	-6.22	-12.05 *
8	BPT 3291 × MCM 100	-7.20 **	-15.17 **	-4.34	-11.20 **	-2.18	-5.03	63.51 **	57.46 **
9	BPT 3291 × MTU 1121	-3.46 *	-11.67 **	-16.05 **	-17.87 **	22.80 **	9.14 **	-26.27 **	-31.17 **
10	BPT 3291 × MTU 1140	-17.11 **	-21.67 **	-19.35 **	-22.47 **	-0.25	-18.24 **	83.21 **	72.09 **
11	BPT 3291 × MTU 1064	-7.24 **	-12.50 **	2.71	-5.27 *	28.44 **	22.02 **	32.78 **	20.25 **
12	BPT 3291 × MTU 1061	-11.99 **	-16.17 **	-1.97	-3.87	27.76 **	18.43 **	-31.97 **	-38.75 **
13	BPT 3291 × MTU 7029	-5.27 **	-13.17 **	5.25 *	-5.73 *	25.60 **	13.91 **	89.17 **	78.98 **
14	MCM 100 × MTU 1121	-6.74 **	-14.67 **	3.68	-4.81	20.73 **	10.30 **	17.91 **	13.94 **
15	MCM 100 × MTU 1140	-7.58 **	-12.67 **	7.59 **	0.43	9.59 **	-7.92 **	3.07	-6.36
16	MCM 100 × MTU 1064	-11.13 **	-16.17 **	9.04 **	6.16 *	32.61 **	29.81 **	-31.05 **	-35.44 **
17	MCM 100 × MTU 1061	-5.34 **	-9.83 **	3.86	-4.85	12.05 **	6.93 *	54.57 **	43.83 **
18	MCM 100 × MTU 7029	-14.36 **	-21.50 **	9.09 **	8.50 **	23.21 **	14.96 **	74.26 **	59.42 **
19	MTU 1121 × MTU 1140	-7.76 **	-12.83 **	-3.33	-7.07 **	-6.29 **	-14.55 **	63.77 **	44.40 **
20	MTU 1121 × MTU 1064	-11.31 **	-16.33 **	-3.36	-10.87 **	19.68 **	11.44 **	-26.49 **	-28.92 **
21	MTU 1121 × MTU 1061	-13.39 **	-17.50 **	-2.72	-4.60	16.94 **	11.61 **	-6.92	-10.57 **
22	MTU 1121 × MTU 7029	-9.64 **	-17.17 **	2.42	-8.27 **	9.00 **	6.47 *	58.44 **	40.63 **
23	MTU 1140 × MTU 1064	-8.48 **	-13.67 **	2.35	-5.60 *	-7.03 **	-20.49 **	-6.17	-19.33 **
24	MTU 1140 × MTU 1061	-10.76 **	-15.00 **	-7.89 **	-9.67 **	3.12	-9.84 **	65.61 **	41.59 **
25	MTU 1140 × MTU 7029	-10.91 **	-18.33 **	-6.07 *	-15.87 **	-8.03 **	-17.90 **	86.77 **	86.20 **
26	MTU 1064 × MTU 1061	-8.14 **	-12.50 **	7.87 **	-1.18	38.33 **	34.67 **	-43.15 **	-43.66 **
27	MTU 1064 × MTU 7029	-6.00 **	-13.83 **	21.91 **	21.25 **	28.70 **	22.43 **	-23.23 **	-33.69 **
28	MTU 1061 × MTU 7029	-12.00 **	-19.33 **	11.57 **	-0.07	21.00 **	18.26 **	2.88	-11.70 **
	Mean	-8.40	-14.52	-1.28	-6.96	11.80	2.43	25.02	15.83
	Range	-17.11 to 0.91	-21.67 to -7.67	-19.35 to 21.91	-22.47 to 21.25	-15.50 to 38.33	-28.94 to 34.67	-43.15 to 89.17	-43.66 to 86.20

Table 4.34. (Cont.)

S. No.	Crosses	Alkali spreading value (mm)		Amylose content (%)		Grain yield per plant (g)	
		Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis	Relative heterosis	Heterobeltiosis
1	MTU 1001 × BPT 3291	-4.87	-14.78 **	-12.83 **	-16.16 **	1.95	-0.86
2	MTU 1001 × MCM 100	5.97	-17.61 **	-4.55 *	-13.07 **	42.94 **	36.43 **
3	MTU 1001 × MTU 1121	-3.13	-26.89 **	-9.00 **	-12.63 **	22.70 **	19.92 **
4	MTU 1001 × MTU 1140	-8.37 **	-19.44 **	5.05 **	3.17	87.04 **	70.27 **
5	MTU 1001 × MTU 1064	-17.22 **	-17.61 **	-8.04 **	-9.52 **	52.07 **	46.39 **
6	MTU 1001 × MTU 1061	-7.39 **	-7.39 *	-14.63 **	-17.97 **	49.09 **	45.14 **
7	MTU 1001 × MTU 7029	-8.91 **	-28.72 **	-15.37 **	-20.43 **	-23.61 **	-26.25 **
8	BPT 3291 × MCM 100	-37.25 **	-47.73 **	28.08 **	21.22 **	-6.54	-13.30 *
9	BPT 3291 × MTU 1121	-15.93 **	-32.27 **	-2.55	-2.56	-4.27	-4.95
10	BPT 3291 × MTU 1140	-41.85 **	-44.47 **	-7.23 **	-9.36 **	44.60 **	28.14 **
11	BPT 3291 × MTU 1064	-8.62 **	-15.87 **	-16.21 **	-18.28 **	11.79 *	4.57
12	BPT 3291 × MTU 1061	-12.18 **	-19.50 **	29.99 **	29.87 **	24.41 **	17.64 **
13	BPT 3291 × MTU 7029	36.43 **	14.47 **	-4.06 *	-6.12 **	-24.00 **	-24.42 **
14	MCM 100 × MTU 1121	-17.45 **	-18.21 **	36.95 **	30.98 **	-16.78 **	-22.84 **
15	MCM 100 × MTU 1140	-30.77 **	-42.56 **	-15.27 **	-20.73 **	74.47 **	67.24 **
16	MCM 100 × MTU 1064	20.46 **	-9.37 **	-6.41 **	-12.59 **	36.89 **	34.63 **
17	MCM 100 × MTU 1061	-20.96 **	-40.72 **	-17.67 **	-21.32 **	23.63 **	20.23 **
18	MCM 100 × MTU 7029	-18.31 **	-23.01 **	-1.94	-4.19	10.67	1.42
19	MTU 1121 × MTU 1140	-7.28	-23.08 **	-11.29 **	-13.33 **	31.49 **	16.52 **
20	MTU 1121 × MTU 1064	16.81 **	-12.11 **	1.73	-0.79	-14.53 *	-20.05 **
21	MTU 1121 × MTU 1061	9.85 **	-17.61 **	-10.06 **	-10.14 **	-12.45 *	-17.21 **
22	MTU 1121 × MTU 7029	51.28 **	42.58 **	37.31 **	34.36 **	-14.13 *	-14.60 *
23	MTU 1140 × MTU 1064	-49.25 **	-53.28 **	-14.46 **	-14.81 **	39.16 **	30.46 **
24	MTU 1140 × MTU 1061	-17.15 **	-24.06 **	1.93	-0.10	36.35 **	26.46 **
25	MTU 1140 × MTU 7029	7.27 *	-10.00 **	-7.81 **	-11.63 **	67.72 **	47.05 **
26	MTU 1064 × MTU 1061	-56.44 **	-56.44 **	-15.27 **	-16.96 **	-8.60	-8.72
27	MTU 1064 × MTU 7029	11.25 **	-12.94 **	23.07 **	17.97 **	-30.78 **	-34.96 **
28	MTU 1061 × MTU 7029	24.25 **	-2.78	1.29	-0.88	6.83	0.37
	Range	-56.44 to 51.28	-56.44 to 42.56	-17.67 to 37.31	-21.32 to 34.36	-30.78 to 87.04	-34.96 to 70.27

* Significant at 5% level

** Significant at 1% level

Table 4.35. The best heterotic combinations identified for yield, yield contributing characters and quality traits of F₁s ratoon in rice (*Oryza sativa* L.) based on overall performance

S. No.	Characters	Crosses combinations	Per se performance	sca effects	Relative heterosis	Hetero-beltiosis
1	Days to 50% flowering	MTU 1001 × MTU 1061	55.67	-6.011**	-11.64 **	-15.66 **
		MTU 1001 × MTU 7029	56.00	-3.644**	-7.69 **	-8.70 **
		BPT 3291 × MTU 1064	59.00	-2.344*	-6.60 **	-11.06 **
		MCM 100 × MTU 1064	60.33	-3.378**	-6.70 **	-9.05 **
2	Days to maturity	MTU 1001 × MTU 1061	84.00	-6.337**	-8.86 **	-14.58 **
		MTU 1001 × MTU 7029	82.67	-4.304**	-7.29 **	-10.47 **
		BPT 3291 × MTU 1064	86.67	-4.537**	-8.13 **	-12.16 **
3	Plant height (cm)	MTU 1001 × MTU 7029	89.75	- 12.493**	-9.86 **	-12.13 **
		BPT 3291 × MTU 7029	85.05	- 13.795**	-12.84 **	-16.74 **
		MTU 1121 × MTU 1064	96.63	-7.614**	-4.79 **	-7.97 **
4	Total number of tillers per plant	MTU 1001 × MTU 1140	11.67	1.963**	22.81 **	16.67 *
		BPT 3291 × MTU 1061	11.33	1.396**	21.43 **	17.24 *
		MCM 100 × MTU 7029	11.33	1.663**	17.24 *	13.33
5	Number of ratoon tillers as percentage of main crop tillers	MCM 100 × MTU 7029	65.47	1.538	-14.35	-19.17 *
		MTU 1140 × MTU 7029	62.80	0.596	-13.31	-13.97
6	Number of vegetative buds after the harvest of main crop	MTU 1001 × MTU 1140	13.00	1.333**	13.04 *	8.33
		BPT 3291 × MTU 1121	12.00	1.033*	12.50 *	5.88
		BPT 3291 × MTU 1061	12.67	1.267**	15.15 **	5.56
7	Number of ear bearing tillers per plant	MTU 1001 × MTU 1140	9.00	1.452**	45.95 **	42.11 **
		MCM 100 × MTU 1140	8.33	0.485	25.00 **	19.05 *
		MTU 1140 × MTU 7029	8.67	1.752**	44.44 **	44.44 **
8	Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers	MTU 1140 × MTU 7029	72.32	15.083**	23.24 *	18.56
9	Panicle length per plant (cm)	BPT 3291 × MTU 1140	30.30	2.840**	23.26 **	20.39 **
		MCM 100 × MTU 1140	33.14	3.025**	32.10 **	31.65 **
		MTU 1140 × MTU 1061	31.44	1.713*	22.33 **	19.09 **
10	Number of grains per panicle	MTU 1001 × BPT 3291	161.09	12.842*	45.32 **	42.92 **
		BPT 3291 × MTU 7029	162.60	16.637**	41.55 **	39.27 **
		MCM 100 × MTU 1140	222.28	33.239**	43.27 **	30.53 **
11	Test weight (gm)	MTU 1001 × MCM 100	23.78	2.772**	28.11 **	18.92 **
		BPT 3291 × MCM 100	22.04	2.308**	25.50 **	22.46 **
		MTU 1121 × MTU 1064	21.56	2.069**	19.42 **	19.08 **

Table 4.35. (Cont.)

S. No.	Characters	Crosses combinations	Per se performance	sca effects	Relative heterosis	Hetero-beltiosis
12	Leaf area index (LAI) at maximum tillering stage	MTU 1001 × BPT 3291	2.57	0.807**	57.55 **	28.67 **
		BPT 3291 × MTU 1140	2.62	0.418**	67.98 **	23.55 **
		MTU 1140 × MTU 7029	2.22	0.214**	25.66 **	11.00 *
13	Hulling percentage	MTU 1001 × BPT 3291	80.23	2.092**	5.08 **	4.19 **
		BPT 3291 × MTU 1064	81.02	2.076**	4.89 **	3.23 **
		MTU 1064 × MTU 7029	80.30	1.798**	4.29 **	2.94 **
14	Milling percentage	MTU 1001 × BPT 3291	75.52	1.678*	7.62 **	7.35 **
		MTU 1001 × MTU 1140	76.89	3.241**	8.38 **	6.96 **
		BPT 3291 × MTU 1064	75.42	2.715**	7.09 **	6.44 **
15	Head rice recovery	MTU 1001 × BPT 3291	71.57	1.645**	5.48 **	5.25 **
		MTU 1001 × MTU 1140	72.35	1.550**	4.95 **	3.55 **
		MTU 1064 × MTU 7029	70.51	2.366**	5.55 **	3.69 **
16	Kernel length (mm)	BPT 3291 × MTU 1140	5.97	0.502**	13.40 **	8.03 **
		MCM 100 × MTU 7029	5.67	0.297**	11.99 **	10.68 **
17	Kernel breadth (mm)	MTU 1001 × MTU 1061	2.13	0.106**	10.08 **	6.50 **
		MTU 1001 × MTU 7029	2.23	0.178**	15.22 **	11.67 **
		MCM 100 × MTU 7029	2.15	0.127**	11.09 **	7.67 **
18	Kernel L/B ratio	MTU 1001 × MTU 1061	2.66	-0.088*	-10.20 **	-11.44 **
		MTU 1001 × MTU 7029	2.50	-0.0180**	-12.79 **	-16.67 **
		MTU 1121 × MTU 1061	2.66	-0.084*	-10.20 **	-11.44 **
19	Kernel length after cooking (mm)	BPT 3291 × MTU 1121	9.78	0.546**	7.40 **	6.19 **
		BPT 3291 × MTU 7029	9.41	0.372**	7.28 **	4.52 **
20	Kernel breadth after cooking (mm)	BPT 3291 × MTU 1061	3.27	0.283**	12.63 **	9.00 **
		MCM 100 × MTU 1140	3.29	0.325**	15.32 **	9.56 **
		MCM 100 × MTU 1061	3.26	0.286**	12.28 **	8.67 **
21	Volume expansion ratio	MTU 1064 × MTU 7029	4.85	0.357**	21.91 **	21.25 **
22	Water uptake (ml)	MTU 1001 × MTU 1064	285.33	55.256**	37.07 **	17.42 **
		MCM 100 × MTU 1064	225.00	22.239**	32.61 **	29.81 **
		MTU 1064 × MTU 1061	246.00	24.006**	38.33 **	34.67 **
23	Gel consistency (mm)	BPT 3291 × MTU 7029	94.86	28.954**	89.17 **	78.98 **
		MTU 1140 × MTU 7029	88.05	15.737**	86.77 **	86.20 **
24	Alkali spreading value (mm)	BPT 3291 × MTU 7029	5.72	1.324	36.43 **	14.47 **
		MTU 1121 × MTU 7029	4.83	0.840**	51.28 **	42.58 **
25	Amylose content (%)	MCM 100 × MTU 1121	30.13	6.747**	36.95 **	30.98 **
		MTU 1121 × MTU 7029	30.90	6.564**	37.31 **	34.36 **
26	Grain yield per plant (gm)	MTU 1001 × MTU 1140	35.27	7.087**	87.04 **	70.27 **
		MCM 100 × MTU 1140	34.65	6.573**	74.47 **	67.24 **
		MTU 1140 × MTU 7029	30.88	7.434**	67.72 **	47.05 **

Table 4.37. Genotypic (rg) correlation among grain yield, yield contributing and quality characters of F₁ ratoon in rice (*Oryza sativa* L.)

S.No	Characters	DFF	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TPTP	NRTPPM CPT	PL (cm)	NGPP	TW (g)	LAI	HP	MP	HRR	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)	
1	DFF	r _g	1.000	0.968**	0.521**	0.220	0.059	0.159	0.559**	0.565**	0.481**	0.372**	0.165	0.609**	0.305**	-0.211*	0.233*	-0.233*	-0.327**	0.197*	-0.050	-0.256**	0.144	0.052	-0.065	-0.087	-0.059	0.052	0.484**
2	DM	r _g		1.000	0.564**	0.246*	0.077	0.157	0.594**	0.563**	0.508**	0.430**	0.110	0.552**	0.329**	-0.199*	0.261**	-0.222*	-0.338**	0.225*	-0.005	-0.237**	0.181	-0.055	-0.060	-0.116	-0.211	-0.032	0.495**
3	PH	r _g			1.000	0.603**	-0.345**	0.138	0.673**	0.245**	0.871**	0.627**	0.435**	0.514**	0.477**	0.260**	0.471**	0.144	-0.009	0.095	-0.104	0.020	-0.215*	-0.233*	0.161	0.328**	-0.349**	-0.051	0.676**
4	TNTP	r _g				1.000	-0.217*	0.910**	0.826**	0.452**	0.380**	0.453**	0.125	0.310**	0.390**	0.292**	0.297**	0.027	0.177	-0.213	-0.054	0.158	-0.085	-0.113	0.086	0.273**	-0.286*	0.104	0.596**
5	NRTPMCPT	r _g					1.000	0.073	0.056	0.727**	-0.614**	-0.531**	-0.496**	0.016	-0.370**	-0.651**	-0.523**	0.046	-0.320**	0.419**	0.100	-0.550**	0.057	0.123	-0.382**	-0.182	0.164	0.117	-0.165
6	NVGBAHMC	r _g						1.000	0.612**	0.326**	0.024	0.106	-0.048	0.157	0.033	0.167	0.000	-0.004	0.442**	-0.553**	0.035	0.300**	0.028	-0.149	-0.015	-0.094	-0.237**	-0.045	0.357**
7	TEBTP	r _g							1.000	0.751**	0.622**	0.579**	0.196*	0.598**	0.371**	0.159	0.499**	-0.042	-0.141	0.143	0.103	-0.095	0.159	-0.257	0.126	0.235*	-0.042	-0.191*	0.935**
8	NRTPMCT	r _g								1.000	0.098	0.150	-0.230*	0.442**	-0.001	-0.278**	0.147	-0.159	-0.414**	0.387**	0.167	-0.342**	0.318**	-0.025	-0.147	0.017	0.187	-0.163	0.635**
9	PL	r _g									1.000	0.620**	0.433**	0.359**	0.440**	0.190*	0.461**	-0.054	-0.045	-0.001	-0.192*	0.070	-0.150	-0.107	0.381**	0.189*	-0.332**	-0.073	0.597**
10	NGPP	r _g										1.000	0.355**	0.567**	0.623**	0.467**	0.588**	-0.011	0.105	-0.141	0.135	0.364**	0.168	-0.044	0.143	0.351**	-0.200*	-0.221*	0.688**
11	TW	r _g											1.000	0.514**	0.336**	0.558**	0.617**	0.118	0.112	-0.053	0.075	-0.094	0.018	-0.276**	0.056	0.286**	-0.053	0.007	0.469**
12	LAI	r _g												1.000	0.431**	0.283*	0.581**	-0.036	-0.164	0.158	0.082	-0.107	0.139	-0.305**	-0.092	0.102	-0.025	-0.116	0.720**
13	HP	r _g													1.000	0.612**	0.753**	0.185	0.258**	-0.198*	0.108	0.190	-0.022	0.077	0.099	0.102	-0.158	0.016	0.367**
14	MP	r _g														1.000	0.751**	0.252*	0.301**	-0.171	0.285**	0.340**	0.133	-0.342**	0.108	0.490**	-0.079	-0.149	0.349**
15	HRR	r _g															1.000	0.108	0.192*	-0.167	0.320**	0.118	0.284**	-0.098	0.079	0.106	-0.066	-0.268**	0.604**
16	KL	r _g																1.000	0.601**	-0.003	0.483**	-0.011	-0.276**	0.002	0.181	0.175	0.123	-0.108	-0.079
17	KB	r _g																	1.000	-0.798**	0.216*	0.345**	-0.255**	0.091	0.064	0.081	-0.026	-0.146	-0.121
18	L/B ratio	r _g																		1.000	0.104	-0.453**	0.126	-0.115	0.083	0.029	0.128	0.086	0.090
19	KLAC	r _g																			1.000	-0.130	0.708**	0.054	0.216*	0.090	0.289**	-0.165	0.041
20	KBAC	r _g																				1.000	-0.134	0.025	-0.017	0.037	-0.182	0.134	0.007
21	KLER	r _g																					1.000	0.045	0.092	-0.027	0.214*	-0.098	0.128
22	VER	r _g																						1.000	0.218*	-0.211*	0.274**	0.122	-0.280**
23	WU	r _g																							1.000	-0.072	0.169	0.038	0.120
24	GC	r _g																								1.000	-0.061	-0.027	0.328**
25	ASV	r _g																									1.000	0.131	-0.123
26	AC	r _g																										1.000	-0.283**
27	GYPP	r _g																											1.000

* Significant at 5% level

** Significant at 1% level

G: Genotypic level

DFD: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCET: Number of ratoon productive tillers as percentage of main crop productive tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.5. Phenotypic correlations among grain yield, yield contributing and quality characters in rice (*Oryza sativa* L.)

Characters		DDF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DDF	r _p	1.000	0.957**	0.333**	0.142	-0.263*	0.168	0.369**	-0.683**	0.107	0.244	0.214	0.227	-0.435**	-0.272*	-0.017	-0.318*	-0.397**	0.143	-0.372**	-0.099	0.110	-0.315*	0.069	-0.313*
DM	r _p		1.000	0.336**	0.148	-0.237	0.170	0.344**	-0.677**	0.146	0.231	0.193	0.228	-0.372**	-0.234	-0.019	-0.299*	-0.343**	0.125	-0.407**	-0.098	0.122	-0.319*	0.089	-0.294*
PH	r _p			1.000	0.378**	0.072	0.592**	0.239	-0.021	0.114	-0.005	-0.010	0.302*	-0.008	0.012	-0.053	0.233	-0.213	0.160	-0.033	0.440**	0.333**	0.031	0.442**	0.213
TNTP	r _p				1.000	0.236	0.165	0.478**	-0.236	0.392 **	0.146	0.146	0.264*	0.116	-0.229	0.400**	0.185	-0.303*	0.273*	-0.005	0.097	0.165	-0.013	0.180	0.304*
EBTP	r _p					1.000	0.161	0.206	0.187	0.411**	0.145	0.282*	0.568**	0.289*	0.157	0.018	0.512**	0.253	0.314*	0.233	0.205	0.388**	0.373**	-0.239	0.488**
PL	r _p						1.000	0.165	0.178	0.130	-0.093	0.008	0.222	0.277*	0.308*	-0.205	0.102	-0.129	-0.074	0.052	0.179	0.233	0.131	0.017	0.263*
NGPP	r _p							1.000	-0.531**	0.472**	0.487**	0.324*	0.228	-0.205	-0.695**	0.761**	0.085	-0.634**	0.568**	-0.032	-0.211	0.335**	-0.238	0.149	0.203
TW	r _p								1.000	-0.153	-0.466**	-0.274*	-0.154	0.528**	0.598**	-0.361**	0.529**	0.503**	-0.223	0.317*	0.343**	-0.069	0.635**	-0.061	0.411**
LAI	r _p									1.000	0.191	0.373 **	0.380**	0.212	-0.165	0.390**	0.376**	-0.108	0.350**	0.070	-0.335**	0.069	0.077	0.031	0.501**
HP	r _p										1.000	0.316 *	0.204	-0.378**	-0.506**	0.370**	-0.150	-0.367**	0.137	-0.107	-0.141	0.350**	-0.260*	0.021	-0.077
MP	r _p											1.000	0.548**	-0.011	-0.199	0.260 *	0.207	-0.376**	0.341**	0.137	-0.304*	-0.084	0.031	-0.269*	-0.046
HRR	r _p												1.000	0.080	0.069	-0.047	0.362**	-0.095	0.372**	0.096	0.061	0.332**	0.112	-0.176	0.101
KL	r _p													1.000	0.679**	-0.104	0.252	0.289*	-0.348**	-0.098	0.144	0.192	0.246	-0.128	0.420**
KB	r _p														1.000	-0.799**	0.073	0.612**	-0.562**	0.022	0.313*	0.023	0.338**	-0.221	0.116
L/B	r _p															1.000	0.117	-0.586**	0.476**	-0.074	-0.315*	0.090	-0.242	0.189	0.182
KLAC	r _p																1.000	0.070	0.550**	0.427**	0.193	0.022	0.673**	0.062	0.479**
KBAC	r _p																	1.000	-0.284*	0.095	0.245	-0.126	0.361**	-0.221	0.186
KLER	r _p																		1.000	0.377**	-0.124	-0.008	0.245	0.058	0.152
VER	r _p																			1.000	-0.055	-0.384**	0.266*	-0.193	0.173
WU	r _p																				1.000	0.239	0.351**	0.296*	0.134
GC	r _p																					1.000	0.004	0.185	0.197
ASV	r _p																						1.000	-0.003	0.369**
AC	r _p																							1.000	0.094
GYPP	r _p																								1.000

* Significant at 5% level

** Significant at 1% level

r_p: Phenotypic level

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.4. Genotypic (rg) correlation among grain yield, yield contributing and quality characters in rice (Oryza sativa L.)

Characters		DFF	DM	PH (cm)	TNTP	EBTP	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DFF	r _g	1.000	0.983**	0.377**	0.270*	-0.260*	0.205	0.412**	-0.735**	0.129	0.334**	0.259*	0.238	-0.457**	-0.295*	-0.008	-0.338**	-0.458**	0.153	-0.476**	-0.125	0.108	-0.341**	0.130	-0.370**
DM	r _g		1.000	0.418**	0.255*	-0.277*	0.234	0.414**	-0.728**	0.158	0.300*	0.279*	0.254*	-0.410**	-0.281*	0.008	-0.353**	-0.468**	0.122	-0.540**	-0.109	0.131	-0.348**	0.140	-0.356**
PH	r _g			1.000	0.479**	0.061	0.663**	0.267*	-0.02	0.141	0.060	-0.078	0.388**	0.015	0.019	-0.048	0.257*	-0.332**	0.156	-0.078	0.488**	0.365**	0.028	0.504**	0.272*
TNTP	r _g				1.000	0.238	0.235	0.615**	-0.287*	0.481**	0.189	0.192	0.361**	0.121	-0.286*	0.490**	0.269*	-0.389**	0.425**	0.041	0.096	0.194	-0.013	0.152	0.527**
EBTP	r _g					1.000	0.141	0.218	0.235	0.461**	0.241	0.477**	0.737**	0.363**	0.201	0.023	0.611**	0.205	0.382**	0.354**	0.217	0.469**	0.459**	-0.300	0.657
PL	r _g						1.000	0.189	0.212	0.163	-0.031	0.138	0.211	0.346**	0.358**	-0.224	0.135	-0.215	-0.102	0.072	0.176	0.279*	0.156	0.049	0.425**
NGPP	r _g							1.000	-0.583**	0.500*	0.701**	0.491**	0.248	-0.219	-0.735**	0.811**	0.100	-0.841**	0.628**	-0.037	-0.244	0.343**	-0.252	0.189	0.238
TW	r _g								1.000	-0.159	-0.602**	-0.353**	-0.169	0.543**	0.623**	-0.383**	0.565**	0.621**	-0.224	0.382**	0.347**	-0.077	0.651**	-0.041	0.523**
LAI	r _g									1.000	0.254*	0.498**	0.412**	0.217	-0.168	0.402**	0.388**	-0.135	0.366**	0.091	-0.347**	0.075	0.077	0.020	0.671**
HP	r _g										1.000	0.318*	0.247	-0.508**	-0.632**	0.436**	-0.196	-0.627**	0.213	-0.078	-0.175	0.485**	-0.306*	0.066	-0.174
MP	r _g											1.000	0.714**	-0.005	-0.215	0.301*	0.312*	-0.445**	0.487**	0.243	-0.416**	-0.106	0.039	-0.498**	-0.097
HRR	r _g												1.000	0.085	0.074	-0.053	0.410**	-0.088	0.425**	0.134	0.058	0.350**	0.122	-0.258*	0.236
KL	r _g													1.000	0.690**	-0.117	0.264**	0.379**	-0.346**	-0.122	0.146	0.193	0.250	-0.144	0.591**
KB	r _g														1.000	-0.798**	0.072	0.718**	-0.595**	-0.035	0.325*	0.015	0.342**	-0.269*	0.195
L/B	r _g															1.000	0.130	-0.672**	0.525**	-0.018	-0.331**	0.102	-0.247	0.240	0.220
KLAC	r _g																1.000	0.095	0.536**	0.513**	0.220	0.025	0.693**	0.042	0.733**
KBAC	r _g																	1.000	-0.372**	0.080	0.335**	-0.153	0.468**	-0.301*	0.252*
KLER	r _g																		1.000	0.458**	-0.112	-0.008	0.256*	0.033	0.276*
VER	r _g																			1.000	-0.060	-0.471**	0.296*	-0.263*	0.252*
WU	r _g																				1.000	0.237	0.363**	0.371**	0.168
GC	r _g																					1.000	0.005	0.222	0.312*
ASV	r _g																						1.000	-0.014	0.510**
AC	r _g																							1.000	0.278*
GYPP	r _g																								1.000

* Significant at 5% level

** Significant at 1% level

r_g: Genotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.6. Genotypic (G) direct and indirect effects of different traits on grain yield in rice (*Oryza sativa* L.)

Characters	DDF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DDF	4.041	-0.342	0.588	0.005	-0.124	-0.580	0.487	-3.154	-0.247	1.228	-0.289	0.376	-9.191	7.592	0.135	0.925	-0.302	-0.021	-0.974	0.224	-0.315	-0.597	0.164	-0.370**
DM	4.100	-0.337	0.653	0.004	-0.132	-0.661	0.489	-3.123	-0.303	1.104	-0.311	0.401	-8.235	7.216	-0.140	0.967	-0.308	-0.017	-1.103	0.196	-0.382	-0.610	0.177	-0.356**
PH	1.523	-0.141	1.561	0.008	0.029	-1.874	0.315	-0.086	-0.271	0.222	0.087	0.613	0.302	-0.499	0.842	-0.704	-0.218	-0.021	-0.160	-0.874	-1.068	0.049	0.638	0.272*
TNT	1.092	-0.086	0.747	0.017	0.113	-0.664	0.726	-1.230	-0.921	0.695	-0.214	0.571	2.429	7.355	-8.564	-0.736	-0.256	-0.059	0.083	-0.172	-0.568	-0.023	0.192	0.527**
EBT	-1.051	0.093	0.096	0.004	0.475	-0.399	0.258	1.007	-0.883	0.886	-0.531	1.164	7.293	-5.163	-0.394	-1.671	0.135	-0.053	0.724	-0.389	-1.369	0.805	-0.380	0.657**
PL	0.829	-0.079	1.035	0.004	0.067	-2.827	0.223	0.908	-0.313	-0.115	-0.153	0.333	6.943	-9.195	3.909	-0.369	-0.142	0.014	0.147	-0.315	-0.814	0.273	0.063	0.425**
NGP	1.665	-0.139	0.416	0.011	0.104	-0.534	1.181	-2.501	-0.958	2.581	-0.547	0.391	-4.394	18.892	-14.171	-0.274	-0.554	-0.086	-0.076	0.437	-1.003	-0.442	0.238	0.238
TW	-2.969	0.245	-0.031	-0.005	0.111	-0.598	-0.688	4.292	0.305	-2.218	0.393	-0.267	10.918	-16.022	6.694	-1.547	0.409	0.031	0.780	-0.622	0.224	1.141	-0.052	0.523**
LAI	0.521	-0.053	0.221	0.008	0.219	-0.462	0.590	-0.682	-1.917	0.935	-0.555	0.651	4.362	4.319	-7.033	-1.063	-0.089	-0.050	0.186	0.622	-0.218	0.134	0.026	0.671**
HP	1.348	-0.101	0.094	0.003	0.114	0.089	0.828	-2.585	-0.486	3.684	-0.354	0.390	-10.207	16.260	-7.628	0.536	-0.413	-0.029	-0.160	0.313	-1.418	-0.536	0.083	-0.174
MP	1.046	-0.094	-0.121	0.003	0.226	-0.389	0.580	-1.513	-0.955	1.169	-1.115	1.128	-0.105	5.525	-5.262	-0.853	-0.293	-0.067	0.496	0.747	0.311	0.067	-0.630	-0.097
HRR	0.963	-0.086	0.606	0.006	0.350	-0.597	0.293	-0.725	-0.790	0.910	-0.796	1.579	1.701	-1.905	0.931	-1.122	-0.058	-0.058	0.273	-0.105	-1.022	0.214	-0.326	0.236
KL	-1.848	0.138	0.023	0.002	0.172	-0.977	-0.258	2.332	-0.416	-1.871	0.006	0.134	20.096	-17.749	2.053	-0.722	0.249	0.048	-0.250	-0.262	-0.565	0.437	-0.182	0.591**
KB	-1.193	0.095	0.030	-0.005	0.095	-1.011	-0.868	2.674	0.322	-2.329	0.239	0.117	13.869	-25.717	13.957	-0.197	0.472	0.082	-0.072	-0.583	-0.044	0.600	-0.340	0.195
L/B	-0.031	-0.003	-0.075	0.009	0.011	0.632	0.957	-1.644	-0.771	1.607	-0.336	-0.084	-2.360	20.532	-17.482	-0.356	-0.442	-0.072	-0.038	0.593	-0.299	-0.433	0.304	0.220
KLAC	-1.366	0.119	0.401	0.005	0.290	-0.381	0.118	2.427	-0.744	-0.722	-0.347	0.647	5.302	-1.848	-2.272	-2.737	0.063	-0.074	1.050	-0.394	-0.074	1.215	0.053	0.733**
KBAC	-1.852	0.158	-0.518	-0.007	0.097	0.608	-0.993	2.664	0.259	-2.311	0.496	-0.139	7.611	-18.457	11.741	-0.260	0.658	0.051	0.163	-0.601	0.447	0.820	-0.381	0.252*
ER	0.618	-0.041	0.243	0.007	0.181	0.287	0.742	-0.960	-0.701	0.786	-0.542	0.671	-6.946	15.310	-9.182	-1.466	-0.245	-0.138	0.936	0.201	0.022	0.449	0.042	0.276*
VER	-1.924	0.182	-0.122	0.001	0.168	-0.204	-0.044	1.638	-0.174	-0.287	-0.271	0.211	-2.452	0.910	0.322	-1.405	0.052	-0.063	2.045	0.107	1.375	0.519	-0.333	0.252*
WU	-0.506	0.037	0.761	0.002	0.103	-0.497	-0.288	1.489	0.665	-0.644	0.464	0.092	2.938	-8.365	5.784	-0.601	0.221	0.015	-0.122	-1.793	-0.692	0.636	0.469	0.168
GC	0.436	-0.044	0.570	0.003	0.223	-0.788	0.405	-0.329	-0.143	1.788	0.119	0.553	3.887	-0.388	-1.789	-0.069	-0.101	0.001	-0.963	-0.425	-2.921	0.008	0.280	0.312*
ASV	-1.377	0.117	0.043	0.000	0.218	-0.440	-0.298	2.794	-0.147	-1.127	-0.043	0.193	5.013	-8.806	4.318	-1.897	0.308	-0.035	0.605	-0.651	-0.013	1.753	-0.018	0.510**
AC	0.524	-0.047	0.787	0.003	-0.143	-0.140	0.223	-0.177	-0.039	0.243	0.555	-0.407	-2.886	6.905	-4.195	-0.115	-0.198	-0.005	-0.538	-0.665	-0.647	-0.024	1.265	0.278*

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.2792

DDF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNT: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g)

Table 4.10. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of ratoon crop in rice (*Oryza sativa* L.)

S.No.	Characters		DFD	DM	PH (cm)	TNTP	NRTPMC T	NVBAHM C	TPTP	NRTPM CPT	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_p	1.000	0.921**	0.422**	0.279*	0.072	0.211	0.537**	0.440**	0.378**	0.538**	-0.314*	0.191	-0.115	0.316*	0.350**	-0.129	-0.404**	0.326*	0.326*	-0.023	0.475**	0.177	-0.037	0.189	0.053	-0.058	0.527**
2	DM	r_p		1.000	0.388**	0.330**	0.123	0.272*	0.470**	0.372**	0.357**	0.565**	-0.401**	0.228	-0.124	0.402**	0.372**	-0.233	-0.415**	0.250	0.258*	-0.070	0.495**	0.186	-0.117	0.251	0.050	-0.028	0.452**
3	PH	r_p			1.000	0.355**	0.174	0.298*	0.286*	0.307*	0.584**	0.157	-0.023	0.233	-0.009	0.188	0.333**	0.147	-0.124	0.254	0.283*	0.005	0.187	0.331*	0.296*	0.448**	0.236	0.245	0.296*
4	TNTP	r_p				1.000	0.845**	0.859**	0.536**	0.596**	0.200	0.274*	-0.079	-0.006	-0.105	0.265*	0.507**	0.156	-0.081	0.211	0.541**	-0.061	0.471**	0.182	0.085	0.306*	0.174	0.193	0.485**
5	NRTPMCPT	r_p					1.000	0.746**	0.482**	0.589**	0.098	0.081	0.026	-0.126	-0.040	0.307*	0.519**	0.163	0.109	0.013	0.392**	0.041	0.288*	0.150	0.067	0.200	0.143	0.145	0.470**
6	NVGBAHMC	r_p						1.000	0.434**	0.441**	0.113	0.122	-0.025	-0.090	-0.010	0.208	0.489**	0.259*	-0.012	0.228	0.505**	-0.125	0.342**	0.145	0.072	0.249	0.292*	0.141	0.399**
7	TEBTP	r_p							1.000	0.872**	0.277*	0.292*	0.184	-0.013	-0.013	0.291*	0.559**	0.284*	0.031	0.185	0.556**	0.173	0.363**	0.087	0.037	0.378**	0.288*	-0.118	0.860**
8	NRTPMCCT	r_p								1.000	0.314*	0.290*	0.138	-0.029	-0.010	0.252	0.508**	0.174	0.024	0.102	0.487**	0.129	0.382**	0.149	0.099	0.293*	0.201	0.125	0.754**
9	PL	r_p									1.000	0.053	-0.226	-0.133	-0.108	0.165	0.374**	-0.072	-0.146	0.096	-0.122	0.167	-0.090	0.318*	-0.103	0.617**	-0.165	0.190	0.266*
10	NGPP	r_p										1.000	-0.494**	0.157	-0.208	0.491**	0.320*	-0.361**	-0.636**	0.368**	0.230*	-0.459**	0.665**	0.007	0.039	0.074	-0.116	-0.054	0.275*
11	TW (g)	r_p											1.000	-0.149	0.217	-0.433**	-0.181	0.739**	0.676**	-0.114	0.330**	0.416**	-0.282*	-0.067	0.349**	-0.122	0.375**	-0.107	0.293*
12	LAI	r_p												1.000	0.257*	0.223	0.079	-0.170	-0.062	-0.089	-0.085	0.034	0.071	0.010	0.012	-0.234	0.272*	-0.114	-0.024
13	HL%	r_p													1.000	-0.102	0.079	0.119	0.075	0.006	0.006	0.096	-0.098	0.007	-0.095	-0.162	0.344**	-0.021	-0.063
14	ML%	r_p														1.000	0.698**	-0.299*	-0.309*	0.070	0.002	-0.248	0.259*	-0.016	-0.315*	0.192	-0.127	-0.121	0.302*
15	HRR%	r_p															1.000	0.093	-0.225	0.297*	0.320*	-0.064	0.262*	0.081	-0.261*	0.417**	-0.030	-0.018	0.519**
16	KL (mm)	r_p																1.000	0.452**	0.338**	0.539**	0.322*	-0.277*	-0.041	0.375**	0.057	0.383**	-0.165	0.396**
17	KB (mm)	r_p																	1.000	-0.685**	-0.060	0.595**	-0.479**	-0.131	0.170	-0.237	0.279*	-0.019	0.150
18	L/B ratio	r_p																		1.000	0.505**	-0.361**	0.281*	0.100	0.127	0.289*	0.010	-0.112	0.154
19	KLAC (mm)	r_p																			1.000	-0.022	0.659**	-0.047	0.305*	0.100	0.242	-0.042	0.590**
20	KBAC (mm)	r_p																				1.000	-0.322*	-0.134	-0.055	-0.080	0.005	-0.242	0.201
21	KLER	r_p																					1.000	-0.014	0.017	0.054	-0.058	0.089	0.300*
22	VER	r_p																						1.000	-0.009	0.164	-0.009	0.158	0.067
23	WU (ml)	r_p																							1.000	-0.150	0.583**	0.239	0.171
24	GC (mm)	r_p																								1.000	-0.113	0.090	0.297*
25	ASV (mm)	r_p																									1.000	0.035	0.257*
26	AC (%)	r_p																										1.000	-0.079
27	GYPP (g)	r_p																											1.000

r_p : Phenotypic level

* Significant at 5% level

** Significant at 1% level

DFD: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth; L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.11. Genotypic (r_g) correlation among grain yield, yield contributing and quality characters of ratoon crop in rice (*Oryza sativa* L.)

S. No	Characters		DFF	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TPTP	NRTPM CPT	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_g	1.000	0.998**	0.478**	0.416**	0.149	0.376**	0.600**	0.568**	0.413**	0.619**	-0.351**	0.288*	-0.165	0.400**	0.416**	-0.175	-0.441**	0.406**	0.346**	0.001	0.580**	0.305*	-0.056	0.199	0.050	-0.060	0.547**
2	DM	r_g		1.000	0.492**	0.456**	0.170	0.407**	0.591**	0.579**	0.451**	0.651**	-0.480**	0.383**	-0.124	0.467**	0.455**	-0.242	-0.531**	0.458**	0.309*	-0.055	0.593**	0.146	-0.127	0.285*	0.068	-0.092	0.500**
3	PH	r_g			1.000	0.477**	0.215	0.441**	0.352**	0.446**	0.658**	0.205	-0.022	0.261	-0.001	0.225	0.399**	0.177	-0.162	0.355**	0.316*	0.002	0.247	0.713**	0.330**	0.489**	0.258*	0.360**	0.326*
4	TNTP	r_g				1.000	0.864**	0.999**	0.699**	0.828**	0.307*	0.446**	-0.080	0.065	-0.047	0.322*	0.672**	0.302*	-0.165	0.469**	0.733**	-0.125	0.666**	0.184	0.154	0.416**	0.235	0.297*	0.633**
5	NRTPMCPT	r_g					1.000	0.860**	0.763**	0.949**	0.228*	0.278*	0.084	-0.171	0.095	0.439**	0.787**	0.387**	0.078	0.224	0.620**	0.036	0.436**	-0.013	0.140	0.321*	0.256*	0.349**	0.709**
6	NVGBAHMC	r_g						1.000	0.749**	0.833**	0.187	0.298*	0.040	0.113	0.035	0.295*	0.654**	0.406**	-0.115	0.489**	0.798**	-0.229	0.665**	0.190	0.181	0.420**	0.445**	0.341**	0.631**
7	TEBTP	r_g							1.000	0.917**	0.378**	0.341**	0.178	-0.126	0.081	0.377**	0.684**	0.385**	0.051	0.267*	0.609**	0.193	0.426**	0.195	0.058	0.441**	0.315*	-0.161	0.948**
8	NRTPMCT	r_g								1.000	0.496**	0.407**	0.124	-0.206	0.031	0.394**	0.661**	0.280*	0.069	0.151	0.591**	0.163	0.491**	0.383**	0.147	0.400**	0.249	0.175	0.937**
9	PL	r_g									1.000	0.088	-0.243	-0.057	-0.226	0.229	0.368**	-0.147	-0.192	0.107	-0.123	0.172	-0.047	0.808**	-0.126	0.695**	-0.188	0.236	0.292*
10	NGPP	r_g										1.000	-0.549**	0.182	-0.341**	0.556**	0.405	-0.402**	-0.745**	0.581**	0.320*	-0.511**	0.752**	-0.010	0.044	0.058	-0.131	-0.061	0.284*
11	TW	r_g											1.000	-0.251	0.305*	-0.480**	-0.185	0.936**	0.739**	-0.112	0.343**	0.446**	-0.362**	-0.101	0.369**	-0.122	0.386**	-0.191	0.301*
12	LAI	r_g												1.000	0.444**	0.281*	0.134	-0.136	-0.038	-0.079	-0.135	0.028	-0.046	0.131	0.025	-0.331*	0.363**	-0.226	-0.038
13	HL	r_g													1.000	-0.137	0.046	0.071	0.136	-0.122	-0.030	0.145	-0.088	0.823**	-0.172	-0.255*	0.510	-0.170	-0.130
14	ML	r_g														1.000	0.789**	-0.332*	-0.360**	0.143	0.007	-0.286*	0.278*	-0.003	-0.335**	0.204	-0.120	-0.190	0.349**
15	HRR	r_g															1.000	0.088	-0.254*	0.374**	0.344**	-0.082	0.342**	0.342**	-0.278*	0.474**	-0.032	-0.048	0.567**
16	KL	r_g																1.000	0.615**	0.098	0.626**	0.375**	-0.060	-0.155	0.457**	0.079	0.454**	-0.144	0.488**
17	KB	r_g																	1.000	-0.724**	-0.069	0.642**	-0.621**	-0.260*	0.191	-0.245	0.306*	-0.021	0.170
18	L/B	r_g																		1.000	0.643**	-0.475**	0.744**	0.185	0.161	0.374**	0.005	-0.094	0.206
19	KLAC	r_g																			1.000	-0.015	0.741**	0.033	0.308*	0.105	0.246	-0.050	0.607**
20	KBAC	r_g																				1.000	-0.355**	-0.281*	-0.047	-0.083	0.006	-0.287	0.215
21	KLER	r_g																					1.000	0.152	0.006	0.054	-0.065	0.050	0.336**
22	VER	r_g																						1.000	0.050	0.258*	0.010	0.641**	0.142
23	WU	r_g																							1.000	-0.157	0.597**	0.294**	0.186
24	GC	r_g																								1.000	-0.118	0.141	0.305*
25	ASV	r_g																									1.000	0.051	0.260*
26	AC	r_g																										1.000	-0.113
27	GYPP	r_g																											1.000

** Significant at 1% level

* Significant at 5% level

rg: Genotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.12. Genotypic (G) direct and indirect effects of different traits on grain yield of ratoon crop in rice (Oryza sativa L.)

S.N o	Character	DFE	DM	PH	TNTP	NRTMCT	NVBAHMC	TPTP	NRTPMCT	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP
1	DF	0.298	0.801	-0.150	-0.143	-0.010	0.139	-0.535	0.600	-0.131	-0.215	0.129	-0.033	-0.047	-0.027	-0.004	-0.935	5.322	-4.245	2.042	0.000	-2.434	0.039	-0.048	0.124	-0.034	0.042	0.547**
2	DM	0.298	0.802	-0.155	-0.157	-0.011	0.151	-0.528	0.611	-0.143	-0.226	0.176	-0.043	-0.035	-0.032	-0.004	-1.293	6.408	-4.782	1.823	0.022	-2.489	0.019	-0.110	0.177	-0.046	0.064	0.500**
3	PH (cm)	0.143	0.395	-0.314	-0.164	-0.014	0.163	-0.314	0.471	-0.208	-0.071	0.008	-0.030	0.000	-0.015	-0.004	0.947	1.950	-3.702	1.869	-0.001	-1.036	0.090	0.284	0.304	-0.175	-0.250	0.326*
4	TNTP	0.124	0.365	-0.150	-0.344	-0.058	0.370	-0.624	0.873	-0.097	-0.155	0.029	-0.007	-0.013	-0.022	-0.006	1.618	1.989	-4.894	4.330	0.051	-2.798	0.023	0.133	0.259	-0.159	-0.206	0.633**
5	NRTPMCT	0.045	0.136	-0.068	-0.297	-0.067	0.319	-0.681	1.002	-0.072	-0.096	-0.031	0.019	0.027	-0.030	-0.007	2.069	-0.937	-2.341	3.660	-0.014	-1.829	-0.002	0.121	0.200	-0.173	-0.243	0.709**
6	NVBAHMC	0.112	0.327	-0.138	-0.344	-0.057	0.371	-0.669	0.879	-0.059	-0.103	-0.015	-0.013	0.010	-0.020	-0.006	2.171	1.384	-5.112	4.711	0.092	-2.794	0.024	0.156	0.262	-0.302	-0.237	0.631**
7	TPTP	0.179	0.474	-0.110	-0.240	-0.051	0.278	-0.893	0.968	-0.119	-0.118	-0.065	0.014	0.023	-0.026	-0.006	2.062	-0.615	-2.784	3.597	-0.078	-1.790	0.025	0.050	0.275	-0.214	0.112	0.948**
8	NRTPMCT	0.169	0.464	-0.140	-0.285	-0.063	0.309	-0.819	1.055	-0.157	-0.141	-0.046	0.023	0.009	-0.027	-0.006	1.497	-0.831	-1.572	3.489	-0.066	-2.061	0.048	0.126	0.249	-0.169	-0.122	0.937**
9	PL (cm)	0.123	0.362	-0.207	-0.105	-0.015	0.069	-0.337	0.523	-0.316	-0.031	0.089	0.006	-0.064	-0.016	-0.003	-0.785	2.321	-1.115	-0.727	-0.069	0.198	0.102	-0.108	0.433	0.127	-0.164	0.292*
10	NGPP	0.185	0.522	-0.065	-0.154	-0.019	0.110	-0.304	0.430	-0.028	-0.347	0.202	-0.021	-0.097	-0.038	-0.004	-2.151	8.978	-6.063	1.892	0.206	-3.158	-0.001	0.038	0.036	0.089	0.042	0.284*
11	TW (g)	-0.105	-0.385	0.007	0.028	-0.006	0.015	-0.159	0.131	0.077	0.191	-0.367	0.028	0.087	0.033	0.002	5.007	-8.914	1.166	2.028	-0.180	1.519	-0.013	0.317	-0.076	-0.262	0.133	0.301*
12	LAI	0.086	0.307	-0.082	-0.023	0.011	0.042	0.113	-0.217	0.018	-0.063	0.092	-0.113	0.126	-0.019	-0.001	-0.730	0.459	0.829	-0.799	-0.011	0.192	0.017	0.022	-0.206	-0.246	0.158	-0.038
13	HP (%)	-0.049	-0.100	0.000	0.016	-0.006	0.013	-0.072	0.033	0.072	0.118	-0.112	-0.050	0.284	0.009	0.000	0.381	-1.642	1.273	-0.176	-0.059	0.369	0.104	-0.148	-0.159	-0.346	0.118	-0.130
14	MP (%)	0.119	0.374	-0.071	-0.111	-0.029	0.109	-0.336	0.416	-0.072	-0.193	0.176	-0.032	-0.039	-0.068	-0.007	-1.773	4.341	-1.495	0.039	0.116	-1.167	0.000	-0.289	0.127	0.081	0.132	0.349*
15	HRR (%)	0.124	0.365	-0.125	-0.231	-0.052	0.243	-0.610	0.698	-0.116	-0.141	0.068	-0.015	0.013	-0.054	-0.009	0.469	3.066	-3.907	2.030	0.033	-1.436	0.043	-0.240	0.295	0.022	0.034	0.567**
16	KL (mm)	-0.052	-0.194	-0.056	-0.104	-0.026	0.150	-0.344	0.295	0.046	0.140	-0.344	0.015	0.020	0.023	-0.001	5.349	-7.418	-1.022	3.695	-0.151	0.250	-0.020	0.393	0.049	-0.308	0.100	0.488**
17	KB (mm)	-0.132	-0.426	0.051	0.057	-0.005	-0.043	-0.046	0.073	0.061	0.258	-0.271	0.004	0.039	0.024	0.002	3.290	-12.059	7.566	-0.408	-0.259	2.608	-0.033	0.164	-0.153	-0.207	0.014	0.170
18	L/B ratio	0.121	0.367	-0.111	-0.161	-0.015	0.181	-0.238	0.159	-0.034	-0.202	0.041	0.009	-0.035	-0.010	-0.004	0.524	8.735	-10.445	3.797	0.192	-3.124	0.023	0.138	0.233	-0.004	0.065	0.206
19	KLAC (mm)	0.103	0.248	-0.099	-0.252	-0.041	0.296	-0.544	0.623	0.039	-0.111	-0.126	0.015	-0.009	0.000	-0.003	3.346	0.834	-6.714	5.906	0.006	-3.112	0.004	0.265	0.065	-0.167	0.035	0.607**
20	KBAC (mm)	0.000	-0.044	-0.001	0.043	-0.002	-0.085	-0.172	0.172	-0.054	0.177	-0.164	-0.003	0.041	0.019	0.001	2.006	-7.747	4.960	-0.089	-0.404	1.492	-0.035	-0.040	-0.051	-0.004	0.200	0.215
21	KLER	0.173	0.475	-0.078	-0.229	-0.029	0.247	-0.381	0.518	0.015	-0.261	0.133	0.005	-0.025	-0.019	-0.003	-0.319	7.491	-7.770	4.378	0.143	-4.199	0.019	0.005	0.034	0.044	-0.035	0.336**
22	VER	0.091	0.117	-0.224	-0.063	0.001	0.070	-0.174	0.404	-0.256	0.004	0.037	-0.015	0.234	0.000	-0.003	-0.827	3.130	-1.929	0.192	0.113	-0.638	0.126	0.043	0.161	-0.007	-0.446	0.142
23	WU (ml)	-0.017	-0.102	-0.104	-0.053	-0.009	0.067	-0.052	0.155	0.040	-0.015	-0.135	-0.003	-0.049	0.023	0.003	2.444	-2.299	-1.677	1.816	0.019	-0.026	0.006	0.861	-0.098	-0.404	-0.205	0.186
24	GC (mm)	0.059	0.229	-0.153	-0.143	-0.021	0.156	-0.394	0.422	-0.220	-0.020	0.045	0.037	-0.072	-0.014	-0.004	0.424	2.956	-3.908	0.620	0.033	-0.228	0.033	-0.135	0.623	0.080	-0.098	0.305*
25	ASV (mm)	0.015	0.055	-0.081	-0.081	-0.017	0.165	-0.281	0.263	0.059	0.045	-0.142	-0.041	0.145	0.008	0.000	2.431	-3.683	-0.054	1.455	-0.002	0.273	0.001	0.514	-0.074	-0.678	-0.036	0.260*
26	AC (%)	-0.018	-0.074	-0.113	-0.102	-0.023	0.126	0.144	0.185	-0.075	0.021	0.070	0.026	-0.048	0.013	0.001	-0.772	0.248	0.979	-0.297	0.116	-0.210	0.081	0.253	0.088	-0.035	-0.696	-0.113

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.1420

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEPTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.23. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of F₁s in rice (*Oryza sativa* L.)

Characters	DFE	DM	PH	TNTP	TEBTP	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP	
DFE	r _p	1.000	0.975**	0.048	-0.290**	-0.271**	-0.288**	0.070	-0.420**	0.039	-0.169	-0.252**	-0.338**	-0.156	-0.248**	0.171	-0.082	-0.095	0.030	-0.097	0.217*	-0.273**	0.133	-0.078	-0.250**
DM	r _p		1.000	0.057	-0.322**	-0.283**	-0.288**	0.070	-0.375**	0.063	-0.168	-0.245*	-0.323**	-0.185	-0.284**	0.189*	-0.079	-0.121	0.056	-0.091	0.233*	-0.292**	0.154	-0.078	-0.264**
PH	r _p			1.000	0.427**	0.395**	0.272**	0.489**	0.412**	0.448**	0.167	0.288**	0.479**	0.098	0.028	0.025	-0.101	-0.027	-0.166	-0.250**	0.125	0.272**	-0.229*	0.046	0.498**
TNTP	r _p				1.000	0.623**	0.619**	0.461**	0.283**	0.132	0.278**	0.523**	0.356**	0.004	0.355**	-0.389**	-0.115	0.390**	-0.111	-0.108	-0.001	0.288**	-0.171	0.079	0.662**
TEBTP	r _p					1.000	0.442**	0.417**	0.345**	0.122	0.241*	0.431**	0.394**	0.186	0.308**	-0.209*	-0.051	0.241*	-0.186	-0.015	-0.061	0.240*	-0.169	0.026	0.404**
PL	r _p						1.000	0.451**	0.380**	0.057	0.142	0.443**	0.292**	0.228*	0.395**	-0.273**	0.004	0.338**	-0.162	-0.044	-0.176	0.302**	-0.107	0.073	0.406**
NGPP	r _p							1.000	0.174	0.316**	0.109	0.389**	0.341**	0.110	0.155	-0.101	0.076	0.238*	-0.004	-0.068	-0.124	0.245*	-0.107	-0.202*	0.409**
TW	r _p								1.000	0.419**	0.063	0.302**	0.499**	0.188	0.223*	-0.122	0.154	-0.104	0.023	-0.162	-0.048	0.234*	-0.103	0.138	0.322**
LAI	r _p									1.000	0.171	0.229*	0.554**	-0.033	-0.155	0.142	0.017	-0.068	0.048	-0.425**	-0.036	0.070	-0.112	-0.116	0.281**
HP	r _p										1.000	0.464**	0.414**	0.048	0.109	-0.096	0.057	0.060	0.032	-0.107	-0.132	0.145	0.010	0.034	0.198*
MP	r _p											1.000	0.645**	0.120	0.270**	-0.202*	0.201*	0.150	0.128	-0.066	-0.159	0.512**	0.086	-0.060	0.499**
HRR	r _p												1.000	0.008	0.154	-0.156	0.125	-0.023	0.133	-0.332**	-0.258**	0.434**	-0.125	-0.199*	0.459**
KL	r _p													1.000	0.464**	0.156	0.387**	0.021	-0.358**	0.171	0.156	0.102	0.058	-0.102	0.002
KB	r _p														1.000	-0.799**	0.088	0.291**	-0.262**	0.273**	-0.141	0.127	-0.024	-0.047	0.088
L/B	r _p															1.000	0.178	-0.323**	0.066	-0.175	0.278**	-0.067	0.080	-0.030	-0.093
KLAC	r _p																1.000	-0.151	0.721**	-0.002	-0.236*	0.048	0.292**	-0.176	0.138
KBAC	r _p																	1.000	-0.169	-0.013	-0.136	0.088	-0.104	0.133	0.241*
KLER	r _p																		1.000	-0.136	0.119	-0.021	0.246*	-0.105	0.145
VER	r _p																			1.000	0.150	-0.157	0.199*	0.019	-0.179
WU	r _p																				1.000	-0.255**	0.246**	0.052	0.122
GC	r _p																					1.000	-0.002	0.029	0.320**
ASV	r _p																						1.000	0.084	-0.006
AC	r _p																							1.000	-0.152
GYPP	r _p																								1.000

* Significant at 5% level

** Significant at 1% level

rg: Genotypic level

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBTTP: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

Table 4.24. Genotypic (rg) correlation among grain yield, yield contributing and quality characters of F₁s in rice (*Oryza sativa* L.)

Characters		DFF	DM	PH (cm)	TNT	EBT	PL (cm)	NGP	TW (g)	LAI	HP (%)	MP (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	ER	VER	WU (ml)	GC (mm)	ASV	AC (%)	GYPP (g)
DFF	r _g	1.000	0.999*	0.056	-0.323**	-0.350**	-0.389**	0.094	-0.451**	0.053	-0.299**	-0.299**	-0.387**	-0.197*	-0.264**	0.171	-0.093	-0.127	0.051	-0.102	0.237*	-0.284**	0.146	-0.070	-0.271**
DM	r _g		1.000	0.049	-0.344**	-0.388**	-0.381**	0.075	-0.407**	0.085	-0.326**	-0.307**	-0.379**	-0.226*	-0.287**	0.181	-0.080	-0.147	0.086	-0.101	0.243*	-0.307**	0.165	-0.075	-0.278**
PH	r _g			1.000	0.492**	0.513**	0.358**	0.546**	0.442**	0.479**	0.302**	0.341**	0.543**	0.131	0.039	0.027	-0.088	-0.061	-0.193*	-0.271**	0.127	0.281**	-0.241*	0.044	0.544**
TNTP	r _g				1.000	0.942**	0.846**	0.597**	0.338**	0.136	0.424**	0.660**	0.485**	0.048	0.422**	-0.442**	-0.138	0.492**	-0.184	-0.111	-0.014	0.325**	-0.185	0.068	0.752**
TEBTP	r _g					1.000	0.947**	0.526**	0.467**	0.170	0.614**	0.710**	0.571**	0.223*	0.486**	-0.387**	-0.015	0.268**	-0.181	-0.079	-0.113	0.349**	-0.223*	0.074	0.615**
PL	r _g						1.000	0.716**	0.562**	0.090	0.449**	0.750**	0.481**	0.369**	0.531**	-0.365**	0.093	0.477**	-0.182	-0.001	-0.231*	0.395**	-0.125	0.069	0.556**
NGPP	r _g							1.000	0.213*	0.361**	0.134	0.486**	0.394**	0.081	0.214*	-0.187	0.065	0.292**	0.015	-0.124	-0.164	0.280**	-0.110	-0.227*	0.481**
TW	r _g								1.000	0.450**	0.157	0.361**	0.588**	0.237*	0.239*	-0.123	0.151	-0.123	-0.011	-0.183	-0.041	0.245*	-0.015	0.145	0.327**
LAI	r _g									1.000	0.253*	0.281**	0.623**	-0.004	-0.165	0.176	0.005	-0.102	0.021	-0.453**	-0.046	0.071	-0.121	-0.138	0.291**
HP	r _g										1.000	0.954**	0.708**	0.176	0.243*	-0.169	0.095	0.235*	-0.010	-0.158	-0.339**	0.312**	0.010	0.004	0.390**
MP	r _g											1.000	0.757**	0.207*	0.300**	-0.191*	0.283**	0.241*	0.173	-0.117	-0.185	0.584**	0.113	-0.100	0.605**
HRR	r _g												1.000	0.001	0.145	-0.154	0.187	-0.011	0.230*	-0.396**	-0.317**	0.495**	-0.148	-0.243*	0.549**
KL	r _g													1.000	0.487**	0.088	0.494**	0.006	-0.248**	0.185	0.177	0.129	0.079	-0.103	-0.003
KB	r _g														1.000	-0.825**	0.101	0.348**	-0.283**	0.304**	-0.157	0.140	-0.025	-0.062	0.077
L/B	r _g															1.000	0.218*	-0.409**	0.181	-0.210*	0.306**	-0.072	0.093	-0.013	-0.086
KLAC	r _g																1.000	-0.181	0.720**	-0.009	0.276**	0.071	0.335**	-0.197*	0.127
KBAC	r _g																	1.000	-0.204*	-0.030	-0.171	0.091	-0.107	0.151	0.271**
KLER	r _g																		1.000	-0.166	0.159	-0.016	0.302**	-0.143	0.154
VER	r _g																			1.000	0.162	-0.175	0.219*	0.018	-0.209*
WU	r _g																				1.000	-0.264**	0.255**	0.047	0.131
GC	r _g																					1.000	-0.003	0.026	0.346**
ASV	r _g																						1.000	0.082	-0.001
AC	r _g																							1.000	-0.154
GYPP	r _g																								1.000

* Significant at 5% level

** Significant at 1% level

r_p: Phenotypic level

DFF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GY: Grain Yield per plant (g).

rg: Genotypic level

Table 4.25. Genotypic (G) direct and indirect effects of different traits on grain yield of F₁s in rice (*Oryza sativa* L.)

Characters		DF	DM	PH	TNTP	TEBTP	PL	NGPP	TW	LAI	HP	MP	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC
DF	G	-0.490	-0.489	-0.028	0.159	0.171	0.191	-0.046	0.221	-0.026	0.147	0.147	0.189	0.097	0.129	-0.084	0.046	0.062	-0.025	0.050	-0.116	0.139	-0.072	0.034
DM	G	0.609	0.610	0.030	-0.210	-0.237	-0.232	0.046	-0.248	0.052	-0.199	-0.187	-0.231	-0.138	-0.175	0.110	-0.049	-0.090	0.053	-0.062	0.148	-0.187	0.100	-0.046
PH	G	-0.008	-0.007	-0.147	-0.072	-0.075	-0.053	-0.080	-0.065	-0.070	-0.044	-0.050	-0.080	-0.019	-0.006	-0.004	0.013	0.009	0.028	0.040	-0.019	-0.041	0.035	-0.007
TNTP	G	-0.231	-0.246	0.352	0.715	0.673	0.605	0.427	0.241	0.097	0.303	0.472	0.347	0.034	0.301	-0.316	-0.099	0.351	-0.132	-0.080	-0.010	0.232	-0.132	0.049
TEBTP	G	-0.051	-0.056	0.074	0.137	0.145	0.137	0.076	0.068	0.025	0.089	0.103	0.083	0.032	0.070	-0.056	-0.002	0.039	-0.026	-0.011	-0.016	0.051	-0.032	0.011
PL	G	-0.232	-0.228	0.214	0.505	0.566	0.597	0.428	0.335	0.054	0.268	0.448	0.287	0.221	0.317	-0.218	0.055	0.285	-0.109	-0.001	-0.138	0.236	-0.075	0.041
NGPP	G	-0.019	-0.015	-0.110	-0.120	-0.106	-0.144	-0.201	-0.043	-0.073	-0.027	-0.098	-0.079	-0.016	-0.043	0.038	-0.013	-0.059	-0.003	0.025	0.033	-0.056	0.022	0.046
TW	G	0.234	0.212	-0.230	-0.175	-0.243	-0.292	-0.111	-0.520	-0.234	-0.082	-0.187	-0.306	-0.123	-0.124	0.064	-0.079	0.064	0.006	0.095	0.021	-0.127	0.008	-0.075
LAI	G	-0.008	-0.013	-0.073	-0.021	-0.026	-0.014	-0.055	-0.069	-0.152	-0.039	-0.043	-0.095	0.001	0.025	-0.027	-0.001	0.016	-0.003	0.069	0.007	-0.011	0.018	0.021
HP	G	0.036	0.040	-0.037	-0.052	-0.075	-0.055	-0.016	-0.019	-0.031	-0.122	-0.116	-0.086	-0.021	-0.030	0.021	-0.012	-0.029	0.001	0.019	0.041	-0.038	-0.001	-0.001
MP	G	0.199	0.205	-0.228	-0.440	-0.473	-0.500	-0.324	-0.240	-0.187	-0.636	-0.667	-0.505	-0.138	-0.200	0.127	-0.189	-0.161	-0.115	0.078	0.123	-0.389	-0.075	0.066
HRR	G	-0.519	-0.509	0.728	0.651	0.766	0.645	0.528	0.789	0.836	0.950	1.015	1.342	0.001	0.194	-0.206	0.251	-0.015	0.309	-0.532	-0.425	0.664	-0.199	-0.325
KL	G	-0.605	-0.691	0.402	0.147	0.682	1.131	0.250	0.725	-0.013	0.538	0.634	0.003	3.063	1.492	0.269	1.512	0.018	-0.759	0.568	0.543	0.394	0.243	-0.314
KB	G	2.007	2.186	-0.294	-3.211	-3.700	-4.044	-1.626	-1.823	1.258	-1.853	-2.282	-1.103	-3.710	-7.616	6.285	-0.769	-2.650	2.158	-2.315	1.196	-1.063	0.188	0.468
L/B ratio	G	-1.076	-1.136	-0.171	2.779	2.432	2.295	1.173	0.773	-1.104	1.062	1.199	0.965	-0.552	5.184	-6.282	-1.367	2.570	-1.139	1.322	-1.925	0.454	-0.586	0.083
KLAC	G	-0.146	-0.126	-0.138	-0.217	-0.024	0.146	0.103	0.238	0.008	0.149	0.445	0.294	0.775	0.159	0.342	1.570	-0.285	1.131	-0.015	0.434	0.112	0.526	-0.309
KBAC	G	0.002	0.003	0.001	-0.009	-0.005	-0.008	-0.005	0.002	0.002	-0.004	-0.004	0.000	0.000	-0.006	0.007	0.003	-0.018	0.004	0.001	0.003	-0.002	0.002	-0.003
KLER	G	-0.069	-0.117	0.262	0.251	0.246	0.247	-0.021	0.015	-0.028	0.013	-0.235	-0.314	0.337	0.386	-0.247	-0.980	0.277	-1.361	0.226	-0.216	0.021	-0.410	0.194
VER	G	-0.021	-0.021	-0.056	-0.023	-0.016	0.000	-0.025	-0.038	-0.093	-0.032	-0.024	-0.081	0.038	0.062	-0.043	-0.002	-0.006	-0.034	0.205	0.033	-0.036	0.045	0.004
WU	G	0.086	0.088	0.046	-0.005	-0.041	-0.084	-0.060	-0.015	-0.017	-0.123	-0.067	-0.115	0.064	-0.057	0.111	0.100	-0.062	0.058	0.059	0.364	-0.096	0.093	0.017
GC	G	-0.026	-0.028	0.026	0.030	0.032	0.037	0.026	0.023	0.007	0.029	0.054	0.046	0.012	0.013	-0.007	0.007	0.008	-0.001	-0.016	-0.025	0.093	0.000	0.002
ASV	G	0.046	0.051	-0.075	-0.058	-0.070	-0.039	-0.035	-0.005	-0.038	0.003	0.035	-0.046	0.025	-0.008	0.029	0.105	-0.033	0.094	0.069	0.080	-0.001	0.313	0.026
AC	G	0.010	0.010	-0.006	-0.009	-0.010	-0.009	0.031	-0.020	0.019	-0.001	0.014	0.033	0.014	0.008	0.002	0.027	-0.021	0.019	-0.002	-0.006	-0.004	-0.011	-0.136
GYPP	G	-0.271**	-0.278**	0.544**	0.752**	0.615**	0.556**	0.481**	0.327**	0.291**	0.390**	0.605**	0.549**	-0.003	0.077	-0.086	0.127	0.271**	0.154	-0.209*	0.131	0.346**	-0.001	-0.154

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

G: Genotypic level

Residual effect at genotypic level = 0.447

DF: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height (cm); TNTP: Total Number of Tillers per Plant; EBT: Total number of Ear Bearing Tillers per Plant; PL: Panicle Length per plant (cm); NGPP: Number of Grains Per Panicle; TW: Test Weight (g); LAI: Leaf Area Index at maximum tillering stage; HP: Hulling percentage; ML: Milling percentage; HRR: Head Rice Recovery; KL: Kernel Length (mm); KB: Kernel Breadth (mm); L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC: Amylose Content (%); GYPP: Grain Yield per plant (g).

Table 4.36. Phenotypic (r_p) correlation among grain yield, yield contributing and quality characters of F₁ ratoon in rice (*Oryza sativa* L.)

S. No.	Characters		DFE	DM	PH (cm)	TNTP	NRTPM CT	NVBAH MC	TETP	NRETP MCET	PL (cm)	NGPP	TW (g)	LAI	HL%	ML%	HRR%	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	KLER	VER	WU (ml)	GC (mm)	ASV (mm)	AC (%)	GYPP (g)
1	DF	r_p	1.000	0.869**	0.417**	0.109	0.038	0.032	0.405**	0.371**	0.314**	0.296**	0.119	0.489**	0.224*	-0.096	0.201*	-0.171	-0.204*	0.077	-0.039	-0.240*	0.100	0.027	-0.064	-0.076	-0.052	0.041	0.380**
2	DM	r_p		1.000	0.507**	0.145	0.084	0.028	0.425**	0.364**	0.379**	0.368**	0.095	0.480**	0.287**	-0.086	0.207*	-0.184	-0.257**	0.134	-0.012	-0.198*	0.138	-0.044	-0.061	-0.108	-0.179	-0.027	0.447**
3	PH	r_p			1.000	0.356**	-0.218*	0.128	0.498**	0.159	0.697**	0.562**	0.424**	0.474**	0.409**	0.171	0.381**	0.094	-0.015	0.067	-0.098	0.018	-0.154	-0.195*	0.154	0.306**	-0.333**	-0.051	0.640**
4	TNTP	r_p				1.000	0.387**	0.555**	0.410**	0.295**	0.160	0.296**	0.027	0.173	0.265**	0.138	0.183	0.113	0.043	0.029	-0.022	0.172	-0.106	-0.097	0.049	0.174	-0.158	0.048	0.381**
5	NRTPMCPT	r_p					1.000	0.208*	-0.012	0.391**	-0.385**	-0.279*	-0.357**	0.004	-0.168	-0.279**	-0.278**	0.110	-0.230*	0.333**	0.078	-0.260**	-0.015	0.077	-0.272**	-0.117	0.150	0.063	-0.089
6	NVGBAHMC	r_p						1.000	0.231*	0.153	0.037	0.062	-0.048	0.030	0.097	-0.065	0.032	0.071	0.180	-0.150	0.003	0.190*	-0.055	-0.040	-0.009	-0.075	-0.124	0.003	0.188
7	TEBTP	r_p							1.000	0.749**	0.376**	0.414**	0.146	0.456**	0.268**	0.081	0.304**	0.024	-0.087	0.113	0.054	-0.050	0.035	-0.157	0.132	0.174	-0.008	-0.141	0.711**
8	NRTPMCT	r_p								1.000	0.040	0.103	-0.158	0.316**	0.049	-0.140	0.076	-0.025	-0.260 **	0.265**	0.075	-0.194*	0.088	-0.020	-0.043	0.022	0.162	-0.091	0.439**
9	PL	r_p									1.000	0.436**	0.337**	0.297**	0.303**	0.120	0.328**	-0.026	-0.027	0.002	-0.170	0.029	-0.132	-0.027	0.325**	0.161	-0.287**	-0.069	0.478**
10	NGPP	r_p										1.000	0.310**	0.497**	0.500**	0.274**	0.479**	-0.021	0.063	-0.085	0.104	0.266**	0.124	-0.048	0.127	0.313**	-0.180	-0.201*	0.633**
11	TW	r_p											1.000	0.478**	0.293 **	0.386**	0.477**	0.101	0.104	-0.044	0.054	-0.101	-0.005	-0.211*	0.059	0.265**	-0.051	0.004	0.439**
12	LAI	r_p												1.000	0.332**	0.196*	0.490**	-0.014	-0.154	0.143	0.076	-0.115	0.098	-0.254**	-0.099	0.103	-0.035	-0.112	0.688**
13	HL	r_p													1.000	0.348**	0.571**	0.102	0.194*	-0.148	0.054	0.155	-0.021	0.110	0.104	0.069	-0.119	0.028	0.287**
14	ML	r_p														1.000	0.541**	0.155	0.275**	-0.192*	0.219*	0.164	0.097	-0.243*	0.070	0.335**	-0.031	-0.092	0.223*
15	HRR	r_p															1.000	0.057	0.131	-0.113	0.252**	0.071	0.209*	-0.076	0.059	0.101	-0.055	-0.222*	0.477**
16	KL	r_p																1.000	0.490**	0.171	0.364**	0.031	-0.444**	0.018	0.147	0.145	0.101	-0.097	-0.027
17	KB	r_p																	1.000	-0.771**	0.178	0.250**	-0.222*	0.066	0.041	0.065	-0.011	-0.112	-0.115
18	L/B	r_p																		1.000	0.075	-0.269**	-0.059	-0.057	0.086	0.031	0.092	0.039	0.109
19	KLAC	r_p																			1.000	-0.131	0.672**	0.029	0.189*	0.101	0.277**	-0.156	0.033
20	KBAC	r_p																				1.000	-0.150	-0.002	0.005	0.026	-0.156	0.115	-0.007
21	KLER	r_p																					1.000	0.003	0.066	-0.005	0.180	-0.076	0.068
22	VER	r_p																						1.000	0.204*	-0.202*	0.231*	0.116	-0.222*
23	WU	r_p																							1.000	-0.070	0.165	0.039	0.112
24	GC	r_p																								1.000	-0.057	-0.026	0.314**
25	ASV)	r_p																									1.000	0.129	-0.125
26	AC	r_p																										1.000	-0.272**
27	GYPP	r_p																											1.000

r_g : Genotypic level

* Significant at 5% level

** Significant at 1% level

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NREBTPMCEBT: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).

Table 4.38. Genotypic (G) direct and indirect effects of different traits on grain yield F₁ ratoon in rice (*Oryza sativa* L.)

S.N o	Character	DFE	DM	PH	TNTP	NRTPMCT	NVBAHMC	TPTP	NRTPMCPT	PL	NGPP	TW	LAI	HL	ML	HRR	KL	KB	L/B ratio	KLAC	KBAC	KLER	VER	WU	GC	ASV	AC	GYPP
1	DF	-1.463	1.595	-0.099	-0.006	0.019	0.023	0.221	-0.002	0.053	0.044	0.033	0.190	-0.144	-0.030	0.107	-0.423	-0.015	0.000	0.143	-0.037	0.314	0.012	-0.014	-0.024	-0.011	-0.001	0.484**
2	DM	-1.416	1.648	-0.107	-0.007	0.025	0.023	0.235	-0.002	0.056	0.050	0.022	0.172	-0.155	-0.029	0.120	-0.403	-0.015	0.000	0.015	-0.034	0.396	-0.012	-0.012	-0.032	-0.040	0.001	0.495**
3	PH (cm)	-0.762	0.929	-0.190	-0.016	-0.111	0.020	0.266	-0.001	0.095	0.073	0.088	0.160	-0.225	0.037	0.216	0.261	0.000	0.000	0.295	0.003	-0.469	-0.053	0.033	0.092	-0.067	0.001	0.676**
4	TNTP	-0.322	0.405	-0.115	-0.027	-0.070	0.130	0.327	-0.002	0.042	0.053	0.025	0.097	-0.184	0.042	0.136	0.049	0.008	0.000	0.153	0.023	-0.186	-0.026	0.018	0.077	-0.055	-0.002	0.596**
5	NRTPMCT	-0.086	0.127	0.066	0.006	0.321	0.011	0.022	-0.003	-0.067	-0.062	-0.100	0.005	0.175	-0.093	-0.240	0.083	-0.015	0.000	-0.286	-0.079	0.124	0.028	-0.079	-0.051	0.031	-0.003	-0.165
6	NVBAHMC	-0.233	0.259	-0.026	-0.024	0.024	0.143	0.242	-0.001	0.003	0.012	-0.010	0.049	-0.016	0.024	0.000	-0.008	0.020	0.000	-0.099	0.043	0.062	-0.034	-0.003	-0.026	-0.045	0.001	0.357**
7	TPTP	-0.818	0.978	-0.128	-0.022	0.018	0.088	0.395	-0.003	0.068	0.068	0.039	0.187	-0.175	0.023	0.229	-0.076	-0.006	0.000	-0.292	-0.014	0.348	-0.058	0.026	0.066	-0.008	0.004	0.935**
8	NRTPMCPT	-0.826	0.928	-0.047	-0.012	0.233	0.047	0.297	-0.004	0.011	0.018	-0.046	0.138	0.000	-0.040	0.068	-0.289	-0.019	0.000	-0.475	-0.049	0.695	-0.006	-0.030	0.005	0.036	0.004	0.635**
9	PL (cm)	-0.703	0.838	-0.166	-0.010	-0.197	0.003	0.246	0.000	0.110	0.073	0.087	0.112	-0.207	0.027	0.211	-0.098	-0.002	0.000	0.548	0.010	-0.328	-0.024	0.079	0.053	-0.064	0.002	0.597**
10	NGPP	-0.544	0.709	-0.119	-0.012	-0.171	0.015	0.229	-0.001	0.068	0.117	0.071	0.177	-0.294	0.067	0.270	-0.020	0.005	0.000	-0.384	0.052	0.368	-0.010	0.030	0.098	-0.038	0.005	0.688**
11	TW (g)	-0.241	0.181	-0.083	-0.003	-0.159	-0.007	0.077	0.001	0.047	0.042	0.201	0.160	-0.159	0.080	0.283	0.214	0.005	0.000	-0.215	-0.014	0.039	-0.063	0.012	0.080	-0.010	0.000	0.469**
12	LAI	-0.891	0.909	-0.098	-0.008	0.005	0.023	0.236	-0.002	0.039	0.066	0.103	0.312	-0.204	0.041	0.266	-0.065	-0.008	0.000	-0.233	-0.015	0.304	-0.069	-0.019	0.029	-0.005	0.003	0.72
13	HL (%)	-0.446	0.543	-0.091	-0.011	-0.119	0.005	0.147	0.000	0.048	0.073	0.068	0.135	-0.472	0.088	0.345	0.336	0.012	0.000	-0.309	0.027	-0.047	0.018	0.021	0.029	-0.030	0.000	0.367
14	ML (%)	0.309	-0.327	-0.049	-0.008	-0.209	0.024	0.063	0.001	0.021	0.055	0.112	0.088	-0.289	0.144	0.345	0.457	0.014	0.000	-0.812	0.049	0.292	-0.078	0.022	0.137	-0.015	0.003	0.349
15	HRR (%)	-0.341	0.431	-0.090	-0.008	-0.168	0.000	0.197	-0.001	0.051	0.069	0.124	0.181	-0.356	0.108	0.459	0.195	0.009	0.000	-0.911	0.017	0.621	-0.022	0.016	0.030	-0.013	0.006	0.604
16	KL (mm)	0.341	-0.366	-0.027	-0.001	0.015	-0.001	-0.017	0.001	-0.006	-0.001	0.024	-0.011	-0.087	0.036	0.049	1.813	0.027	0.000	-1.377	-0.002	-0.602	0.001	0.038	0.049	0.024	0.002	-0.079
17	KB (mm)	0.478	-0.557	0.002	-0.005	-0.103	0.063	-0.056	0.002	-0.005	0.012	0.023	-0.051	-0.122	0.043	0.088	1.089	0.046	0.000	-0.616	0.049	-0.558	0.021	0.013	0.023	-0.005	0.003	-0.121
18	L/B ratio	-0.288	0.371	-0.018	0.006	0.135	-0.079	0.057	-0.002	0.000	-0.017	-0.011	0.049	0.094	-0.025	-0.076	-0.006	-0.036	-0.001	-0.295	-0.065	0.276	-0.026	0.017	0.008	0.025	-0.002	0.09
19	KLAC (mm)	0.074	-0.009	0.020	0.001	0.032	0.005	0.041	-0.001	-0.021	0.016	0.015	0.025	-0.051	0.041	0.147	0.876	0.010	0.000	-2.849	-0.019	1.547	0.012	0.045	0.025	0.055	0.004	0.041
20	KBAC (mm)	0.374	-0.391	-0.004	-0.004	-0.177	0.043	-0.037	0.001	0.008	0.043	-0.019	-0.033	-0.090	0.049	0.054	-0.020	0.016	0.000	0.371	0.144	-0.293	0.006	-0.004	0.010	-0.035	-0.003	0.007
21	KLER	-0.210	0.299	0.041	0.002	0.018	0.004	0.063	-0.001	-0.016	0.020	0.004	0.043	0.010	0.019	0.130	-0.500	-0.012	0.000	-2.017	-0.019	2.186	0.010	0.019	-0.008	0.041	0.002	0.128
22	VER	-0.075	-0.090	0.044	0.003	0.040	-0.021	-0.102	0.000	-0.012	-0.005	-0.056	-0.095	-0.037	-0.049	-0.045	0.004	0.004	0.000	-0.154	0.004	0.098	0.227	0.045	-0.059	0.052	-0.003	-0.280**
23	WU (ml)	0.096	-0.098	-0.031	-0.002	-0.123	-0.002	0.050	0.001	0.042	0.017	0.011	-0.029	-0.047	0.015	0.036	0.329	0.003	0.000	-0.614	-0.003	0.202	0.049	0.207	-0.020	0.032	-0.001	0.120
24	GC (mm)	0.127	-0.190	-0.062	-0.007	-0.059	-0.014	0.093	0.000	0.021	0.041	0.058	0.032	-0.048	0.070	0.049	0.318	0.004	0.000	-0.256	0.005	-0.059	-0.048	-0.015	0.280	-0.012	0.001	0.328**
25	ASV (mm)	0.087	-0.348	0.066	0.008	0.053	-0.034	-0.016	-0.001	-0.036	-0.023	-0.011	-0.008	0.075	-0.011	-0.030	0.223	-0.001	0.000	-0.823	-0.026	0.467	0.062	0.035	-0.017	0.191	-0.003	-0.123
26	AC (%)	-0.076	-0.052	0.010	-0.003	0.038	-0.006	-0.075	0.001	-0.008	-0.026	0.001	-0.036	-0.008	-0.021	-0.123	-0.195	-0.007	0.000	0.469	0.019	-0.215	0.028	0.008	-0.008	0.025	-0.023	-0.283**

* Significant at 5% level

** Significant at 1% level

Diagonal values indicate direct effects

Residual effect at genotypic level = 0.0401

DFE: Days to 50% Flowering; DM: Days to Maturity; PH: Plant Height; TNTP: Total Number of Tillers per Plant; TEBTP: Total number of Ear Bearing Tillers per Plant; NRTPMCT: Number of ratoon tillers as percentage of main crop tillers; NRETPMCET: Number of ratoon ear bearing tillers as percentage of main crop ear bearing tillers NVBAHMC: Number of vegetative buds after the harvest of main crop; PL: Panicle Length per plant; NGPP: Number of Grains Per Panicle; TW: Test Weight; LAI: Leaf Area Index at maximum tillering stage; GYPP: Grain Yield per plant. HP: Hulling percentage; MP: Milling percentage; HRR: Head Rice Recovery percentage; KL: Kernel Length; KB: Kernel Breadth ;L/B: Kernel L/B ratio; KLAC: Kernel Length After Cooking (mm); KBAC: Kernel Breadth After Cooking (mm); KLER: Kernel Linear Elongation Ratio; VER: Volume Expansion Ratio; WU: Water Uptake (ml); GC: Gel Consistency (mm); ASV: Alkali Spreading Value; AC (%): Amylose Content (%).