GENETIC ANALYSIS FOR GRAIN YIELD AND PHYSIOLOGICAL ATTRIBUTES IN RICE (*Oryza sativa* L.)

M. SIVA
B.Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE
(GENETICS AND PLANT BREEDING)

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Place: ***Bapatla***
Date: **(M. SIVA)**

DECLARATION

I, **M. SIVA**, hereby declare that the thesis entitled **"GENETIC ANALYSIS FOR GRAIN YIELD AND PHYSIOLOGICAL ATTRIBUTES IN RICE (*Oryza sativa* L.)"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Masters of Science in Agriculture** is the result of 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 **(M. SIVA)**
Date: **I. D. No. BAM-14-14**

CERTIFICATE

Mr. M. SIVA has satisfactorily prosecuted the course of research and that thesis entitled **"GENETIC ANALYSIS FOR GRAIN YIELD AND PHYSIOLOGICAL ATTRIBUTES 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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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC ANALYSIS FOR GRAIN YIELD AND PHYSIOLOGICAL ATTRIBUTES IN RICE (*Oryza sativa* L.)"** submitted in partial fulfilment of the requirements for the degree of 'Master of science in Agriculture' of the Acharya N. G. Ranga Agricultural University, Guntur is a record of the bonafide original research work carried out by **Mr. M. SIVA** 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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GENETIC ANALYSIS FOR GRAIN YIELD AND PHYSIOLOGICAL ATTRIBUTES IN RICE (*Oryza sativa* L.)

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THESIS SUBMITTED TO THE
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ABSTRACT

Name of the Author	:	**MURUDUDLA SIVA**
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The present investigation was carried out during *kharif* 2015 and *rabi* 2015-16 at Agricultural Research Station, Nellore, to study the variability, heritability, expected genetic advance, combining ability, heterosis, character association and path coefficient analysis involving nine parents (five lines + four testers), 20 F_1s along with two checks in rice for characters viz., days to 50 % flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, leaf area duration at 60-80 DAT, SPAD chlorophyll meter reading at 80 DAT, specific leaf area at 80 DAT, specific leaf weight at 80 DAT, harvest index, shoot dry weight, root dry weight, root shoot ratio and grain yield per plant.

Analysis of variance revealed significant differences among the genotypes for majority of the characters studied, indicating a high degree of variability in the material.

The estimates of PCV and GCV were high for characters viz., number of ill-filled grains per panicle, root dry weight, shoot dry weight and root shoot ratio proposing the existence of wide variation among the genotypes for these traits. The estimates of heritability and genetic advance as per cent of means were high for the characters, number of effective tillers per plant, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT, root dry weight, shoot dry weight, root shoot ratio and grain yield per plant indicating the involvement of additive gene action in the inheritance of these traits.

The analysis of variance for combining ability revealed the existence of significant amount of variability among parents and different cross combinations for majority of the characters studied. The per cent contribution towards the total variance was maximum due to the interaction of lines and testers for majority of the traits studied.

The *gca* and *sca* variances revealed that predominance of both additive and non additive gene action for the traits, days to 50% flowering, days to maturity, number of filled grains per panicle, number of ill-filled grains per panicle, LAD at 60-80 DAT, shoot dry weight, root dry weight, root shoot ratio, panicle length, SLW at 80 DAT, and

grain yield per plant and non additive gene action for the traits, plant height, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT and harvest index. while *gca* component of variance was high for the characters, panicle length, SLW at 80 DAT, indicating the predominance of additive gene action in the inheritance of this trait, but the ratio *gca* component of variance to total genetic variance was intermediate to near unity and heritability narrow sense was low to intermediate indicating the presence of both additive and non additive gene action.

Among five lines tested for their combining abilities pertaining to different character under study, the line JGL 11118, recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT and SCMR at 80 DAT followed by RNR 2465, for days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, SLW at 80 DAT and shoot dry weight, Kavya, for number of filled grains per panicle, SLA at 80 DAT, SLW at 80 DAT and root dry weight and BPT 5204, for number of ill-filled grains per panicle, root dry weight, shoot dry weight and grain yield per plant and among testers, IR 64 recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50% flowering, days to maturity, number of ill-filled grains per panicle, 1000-grain weight followed by NLR 34449 for days to 50% flowering, days to maturity, number of filled grains per panicle and number of ill-filled grains per panicle.

Among the twenty crosses tested for specific combining ability for seventeen different characters, the cross, NLR 3041 x IR 36, recorded significant *sca* effects in desirable direction for majority of the traits viz., days to 50% flowering, days to maturity, number of effective tillers per plant, number of ill-filled grains and root dry weight and root shoot ratio followed by RNR 2465 x IR 64, for number of effective tillers per plant, shoot dry weight and grain yield per plant, BPT 5204 x NLR 34449 for days to 50% flowering, days to maturity, 1000 grain weight and JGL 11118 x IR 36 for 1000 grain weight, harvest index and shoot dry weight.

Heterosis studies revealed that five and two out of 20 crosses registered significant positive heterosis over mid parent and better parent for grain yield per plant, respectively. Out of 20 cross combinations, the crosses, BPT 5204 x IR 36 and JGL 11118 x IR 36, recorded highest significant relative heterosis and heterobeltiosis for grain yield per plant. Further heterotic studies also revealed that the cross, RNR 2465 x IR 64, registered highest significant positive heterosis for grain yield over both the checks (NLR 40024 and NLR 30491.) Though the *per se* performance of the parents involved in the above heterotic crosses are relatively low, the crosses are heterotic indicating better nicking ability of the parents involved in producing a high heterotic hybrid.

Correlation studies revealed that the traits plant height, panicle length, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT, SLA at 80 DAT, SLW at 80 DAT, harvest index and shoot dry weight and root shoot ratio were found to possess significant association in desirable direction with grain yield per plant.

Path analysis revealed that plant height, number of effective tillers per plant 1000 grain weight, SCMR at 80 DAT, SLW at 80 DAT and shoot dry weight showed true relationship by establishing 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 plant height, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT, SLW at 80 DAT and shoot dry weight.

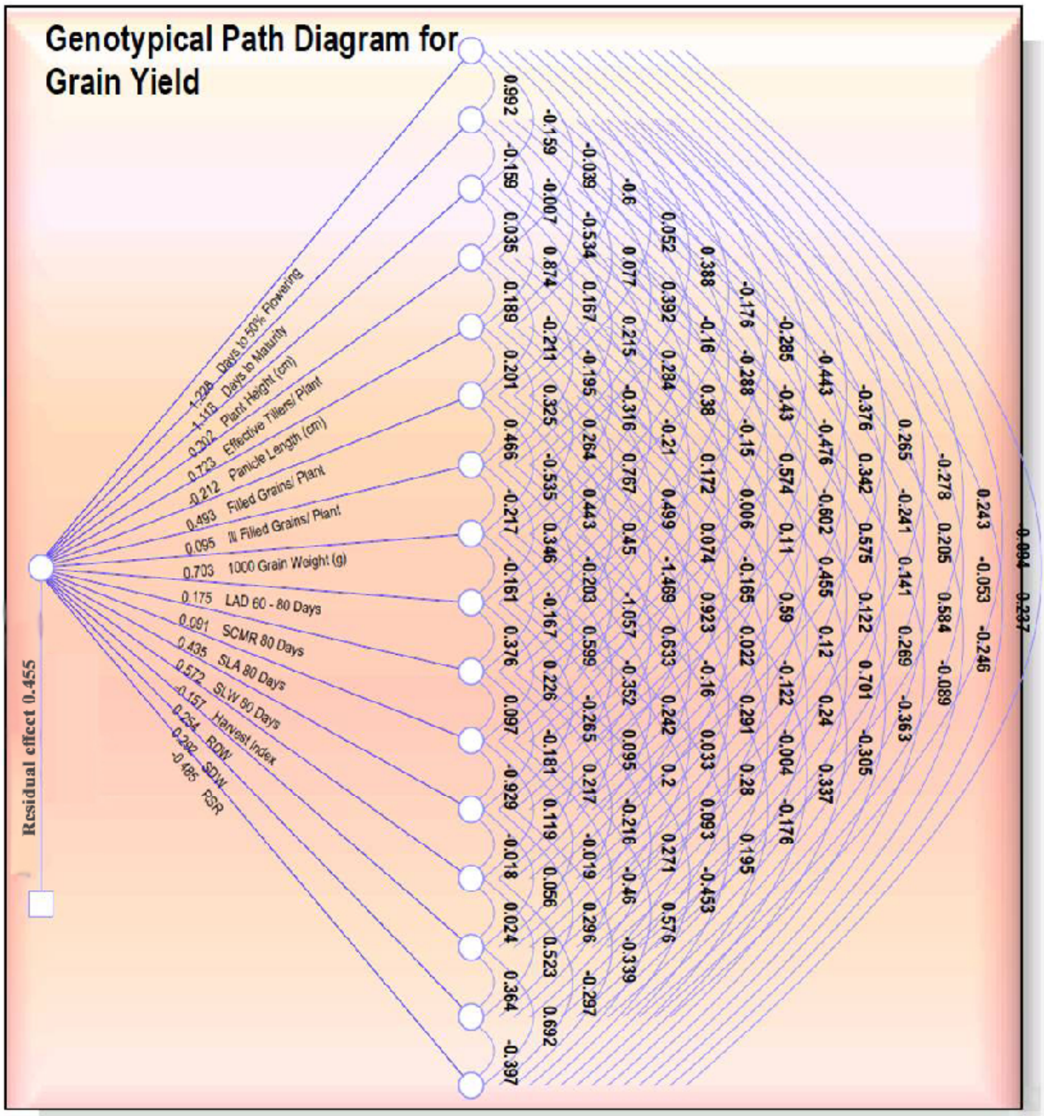

Table 4.1. Genotypic path diagram showing direct and indirect effects of yield components on grain yield per plant in rice (*Oryza sativa* L.)

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
ANOVA	:	Analysis of Variance
CD	:	Critical Difference
cm	:	Centimeter
cm^2/g	:	Centimeter square per gram
CV	:	Coefficient of Variation
DAT	:	Days After Transplanting
DFF	:	Days to 50 % flowering
DM	:	Days to maturity
d.f	:	Degrees of Freedom
et al.,	:	And co workers
F_1	:	First generation hybrid of a cross
g	:	Grams
g/cm^2	:	Gram per centimeter square
GA	:	Genetic advance
GAM	:	Genetic Advance as per cent of mean
gca	:	General combining ability
GCV	:	Genotypic Coefficient of Variation
GW	:	Grain Weight
GYP	:	Grain yield per plant
HI	:	Harvest index
i.e.	:	That is
K_2O	:	Potassium Oxide
kg/ha	:	Kilogram per hectare
LAD	:	Leaf area duration
L x T	:	Line x Tester
m	:	Meter
m^2	:	Meter square
MSL	:	Mean Sea Level
MSS	:	Mean Sum of Square

N	:	Nitrogen
NETP	:	Number of effective tillers per plant
NFGP	:	Number of filled grains per panicle
NIFGP	:	Number of ill-filled grains per panicle
No.	:	Number
NS	:	Non Significant
P_2O_5	:	Phosphorus Pentoxide
PCV	:	Phenotypic Coefficient of Variation
per se	:	As such with mean
PH	:	Plant height
PL	:	Panicle length
RBD	:	Randomized Block Design
RDW	:	Root dry weight
RSR	:	Root shoot ratio
S	:	Significant
sca	:	Specific combining ability
SCMR	:	SPAD chlorophyll meter reading
SDW	:	Shoot dry weight
SE	:	Standard Error
SEm	:	Standard Error mean
SLA	:	Specific leaf area
SLW	:	Specific leaf weight
SPAD	:	Soil plant analytical development
SS	:	Sum of Square
viz.,	:	Namely
vs.	:	Against

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Chapter I

INTRODUCTION

Rice is a staple food for half of the world's population and more than 60% of Indian population. It accounts for about 43% of total food grain production and 46% of total cereal production in India. The demand is increasing because of the expanding rice eating population, particularly in many developing countries of Asia and Africa. In order to meet the needs of increasing population the present day production of 105 mt of milled rice has to be increased to 125 mt by the year 2030. In India rice is cultivated in an area of 43.95 mha, with a production of 104.80 mt and with an average productivity of 2392 $kgha^{-1}$. Andhra Pradesh has an area, production and productivity of 3.80 mha, 11.57 mt and 2856 $kgha^{-1}$, respectively (Indiastat, 2014-15).

Economic product of rice is the grain yield, which exhibits complex genetics as it is influenced by various morphological and physiological yield contributing characters. In general, morphological characters like number of fertile panicles is the single most important yield component associated with rice yield, number of spikelets per panicle, per cent filled grains per panicle are also of secondary and tertiary importance (Jones and Synder, 1987). Yield is a function of physiological combined processes, the limiting component that change with the cultivar. Dry matter production is of great importance to rice as it combines with the harvest index to determine grain yield (Yoshida, 1972). The studies on harvest index and biological yield in relation with grain yield results in better understanding of partitioning of assimilates and their movement to grain. Theoretically, an increase in photosynthetic rate would increase crop yield, since the photosynthesis is highly responsible for the dry matter production. Research on relationship between Specific Leaf Weight (SLW, leaf dry weight per unit leaf area) and photosynthesis were undertaken in alfalfa, soyabean and reed canarygrass (Pearce *et al.*, 1969; Dornhoff & Shibles, 1970 and Anake *et al.*, 1977) and SLW was highly correlated with photosynthesis in each species. Kumara (1975) also used Specific Leaf Area (SLA) which is the reciprocal of SLW as one of the parameters in expressing the relative growth of leaf area in rice, this lead to a suggestion that SLW could be related to the relative efficiency of photosynthesis in rice. Chlorophyll content and Leaf Area Duration (*i.e* how long the crop can maintain an active green leaf canopy that can produce photosynthates) are also directly correlated with photosynthesis. These yield contributing components are interrelated with each other showing a complex chain of relationship (Prasad *et al*., 2001). However, there are limited reports in the literature on the feasibility of selection of these physiological traits in yield improvement of rice. Therefore, information on both morphological and physiological yield contributing traits is of great importance to the plant breeders for the development of improved varieties or lines of rice with increased yield potential.

In any breeding programme, seed yield is the ultimate goal. Success of any breeding programme primarily depends on selection of appropriate parents. Line x Tester analysis (Kempthorne, 1957) which involves the crossing of all lines with all testers is an efficient method for the study of general combining ability (*gca*) and specific combining ability (*sca*) variances and effects and also the gene action involved. This approach has practical utility in identifying the superior lines along with their heterotic effects which in turn can be utilized for genetic improvement of yield. The choice of parents for hybridization should be based not only on high combining ability but also on maximum expression of desirable agronomic traits. The magnitude of heterosis provides a basis for genetic diversity and acts as a guide in choosing desirable lines and cross combinations.

Knowledge on the nature and magnitude of the genetic variation governing the inheritance of quantitative characters like yield and its components is essential for effective genetic improvement. A critical analysis of the genetic variability parameters *viz.,* Genotypic Coefficient of Variability (GCV), Phenotypic Coefficient of Variability (PCV), heritability and genetic advance for different traits of economic importance is a major pre-requisite for any plant breeder to work with crop improvement programmes. Further, information on correlation co-efficients between grain yield and its components is essential for yield improvement, since grain yield in rice is a complex entity and is highly influenced by several yield contributing characters. Studies on path co-efficient also provide useful information regarding the direct and indirect effects of different yield components on grain yield and thus aid in the identification of effective selection criteria for effective yield improvement.

This experiment was therefore conducted to study the various morphological and physiological yield contributing traits in relation with variability, heritability, genetic advance, combining ability, gene action, heterosis, correlation coefficient and path coefficient analysis which is necessary to know the worth of the genotype.

Objectives of Investigation

1. To estimate variability, heritability and genetic advance for various yield and physiological attributes.
2. To analyze the nature of gene action and combining ability for grain yield and physiological parameters.
3. To know the extent of heterosis for grain yield and various physiological characters.
4. To study the correlation for different grain yield and physiological characters.
5. To study the direct and indirect effects of yield components on grain yield per plant.

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Note: The pattern of literature cited presented above is in accordance with the guidelines for Thesis presentation for Acharya N.G. Ranga Agricultural University, Guntur.

Chapter III

MATERIAL AND METHODS

The present investigation was carried out during *Kharif* 2015 & *Rabi* 2015-16 at Agricultural Research Station, Nellore, Andhra Pradesh, which is located at an altitude of 20 m above MSL, latitude of 14^0, 54' N and longitude of 79^0-59' E. The material used and methods followed are described below.

3.1 MATERIAL

The experimental material for the present investigation comprised 20 F_1s derived by crossing five females (lines) with four males (testers) parents in Line x Tester fashion and two checks (Table 3.1). Crossing work (*i.e* Emasculation & Pollination) and evaluation of single cross hybrids, parents along with 2 checks was carried out during *Kharif* 2015 & *Rabi* 2015-16 at Agricultural Research Station, Nellore. The information about the material used in this study is presented in Table 3.2.

Table 3.1 Details of the parents used in the present study

S.No	Parents	Features
1	BPT 5204 (Samba Mahsuri)	Pedigree: (GEB 24 x TN1) x Mahsuri Duration: 145 days Grain type: Medium Slender Specific Features: Excellent cooking quality having export potential. Highly susceptible to blast disease and BPH.
2	RNR 2465 (Sugandha Samba)	Pedigree: Early Samba x RNR 19994 Duration: 130-135 days Grain type: Medium Slender Specific Features: Aromatic high yielding variety, moderately resistant to sheath rot and BLB.
3	WGL 48684 (Kavya)	Pedigree: WGL 27120 x WGL 17672 x Mahsuri x Surekha Duration: 135 days Grain type: Medium Slender Specific Features: Highly resistant to gall midge.

4	JGL 11118	Pedigree: IET 8585 x JGL 1798 Duration: 115-120 days Grain type: Fine grain Specific Features: High yielding and tolerant to gall midge biotype 1, 2 and 3 and tolerant to BLB.
5	IR 36	Pedigree: (IR 1561-228-1-2 x IR 1737) x Cr 94-13 Duration: 111 days Grain type: Long Slender Specific Features: Resistant to blast, bacterial blight, tungro virus, GLH and BPH (1, 2) and gall midge.
6	IR 64	Pedigree: IR 5657-33-2-1 x IR 2061-465-1-5-5 Duration: 120 days Grain type: Long Slender Specific Features: Resistant to blast, bacterial blight, tungro virus, GLH and BPH (2).
7	NLR 34449 (Nellore Mahsuri)	Pedigree: IR 72 x BPT 5204 Duration: 125 days Grain type: Medium (Fine grain) Specific Features: Resistant to blast.
8	NLR 145 (Swarnamukhi)	Pedigree: CICA 4/IR 625-23-3-1//Tetep Duration: 135-140 days Grain type: Long Slender Specific Features: Resistant to blast, tolerant to gall midge, stem borer and moisture stress.
9	NLR 3041 (Nellore Sona)	Pedigree: BPT 5204 x NLR 145 Duration: 145 days Grain type: Fine grain Specific Features: Resistant to blast.
10	NLR 40024 (Swetha)	Pedigree: WGL 14280-1 x NLR 30491 Duration: 120 days Grain type: Fine grain Specific Features: Suitable for early *kharif*, Resistant to blast, non lodging and thermo tolerance.
11	NLR 30491 (Bharani)	Pedigree: IR 36 x Sasyasree Duration: 125 days Grain type: Medium slender Specific Features: Resistant to RTV and suitable for early *kharif*.

3.2` METHODS

3.2.1 Crossing Programme

To generate experimental material crossing was taken up at Agricultural Research Station, Nellore. The crossing block was laid out in field no. 20, staggered sowings of the parents were undertaken at an interval of ten days to ensure synchronus flowering and continuous availability of pollen to produce adequate crossed seed. Emasculation was done by clipping method. The female lines with just emerged panicles were uprooted and potted in the early morning hours of the day into plastic buckets filled with mud and were transferred to the net house and allowed to settle to prevent plant from shock. 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. Top 1/3rd of each floret was clipped with scissors during evening and anthers were removed with needle and the clipped florets were covered with butter paper bags and labeled properly.

Pollination was carried out 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 clipped and 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 and labeled. The process of pollination was continued up to 11.00 AM. Crossed seeds were collected after maturing from the plants maintained in the pots in the net house. The seeds were then sun dried, separated and placed in small envelops separately with label.

3.2.2 Experimental Technique

The detailed experimental technique for the present investigation has been furnished below

Location	:	Agricultural Research Station, Nellore.
Season	:	*Kharif* & *Rabi* 2015-16
Design	:	Randomized Complete Block Design

Entries	:	20 F_1+9 parents (5 lines and 4 testers) +2checks
Replications	:	2
Spacing	:	20 ×15 cm
Row number	:	3
Row length	:	3.15 m
Plot size	:	1.89 m^2
Fertilizers	:	120 kg N: 60 kg P_2O_5: 40 kg K_2O/ha.
Plant protection	:	Need based

3.2.3 Record of Observations

Observations were recorded on ten randomly selected plants per treatment per replication and were used for statistical analysis. However, days to 50% flowering and days to maturity were recorded per plot basis and physiological parameters like leaf area duration, SCMR, specific leaf area and specific leaf weight were recorded at 20 days interval.

Table 3.2 Material used in Line x Tester analysis in rice (*Oryza sativa* L.)

TESTERS / LINES	NLR 145	NLR 34449	IR 64	IR 36
NLR 3041	NLR 3041 x NLR 145	NLR 3041 x NLR 34449	NLR 3041 x IR 64	NLR 3041 x IR 36
JGL 11118	JGL 11118 x NLR 145	JGL 11118 x NLR 34449	JGL 11118 x IR 64	JGL 11118 x IR 36
BPT 5204	BPT 5204 x NLR 145	BPT 5204 x NLR 34449	BPT 5204 x IR 64	BPT 5204 x IR 36
RNR 2465	RNR 2465 x NLR 145	RNR 2465 x NLR 34449	RNR 2465 x IR 64	RNR 2465 x IR 36
Kavya	Kavya x NLR 145	Kavya x NLR 34449	Kavya x IR 64	Kavya x IR 36
Checks	NLR 30491		NLR 40024	

The detailed method of recording observations is presented here under character wise.

3.2.3.1 Morphological parameters

3.2.3.1.1 Days to 50 per cent 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 per cent flowering. Observations for this trait were recorded per plot basis.

3.2.3.1.2 Days to maturity

The number of days taken to complete maturity from the date of sowing till harvest was recorded.

3.2.3.1.3 Plant height (cm)

The plant height was measured in centimeters from ground level to the tip of the panicle of the mother tiller excluding awns at the time of harvest.

3.2.3.1.4 Number of effective tillers per plant

Total number of ear bearing tillers in each randomly selected plant was counted at maturity.

3.2.3.1.5 Panicle length (cm)

Length of panicle was measured from base of the panicle to the top most spikelet and was measured in centimeters.

3.2.3.1.6 Number of filled grains per panicle

The number of filled grains per panicle were counted and recorded.

3.2.3.1.7 Number of ill-filled grains per panicle

The number of ill- filled grains per panicle were counted and recorded.

3.2.3.1.8 1000 grain weight (test weight) (g)

One thousand well filled grains from each treatment were counted and weighed to nearest milligram at 12 % moisture level. The weight was recorded in grams.

3.2.3.1.9 Grain yield per plant (g)

The matured panicles were harvested, threshed, cleaned and seed dried to 12% moisture level. The grain yield per plant was recorded in grams.

3.2.3.2 Physiological parameters

Leaf area was measured at 60 and 80 days after transplanting by using Leaf Area Meter (Model No. LP-80) and was expressed in cm^2.

3.2.3.2.1 Leaf area duration

Leaf area duration represents the persistence of greenness of leaf. It was calculated by using following formula of (Power *et al.*, 1967). This is a measure of the duration of the assimilatory surface.

$$LAD = \frac{LA_1 + LA_2}{2} \times (t_2 - t_1)$$

LA_1 and LA_2 represents leaf area at t_1 and t_2 time interval in days.

3.2.3.2.2 SCMR (SPAD Chlorophyll meter reading)

The total chlorophyll content was measured with SPAD (soil plant analytical development) chlorophyll meter reading (SCMR) following the method of Turner and Jund (1991) at 80 days after transplanting in each treatment. SCMR data was recorded on 3rd or 4th leaf from top of each representative plant, between 10.00 a.m to 12.00 noon of the day. A mean of 25 readings from five representative plants per plot was taken.

3.2.3.2.3 Specific Leaf Area (cm^2/g)

Specific leaf area is the area of leaf surface displayed per unit leaf dry weight, which was calculated by the formula as adopted by Hall *et al.* (1993).

$$SLA = \frac{\text{Leaf Area}}{\text{Leaf Dry Weight}}$$

3.2.3.2.4 Specific Leaf Weight (g/cm^2)

Specific leaf weight is the ratio between leaf dry weight and leaf area which indicates leaf density or relative thickness of the leaves, which was calculated by the formula adopted by Radford (1967).

$$\text{SLW} = \frac{\text{Leaf Dry Weight}}{\text{Leaf Area}}$$

3.2.3.2.5 Harvest index

It is calculated by dividing the grain yield with biological yield per plant and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

3.2.3.2.6 Root dry weight (g)

Root of individual plants were dried after harvest at a temperature of 80^{0}C for about 72 hours in hot air oven to attain a constant dry weight and dry weight was recorded.

3.2.3.2.7 Shoot dry weight (g)

Shoot of individual plants were dried after harvest at a temperature of 80^{0}C for about 72 hours in hot air oven to attain a constant dry weight and dry weight was recorded.

3.2.3.2.8 Root shoot ratio

Ratio of root dry weight to shoot dry weight on per plant basis was recorded.

3.3 STATISTICAL ANALYSIS

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

3.3.1 Analysis of Variance

Analysis of variance of the characters was done as per standard statistical procedure for randomized complete block design as 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

The structure of analysis of variance was as follows.

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	$\sigma^2_e + t\ \sigma^2_r$	$M_r/\ M_e$
Treatments	t-1	M_t	$\sigma^2_e + r\ \sigma^2_g$	$M_t/\ M_e$
Error	(r-1)(t-1)	M_e	σ^2_e	
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^2_e = Environmental variance

σ^2_r = Variance due to replications

σ^2_g = Variance due to genotypes

3.3.2 Estimation of Genetic Parameters

In order to assess and quantify the genetic variability among the parents and F_1s for the characters under study, the following parameters were estimated as given below.

3.3.2.1 Estimation of variance components

Phenotypic and genotypic variances were estimated using the following formula,

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

$$\text{Phenotypic variance } (\sigma^2_p) = \sigma^2_g + M_e = \frac{M_t - M_e}{r} + M_e$$

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

3.3.2.2 Coefficient of variation

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

a) Genotypic coefficient of variation (GCV)

$$\text{GCV \%} = \frac{\text{Genotypic standard deviation } (\sigma_g)}{\text{General mean } (\overline{X})} \times 100$$

b) Phenotypic coefficient of variation (PCV)

$$\text{PCV \%} = \frac{\text{Phenotypic standard deviation } (\sigma_p)}{\text{General mean } (\overline{X})} \times 100$$

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%

3.3.2.3 Heritability

Heritability in broad sense was computed as the ratio of genetic variance to the total phenotypic variance and narrow sense heritability was the ratio of additive genetic variance to the total phenotypic variance as suggested by Hanson *et al.* (1956) and expressed as percentage.

$$\text{Heritability in broad sense } h^2_{(b)}\ \% = \frac{\text{Genotypic variance } (\sigma^2_g)}{\text{Phenotypic variance } (\sigma^2_p)} \times 100$$

$$\text{Heritability in narrow sense } h^2_{(n)}\ \% = \frac{\text{Additive variance } (\sigma^2_A)}{\text{Phenotypic variance } (\sigma^2_p)} \times 100$$

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%

3.3.2.4 Expected genetic advance

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

Expected genetic advance (GA) = K x σ_p x h^2

Where,

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

σ_p = Phenotypic standard deviation

h^2 = Heritability in broad sense

3.3.2.5 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%

3.3.3 Combining Ability Analysis

The combining ability analysis of parents and crosses was taken up for different characters using the Line x Tester model as given by Kempthorne (1957).

Mathematical model for combining ability analysis is

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}$$

Where,

Y_{ijk} = Any measurable character of the cross i x j in the k^{th} replication

μ = Population mean effect

g_i = General combining ability effect of line or female parent

g_j = General combining ability effect of tester or male parent

s_{ij} = Specific combining ability effect of i x j^{th} cross

r_k = Effect due to k^{th} replication

e_{ijk} = Environmental effect on ijk^{th} individual

ANOVA of L x T Mating Design for Combining Ability

Source of variation	**Degrees of freedom**	**MSS**	**Expected MSS**
Replications	(r-1)	M_r	
Entries (genotypes)	(e-1)	M_g	
Parents	(p-1)	M_p	
Crosses	(c-1)	M_c	
Parents vs Crosses	1	M_{pc}	
Lines	(l-1)	M_l	$\sigma^2 + r\sigma^2_s + rt\sigma^2_f$
Testers	(t-1)	M_t	$\sigma^2 + r\sigma^2_s + rl\sigma^2_m$
Lines x testers	(l-1)(t-1)	M_{lt}	$\sigma^2 + r\sigma^2_s$
Error	(e-1)(r-1)	M_e	σ^2

Where,

r = Number of replications

e = Number of entries

p = Number of parents

l = Number of lines or female parents

t = Number of testers or male parents

c = Number of crosses

σ^2 = Random error

σ^2_s = Variance of interaction between lines and testers

σ^2_f = Variance due to lines

σ^2_m = Variance due to testers

3.3.3.1 Estimation of combining ability effects

i. *gca* effect of line and tester

$$\text{Line } g_i = \frac{X_{i..}}{tr} - \frac{X_{...}}{ltr}$$

$$\text{Tester } g_j = \frac{X_{.j.}}{lr} - \frac{X_{...}}{ltr}$$

ii. *sca* effect of cross

$$s_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{tr} - \frac{X_{.j.}}{lr} - \frac{X_{...}}{ltr}$$

Where,

$X_{...}$ = Grand total

$X_{i..}$ = Total of i^th^ line over replications and testers

$X_{.j.}$ = Total of j^th^ tester over replications and lines

$X_{ij.}$ = Total of ij^th^ cross over replications

3.3.3.2 Standard errors for combining ability effects

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

$$S.E\ (g_i) = \left[\frac{M_e}{tr}\right]^{1/2} \quad \text{(for lines)}$$

$$S.E\ (g_j) = \left[\frac{M_e}{lr}\right]^{1/2} \quad \text{(for testers)}$$

$$S.E\ (s_{ij}) = \left[\frac{M_e}{r}\right]^{1/2} \quad \text{(for crosses)}$$

$$S.Ed\ (g_i-g_k) = \left[\frac{2M_e}{tr}\right]^{1/2} \quad \text{(between } gca \text{ effects of two lines)}$$

$$S.Ed\ (g_j-g_l) = \left[\frac{2M_e}{lr}\right]^{1/2} \quad \text{(between } gca \text{ effects of two testers)}$$

$$S.Ed\ (s_{ij}-s_{kl}) = \left[\frac{2M_e}{r}\right]^{1/2} \quad \text{(SEd for any two } sca \text{ effects of hybrids)}$$

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

$$t_{cal} = \frac{|g_i - 0|}{SE(g_i)} \quad \text{(for lines)}$$

$$t_{cal} = \frac{|g_j - 0|}{SE(g_j)} \quad \text{(for testers)}$$

$$t_{cal} = \frac{|s_{ij} - 0|}{SE(s_{ij})} \quad \text{(for crosses)}$$

't' calculated value is compared with 't' table value at error degrees of freedom.

3.3.3.3 Estimation of genetic components of variation

The estimates of variance components were obtained from the algebraic manipulation of mean sum of squares in the ANOVA of L x T mating design for combining ability.

Estimation of covariances

Covariances of full sibs and half sibs were estimated using the formula as given below.

$$\text{Cov (HS)} = \frac{M_t + M_l - 2M_{lt}}{r\,(t + l)}$$

$$\text{Cov (FS)} = 1/\,3r\left[M_t - M_l + M_{lt} - 3M_e + 6r\,\text{Cov (HS)} - r\,(t + l)\,\text{Cov (HS)}\right]$$

The genetic components of variation were estimated by relating the variance components to covariance of half sibs (Cov. HS) and full sibs (Cov. FS) as

$$\sigma^2_f = \sigma^2_m = \text{Cov. HS}$$

$$\sigma^2_s = \text{Cov. FS} - 2\text{Cov. HS}$$

$$\sigma^2_{gca} = \text{Cov.HS} = \left[\frac{1 + F}{4}\right]\sigma^2_A$$

$$\sigma^2_{sca} = \text{Cov. FS} - \text{Cov. HS} = \left[\frac{1 + F}{2}\right]\sigma^2_D$$

Where,

σ^2_{gca} = General combining ability variance

σ^2_{sca} = Specific combining ability variance

F = Inbreeding coefficient

Proportional contribution of lines, testers and their interactions

$$\text{Per cent contribution of lines} = \frac{SS_l}{SS_c} \times 100$$

$$\text{Per cent contribution of tester} = \frac{SS_t}{SS_c} \times 100$$

$$\text{Per cent contribution of l } l \text{ x t} = \frac{SS_{lt}}{SS_c} \times 100$$

Where,

SS_l = Sum of squares of lines

SS_t = Sum of squares of testers

SS_{lt} = Sum of squares of lines x testers

SS_c = Sum of squares of crosses

3.3.4 Estimation of Heterosis

The heterotic effects were measured as deviation of F_1mean from mid parent (relative heterosis), better parent (heterobeltiosis) and the standard check (standard heterosis) 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

$$\text{Standard heterosis} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

Where,

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

$\overline{SP}$ = Mean value of standard check

3.3.4.1 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:

$$\text{Heterosis 't' (mid parent)} = \frac{\text{Mean of F1 - Mean of mid parent}}{\sqrt{3/2EMS/r}}$$

$$\text{Heterosis 't'} = \frac{\text{Mean of } F_1 \text{ –Better parent (or) standard check}}{\sqrt{2EMS/r}}$$

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

3.3.5 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).

$$\text{Phenotypic coefficients of correlation } (r_p) = r(x_i x_j)_p = \frac{Cov(x_i x_j)_p}{\left[V(x_i)_p \, . \, V(x_j)_p\right]^{1/2}}$$

Where,

$r(x_i x_j)_p$ = Phenotypic correlation between i^{th} and j^{th} characters

$Cov(x_i x_j)_p$ = 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

$$\text{Genotypic coefficients of correlation } (r_g) = r(x_i x_j)_g = \frac{Cov(x_i x_j)_g}{\left[V(x_i)_g \, . \, V(x_j)_g\right]^{1/2}}$$

Where,

$r(x_i x_j)_g$ = Genotypic correlation between i^{th} and j^{th} characters

$Cov(x_i x_j)_g$ = Genotypic covariance between i^{th} and j^{th} characters

$V(x_i)_g$ and $V(x_j)_g$ = Genotypic variance of i^{th} and j^{th} characters respectively

3.3.5.1 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.

3.3.6 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:

$$r_{1,y} = P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} P_{3,y} + \ldots + r_{1,k} P_{k,y}$$

$$r_{2,y} = r_{2,1} P_{1,y} + P_{2,y} + r_{2,3} P_{3,y} + \ldots + r_{2,k} P_{k,y}$$

$$\vdots$$

$$r_{k,y} = r_{k,1} P_{1,y} + r_{k,2} P_{2,y} + r_{k,3} P_{3,y} + \ldots + r_{k,k} P_{k,y}$$

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 residual effect was computed by using the formula

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

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’

Chapter IV

RESULTS AND DISCUSSION

The present investigation was carried out with 20 hybrids (derived from crossing 5 lines with 4 testers in line × tester fashion) along with 9 parents and 2 checks, at Agricultural Research Station, Nellore, Andhra Pradesh, during *kharif* 2015 and *rabi* 2015-16 to know the variability, heritability, genetic advance, combining ability, heterosis, character association and direct and indirect effects for yield, yield contributing and physiological traits in rice.

The details of results obtained from the above investigation are discussed character-wise and presented here under in following headings.

4.1 Mean, genetic variability, heritability and genetic advance

4.2 Combining ability

4.3 Heterosis

4.4 Character association

4.5 Path analysis

4.1 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any breeding programme depends on presence of sufficient variability in the population and that the variability observed should be heritable with no or least influence by the environment. In addition to the genetic variability, knowledge on heritability and genetic advance helps the breeder to employ the suitable breeding strategy.

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 (Johnson *et al.*, 1955).

The details of mean values, analysis of variance and genetic variability, Heritability and genetic advance as per cent of mean are presented in Table 4.1, 4.2 and 4.3, respectively. The estimates of variability revealed that PCV values slightly higher than GCV values indicating little role of environment in the expression of traits.

4.1.1 Days to 50% Flowering

In the present study, days to 50% flowering varied from 82.50 (RNR 2465 x IR 36) to 109 (NLR 3041) with a mean of 91.95. The estimates of GCV (7.25) and PCV (7.59) were low indicating less variation among the genotypes studied and high heritability (91%) coupled with moderate genetic advance as per cent of mean (14.27) was observed for this trait. The trait days to 50 % flowering indicates appropriate duration of the variety, which is an important criterion in rice breeding programmes, to develop rice varieties with different duration. The PCV and GCV were low for this trait though the heritability was very high with moderate genetic advance, indicating the operation of both additive and non additive gene actions, thus offering less scope for selection. Similar trend was observed by Khare *et al.* (2014).

4.1.2 Days to Maturity

Days to maturity varied from 115.50 (RNR 2465 x IR 36) to 139.50 (NLR 3041) with a mean of 123.82. The estimates of low GCV (4.95) and PCV (5.26) and high heritability (89%) coupled with low genetic advance as per cent of mean (9.62) was observed for this trait. Genotypes with low days to maturity indicate the earliness of a variety, which is a desirable criterion. The trait exhibited high heritability and low genetic advance indicating the operation of both additive and non additive gene actions in the inheritance and hence simple selection may not be rewarding. The above findings are in agreement with Aishwarya *et al.* (2014).

4.1.3 Plant Height (cm)

In the present investigation, the range of variability from 66.88 cm (BPT 5204 x IR 36) to 83.50 cm (JGL 11118 x IR 36) was observed for plant height with a mean of 74.37 cm. The coefficient of variations for this trait were low with (5.11) for GCV and (6.57) for PCV. High heritability (61%) coupled with low genetic advance as per cent of mean (8.26) was observed for this trait indicates the operation of both additive and non additive gene actions in the inheritance of this trait. These results were in accordance with Ullah *et al.* (2011), Singh *et al.* (2011) and Verma *et al.* (2011).

4.1.4 Number of Effective Tillers per Plant

The range of variation for number of effective tillers per plant varied from 8.09 (JGL 11118) to 19.83 (NLR 3041 x IR 36) with a mean of 12.51. The estimates of GCV (19.28) and PCV (22.38) were moderate and high, respectively. High heritability (74%) coupled with high genetic advance as per cent of mean (34.29) was observed for this trait. The grain yield of any variety mainly depends upon the contribution of yield determining characters and among them effective tillers per plant is important. The large difference between PCV and GCV indicated the high influence of environment. However, high heritability with high genetic advance indicates the predominance of additive gene action and hence offers great scope for improving this trait to the desired extent through simple selection. These findings are in accordance with Binse *et al.* (2006).

4.1.5 Panicle Length (cm)

Length of the panicle ranged from 17.20 cm (BPT 5204) to 25.20 cm (JGL 11118 x IR 36) with a mean of 20.97 cm. The estimates of GCV (7.14) and PCV (10.83) were low and moderate. The heritability was moderate (44%) and genetic advance as per cent of mean (9.71) was low for this trait. Length of the panicle is an important yield contributing trait which exhibited moderate heritability and low genetic advance as per cent of mean suggesting the role of both additive and non additive gene actions in the inheritance of this trait. The above findings are in agreement with Paikhomba *et al.* (2014) and Sathya and Jebaraj (2015).

4.1.6 Number of Filled Grains per Panicle

NLR 3041 x IR 64 and Kavya x IR 36 exhibited the lowest 105.05 and highest 218.30 values for number of filled grains per panicle, respectively with a mean of 159.29. The GCV (16.59) and PCV (18.85) values for this trait were moderate. High values of heritability (77%) and genetic advance as per cent mean (30.10) were also observed.

The range for number of filled grains per panicle is not only an index of the photosynthetic efficiency but also a indicator for source sink relationship of the plant was found to vary from 105.05 to 218.30 with high heritability and genetic advance revealing the preponderance of additive gene action which may be exploited through simple selection procedures. These observations were in conformity with the results of Khatun *et al*. (2015) and Sathya and Jebaraj (2015).

4.1.7 Number of Ill-filled Grains per Panicle

Values for the trait number of ill-filled grains per panicle ranged from 9.00 (NLR 40024) to 82.70 (NLR 3041 x NLR 145) with a mean of 27.48. High values of GCV (53.30) and PCV (55.17), heritability (93%) and genetic advance as per cent of mean (106.10) were observed for this trait indicated the presence of wide variability among genotypes. This character exhibited high values of genotypic and phenotypic coefficient of variation, heritability and genetic advance suggesting the importance of additive gene action in the inheritance of this trait. These findings were in accordance with the results of Shrivastava *et al.* (2014), Khatun *et al.* (2015) and Hossain *et al.* (2015).

4.1.8 1000 Grain Weight (g)

The 1000 grain weight ranged from lowest 11.33 g (NLR 3041 x NLR 34449) to highest 23.05 g (IR 64) with a mean of 16.08 g. The GCV (18.00) and PCV (18.24) were moderate, without much difference indicating that the trait is less influenced by the environment. Whereas high heritability (97%) coupled with high genetic advance as per cent of mean (36.59) was observed for this trait indicates additive gene action was predominate in the inheritance this trait, thus simple selection would be rewarding. Khare *et al*. (2014) and Khatun *et al.* (2015) also reported similar results of high heritability coupled with high genetic advance as per cent mean for this trait.

4.1.9 LAD at 60-80 DAT

Leaf area duration (LAD) is the stay green nature of the crop. The total dry matter production of a crop is a function of how long the crop can maintain an active, green leaf canopy that can produce photosynthates. Rice is a determinate crop, if active green leaf canopy persists upto maturity, it results in increased yield through active participation of green leaves in photosynthesis, and which could produce assimilates and finally remobilized to grains. It results in strong source sink relationship by increasing the total number of filled grains per panicle.

. Wide range of variability was observed for this trait which varied from 480.50 (NLR 40024) to 871.93 (JGL 11118 x NLR 145) with a mean of 657.69. The coefficient of variations for this trait were moderate with (11.58) for GCV and (13.17) for PCV. High heritability (77%) coupled with high genetic advance as per cent of mean (20.97) was observed for this trait. Leaf area duration is an important physiological character and the genotypes with more leaf area duration and high heritability are most preferable. Since the trait LAD at 60-80 DAT exhibited high heritability coupled with high genetic advance, which were in accordance with findings of Murthy *et al.* (1999) additive genes plays dominance role in inheritance of this trait and offer good scope for improving by simple selection to the desired extent.

4.1.10 SCMR at 80 DAT

The rice plant at any point of time is composed of leaves of physiologically different ages, so it follows that the leaves differ in their contributions to the growth of the whole plant and its grain yield. SPAD chlorophyll meter reading is an indication of light transmittance characteristics of the leaf which is dependent on the leaf chlorophyll content (Richardson *et al.*, 2002). As the leaf chlorophyll content (Soil Plant Analytical Division value) is the best indicator of photosynthetic activity in rice, the chlorophyll content of rice at 80 days after transplanting was determined.

SCMR at 80 DAT was ranged from 40.70 (Kavya) to 50.00 (JGL 11118 x NLR 145) with a mean of 44.94. The GCV (5.01) and PCV (6.26) were low, whereas high heritability (64%) and low genetic advance as per cent of mean (8.26) were observed for this trait. High heritability coupled with low genetic advance as per cent of mean for this trait indicated the role of both additive and non additive gene action in the expression of this character. High SCMR values maintains strong source sink relationship leading to increased grain yield for which, high values of heritability was also observed earlier by Ullah *et al.* (2011).

4.1.11 SLA at 80 DAT (cm^2/g)

Specific leaf area is often considered as an indirect measure of leaf expansion. Higher SLA means higher leaf area per unit biomass and large surface for transpiration, on the other hand if SLA is lower the leaf thickness would be more and hence the capacity of photosynthesis would be higher and it leads to increased grain yield.

Genotypes with lower SLA (thicker leaves) are known to have more of photosynthetic machinery i.e. more chlorophyll content (Rao and Wright, 1994). Similarly, Wright *et al.* (1994) suggested that selection of low SLA type might result in the production of more dry matter.

SLA at 80 DAT ranged from 52.36 (Kavya x IR 64) to 75.76 (RNR 2465 x NLR 145) with a mean of 63.19. The coefficient of variation for this trait was low (2.17) for GCV and moderate (10.57) for PCV. Low heritability (4.0%) coupled with low genetic advance as per cent of mean (1.00) was observed for this trait. The presence of low heritability and genetic advance as per cent of mean was observed for this trait indicated that this character is highly influenced by environment and selection would be ineffective.

4.1.12 SLW at 80 DAT (g/cm^2)

High specific leaf weight is a desirable character as it is directly proportional to the photosynthetic rate. High values of specific leaf weight under irrigated condition is attributed to decrease in leaf area and increase in leaf thickness.

The range of variation for specific leaf weight at 80 days after transplanting varied from 0.0133 (RNR 2465 x NLR 145) to 0.0191 (Kavya x IR 64) with a mean of 0.0160. The estimates of GCV (3.04) and PCV (9.89) were low. Similar results were also reported by Adilakshmi and Raghavareddy (2012). Low heritability (09%) coupled with low genetic advance as per cent of mean (1.92) was observed for this trait, indicating the operation of non additive gene action and that this character is highly influenced by environment and selection would be ineffective. The above findings are in agreement with John *et al.* (2011).

4.1.13 Harvest Index

Harvest index ranged from 25.45 (Kavya) to 68.03 (JGL 11118 x IR 36) with a mean of 44.36. The coefficient of variation for GCV (16.16) and PCV (21.34) were moderate and high. Moderate heritability (57%) coupled with high genetic advance as per cent of mean (25.20) was observed for this trait. Grain yield in rice related to biological yield and harvest index. Harvest index is directly proportional to grain yield. Moderate heritability and high genetic advance as per cent of mean indicating the preponderance of both additive and non additive gene actions and further improvement of this character would be possible through heterosis breeding rather than simple selection. These findings were in line with the results of Karim *et al.* (2007).

4.1.14 Root Dry Weight

The range of root dry weight varied from 3.90 (Kavya) to 12.69 (RNR 2465) with a mean of 7.08. High GCV and PCV values were 26.51 and 29.91, respectively with high heritability (79%) and genetic advance as per cent of mean (48.40) were observed for this trait. Root system is an important organ of plants. It absorbs water and nutrients from soil and supplies to plant tops for their metabolic activities. A vigorous root system is responsible for the development of healthy plants and, consequently higher yields. High heritability coupled with high genetic advance was observed for this trait indicating the operation of additive gene action. Hence, the trait can be improved through direct selection. Similar results were reported by Ukaoma *et al.* (2013) and Shajedur *et al.* (2015).

4.1.15 Shoot Dry Weight

Wide variability of 45.52 (Kavya) to 101.04 (NLR 145) with a mean of 71.51 was observed for this trait. The coefficient of variation for GCV (20.55) and PCV (22.88) were high. High heritability (81%) coupled with high genetic advance as per cent of mean (38.03) was observed for this trait. Dry matter production in rice has been reported to be significantly related to shoot biomass as it intercept photo synthetically active radiation. Crop growth rate depends on the amount of radiation intercepted by the crop and on the efficiency of intercepted radiation converted into dry matter. The production of sufficient shoot dry matter is important for improving the grain yield of rice. High heritability and genetic advance revealed the importance of additive gene action. This indicates that the character can be improved through simple selection procedures. These findings were in agreement with the results of Ukaoma *et al.* (2013) and Shajedur *et al.* (2015).

4.1.16 Root Shoot Ratio

Root shoot ratio varied from 0.054 (JGL 11118 x IR 36) to 0.17 (NLR 3041 x NLR 145) with a mean of 0.10. The estimates of GCV (26.27) and PCV (28.56) were high. High heritability (85%) coupled with high genetic advance as per cent of mean

(49.75) was observed for this trait, indicating the preponderance of additive gene action which may be exploited through simple selection procedures. The above findings are in agreement with Sathya and Jebaraj (2015).

4.1.17 Grain Yield per Plant (g)

The range of variation for grain yield per plant varied from 17.33 g (Kavya) to 42.00 g (RNR 2465 x IR 64) with a mean of 30.34 g. The estimates of GCV (19.35) and PCV (23.94) were moderate and high, respectively. High heritability (65%) coupled with high genetic advance as per cent of mean (32.23) indicated the role of additive gene action. The findings of the present study indicated high variability, high heritability and high genetic advance as per cent of mean for grain yield which is a positive indication for improving the productivity levels. High heritability and genetic advance for yield per plant were also reported by Khare *et al*. (2014), Tetwar *et al*. (2014), Kishore *et al.* (2015) and Khatun *et al*. (2015). Since this character exhibited high heritability coupled with high genetic advance, direct selection for grain yield per plant will be useful in isolating superior genotypes for higher productivity.

The estimates of PCV and GCV were high for characters viz., Number of ill-filled grains per panicle, root dry weight, shoot dry weight and root shoot ratio. High PCV and moderate GCV were observed for number of effective tillers per plant, harvest index and grain yield per plant. Moderate PCV and GCV were observed for number of filled grains per panicle, 1000 grain weight and LAD at 60-80 DAT. Moderate PCV and low GCV were observed for panicle length, SLA at 80 DAT while. Low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, SCMR at 80 DAT and SLW at 80 DAT.

PCV values was close to GCV for the traits, Days to 50% flowering, Days to maturity, plant height, number of effective tillers per plant, panicle length, number of filled grains per panicle, number of ill-filled grains per panicle, 1000-grain weight, LAD at 60-80 DAT, SCMR at 80 DAT, shoot dry weight and root shoot ratio exhibiting little or no influence of environment on these traits, while for the traits, SLA at 80 DAT, SLW at 80 DAT, harvest index, root dry weight and grain yield per plant, PCV was high than GCV indicating the involvement of environment in expression of these traits.

The estimates of heritability and genetic advance as per cent of mean were high for the characters viz., number of effective tillers per plant, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT, root dry weight, shoot dry weight, root shoot ratio and grain yield per plant indicating the involvement of additive gene action in the inheritance of these traits hence simple selection would be rewarding. High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, high heritability coupled with low genetic advance as per cent of mean was observed for days to maturity, plant height and SCMR at 80 DAT, moderate heritability coupled with high genetic advance as per cent of mean was observed for harvest index, moderate heritability coupled with low genetic advance as per cent of mean was observed for panicle length indicating involvement of both additive and non additive gene action in the inheritance of these traits thus simple selection may not be effective instead population improvement for these traits would be desirable. While low heritability coupled with low genetic advance as per cent of mean was observed for SLA at 80 DAT and SLW at 80 DAT thus proposing the preponderance of non additive gene action in the inheritance of these traits thus heterosis breeding would be more desirable for these traits.

4.2 COMBINING ABILITY AND GENE ACTION

Combining ability analysis is frequently used for testing the performance of parents and hybrid combinations and to understand the nature and magnitude of gene action involved in the inheritance of the trait. Estimates of combining ability will be useful in selection of desirable parents based on the performance of 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 segregants in F_2 and subsequent generations. Exploitation of heterosis is primarily depends 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). The ultimate objective of the combining ability is to identify superior parents with good general combining abilities and hybrids with specific combining abilities. General combining ability (*gca*) is used to designate the average performance of a line in hybrid combinations while specific combining ability (*sca*) define those cases 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 are 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.

The twenty hybrids, five lines and four testers along with two checks were evaluated during *rabi* 2015-16 to estimate the combining ability for yield and yield components and physiological traits.

Analysis of variance for combining ability for different characters under study is presented in Table 4.4. The results revealed the existence of variability among parents and different cross combinations for majority of the characters studied. The character-wise estimates of *gca* effects of parents and *sca* effects of crosses are presented in Tables 4.5 and 4.6 respectively and estimates of genetic components of variance and proportional contribution of lines, testers and line x tester interaction to total variance are presented in Table 4.7.

The analysis of variance for combining ability revealed the existence of significant amount of variability among parents and different cross combinations for majority of the characters studied. The per cent contribution towards the total variance was maximum due to the interaction of lines and testers for the traits, days to 50% flowering, plant height, number of effective tillers per plant, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, SCMR at 80 DAT, harvest index and grain yield per plant. The maximum contribution of lines alone towards the total variance was observed for days to maturity, panicle length, SLA at 80

DAT, SLW at 80 DAT and shoot dry weight. While contribution of testers alone towards the total variance was maximum for LAD at 60-80 DAT, root dry weight and root shoot ratio.

The component of variance due to both *sca* and *gca* were significant for the characters, days to 50% flowering, days to maturity, number of filled grains per panicle, number of ill-filled grains per panicle, LAD at 60-80 DAT, shoot dry weight, root dry weight, root shoot ratio and grain yield per plant indicating the role of both additive and non additive gene action in the inheritance of these traits, *sca* variance was significant for the characters viz., plant height, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT and harvest index proposing the role of non additive gene action in inheritance of these traits, while *gca* component of variance was high for the characters viz., panicle length and SLW at 80 DAT indicating the predominance of additive gene action in the inheritance of these traits, but the ratio *gca* component of variance to total genetic variance was intermediate to near unity and heritability narrow sense was low to intermediate indicating the presence both additive and non additive gene action.

4.2.1 Days to 50% Flowering

Out of nine parents, two lines viz., RNR 2465 (-3.00) and JGL 11118 (-3.88) and three testers viz., IR 36 (-1.75), IR 64 (-1.85) and NLR 34449 (-1.65), exhibited significant *gca* effects in negative direction and are considered as good general combiners for earliness. The lines, BPT 5204 (2.88) and NLR 3041 (4.50) and tester, NLR 145 (5.25) showed positive significant *gca* effects were good for medium to late duration.

Three out of twenty crosses had expressed significant specific combining ability effects in the desirable direction that is for earliness. The highest *sca* effect was recorded by the cross, Kavya x NLR 145 (-6.00) with low negative x high positive (L^- x H^+) *gca* parental combination followed by BPT 5204 x NLR 34449 (-4.97) (H^+ x H^-) and NLR 3041 x IR 36 (-4.00) (H^+ x H^-). These results indicated that high negative *sca* effects may not only arise in the crosses involving (H^- x H^-) parental *gca* combination, but also in the cross combinations involving (H^+ x H^-) and (L^- x H^+) parental *gca* combinations. The cross with high *gca* parents indicated the involvement of additive component of variance were the improvement in such characters could be easily achieved through simple selection procedure, while the cross with low x high *gca* effects parents producing superior cross combination may be due to complimentary action of both additive and non additive genetic components.

Significance of both *sca* (17.0270) and *gca* (12.1655) components of variance indicated the role of both additive and non additive gene actions in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.59) was intermediate and the estimates of narrow sense heritability (55.75) was moderate (Table 4.7). These results further confirm the involvement of both additive and non additive gene actions in the inheritance of this character. Similar results were also reported earlier by Ramalingam and Jebaraj (2013) and Adilakshmi *et al.* (2013).

4.2.2 Days to Maturity

RNR 2465 (-3.08) and JGL 11118 (-3.95) among lines and IR 64 (-1.73) and NLR 34449 (-1.52) among testers exhibited significant *gca* effects in negative direction and is considered as good general combiners for days to maturity in desirable direction i.e. earliness. Whereas the lines, BPT 5204 (3.17) and NLR 3041 (4.05) and tester, NLR 145 (4.18) showed positive significant *gca* effects indicating good general combiners for medium to late duration.

For the trait days to maturity, three crosses had expressed significant specific combining ability effects for earliness. The cross, BPT 5204 x NLR 34449 (-4.97) with high positive x high negative (H^+ x H^-) parental *gca* combination recorded highest significant *sca*, followed by Kavya x NLR 145 (-4.80) (L^- x H^+) and NLR 3041 x IR 36 (-3.45) (H^+ x L^-). The above results indicated that cross with high negative *sca* effect could also be produced by (H^+ x H^-), (L^- x H^+) and (H^+ x L^-) parental *gca* combinations. The cross involving low and high *gca* parents producing superior cross combination may be due to complimentary action arised out of both additive and non additive genetic components.

Both *sca* (12.2991) and *gca* (9.5477) components of variance were significant for this trait indicating the role of both additive and non additive gene actions in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.61) was intermediate and the estimates of narrow sense heritability (56.36) was moderate (Table 4.7). These results further confirmed the involvement of both additive and non additive gene actions in the inheritance of this character. Similar results were also reported earlier by Ramalingam and Jebaraj (2013) and Adilakshmi *et al.* (2013).

4.2.3 Plant Height (cm)

For the trait plant height, none of the lines and testers exhibited significant *gca* effects in desirable direction (dwarfness), while the line, RNR 2465 (2.58) showed significant but positive *gca* effect.

Out of 20 crosses, the cross, RNR 2465 x NLR 145 (-8.56) with (H^+ x L^-) parental *gca* combination exhibited highest significant *sca* effect in the desirable direction (short plant stature) followed by BPT 5204 x IR 36 (-6.62) with (L^- x L^-) parental combination, indicated that cross with high *sca* effect are also possible from (H^+ x L^-) and (L^- x L^-) *gca* parents. By this, it is evident that heterotic hybrids can be produced even by low general combining parents and one can include some low combiners as well in hybridization programme and the cross involving low and high *gca* parents producing superior cross combination may be due to complimentary action arised out of both additive and non additive genetic components.

The estimated component of variance due to *sca* (23.4137) was significantly greater than the *gca* component (0.7224) indicating the role of non additive gene action in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.06) was for away from unity and further it was confirmed by low narrow sense heritability (4.92) (Table 4.7). These results confirmed the predominance of non additive gene action in the inheritance of this trait were also observed by Bineeta and Lal (2015), Savita *et al.* (2015) and Sathya and Jebaraj (2015). As non additive gene action was predominant, breeding methods involving selection, inter mating among selected ones and reselection may help to improve this trait besides exploiting the methods of heterosis breeding involving production of hybrids and synthetics.

4.2.4 Number of Effective Tillers per Plant

None of the nine parents studied for combining ability for the trait number of effective tillers per plant exhibited significant *gca* effects in desirable direction, while the line, JGL 11118 (-1.60) and NLR 145 (-1.11) showed significant but negative *gca* effect.

Positive and significant *sca* effects was observed in three crosses for this trait, highest significant *sca* effect in the desirable direction was exhibited by the cross, NLR 3041 x IR 36 (5.16) with (L^+ x L^+) parental *gca* combination followed by RNR 2465 x IR 64 (2.54) (L^+ x L^+) and Kavya x NLR 34449 (2.14) (L^- x L^-). This indicated that crosses with high *sca* effect are also possible from (L^+ x L^+) and (L^- x L^-) *gca* parental combinations. The superiority of the crosses having low *gca* parents may be due to high nicking ability of the parents. Therefore, it is evident that heterotic hybrids can be produced even by low general combining parents and one can include some low combiners as well in hybridization programme.

High significant *sca* component of variance (5.1097) than *gca* component (0.7538) indicating the role of non additive gene action in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.23) was away from unity and further it was confirmed by low narrow sense heritability (19.67) (Table 4.7). Thus non additive gene action played predominant role in the inheritance of this trait. These results are in agreement with the results of Bineeta and Lal (2015), Savita *et al.* (2015) and Sathya and Jebaraj (2015). As non additive gene action was predominant, breeding methods involving selection, inter mating among selected ones and reselection may help to improve this trait besides exploiting the methods of heterosis breeding involving production of hybrids and synthetics.

4.2.5 Panicle Length (cm)

Out of nine parents, none of lines and testers exhibited significant *gca* effects in desirable direction while the line, BPT 5204 (-1.86) showed significant but negative *gca* effect.

The g*ca* component of variance (0.3690) was significantly greater than s*ca* variance (0.3935) for this trait indicating the predominance of additive gene action in governing the inheritance of this character. But in contrary, the ratio of general combining ability variance to total genetic variance (0.65) was intermediate and the estimate of narrow sense heritability (28.52) was low (Table 4.7). These results indicated the possible involvement of both additive and non additive gene actions in the inheritance of this character. Rahimi *et al.* (2010) and Ramalingam and Jebaraj (2013) reported similar results for panicle length. Since both additive and non additive gene action control the inheritance, this trait can be improved either by population improvement methods or even by heterosis breeding methods like production of hybrids, synthetics and composites.

4.2.6 Number of Filled Grains per Panicle

Positive significant *gca* effects was recorded by the line, Kavya (21.81) and tester, NLR 34449 (11.45) hence they could be considered as good general combiners for this trait. While the lines, RNR 2465 (-11.48) and NLR 3041 (-21.53) and tester, IR 64 (-16.07) showed significant but negative *gca* effects.

The cross, NLR 3041 x NLR 34449 (40.84) with (H^- x H^+) parental *gca* combination showed highest significant *sca* effect in desirable direction, followed by Kavya x IR 36 (25.11) (H^+ x L^+). These results indicated that high *sca* effects may arise not only in crosses involving (H^+ x H^+) combinations, but also in those involving (H^- x H^+) and (H^+ x L^+) parental *gca* combinations. The superiority of the crosses having high x low *gca* parents producing superior cross combination may be due to complimentary action arised out of both additive and non additive genetic components.

Genetic components of variance due to both *sca* (488.4093) and *gca* (179.7811) were significant for this trait indicating the role of both additive and non additive gene actions in inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.42) was far away from unity and the estimates of narrow sense heritability (37.74) was moderate (Table 4.7). These results further confirmed the involvement of both additive and non additive gene action in the inheritance of this character. Similar results were also reported earlier by Rahimi *et al.* (2010) and Ramalingam and Jebaraj (2013). Since both additive and non additive genes are involved in the inheritance of this trait it can be improved either by population improvement methods or even by heterosis breeding methods like production of hybrids, synthetics and composites.

4.2.7 Number of Ill-filled Grains per Panicle

Three lines, RNR 2465 (-12.68), JGL 11118 (-5.31) and BPT 5204 (-3.01) and two testers, IR 64 (-5.81) and NLR 34449 (-6.43) exhibited significant *gca* effects in desirable direction and considered as good general combiners for the trait number of ill-filled grains per panicle.

The cross, RNR 2465 x NLR 34449 (-15.53) with high negative x high positive (H^- x H^+) parental *gca* combination possessed highest significant *gca* effect in desirable direction, followed by, NLR 3041 x IR 64 (-13.67) (H^+ x H^-), Kavya x NLR 145 (-11.16) (H^+ x H^+), NLR 3041 x IR 36 (-10.90) (H^+ x L^+), NLR 3041 x NLR 34449 (-

7.35) (H^+ x H^-) and Kavya x IR 36 (-6.48) (H^+ x L^+). These results indicated that high *sca* effects may arise not only in crosses involving (H^- x H^-) combinations, but also in those involving (H^- x H^+), (H^+ x H^-), (H^+ x H^+) and (H^+ x L^+) parental *gca* combinations. Cross involving low and high *gca* parents producing significant *sca* effect may be due to complimentary action arised out of both additive and non additive genetic components.

Significance of both *sca* (177.6596) and *gca* (86.9031) components of variance indicated the role of both additive and non additive gene actions in inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.49) was intermediate and the estimates of narrow sense heritability (48.33) was moderate (Table 4.7). These results further confirmed the involvement of both additive and non additive gene action in the inheritance of this character and this trait could be improved either by population improvement methods or even by heterosis breeding methods like production of hybrids, synthetics and composites. The above findings were in agreement with the findings of Gulzar and Wassem *et al.* (2012) and Akram *et al.* (2007).

4.2.8 1000 Grain Weight (g)

Two lines, RNR 2465 (0.48) and JGL 11118 (1.55) and a tester, IR 64 (1.36) exhibited significant *gca* effects in desirable direction for the trait 1000 grain weight and could be considered as good general combiners. The lines, Kavya (-0.59) and NLR 3041 (-1.28) and testers, NLR 34449 (-1.03) and NLR 145 (-0.53) showed significant but negative *gca* effects are good general combiners for fine grain character.

Six out of twenty crosses showed significant *sca* effects in desirable direction, in which the cross, JGL 11118 x IR 36 (3.17) with high positive x low positive (H^+ x L^+) parental *gca* combination exhibited highest *sca* effect, followed by NLR 3041 x IR 64 (2.37) (H^- x H^+), Kavya x IR 64 (2.23) (H^- x H^+), BPT 5204 x NLR 34449 (2.20) (L^- x H^-), RNR2456 x NLR 34449 (1.36) (H^+ x H^-) and BPT 5204 x NLR 145 (0.90) (L^- x H^-). These results indicated that high *sca* effects may arise not only in crosses involving (H^+ x H^+) combination, but also in those involving (H^+ x H^-), (H^+ x L^+), (H^- x H^+) and (L^- x H^-) parental *gca* combinations. The cross with high *gca* parents indicated the involvement of additive component of variance where the improvement in such characters could be easily achieved through simple selection procedure, while the cross with low x high *gca* effects parents producing superior cross combination may be due to complimentary action arised out of both additive and non additive genetic components.

The *sca* component of variance (4.2972) was significantly greater than the *gca* component (1.0896) indicating the role of non additive gene action in the inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.34) was away from unity and further it was confirmed by moderate narrow sense heritability (33.04) (Table 4.7). These results confirm the role of non additive gene action in the inheritance of this trait. Similar results were also reported earlier by Jhansi Rani and Satyanarayana (2015) and Bineeta and Lal (2015). As non additive gene action was predominant, breeding methods involving selection, inter mating among selected ones and reselection may help to improve this trait besides exploiting the methods of heterosis breeding involving production of hybrids and synthetics.

4.2.9 LAD at 60-80 DAT

Out of nine parents, line, JGL 11118 (30.87) and tester, NLR 145 (75.93) exhibited significant *gca* effects in desirable direction and considered as good general combiners for this trait. While none of twenty crosses studied showed significant *sca* effect in desirable direction for this trait.

The genetic components of variance due to both *sca* (1007.0209) and *gca* (1523.1664) were significant which indicated the role of both additive and non additive gene actions in inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.75) was near to unity and the estimates of narrow sense heritability (62.76) was high (Table 4.7). These results confirm the involvement of both additive and non additive gene action and predominance of additive gene action in the inheritance of this character. This trait can be improved either by population improvement methods or even by heterosis breeding methods like production of hybrids, synthetics and composites.

4.2.10 SCMR at 80 DAT

The line, JGL 11118 (1.66) was the only parent exhibited significant *gca* effect in desirable direction out of nine parents studied for combining ability, while the tester, NLR 145 (-1.13) showed significant but negative *gca* effect.

The cross, JGL 11118 x NLR 145 (3.64) with (H^+ x H^-) parental *gca* combination exhibited highest significant *sca* effect in desirable direction followed by NLR 3041 x NLR 34449 (2.94) (L^- x L^-). The superiority of the crosses having low *gca* parents may be due to high nicking ability of those parents. Therefore, it is evident that heterotic hybrids can be produced even by low general combining parents and one can include some low combiners as well in hybridization programme.

The *sca* component of variance (5.4944) was significantly greater than the g*ca* component (0.5999) and the ratio of *gca* component of variance to total genetic variance (0.18) was away from unity and narrow sense heritability was low (14.94) (Table 4.7). These results indicate the involvement of non additive gene action in the inheritance for this character. Similar results were also reported earlier by Gopikannan and Ganesh (2013a) and Sathya and Jebaraj (2015).

4.2.11 SLA at 80 DAT (cm^2/g)

Significant *gca* effects in desirable direction for this trait was exhibited by a line, Kavya (-5.48), while the line, RNR 2465 (4.62) showed significant *gca* effect but in undesirable direction and none of the twenty crosses showed significant desirable negative *sca* effect.

The g*ca* component of variance (5.2511) was significantly greater than the s*ca* component (4.2427) proposing predominance of additive gene action. While the ratio of *gca* component of variance to total genetic variance (0.71) was close to unity and narrow sense heritability was moderate (41.07) (Table 4.7), indicating the involvement of both additive and non additive gene action in the inheritance of this character. The above results are in accordance with the findings of Ali *et al.* (2010) and John *et al.* (2011).

4.2.12 SLW at 80 DAT (g/cm^2)

The line, Kavya (0.00144) exhibited positive significant *gca* effect in desirable direction, for this trait, while line, RNR 2465 (-0.00108) exhibited significant but negative *gca* effect. None of the 20 crosses showed significant positive *sca* effect.

The g*ca* component of variance (0.000021) was significantly greater than the s*ca* component (0.000015) exhibiting the predominance of additive gene action. While the ratio of *gca* component of variance to total genetic variance (0.73) was closer to unity but narrow sense heritability was moderate (42.52) (Table 4.7), indicating the involvement of both additive and non additive gene action in the inheritance of this character. Similar results were also reported earlier by Adilakshmi and Raghavareddy (2012).

4.2.13 Harvest Index

Out of nine parents, the tester, IR 36 (5.30) only exhibited significant *gca* effect in desirable direction and considered as good general combiner for this trait, while significant but negative *gca* effect was shown by the tester, NLR 145 (-4.76).

The cross, JGL 11118 x IR 36 (12.28) with (L^+ x H^+) parental *gca* combination exhibited highest significant *sca* effect in desirable direction followed by the cross, BPT 5204 x NLR 145 (10.47) (L^+ x H^-). These results indicated that cross with high *sca* effect could also be produced by low x high *gca* effect parents which may be due to complimentary action of both additive and non additive genes.

The s*ca* component of variance (36.0741) was significantly greater than the g*ca* component (10.1618), indicating the involvement of non additive gene action in inheritance of the trait. The ratio of *gca* component of variance to total genetic variance (0.36) was away from unity and narrow sense heritability was low (26.52) (Table 4.7), indicating the predominance of non additive gene action in the inheritance of this character. These results are in accordance with the findings of Patil *et al.* (2012) and Utharasu and Anandakumar (2013). As non additive gene action was predominant, breeding methods involving selection, inter mating among selected ones and reselection may help to improve this trait besides exploiting the methods of heterosis breeding involving production of hybrids and synthetics.

4.2.14 Root Dry Weight (g)

Two lines, BPT 5204 (0.91), Kavya (0.81) and a tester NLR 145 (1.68) exhibited significant *gca* effects in desirable direction for this trait, while the line, JGL 11118 (-1.34) and tester, NLR 34449 (-1.26) exhibited significant *gca* effects but in undesirable direction.

Out of 20 crosses studied, only one cross, NLR 3041 x IR 36 (2.47) with (L^+ x L^+) parental *gca* combination exhibited significant *sca* effect in desirable direction.

Significance of both *sca* (0.8984) and *gca* (1.1278) components of variance indicated the role of both additive and non additive gene actions in inheritance of this character. The ratio of *gca* component of variance to total genetic variance (0.72) which was near to unity and the estimates of narrow sense heritability (62.16) was high (Table 4.7), indicating the predominance of additive gene action. Similar results were also reported earlier by Malarvizhi *et al.* (2011) and Utharasu and Anandakumar (2013)

4.2.15 Shoot Dry Weight (g)

Two lines, RNR 2465 (8.43) and BPT 5204 (6.95) and a tester IR 36 (9.58) exhibited positive significant *gca* effects in desirable direction and considered as good general combiners for the trait shoot dry weight, while the line, NLR 3041 (-18.32) and tester, NLR 145 (-16.12) exhibited significant but negative *gca* effects.

Out of 20 crosses, cross, RNR 2465 x IR 64 (11.87) with (H^+ x L^-) parental *gca* combination exhibited highest significant *sca* effect in desirable direction followed by JGL 11118 x IR 36 (11.02) (L^- x H^+).

Both *sca* (88.5384) and *gca* (72.7674) components of variance were significant for this trait indicating the role of both additive and non additive gene actions in inheritance of this character, which was further confirmed by ratio of *gca* component of variance to total genetic variance (0.62) was intermediate and the estimates of narrow sense heritability (56.67) was moderate (Table 4.7). Similar results were also reported earlier by Han and Kon (2000) and Malarvizhi *et al.* (2011).

4.2.16 Root Shoot Ratio

Out of nine parents, line, NLR 3041 (0.0274) and a tester NLR 145 (0.0332) showed positive significant *gca* effects in desirable direction for this trait, while the lines, RNR 2465 (-0.0128) and JGL 11118 (-0.0181) and testers, IR 36 (-0.0117) and NLR 34449 (-0.0180) exhibited significant but negative *gca* effects.

The cross, BPT 5204 x IR 64 (0.0232) with (L^+ x L^-) parental *gca* combination exhibited positive significant *sca* effect in desirable direction followed by NLR 3041 x IR 36 (0.0218) (H^+ x H^-), RNR 2465 x NLR 145 (0.0213) (H^- x H^+) and JGL 11118 x NLR 34449 (0.0196) (H^- x H^-). The superiority of the crosses having low *gca* parents may be due to high nicking ability of those parents. Therefore, it is evident that heterotic hybrids could be produced even by low general combining parents and one can include some low combiners as well in hybridization programme.

Significance of both *sca* (0.0002) and *gca* (0.0004) components of variance indicated the role of both additive and non additive gene actions in inheritance of this character but the ratio of *gca* component of variance to total genetic variance (0.80) was near to unity and the estimates of narrow sense heritability (74.24) was high (Table 4.7) exhibiting the predominance of additive gene action. Similar results were also reported earlier by Malarvizhi *et al.* (2011) and Utharasu and Anandakumar (2013).

4.2.17 Grain Yield per Plant (g)

Significant *gca* effect for the trait Grain yield per plant was reported by the line, BPT 5204 (4.05) and considered as good general combiner for this trait, similarly out of 20 crosses studied, cross, RNR 2465 x IR 64 (7.47) with (L^{+} x L^{+}) parental *gca* combination only exhibited highest significant *sca* effect in desirable direction. The superiority of the cross having low *gca* parents may be due to high nicking ability of those parents. Therefore, it is evident that heterotic hybrids could be produced even by low general combining parents and one can include some low combiners as well in hybridization programme.

Significance of both *sca* (15.8670) and *gca* (7.9774) components of variance indicate the role of both additive and non additive gene actions in inheritance of this character. It was further confirmed by the ratio of *gca* component of variance to total genetic variance (0.50) which was intermediate and the estimates of narrow sense heritability (38.80) was moderate (Table 4.7). Similar results were also reported earlier by Rahimi *et al.* (2010) and Veeresha *et al.* (2013).

Among five lines tested for their combining abilities pertaining to different character under study, the line JGL 11118, recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT and SCMR at 80 DAT followed by RNR 2465, for days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, SLW at 80 DAT and shoot dry weight, Kavya, for number of filled grains per panicle, SLA at 80 DAT, SLW at 80 DAT and root dry weight and BPT 5204, for number of ill-filled grains per panicle, root dry weight, shoot dry weight and grain yield per plant and among testers, IR 64 recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50% flowering, days to maturity, number of ill-filled grains per panicle, 1000-grain weight followed by NLR 34449 for days to 50% flowering, days to maturity, number of filled grains per panicle and number of ill-filled grains per panicle (Table 4.5).

Further the tested lines were given ranking based on the respective combining abilities of all the characters studied. While doing so line, JGL 11118 ranked first followed by Kavya, BPT 5204, RNR 2465 (Table 4.8). Therefore these lines can be utilized in improvement of the respective traits in breeding programmes.

Among the twenty crosses tested for specific combining ability for seventeen different characters, the cross, NLR 3041 x IR 36 recorded significant *sca* effects in desirable direction for majority for of the traits viz., days to 50% flowering, days to maturity, number of effective tillers per plant, number of ill-filled grains and root dry weight and root shoot ratio, followed by RNR 2465 x IR 64, for number of effective tillers per plant, shoot dry weight and grain yield per plant, BPT 5204 x NLR 34449, for days to 50% flowering, days to maturity, 1000 grain weight, and JGL 11118 x IR 36, for 1000 grain weight, harvest index and shoot dry weight (Table 4.6).

4.3 HETEROSIS

Studies on the magnitude of heterosis expressed in percentage in F_1s help to assess the ability of the lines (test genotypes) to transmit the desirable characters to the F_1s upon hybridization. This facilitates the identification of lines that exhibit high amount of exploitable heterosis. In the present investigation, heterosis of F_1s over mid parent (average heterosis), better parent (heterobeltiosis) and standard check (standard heterosis) for grain yield and its component characters was estimated using 20 F_1s obtained by crossing five lines with four testers in Line x Tester fashion.

The estimates of heterosis for yield and yield components over mid parent, better parent and standard checks of 20 F_1s are presented in the Table 4.9 and they are described character-wise hereunder.

4.3.1 Days to 50% Flowering

Negative heterosis is desirable for this trait as it indicates the earliness of the genotype. Relative heterosis for days to 50% flowering ranged from -12.85 to 0.77% and heterobeltiosis from -18.40 to -1.38%. Out of 20 hybrids, 13 hybrids over mid parent and 16 hybrids over better parent exhibited significant negative heterosis among which, BPT 5204 x NLR 34449 showed highest negative heterosis of -12.85% and -18.40% over mid parent and better parent, respectively and considered as best hybrid for earliness, followed by BPT 5204 x IR 64 (-10.1%) and NLR 3041 x IR 64 (-9.95%) over mid parent and NLR 3041 x IR 36 (-18.35%) and NLR 3041 x IR 64 (-16.97%) over better parent. None of the hybrid exhibited significant positive heterosis over mid parent and better parent. Standard heterosis ranged from -9.34 to 18.13% for the check, NLR 40024 and -8.84 to 18.78% for the check, NLR 30491, the hybrid RNR 2465 x IR

36 exhibited highest negative and significant heterosis (-9.34% and -8.84%) over the checks, NLR 40024 and NLR 30491, respectively. Similar results of both positive and negative heterosis were reported earlier by Dar *et al.* (2015) over standard checks and Balakrishna and Satyanarayana (2015) over mid parent and better parent for this trait.

4.3.2 Days to Maturity

Days to maturity indicates the duration of a genotype, early maturity genotypes reduces the duration of the crop. Hence it is desirable to choose the genotypes with negative and significant heterosis for this trait. Relative heterosis for this trait ranged from -8.81 to 1.95% and heterobeltiosis from -12.82 to -0.40%. Out of 20 hybrids, 12 hybrids for relative heterosis and 15 hybrids for heterobeltiosis exhibited significant negative heterosis among which, BPT 5204 x NLR 34449 showed highest negative heterosis -8.81% and -12.82% over mid parent and better parent and it is considered as best hybrid for the trait earliness. The other crosses, NLR 3041 x IR 64 (-7.20%) and Kavya x NLR 145 (-7.07%) over mid parent and NLR 3041 x IR 36 (-12.54%) and NLR 3041 x IR 64 (-12.19%) over better parent exhibited negative significant heterosis. Standard heterosis ranged from -5.71 to 11.02% and -4.94 to 11.93% over the checks, NLR 40024 and NLR 30491, respectively. The hybrid, RNR 2465 x IR 36 exhibited highest negative heterosis (-5.71% and -4.94%) over both the checks, NLR 40024 and NLR 30491, respectively. Both positive and negative heterosis for this trait were reported by Sanjeev *et al.* (2010) over better parent and standard check and Srivastava and Jaiswal (2016) over mid parent.

4.3.3 Plant Height

The relative heterosis, heterobeltiosis and standard heterosis over the checks, NLR 40024 and NLR 30491 ranged from -12.95 to 12.53%, -13.23 to 11.48%, -0.93 to 23.70% and -2.09 to 22.25%, respectively. Plant height indicates dwarfness or tallness of a genotype. However, in the present study the genotypes with dwarfness were taken into consideration. Hence the significant negative heterosis is desirable for this trait. Out of 20 crosses two over mid parent and three over better parent showed significant negative heterosis in desirable direction. Highest negative heterosis of -12.95% and -13.23% over mid parent and better parent, respectively was exhibited by the cross, RNR 2465 x NLR 145 and considered as best hybrid for this trait, followed by BPT 5204 x IR 36 (-8.77% and -9.01%) over mid parent and better parent, respectively and JGL 11118 x NLR 145 (-8.91%) over better parent. None of the hybrid exhibited significant negative heterosis over both the checks, however Sasikala *et al.* (2015) for standard heterosis and Balakrishna and Satyanarayana (2015) for relative heterosis and heterobeltiosis recorded both positive and negative heterosis.

4.3.4 Number of Effective Tillers per Plant

The per cent range of heterosis was from -15.86 to 68.69% over mid parent, from -22.50 to 41.64% over better parent, from -38.66 to 23.55% over NLR 40024 and from -4.42 to 92.52% over NLR 30491 (standard check). More number of effective tillers results in more effective panicles which increases the number of filled grains and finally contributes to grain yield hence significant positive heterosis is desirable for this trait, 10 crosses over mid parent and four over better parent showed significant positive heterosis for this trait among which, NLR 3041 x IR 36 exhibited highest positive significant heterosis (68.69%, 41.64%, 23.55% and 92.52%) over mid parent, better parent and standard checks, NLR 40024 and NLR 30491 respectively and considered as best hybrid for this trait. The other best crosses with significant positive heterosis over mid parent and better parent were, BPT 5204 x IR 36 (52.35% and 40.11%) and Kavya x NLR 145 (45.45% and 31.34%), respectively. Similar results of both positive and negative heterosis for this trait were reported earlier by Dar *et al.* (2014) over standard checks and Balakrishna and Satyanarayana (2015) over better parent and mid parent.

4.3.5 Panicle Length

Positive significant heterosis is desirable for the trait panicle length as the length of the panicle increases, the number of grains which could accommodate in the panicle increases, results in increased grain yield. The per cent relative heterosis, heterobeltiosis and standard heterosis over checks, NLR 40024 and NLR 30491 ranged from -2.40 to 22.63%, -8.81 to 18.31%, 0.00 to 39.23% and 0.00 to 39.23%, respectively. Three hybrids over mid parent and a hybrid over better parent showed significant positive heterosis. The cross JGL 11118 x IR 36 was found to be the best cross for this trait, as it exhibited highest positive significant heterosis of 22.63%, 18.31%, 39.23% and 39.23% over mid parent, better parent and standard checks, NLR 40024 and NLR 30491, respectively. The other crosses viz., Kavya x NLR 34449 (18.19%) and Kavya x IR 64 (15.35%) exhibited positive significant heterosis over mid parent. Similar results of both positive and negative heterosis were also reported earlier by Dar *et al.* (2014) and Balakrishna and Satyanarayana (2015) for standard heterosis, relative heterosis and heterobeltiosis.

4.3.6 Number of Filled Grains per Panicle

The range of relative heterosis, heterobeltiosis and standard heterosis for the checks, NLR 40024 and NLR 30491 were found to be from -30.80 to 36.74%, -42.63 to 23.10%, -5.28 to 96.84% and from -4.15 to 99.18%, respectively. Number of filled grains per panicle directly account to grain yield. Hence positive significant heterosis is a desirable feature for this trait. Out of 20 crosses, five crosses over mid parent and two crosses over better parent recorded significant positive heterosis. Highest positive significant heterosis was exhibited by the cross, Kavya x IR 36 over mid parent (36.74%) and standard checks, NLR 40024 (96.84%) and NLR 30491 (99.18%) while the cross, BPT 5204 x IR 36(23.10%) exhibited highest positive over better parent. The other crosses viz., BPT 5204 x IR 36 (28.14%), BPT 5204 x NLR 145 (24.52%) over mid parent and Kavya x IR 36 (21.21%) over better parent exhibited positive significant heterosis. Likewise Both positive and negative heterosis for this trait were reported by Tiwari *et al.* (2011) over mid parent and standard check and Sharma *et al.* (2013) over better parent.

4.3.7 Number of Ill-filled Grains per Panicle

For the trait number of ill-filled grains per panicle, negative significant heterosis is desirable as less number of ill-filled grains per panicle is directly proportional to more grain yield. Heterosis for this character ranged from -51.15 to 135.28%, -62.60 to 124.12%, 38.89 to 818.89% and -14.38 to 466.44% over mid parent, better parent, standard checks NLR 40024 and NLR 30491, respectively. One cross over mid parent and four crosses over better parent recorded significant negative heterosis among which, RNR 2465 x NLR 145 exhibited highest significant negative heterosis (-51.15% and -62.60%) over both mid parent and better parent, respectively and this cross was considered as best cross for this trait, as it recorded less number of ill-filled grains (13.80) per panicle. The other crosses, NLR 3041 x IR 64 (-42.81%) and JGL 11118 x NLR 34449 (-36.97%) showed negative significant heterosis over better parent. None of the hybrid exhibited significant negative heterosis over standard checks. These findings are in agreement with Singh *et al.* (2007b) and Gouri *et al.* (2010) over better parent and standard checks for both positive and negative heterosis for this trait.

4.3.8 1000 Grain Weight

For this trait negative heterosis is related to fine grain genotypes whereas, positive heterosis is for bold grain types with more 1000 grain weight. The heterosis ranged from -30.83 to 19.93% over mid parent, from -41.29 to 18.20% over better parent, from -39.13 to 8.55% and from -38.11 to 10.36% over standard checks, NLR 40024 and NLR 30491, respectively. Three hybrids over mid parent and a hybrid over better parent showed significant positive heterosis. Among them, BPT 5204 x NLR 34449 recorded highest significant positive heterosis (19.93% and 18.20%) over mid parent and better parent, respectively and this cross considered as best cross for this trait. The cross, JGL 11118 x IR 36 (8.55% and 10.36%) exhibited highest positive significant heterosis over standard checks, NLR 40024 and NLR 30491, respectively. As the present study is on grain yield and the bold grain types are generally associated with high 1000 grain weight for which positive heterosis may be considered important. For fine grain (low 1000 grain weight) the cross, NLR 3041 x NLR 145 (-41.29%) exhibited highest significant heterosis over better parent. The negative and positive heterosis for this trait was reported earlier by Ali *et al.* (2014) over standard parent and Balakrishna and Satyanarayana (2015) over better parent and mid parent.

4.3.9 LAD at 60-80 DAT

Range of heterosis for LAD at 60-80 DAT varied from -8.87 to 27.24%, -13.35 to 24.61%, 27.71 to 81.46% and 10.62 to 57.17% over mid parent, better parent, standard checks NLR 40024 and NLR 30491, respectively. It is desirable to isolate the genotypes with positive and significant heterosis for leaf area duration at 60-80 DAT, because at this stage the crop completes flowering and will be close to maturity, for which the genotypes with active green leaf area yield more than the genotypes with inactive leaf area. Out of 20 crosses, 11 crosses over mid parent, 5 crosses over better parent, all the crosses over standard check, NLR 40024 and 18 crosses over check NLR 30491 recorded significant and positive heterosis among which, BPT 5204 x NLR 145 (27.24%) over mid parent, NLR 3041 x IR 64 (24.61%) over better parent, JGL 11118 x NLR 145 (81.46% and 57.17%) over checks, NLR 40024 and BLR30491, respectively exhibited highest significant positive heterosis and these crosses were considered as best crosses for this trait followed by NLR 3041 x IR 64 (25.61%) and RNR 2465 x IR 64 (23.80%) over mid parent, BPT 5204 x IR 64 (21.51%), RNR 2465 x IR 64 (21.17%) over better parent, BPT 5204 x NLR 145 (59.64% and 38.27%), RNR 2465 x NLR 145 (57.47% and 36.39%) over both checks NLR 40024 and NLR 30491, respectively.

4.3.10 SCMR at 80 DAT

Heterosis for SCMR at 80 DAT, varied from -7.37 to 16.41% over mid parent, from -11.18 to 12.87% over better parent, from -0.85 to 20.92% over the check, NLR 40024 and -1.29 to 17.23% over the check, NLR 30491. Out of 20 crosses, eight crosses over mid parent, four crosses over better parent, 14 crosses over check, NLR 40024 and eight crosses over check, NLR 30491 exhibited significant positive heterosis. Highest positive and significant heterosis for this trait was recorded by JGL 11118 x NLR 145 (16.41%, 12.87%, 20.92% and 17.23%) over mid parent, better parent and standard checks, NLR 40024 and NLR 30491, respectively. At this stage the leaf chlorophyll content is directly proportional to total number of filled grains because it coincides with grain filling stage. However, the genotypes with high leaf chlorophyll content and more leaf area duration are most preferable.

4.3.11 SLA at 80 DAT (cm^2/g)

Variation in heterosis over mid parent, better parent and standard checks, NLR 40024 and NLR 30491 were ranged from -21.41 to 20.22%, from -23.16 to 12.09%, from -24.38 to 9.41% and from -13.14 to 25.67%, respectively. Significant negative heterosis is desirable for this trait. Kavya x IR 36 exhibited highest significant heterosis over mid parent (-21.41%), better parent (-23.16%) and standard check, NLR 40024 (-24.38%). While none of the crosses recorded significant negative heterosis over standard check, NLR 30491.

4.3.12 SLW at 80 DAT (g/cm^2)

Heterosis for SLW at 80 DAT varied from -16.62 to 26.84% over mid parent, from -22.05 to 23.71% over better parent, from -14.64 to 22.23% over the check, NLR 40024 and from -19.68 to 15.02% over the check, NLR 30491. Significant positive heterosis is desirable for this trait. The cross, Kavya x IR 64 (26.84%, 23.71%, 22.23% and 15.02%) only showed significant average heterosis, heterobeltiosis and standard heterosis over the check, NLR 40024 and the check, NLR 30491, respectively in desirable direction.

4.3.13 Harvest Index

The range of relative heterosis, heterobeltiosis, standard heterosis over the checks, NLR 40024 and NLR 30491 were found to be from -27.86 to 49.87%, from -28.00 to 44.06%, from -39.05 to 27.12% and from -8.92 to 89.95%, respectively. Harvest index directly related to grain yield. Hence positive significant heterosis is desirable for this trait. Out of 20 crosses, six crosses over mid parent, one cross over better parent and over the check, NLR 40024 and six crosses over the check, NLR 30491 showed significant positive heterosis. Highest positive significant heterosis exhibited by the cross JGL 11118 x IR 36 over mid parent (49.87%), better parent (44.06%) and standard checks, NLR 40024 (27.12%) and NLR 30491 (89.95%), respectively. Hence, this cross was considered as a best cross for this trait. Positive and negative heterosis for this trait was reported by Adilakshmi *et al.* (2013) over standard check and Adilakshmi and Raghavareddy (2012) over better parent and mid parent.

4.3.14 Root Dry Weight (g)

The per cent relative heterosis, heterobeltiosis, standard heterosis over check NLR 40024 and NLR 30491 ranged from -44.86 to 57.28%, from -55.91 to 38.65%, from -25.38 to 61.76% and from -5.72 to 104.39%, respectively. Positive significant heterosis is a desirable feature for this trait. Six crosses over mid parent, a cross over better parent, five crosses over the check, NLR 40024, and 10 crosses over the check, NLR 30491 showed significant positive heterosis among which, Kavya x IR 64 (57.28%) for relative heterosis, BPT 5204 x IR 64 (38.65%) for heterobeltiosis, BPT 5204 x NLR 145 (61.76% and 104.39%) for standard heterosis over both the checks exhibited highest positive significant heterosis and they were considered as best crosses for this trait.

4.3.15 Shoot Dry Weight (g)

Range in heterosis for shoot dry weight varied from -43.73 to 46.71%, -46.53 to 40.74%, -22.71 to 54.55% and -9.32 to 81.31% over mid parent, better parent, check, NLR 40024 and check, NLR 30491, respectively. The production of sufficient shoot dry matter is important for improving the grain yield of rice. Positive significant heterosis is a desirable feature for this trait. six crosses over mid parent, three crosses over better parent, 11 crosses over NLR 40024 (C) and 15 crosses over NLR 30491(C) showed positive significant heterosis among which, JGL 11118 x IR 36 (46.71%, 40.74%, 54.55% and 81.31%) exhibited highest positive significant heterosis over mid parent, better parent, over the check, NLR 40024 and over the check, NLR 30491, respectively. Hence, the cross regarded as best cross for this trait.

4.3.16 Root Shoot Ratio

Heterosis for root shoot ratio over mid parent, better parent and standard checks, NLR 40024 and NLR 30491 ranged from -62.73 to 85.87%, from -67.25 to 76.21%, from -47.90 to 61.82 and from -43.68 to 74.94%, respectively. Positive significant heterosis is a desirable feature for this trait for which, four crosses over mid parent, two over better parent, three over NLR 40024 (C) and five over NLR 30491 (C) showed significant heterosis. Among the significant crosses, NLR 3041 x NLR 145 exhibited highest positive significant heterosis for relative heterosis, heterobeltiosis and standard heterosis over the checks, NLR 40024 and NLR 30491 (85.87%, 76.21%, 61.82% and 74.94%) respectively. Hence, it could be considered as a best cross for this trait.

4.3.17 Grain Yield per Plant (g)

The desirable Positive significant heterosis for this trait was exhibited by five hybrids over mid parent, two hybrids over better parent, one hybrid over the check, NLR 40024 and 14 hybrids over the check, NLR 30491. The heterosis for this trait ranged from -46.84 to 61.51% over mid parent, -47.72 to 39.05% over better parent, -35.38 to 29.23% over the check, NLR 40024 and 3.30 to 106.59% over check, NLR 30491. The cross, BPT 5204 x IR 36 (61.51% and 39.05%) for relative heterosis and heterobeltiosis, RNR 2465 x IR 64 (29.23% and 106.59%) for standard heterosis over both checks, NLR 40024 and NLR 30491, respectively exhibited highest positive and significant heterosis and these hybrids are considered to be best crosses for this trait. positive and negative heterosis was reported by Balakrishna and Satyanarayana (2015) for relative heterosis and heterobeltiosis and Tiwari *et al.* (2011) for standard heterosis.

Based on overall performances (*per se* performance, high *sca* effects and standard heterosis) the cross, RNR 2465 x IR 64, showed best heterosis for five characters *i.e.,* number of effective tillers per plant, SLA at 80 DAT, SLW at 80 DAT, shoot dry weight and grain yield per plant followed by JGL 11118 x IR 36 for 1000 grain weight, LAD at 40-60 DAT, harvest index and shoot dry weight and NLR 3041 x IR 36 for root shoot ratio, root dry weight and panicle length (Table 4.10).

4.4 CHARACTER ASSOCIATION

Yield is a complex polygenically controlled character resulting from multiplicative interaction of yield components. The cumulative effects of such characters determine the dependent variable yield. These characters play an important role in modification of yield as a whole in magnitude as well as in direction. Further, direct selection for seed yield is not effective as it is a complex quantitative character and much influenced by environment. The change in one character brings about a series of changes in other characters, since they are interrelated. Therefore, the study of correlation between yield and yield components are of considerable importance in selection programmes.

The genotypic correlation coefficients between yield and other related component characters and among themselves were estimated and are presented in Table 4.11. The significant results of correlation are discussed character wise hereunder.

Character association revealed that grain yield per plant at genotypic level, showed positive significant association with plant height (0.5218), panicle length (0.7120), number of effective tillers per plant (0.4314), 1000 grain weight (0.3087) showing that, these are the main yield contributing characters in present study and yield can be improved by making direct selection based on these characters.

Grain yield also having significant positive association with physiological traits like SCMR at 80 DAT (0.3147), SLW at 80 DAT (0.5764), harvest index (0.6353) and shoot dry weight (0.9279) and significant negative and desirable association with SLA at 80 DAT (-0.7135) indicating the importance of physiological parameters like SCMR, SLW and SLA in getting higher yields.

4.4.1 Days to 50 % Flowering

The trait, days to 50% flowering, showed positive significant association with days to maturity (0.9922), number of ill-filled grains per panicle (0.3881), SLW at 80DAT (0.2649) and root shoot ratio (0.3117). The positive association of this trait with days to maturity, SLW, root shoot ratio is common. Its positive association with ill-filled grains may be due to less variation among the genotypes studied as most of them are early maturing in nature and similar result for days to maturity was reported by Prasad *et al.* (2015). The trait showed negative significant association with panicle length (-0.6001) and SCMR at 80 DAT (-0.4433), LAD at 60-80 DAT (-0.2847), SLA at 80 DAT (-0.3758) and harvest index (-0.2784). Negative association of physiological characters may be due to reason that, as the crop progresses towards days to 50% flowering, the activity of these characters viz., SCMR at 80 DAT, LAD at 60-80 DAT and SLA at 80 DAT decreases and the material under study was early duration type with an average days to 50 % flowering was 91.95 days. The similar type of associations was also observed with the trait days to maturity. Similar results were earlier reported by Nilanjaya and Kumar (2015) for SCMR and Saikumar *et al.* (2014) for harvest index.

4.4.2 Days to Maturity

The trait, days to maturity, also showed positive significant association with number of ill-filled grains (0.3924). The positive association of ill-filled grains with days to 50% flowering and days to maturity indicating that decrease in duration reduces ill-filled grains. As in the present study the average duration of the genotypes is 124 days (Early) which may be the reason to get positive association between these traits. However, results of positive but non significant association with ill-filled grains per panicle were earlier reported by Sarwar *et al.* (2015) and Prasad *et al.* (2015). Positive significant association with SLW at 80 DAT (0.3422) is desirable. The trait showed negative significant association with panicle length (-0.5341) was also reported by Kumar and Verma (2015) at phenotypic level. The negative association of days to maturity with SCMR at 80DAT (-0.4300), LAD at 60-80 DAT (-0.2879) and SLA at 80 DAT (-0.4760) might be due to determinate nature of rice crop, after panicle initiation, assimilates are diverted more towards grain filling from leaves and exhibited yellowing of leaves that resulted in decrease in SCMR readings ultimately decreasing persistence of greenness towards maturity. Similar result was earlier reported by Nilanjaya and Kumar (2015) for SCMR.

4.4.3 Plant Height (cm)

The trait, plant height showed positive significant association with panicle length (0.8740), 1000 grain weight (0.2844) and SLA at 80 DAT (0.5742), LAD at 60-80 DAT (0.3800), harvest index (0.5749), shoot dry weight (0.5843) and grain yield per plant (0.5218). The genotypes with low plant height are having advantage of non lodging habit with erect plant stature intercepting more sunlight and in present study all the parents and crosses were of dwarf (66.88 to 83.50 cm) in nature and naturally the positive association of plant height with LAD at 60-80 DAT, SLA at 80 DAT, shoot dry weight resulted in lengthy panicle with high 1000 grain weight, higher harvest index and finally leads to increased grain yield per plant. Similar results of positive significant association with plant height were earlier reported by Prasad *et al.* (2015) for panicle length, Ramanjaneyulu *et al.* (2014) for harvest index and Nilanjaya and Kumar (2015) for 1000 grain weight and grain yield per plant. This trait also showed negative significant association with SLW at 80 DAT (-0.6020).

4.4.4 Number of Effective Tillers per Plant

The trait, number of effective tillers per plant, showed positive significant association with harvest index (0.4549), shoot dry weight (0.2692) and grain yield (0.4314). The higher shoot biomass leads to more number of effective tillers which produces high harvest index thus increasing the grain yield per plant. Significant positive association with grain yield indicating that selection for high grain yield per plant based on number of effective tillers per plant is beneficial. The results were in agreement with Ramanjaneyulu *et al.* (2014) for harvest index and Kishore *et al.* (2015) for grain yield per plant. On other hand it showed negative significant association with 1000 grain weight (-0.3162) may be due to the reason that the average 1000 grain weight of parents and their crosses was low (16.08 g) which resulted in strong negative association. Similar association with 1000 grain weight was also reported by Nilanjaya and Kumar (2015).

4.4.5 Panicle Length (cm)

The trait, showed positive significant association with physiological traits like LAD at 60-80 DAT (0.7675), SCMR at 80 DAT (0.4989), shoot dry weight (0.7015), harvest index (0.5897) and grain yield per plant (0.7120). When leaf area duration and chlorophyll content of leaves increases, the amount of photosynthetic assimilates increases shoot biomass which results in lengthy panicle with high 1000 grain weight, high harvest index and finally high grain yield per plant. Similar results of positive significant association with panicle length were earlier reported by Sudharani *et al.* (2012) for SCMR, Saikumar *et al.* (2014) for harvest index and Ratna *et al.* (2015) for grain yield per plant. It also showed positive association with 1000 grain weight

(0.2640) which was desirable and number of ill-filled grains per panicle (0.3248). The positive association of ill-filled grains per panicle (0.3248) may be due to inability of the genotype to translocate photosynthates to more number of grains per lengthy panicle resulted in to some ill-filled grains. Similar associations for 1000 grain weight and number of ill-filled grains per panicle were earlier presented by Prasad *et al.* (2015) and Hossain *et al.* (2015).

4.4.6 Number of Filled Grains per Panicle

The trait number of filled grains per panicle, showed positive significant association with number of ill-filled grains (0.4658) probably due to competition for a common possibility, such as assimilates supply. It also showed positive significant association with LAD at 60-80 DAT (0.4431), SCMR at 80 DAT (0.4503) and SLW at 80 DAT (0.9230). In the present study, it clearly explains that the dependence of this trait on physiological characters to attain effective grains finally leads to increased grain yield per plant. Hence, these associations were considered to be desirable. However the association of grain yield was positive but non significant (0.1678) was also reported by Hossain *et al.* (2015) and Sarwar *et al.* (2015). On contrary, it showed negative significant association with 1000 grain weight (-0.5353) may be due to majority of the crosses and their parents were of fine grain types. The association of filled grains with SLA at 80DAT (-0.4688) is in desirable direction i.e., significantly negative and its association with root shoot ratio (-0.3048) also negative. However, Sudharani *et al.* (2012) reported positive significant association of this trait with root shoot ratio.

4.4.7 Number of Ill-filled Grains per Panicle

The trait number of ill-filled grains per panicle, showed positive significant association with LAD 60-80 (0.3458), root dry weight (0.2912), root shoot ratio (0.3368) and SLW at 80 DAT (0.6326). Even though the genotypes with persistent greenness at 60 to 80 DAT, high SLW at 80 DAT and high root to shoot ratio may leads to more number of ill-filled grains rather than filled grains which may be due to competition for nutrient supply and influence of environment. However the positive and non significant association of this trait with root dry weight was observed by Shajedur *et al.* (2015). Number of ill-filled grains per panicle also showed negative significant association with SLA at 80 DAT (-0.5751).

4.4.8 1000 Grain Weight (g)

The trait, 1000 grain weight, showed positive significant association with SLA at 80 DAT (0.5990), shoot dry weight (0.2802) and grain yield per plant (0.3087). This indicated that all these characters were important for yield improvement. Hence, these characters could be considered as criteria for selection for higher yield as these were mutually and directly associated with grain yield. Similar results of positive and significant association of 1000 grain weight with grain yield were earlier presented by Reddy *et al.* (2013), Saikumar *et al.* (2014) and Prasad *et al.* (2015). The negative association of this trait with SLW at 80 DAT (-0.3518) was earlier reported by Adilakshmi and Raghavareddy (2012).

4.4.9 LAD at 60-80 DAT

The positive significant association of LAD at 60-80 DAT with SCMR at 80 DAT (0.3761) indicated that persistent greenness at 60-80 DAT with high SCMR at 80 DAT would result in increased yield. It also showed significant negative association with SLW at 80 DAT (-0.2649). However, positive significant association of LAD with grain yield per plant was reported earlier by Caglar *et al.* (2010).

4.4.10 SCMR at 80 DAT

The trait, SCMR at 80 DAT, showed positive significant association with shoot dry weight (0.2707) and grain yield per plant (0.3147) indicated that chlorophyll pigments play an important role in the photosynthetic process as well as biomass production. Genotypes maintaining higher leaf chlorophyll content during active growth period may be considered as potential donors for the ability of producing higher biomass and photosynthetic capacity which results in higher yields. Similar result of positive significant association with grain yield per plant was presented earlier by Gopikannan and Ganesh (2013b). It exhibited negative significant association with root shoot ratio (-0.4525), but Malath and Gomathinayagam (2013) observed negative and non significant association with root shoot ratio.

4.4.11 SLA at 80 DAT (cm^2/g)

SLA at 80 DAT, showed positive significant association with root shoot ratio (0.5762) and negative significant association with SLW at 80 DAT (-0.9290), shoot dry weight (-0.4603) and grain yield per plant (-0.7135). Strong negative association of this trait with specific leaf weight and shoot dry weight would results in increased grain yield, as the leaf area decreases, leaf thickness and shoot dry weight increases correspondingly. Similar association of SLA with grain yield was reported by Mohankumar *et al*. (2011) but non significant.

4.4.12 SLW at 80 DAT (g/cm^2)

This trait, showed positive significant association with shoot dry weight (0.2962) and grain yield per plant (0.5764). The positive significant association with grain yield showed strong relation between them indicating that high specific leaf weight at 80 days after transplanting directly contributes to grain yield. However, positive non significant association with grain yield at phenotypic level was reported earlier by Ali *et al.* (2010). Negative significant association with root shoot ratio (-0.3387) was also showed by this trait.

4.4.13 Harvest Index

Harvest index, showed positive significant association with shoot dry weight (0.5225) and grain yield per plant (0.6353). This type of positive association of harvest index with shoot dry weight and grain yield in present investigation indicating that yield is a function of total dry matter and harvest index which can be increased by increasing either biomass or harvest index or both. Similar association with grain yield was earlier reported by Chakraborthi *et al.* (2010), Sudharani *et al.* (2012), Reddy *et al.* (2013), Saikumar *et al.* (2014) and Roy *et al.* (2015). It also showed negative significant association with root shoot ratio (-0.2967) but Sudharani *et al.* (2012) reported positive and significant association of harvest index with root shoot ratio.

4.4.14 Root Dry Weight (g)

Root dry weight, showed strong significant positive association with shoot dry weight (0.3641) and root shoot ratio (0.6920) revealed that root dry weight had the significant effect on shoot dry weight and root shoot ratio. However findings of Sathya and Jebaraj (2015) at phenotypic level showed negative non significant association of root dry weight with shoot dry weight and positive significant association with root shoot ratio.

4.4.15 Shoot Dry Weight (g)

The trait, shoot dry weight, showed highly significant positive correlation (0.9279) with grain yield per plant indicated that close association of this character with grain yield per plant and this meaningful association can be exploited in selection programme leading towards the improvement of rice varieties. However negative non significant association with grain yield at phenotypic level was earlier reported by Sathya and Jebaraj (2015). This trait also showed negative significant association with root shoot ratio (-0.3973), Sathya and Jebaraj (2015) also reported negative but non significant association of shoot dry weight with root shoot ratio at phenotypic level.

4.4.16 Root Shoot Ratio

Root shoot ratio showed negative significant correlation (-0.4894) with grain yield per plant. The highly significant negative association with grain yield per plant was in conformity with the previous reports of Malath and Gomathinayagam (2013).

Correlation studies revealed that the grain yield per plant was positively and significantly correlated with plant height, panicle length, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT, SLA at 80 DAT, SLW at 80 DAT, harvest index and shoot dry weight and root shoot ratio. By this study it is clearly observed that for getting high grain yield both yield attributes and physiological characters were equally important. Hence, these characters could be considered as the selection criteria for getting higher grain yield.

4.5 PATH ANALYSIS

The observed correlation between yield and its component character is the net result of the direct and indirect effects of the component character through other yield attributes. The total correlation coefficient between yield and its component characters may sometimes be misleading, as it may be an over or under estimate of its association with other characters. In these cases, direct selection on the basis of correlated response may not be fruitful. For critical evaluation, the correlation coefficient need to be split into direct and indirect effects using path coefficient analysis since, many characters affect a given trait. Thus, the correlation and path coefficients in combination can give a better insight into cause and effect relationship between different pairs of character.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct 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 the 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 are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.

If correlation coefficient is negative and direct effect is also negative, then the character cannot be considered as a selection criterion.

The residual effect determines how best the causal factors account for the variability of the dependent factor. If the 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

In the present study, path analysis was used to work out the direct and indirect effects of yield contributing characters on yield in 20 F_1s and nine parents along with two checks and the results are presented (Table 4.12) character wise hereunder. The path diagram is given in Figure 4.1.

Path coefficient analysis of grain yield in rice revealed that days to 50% flowering (1.2285), plant height (0.2017), number of effective tillers per plant (0.7231), number of filled grains per panicle (0.4927), number of ill-filled grains per panicle (0.0952), 1000 grain weight (0.7030), LAD at 60-80 DAT (0.1752), SCMR at 80 DAT (0.0907), SLA at 80 DAT (0.4354), SLW at 80 DAT (0.5722) root dry weight (0.2545) and shoot dry weight (0.2921) exhibited positive direct effect on grain yield per plant.

On contrary, the traits days to maturity (-1.1177), panicle length (-0.2118), harvest index (-0.1570) and root shoot ratio (-0.4848) contributed negative direct effects on grain yield per plant.

4.5.1 Days to 50% Flowering

Days to 50% flowering exhibited positive direct effect (1.2285) and non significant negative correlation (-0.0491) on grain yield per plant. The positive direct effect of this trait on grain yield per plant was nullified majorly by negative indirect effects like days to maturity (-1.1090), 1000 grain weight (-0.1234), SLA at 80 DAT (-0.1636) and root shoot ratio (-0.1511). Under these circumstances, a restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect. Similar results of negative non significant correlation and positive direct effect on grain yield per plant was reported by Bhadru *et al.* (2012b) and Gopikannan and Ganesh (2013b).

4.5.2 Days to Maturity

The trait days to maturity exhibited negative direct effect (-1.1177) and non significant negative correlation (-0.0015) on grain yield per plant. Hence this character cannot be considered as a selection criterion. For this trait, Prasad *et al.* (2015) reported negative direct effect with significant negative association.

4.5.3 Plant Height (cm)

Low positive direct effect (0.2017) and positive significant correlation (0.5218) on grain yield per plant were exhibited by this trait. The significant correlation and positive direct effect explains the true relationship of this trait with grain yield thus, direct selection for this trait will be effective. Since direct effect of this trait is low, high positive significant association on grain yield might be attributed through positive indirect effects like SLA at 80 DAT (0.2500), 1000 grain weight (0.1999), shoot dry weight (0.1707), days to maturity (0.1781) and root shoot ratio (0.1191), making selection based on these traits would be rewarding. Similar results of positive significant correlation and positive direct effects on grain yield per plant were also reported by Bhadru *et al.* (2012) and Khare *et al.* (2014).

4.5.4 Number of Effective Tillers per Plant

The trait number of effective tillers per plant, exhibited positive direct effect (0.7231) and positive significant correlation (0.4314) on grain yield per plant. As the direct effect of this trait on grain yield was high and association was positive, this trait showed true relationship with grain yield per plant hence, a direct selection on this trait would be effective. Bhadru *et al.* (2012) and Kishore *et al.* (2015) also reported similar results of positive significant correlation and positive direct effects on grain yield per plant.

4.5.5 Panicle Length (cm)

Negative direct effect (-0.2118) combined with significant (0.7120) positive association on grain yield per plant was expressed by the trait panicle length indicated that positive indirect effects contribute to the positive association. Under this situation, the positive indirect causal factors such as days to maturity (0.5969), plant height (0.1763), number of effective tillers per plant (0.1363), 1000 grain weight (0.1856), shoot dry weight (0.2049) and root shoot ratio (0.1760) could be effective in selection. Similar results of positive significant correlation and negative direct effects on grain yield per plant were reported by Khare *et al.* (2014) and Kishore *et al.* (2015).

4.5.6 Number of Filled Grains per Panicle

Number of filled grains per panicle exhibited positive direct effect (0.4927) and positive non significant correlation (0.1678) on grain yield per plant. This result suggested that though, the direct effect of this parameter is high, it was reduced by negative indirect effects of SLA (-0.6394) and 1000 grain weight (-0.3763). However, components like SLW at 80 DAT (0.5281) and root shoot ratio (0.1478) are contributing indirectly for grain yield per plant showing their importance in selection criteria. Similar results of positive non significant correlation and positive direct effects on grain yield per plant were reported by Kishore *et al.* (2015).

4.5.7 Number of Ill-filled Grains per Panicle

Low positive direct effect (0.0952) along with non significant negative correlation (-0.0772) on grain yield per plant was exhibited by the trait number of ill-filled grains per panicle. The negative non significant correlation indicate the independent and antagonistic association of number of ill-filled grains with grain yield per plant and low direct effects suggests that very low contribution of this trait towards yield improvement. Sarwar *et al.* (2015) reported positive direct effect and significant association on grain yield per plant for this trait.

4.5.8 1000 Grain Weight (g)

Positive direct effect (0.7030) and significant positive correlation (0.3087) were exhibited by this trait on grain yield per plant. Thus the trait, 1000 grain weight showed true relationship and can be considered as one of the contributors for improving grain yield per plant by placing greater emphasis on direct selection of this trait. However, positive but non significant correlation and positive direct effects on grain yield per plant were reported by Kumar *et al.* (2013) and Saikumar *et al.* (2014).

4.5.9 LAD at 60-80 DAT

Low positive (0.1752) direct effect along with non significant negative correlation (-0.0019) was exhibited by the trait LAD at 60-80 DAT on grain yield per plant. The direct effect of this trait was low and negative indirect effect like days to 50 % flowering (-0.3497), specific leaf weight (-0.1515) and panicle length (-0.1626) nullified the positive effect of this trait producing non significant negative association hence restriction should be on above mention negative indirect effects applied during selection.

4.5.10 SCMR at 80 DAT

Low positive direct effect (0.0907) along with significant positive correlation (0.3147) on grain yield per plant was exhibited by the trait SCMR at 80 DAT. Results of direct effect and correlation for this trait indicated that this trait exhibits true relationship with grain yield per plant but, the contribution of direct effect was low thus selection based on the Indirectly contributing characters like days to maturity (0.4806), number of filled grains (0.2219) and root shoot ratio (0.2194), would be effective than selection on direct effect alone. Similar results of positive significant correlation and positive direct effect on grain yield per plant were also reported by Adilakshmi and Raghavareddy (2012).

4.5.11 SLA at 80 DAT (cm^2/g)

SLA at 80 DAT exhibited positive direct effect (0.4354) along with significant negative correlation (-0.7135) on grain yield per plant. Under these circumstances, a restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect. Positive direct effect with non significant negative association was reported by Mohankumar *et al*. (2011) for this trait.

4.5.12 SLW at 80 DAT (g/cm^2)

SLW at 80 DAT, exhibited positive direct effect (0.5722) and significant positive correlation (0.5764) on grain yield per plant. Significant association in desirable direction along with positive direct effect proposes existence of true relation of this trait with grain yield and a direct selection through this trait will be effective. However for this trait Adilakshmi and Raghavareddy (2012) reported negative direct effect and negative non significant correlation on grain yield per plant).

4.5.13 Harvest Index

Negative direct effect (-0.1570) and significant positive correlation (0.6353) on grain yield per plant were exhibited the trait harvest index. Significant positive association with grain yield even in the presence of negative direct effect indicated the involvement of positive indirect effects in producing positive correlation thus indirect positive effects like days to maturity (0.2688), number of effective tillers per plant (0.3289), 1000 grain weight (0.1700) and shoot dry weight (0.1526) should be given greater emphasis for improving the yield. Positive direct effect and positive correlation shows true relationship and direct selection on this trait will be effective. Similar results of positive significant correlation and negative direct effect on grain yield per plant were reported by Nagaraju *et al.* (2013).

4.5.14 Root Dry Weight (g)

The trait root dry weight exhibited positive direct effect (0.2545) and non significant positive correlation (0.2131) on grain yield per plant. The result of low direct effect and non significant positive association expressed that the trait root dry weight had little effect on grain yield per plant on its own hence selection on root dry weight along with indirect effects like days to flowering (0.2990) and shoot dry weight (0.1063) would be rewarding. Shajedur *et al.* (2015) also reported similar results of non significant positive correlation and positive direct effects on grain yield per plant.

4.5.15 Shoot Dry Weight (g)

Shoot dry weight exhibited low positive direct effect (0.2921) and significant positive correlation (0.9279) on grain yield per plant. High Positive significant association and low positive direct effect indicated the additional role of positive indirect factors towards high positive association with grain yield thus selection of positive direct effect along with indirect positive effects like number of effective tillers (0.1947), plant height (0.1178), SLW at 80 DAT (0.1695) and root shoot ratio (0.1926) would be effective.

4.5.16 Root Shoot Ratio

The trait root shoot ratio exhibited significant negative correlations (-0.4894) and negative direct effect (-0.4848) on grain yield per. As both direct effect and correlation are negative, this character could not be considered as a selection criterion for yield improvement. While Sudharani *et al.* (2012) reported positive direct effect along with significant positive association of root shoot ratio on grain yield per plant.

Maximum contribution to grain yield was showed by days to 50% flowering in the path analysis, which was followed by number of effective tillers per plant, 1000 grain weight, specific leaf weight, number of filled grains per panicle, specific leaf area, shoot dry weight, root dry weight, plant height and leaf area duration through higher direct effect indicated that these traits enhancing grain yield directly. Traits like days to maturity and root shoot ratio exhibited positive indirect effects through other characters.

In the present investigation path analysis clearly explains the importance of physiological parameters in their contribution towards grain yield per plant directly as well as indirectly. .

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. The residual effect at genotypic level was 0.455 indicating that the characters included in the study are contributing more than 54 per cent of variability pertaining to the dependent variable *i.e.,* yield. Less than 46 per cent of contribution is from the few other characters which were not included in the present study.

FUTURE LINE OF WORK

The present study, combining ability analysis using line x tester analysis, has identified the lines JGL 11118 (days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT, SCMR at 80 DAT), RNR 2465 (days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, SLW at 80 DAT and shoot dry weight) and Kavya (number of filled grains per panicle, SLA at 80 DAT, SLW at 80 DAT and root dry weight) and testers IR 64 (days to 50% flowering, days to maturity, number of ill-filled grains per panicle, 1000-grain weight) and NLR 34449 (days to 50% flowering, days to maturity, number of filled grains per panicle and number of ill-filled grains per panicle) as good general combiners in desirable direction while the cross, RNR 2465 x IR 64 only recorded significant *sca* effect for grain yield per plant.

The lines, JGL 11118, RNR 2465 and Kavya and testers, IR 64 and NLR 34449 having potential general combining ability for yield and its components can be used as parents in yield improvement programme in future.

For the cross, RNR 2465 x IR 64 having high *sca* effect for grain yield, transgressive segregants may be selected in the future segregating generations or F_1 x F_1 may also be attempted for overall improvement of traits in population for developing potential cultivar.

Chapter II

REVIEW OF LITERATURE

The review of literature on rice (*Oryza sativa* L.) regarding the present study is presented under the following headings.

2.1 Genetic variability

2.2 Heritability

2.3 Genetic advance and genetic advance as per cent mean

2.4 Combining ability and gene action

2.5 Heterosis

2.6 Character association

2.7 Path co-efficient analysis

2.1 GENETIC VARIABILITY

Presence of variation in a given population is a primary requirement for improvement of any crop species and for developing an effective breeding programme. Selection is effective only when there is enough magnitude of genetic variability in the breeding population, hence an insight into the magnitude of genetic variability present in the population is utmost importance to a plant breeder for starting a plant breeding programme for crop improvement.

The available literature on genetic variability studies in rice is reviewed and presented in Table 2.1.

2.2 HERITABILITY

Hanson *et al.* (1956) defined heritability in broad sense $h^2_{(b)}$ as the ratio of genotypic variance to the total phenotypic variance. Heritability (h^2) measures the relative amount of heritable portion of total variability. It is the measure of the efficiency of a selection and useful for the breeder in selecting superior individuals in the population

The available literature on heritability in rice is presented in Table 2.2.

2.3 GENETIC ADVANCE (GA) AND GENETIC ADVANCE AS PER CENT OF MEAN (GAM)

Genetic advance is a measure for knowing the degree of genetic gain achieved by a character under a particular selection pressure. Johnson *et al.* (1955) reported that estimates of heritability (h^2) coupled with the estimates of genetic advance (GA) are more useful in the choice of selection methods rather than heritability or genetic advance alone. High heritability coupled with high genetic advance indicates the operation of additive gene effect in the expression of the trait and improvement could be made for that character by simple selection on phenotypic performance, Johnson *et al.* (1955).

The available literature on genetic advance and genetic advance as percent mean is presented in Table 2.2

2.4 COMBINING ABILITY AND GENE ACTION

The ability of a parent to transmit superior performance to its hybrids is known as combining ability. It is used to test the breeding value of the parental lines used in hybridization programme. There are two types of combining ability *viz.*, 1. General combining ability (*gca*) and 2. Specific combining ability (*sca*). General combining ability is the average performance of a line in a series of hybrid combinations. Specific combining ability is the deviation of a particular cross from the general combining ability. The idea of combining ability as a measure of gene action was proposed by Sprauge and Tatum (1942), they also reported that general combining ability was primarily the result of additive gene effect and specific combining ability was the result of non-additive gene effect.

The available literature on combining ability and gene action is presented in Table 2.3.

2.5 HETEROSIS

Exploitation of heterosis and its utilization for maximizing the yield of crops has been an important technique in hybrid production. Shull (1914) coined the term heterosis and it is the phenomenon in which the F_1 of two genetically dissimilar parents shows increased vigour or size for various characters over the mid parent (relative or mid parent heterosis) or over the better parent (heterobeltiosis) or over the superior check (standard heterosis).

The available literature on heterosis over standard check, better parent and mid parent in rice is presented in Tables 2.4-2.6.

2.6 CHARACTER ASSOCIATION

Yield is polygenically controlled character and highly influenced by environment, thus selection based on component characters is more effective compared to selection based on only yield. Correlation studies show the extent of association between the yield and its component characters. If the correlation between a set of characters is favourable and strong then selection for one character is sufficient. If the correlation between set of desirable characters is unfavorable, selection for the character may limit the genetic advance. Thus, knowledge on character association between the yield and yield components is essential for selecting genotypes with desirable combinations of characters and for planning effective selection programme.

The available literature on character association among the yield component characters with grain yield per plant and the association among the yield component characters is presented in Tables 2.7 and 2.8, respectively.

2.7 PATH COEFFICIENT ANALYSIS

Path coefficient analysis is simply a standardized partial regression coefficient, which helps in splitting the correlation coefficient into direct and indirect effects of independent variables on dependent variable (Wright, 1921). Path analysis helps to elucidate the intrinsic nature of the observed associations and imparts a degree of confidence in the selection schemes adopted for a given situation (Dewey and Lu, 1959).

The available literature on direct and indirect effects of yield components on grain yield is presented in Tables 2.9 and 2.10, respectively.

Table 2.1. Review of literature on genetic variability of yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S.No.	Character	Variability	Reference
1.	Days to 50% flowering	High PCV, GCV	Sharma and Sharma (2007) Seyoum *et al.* (2012) Mamun *et al.* (2012) Shobharani *et al.* (2013)
		Moderate PCV, GCV	Jaiswal *et al.* (2007) Vijayalakshmi *et al.* (2008) Lal and Chauhan (2011) Kumar and Saravanan (2012) Bekele *et al.* (2013) Vanisree *et al.* (2013) Vineeth *et al.* (2014) Kishore *et al.* (2015)
		Low PCV, GCV	Devi *et al.* (2006) Singh *et al.* (2007a) Kole *et al.* (2008) Prasad *et al.* (2009) Sreeparvathy *et al.* (2010) Parvathi (2011) Sravan *et al.* (2012) Gangashetty *et al.* (2013) Khare *et al.* (2014) Tetwar *et al.* (2014) Sathya and Jebaraj (2015) Harsh *et al.* (2015)
2.	Days to maturity	High PCV, GCV	Prasad *et al.* (2011) Neha *et al.* (2014)
		Moderate PCV, GCV	Prasad *et al.* (2011) Aishwarya *et al.* (2014) Vineeth *et al.* (2014)
		Low PCV, GCV	Karim *et al.* (2007) Kumar and Ramesh (2008) Aishwarya *et al.* (2014) Khare *et al.* (2014) Ria *et al.* (2015) Khatun *et al.* (2015)

Table 2.1 (contd.)

S.No.	Character	Variability	Reference
3.	Plant height (cm)	High PCV, GCV	Padmaja *et al.* (2008) Lal and Chauhan (2011) Bhadru *et al.* (2012a) Neha *et al.* (2014) Bornare *et al.* (2014) Sindhumole *et al.* (2015) Harsh *et al.* (2015)
		Moderate PCV, GCV	Binse *et al.* (2006) Sharma and Sharma (2007) Krishna *et al.* (2008) Prasad *et al.* (2009) Saidaiah *et al.* (2010) Nandeshwar *et al.* (2010) Parvathi (2011) Kumar and Saravanan (2012) Sharma *et al.* (2013) Vineeth *et al.* (2014) Uday *et al.* (2014) Khatun *et al.* (2015) Bhuvaneswari *et al.* (2015)
		Moderate PCV, Low GCV	Ramanjaneyulu *et al.* (2014)
		Low PCV, GCV	Manna *et al.* (2006) Singh *et al.* (2007a) Kole *et al.* (2008) Kuchanur *et al.* (2009) Ullah *et al.* (2011) Paikhomba *et al.* (2014) Tetwar *et al.* (2014) Kishore *et al.* (2015) Hossain *et al.* (2015)
4.	Number of effective tillers per plant	High PCV, GCV	Vaithiyalingan and Nadarajan (2006) Singh *et al.* (2007a) Padmaja *et al.* (2008) Prasad *et al.* (2009) Babu *et al.* (2011) Seyoum *et al.* (2012) Ukaoma *et al.* (2013) Bornare *et al.* (2014) Uday *et al.* (2014) Khare *et al.* (2014) Bhuvaneswari *et al.* (2015) Hossain *et al.* (2015)

Table 2.1 (contd.)

S.No.	Character	Variability	Reference
		High PCV, Moderate GCV	Devi *et al* .(2006) Binse *et al.* (2006) Vijayalakshmi *et al.* (2008) Chandra *et al.* (2009) Saidaiah *et al.* (2010) Ramanjaneyulu *et al.* (2014)
		Moderate PCV, Low GCV	Karthikeyan *et al.* (2007) Kuchanur *et al.* (2009)
		Moderate PCV, GCV	Ullah *et al.* (2011) Sathya and Jebaraj (2015)
5.	Panicle length (cm)	High PCV, GCV	Chaudhary *et al.* (2004) Nayudu *et al.* (2007)
		High PCV, Moderate GCV	Khatun *et al.* (2015)
		Moderate PCV, GCV	Hasib (2005) Devi *et al.* (2006) Sharma and Sharma (2007) Vijayalakshmi *et al.* (2008) Saidaiah *et al.* (2010) Prasad *et al.* (2011) Gangashetty *et al.* (2013) Singh *et al.* (2014) Khare *et al.* (2014) Harsh *et al.* (2015)
		Moderate PCV, Low GCV	Vaithiyalingan and Nadarajan (2006) Chandra *et al.*(2009) Parvathi (2011) Ghosh and Sharma (2012) Uday *et al.* (2014)
		Low GCV, PCV	Singh *et al.* (2005) Binse *et al.* (2006) Singh *et al.* (2007a) Padmaja *et al.* (2008) Prasad *et al.* (2009) Nandeshwar *et al.* (2010) Ullah *et al.* (2011) Tetwar *et al.* (2014) Vineeth *et al.* (2014) Kishore *et al.* (2015) Hossain *et al.* (2015)

Table 2.1 (contd.)

S.No.	Character	Variability	Reference
6.	Number of filled grains per panicle	High PCV, GCV	Hasib (2005) Devi *et al.* (2006) Karim *et al.* (2007) Padmaja *et al.* (2008)
		High PCV, Moderate GCV	Kuchanur *et al.* (2009) Laxuman *et al.* (2010)
		Moderate PCV, GCV	Tetwar *et al.* (2014) Sathya and Jebaraj (2015) Hossain *et al.* (2015)
		Low PCV, GCV	Bhavana (2003) Vineeth *et al.* (2014)
7.	Number of ill-filled grains per panicle	High PCV, GCV	Mamun *et al.* (2012) Vineeth *et al.* (2014) Shrivastava *et al.* (2014) Khatun *et al.* (2015)
		Moderate PCV, GCV	Hossain *et al.* (2015)
8.	1000 grain weight (g)	High PCV, GCV	Hasib (2005) Binse *et al.* (2006) Gangashetty *et al.* (2013) Vineeth *et al.* (2014) Ramanjaneyulu *et al.* (2014) Nirmaladevi *et al.* (2015)
		Moderate PCV, GCV	Kumar *et al.* (2006) Vaithiyalingan and Nadarajan (2006) Ukaoma *et al.* (2013) Singh *et al.* (2014) Khare *et al.* (2014) Bhuvaneswari *et al.* (2015)
		Low GCV, Moderate PCV	Nandeshwar *et al.* (2010) Singh *et al.* (2007a) Krishna *et al.* (2008) Chandra *et al.* (2009) Ullah *et al.* (2011) Sharma *et al.* (2013) Bornare *et al.* (2014) Singh *et al.* (2014) Kishore *et al.* (2015) Khatun *et al.* (2015)
		Moderate PCV, Low GCV	Vijayalakshmi *et al.* (2008) Kuchanur *et al.* (2009) Sathya and Jebaraj (2015)

Table 2.1 (contd.)

S.No.	Character	Variability	Reference
		Low PCV, GCV	Kole *et al.* (2008) Paikhomba *et al.* (2014) Tetwar *et al.* (2014) Hossain *et al.* (2015)
9.	Grain yield per plant (g)	High PCV, GCV	Binse *et al.* (2006) Devi *et al.* (2006) Sarkar *et al.* (2007) Jaiswal *et al.* (2007) Singh *et al.* (2007a) Krishna *et al.* (2008) Prasad *et al.* (2009) Nandeshwar *et al.* (2010) Prasad *et al.* (2011) Bhadru *et al.* (2012a) Ukaoma *et al.* (2013) Dhurai *et al.* (2014b) Vineeth *et al.* (2014) Singh *et al.* (2014) Kishore *et al.* (2015) Khatun *et al.* (2015) Hossain *et al.* (2015)
		Moderate GCV, PCV	Kumar *et al.* (2006) Kole *et al.* (2008) Chandra *et al.* (2009) Saidaiah *et al.* (2010) Ullah *et al.* (2011) Paikhomba *et al.* (2014)
		High PCV Moderate GCV	Nagajyothi (2001) Manna *et al.* (2006) Laxuman *et al.* (2010) Ramanjaneyulu *et al.* (2014)
		Low PCV, GCV	Sathya and Jebaraj (2015)
10.	LAD	High PCV, GCV	Murthy *et al.* (1999)
11.	SPAD	High PCV, GCV	Sathya and Jebaraj (2015)
		High PCV, Moderate GCV	Adilakshmi and Raghavareddy (2012)
		Low PCV, GCV	Abarshahr *et al.* (2011) Ullah *et al.* (2011) Khatun *et al.* (2015)

Table 2.1 (contd.)

S.No.	Character	Variability	Reference
12.	SLA (cm^2/g)	High PCV, GCV	Mohankumar *et al.* (2011) Elango *et al.* (2012)
		High PCV, Moderate GCV	John *et al.* (2011)
13.	SLW (g/cm^2)	High PCV, GCV	John *et al.* (2011)
		Low PCV, GCV	Adilakshmi and Raghavareddy (2012)
14.	HI	High PCV, GCV	Singh *et al.* (2011) Ukaoma *et al.* (2013) Khatun *et al.* (2015)
		Moderate PCV, GCV	Karim *et al.* (2007) Kole *et al.* (2008) Paikhomba *et al.* (2014) Vineeth *et al.* (2014) Sathya and Jebaraj (2015)
		Moderate PCV, Low GCV	Ullah *et al.* (2011) Ramanjaneyulu *et al.* (2014)
		Low PCV, GCV	Adilakshmi and Raghavareddy (2012) Tetwar *et al.* (2014)
15.	SDW (g)	High PCV, GCV	Ukaoma *et al.* (2013)
		High PCV, Moderate GCV	Sathya and Jebaraj (2015)
16.	RDW (g)	High PCV, GCV	Ukaoma *et al.* (2013) Shajedur *et al.* (2015)
		High PCV, Moderate GCV	Sathya and Jebaraj (2015)
17.	RSR	High PCV, GCV	Sathya and Jebaraj (2015)

Table 2.2. Review of literature on heritability $h^2_{(b)}$ and genetic advance as per cent of mean for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
1.	Days to 50% flowering	High	High	Sharma and Sharma (2007) Vijayalakshmi *et al.* (2008) Singh *et al.* (2011) Mamun *et al.* (2012) Vanisree *et al.* (2013) Neha *et al.* (2014) Vineeth *et al.* (2014) Kishore *et al.* (2015)
		High	Moderate	Vaithiyalingan and Nadarajan (2006) Singh *et al.* (2007a) Padmaja *et al.* (2008) Binse *et al.* (2009) Saidaiah *et al.* (2010) Parvathi (2011) Gangashetty *et al.* (2013) Singh *et al.* (2014) Khare *et al.* (2014)
		High	Low	Sreeparvathy *et al.* (2010) Osman *et al.* (2012) Tetwar *et al.* (2014) Harsh *et al.*(2015)
		Moderate	Low	Sathya and Jebaraj (2015)
		Low	Low	Ria *et al.* (2015)
2.	Days to maturity	High	High	Kumar and Ramesh (2008) Prasad *et al.* (2011) Neha *et al.* (2014) Vineeth *et al.* (2014)
		High	Moderate	Aishwarya *et al.* (2014) Singh *et al.* (2014) Khare *et al.* (2014) Khatun *et al.* (2015)
		High	Low	Madhavilatha and Suneetha (2005) Karim *et al.* (2007) Singh *et al.* (2011) Verma *et al.* (2011) Osman *et al.* (2012) Aishwarya *et al.* (2014)

Table 2.2 (contd.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
3.	Plant height (cm)	High	High	Elayaraja *et al.* (2005) Singh *et al.* (2005) Singh *et al.* (2006) Karthikeyan *et al.* (2007) Padmaja *et al.* (2008) Prasad *et al.* (2009) Chandra *et al.* (2009) Anjaneyulu *et al.* (2010) Saidaiah *et al.* (2010) Parvathi (2011)
		High	Moderate	Vaithiyalingan and Nadarajan (2006) Singh *et al.* (2007a) Nikil *et al.* (2014) Paikhomba *et al.* (2014) Sathya and Jebaraj (2015) Hossain *et al.* (2015)
		Moderate	Low	Kuchanur *et al.* (2009) Tetwar *et al.* (2014)
		High	Low	Ullah *et al.* (2011) Singh *et al.* (2011) Verma *et al.* (2011)
		Low	High	Mishra and Pravin (2004) Krishna *et al.* (2008)
		Low	Low	Manna *et al.* (2006) Ramanjaneyulu *et al.* (2014)
4.	Number of effective tillers per plant	High	High	Singh *et al.* (2005) Binse *et al.* (2006) Singh *et al.* (2007a) Padmaja *et al.* (2008) Anbanandan *et al.* (2009) Sreeparvathy *et al.* (2010) Parvathi (2011) Ukaoma *et al.* (2013) Dhurai *et al.* (2014b) Singh *et al.* (2014) Khatun *et al.* (2015) Sathya and Jebaraj (2015) Hossain *et al.* (2015)

Table 2.2 (contd.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
		High	Moderate	Elayaraja *et al.* (2005) Kole *et al.* (2008) Ullah *et al.* (2011) Bornare *et al.* (2014)
		High	Low	Prasad *et al.* (2011) Vineeth *et al.* (2014)
		Moderate	High	Prasad *et al.* (2009) Paikhomba *et al.* (2014)
		Moderate	Moderate	Manna *et al.* (2006) Bharadwaj *et al.* (2007) Garg *et al.* (2011) Ramanjaneyulu *et al.* (2014)
		Low	Low	Karthikeyan *et al.* (2007) Kuchanur *et al.* (2009) Lingaiah (2015)
5.	Panicle length (cm)	High	High	Elayaraja *et al.* (2005) Vaithiyalingan and Nadarajan (2006) Bharadwaj *et al.* (2007) Vijayalakshmi *et al.* (2008) Kumar and Saravanan (2012) Gangashetty *et al.* (2013) Vanisree *et al.* (2013) Dhurai *et al.* (2014b) Khare *et al.* (2014) Allam *et al.* (2015)
		High	Moderate	Singh *et al.* (2005) Binse *et al.* (2006) Karthikeyan *et al.* (2007) Padmaja *et al.* (2008) Binse *et al.* (2009) Saidaiah *et al.* (2010) Shobharani *et al.* (2013) Singh *et al.* (2014) Harsh *et al.* (2015) Hossain *et al.* (2015)
		High	Low	Singh *et al.* (2007a) Prasad *et al.* (2009) Shobharani *et al.* (2013) Vineeth *et al.* (2014) Kishore *et al.* (2015)

Table 2.2 (contd.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
		Moderate	High	Patil *et al.* (2003) Khatun *et al.* (2015)
		Moderate	Moderate	Parvathi (2011)
		Moderate	Low	Bhavana (2003) Ullah *et al.* (2011) Paikhomba *et al.* (2014) Sathya and Jebaraj (2015)
		Low	High	Mishra and Pravin (2004)
		Low	Moderate	Manna *et al.* (2006)
		Low	Low	Krishna *et al.* (2008) Chandra *et al.* (2009) Tetwar *et al.* (2014)
6.	Number of filled grains per panicle	High	High	Panwar (2005) Binse *et al.* (2006) Karthikeyan *et al.* (2007) Prasad *et al.* (2009) Saidaiah *et al.* (2010) Parvathi (2011) Sharma *et al.* (2013) Dhurai *et al.* (2014b) Vineeth *et al.* (2014) Khatun *et al.* (2015) Sathya and Jebaraj (2015)
		Moderate	High	Bharadwaj *et al.* (2007)
		Low	Moderate	Tetwar *et al.* (2014)
		Low	Low	Mamun *et al.* (2012)
7.	Number of ill-filled grains per panicle	High	High	Vineeth *et al.* (2014) Shrivastava *et al.* (2014) Khatun *et al.* (2015) Hossain *et al.* (2015)
		Moderate	High	Mamun *et al.* (2012)
		Low	High	Tetwar *et al.* (2014)
8.	1000 grain weight (g)	High	High	Hasib (2005) Vaithiyalingan and Nadarajan (2006) Karim *et al.* (2007) Vijayalakshmi *et al.* (2008) Anbanandan *et al.* (2009) Saidaiah *et al.* (2010) Prasad *et al.* (2011) Bhadru *et al.* (2012a) Ukaoma *et al.* (2013) Vanisree *et al.* (2013)

Table 2.2 (contd.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
				Ramanjaneyulu *et al.* (2014) Khare *et al.* (2014) Ria *et al.* (2015) Kishore *et al.* (2015) Khatun *et al.* (2015)
		High	Low	Singh *et al.* (2011) Verma *et al.* (2011) Nikam *et al.* (2014) Vineeth *et al.* (2014)
		High	Moderate	Elayaraja *et al.* (2005) Hossain *et al.* (2015)
		Low	High	Krishna *et al.* (2008) Paikhomba *et al.* (2014)
		Moderate	Low	Singh *et al.* (2005) Tetwar *et al.* (2014) Sathya and Jebaraj (2015)
9.	Grain yield per plant (g)	High	High	Madhavilatha and Suneetha (2005) Manna *et al.* (2006) Nayudu *et al.* (2007) Padmaja *et al.* (2008) Prasad *et al.* (2009) Anjaneyulu *et al.* (2010) Sreeparvathy *et al.* (2010) Parvathi (2011) Bhadru *et al.* (2012a) Ukaoma *et al.* (2013) Ramanjaneyulu *et al.* (2014) Khare *et al.* (2014) Kishore *et al.* (2015) Khatun *et al.* (2015) Hossain *et al.* (2015)
10.	LAD	High	High	Murthy *et al.* (1999)
11.	SPAD	High	High	Adilakshmi and Raghavareddy (2012) Sathya and Jebaraj (2015)
12.	SLA (cm^2/g)	High	Low	Ullah *et al.* (2011)
		Moderate	Low	Khatun *et al.* (2015)
		Low	Low	Abarshahr *et al.* (2011)
		High	High	Mohankumar *et al.* (2011) Elango *et al.* (2012)

Table 2.2 (contd.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
		Moderate	Moderate	John *et al.* (2011)
13.	SLW (g/cm^2)	Low	Low	John *et al.* (2011)
		High	Moderate	Adilakshmi and Raghavareddy (2012)
14.	HI	High	High	Kole *et al.* (2008) Ukaoma *et al.* (2013) Paikhomba *et al.* (2014) Khatun *et al.* (2015) Sathya and Jebaraj (2015)
		High	Moderate	Singh *et al.* (2011) Adilakshmi and Raghavareddy (2012) Vineeth *et al.* (2014)
		Moderate	Moderate	Ullah *et al.* (2011)
		Moderate	High	Karim *et al.* (2007)
		Low	Low	Ramanjaneyulu *et al.* (2014) Tetwar *et al.* (2014)
15.	SDW (g)	High	High	Ukaoma *et al.* (2013)
		Low	High	Sathya and Jebaraj (2015)
16.	RDW (g)	High	High	Ukaoma *et al.* (2013) Sathya and Jebaraj (2015) Shajedur *et al.* (2015)
17.	RSR	High	High	Sathya and Jebaraj (2015)
		Low	Low	Haider *et al.* (2012)

Table 2.3. Review of literature on gene action for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

Days to 50 % flowering

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ganesan and Rangaswamy (1998) Patil *et al.* (2003) Rosamma and Vijayakumar (2005) Anand *et al.* (2006) Gnanasekaran *et al.* (2006) Rashid *et al.* (2007) Dalvi and Patel (2009) Chandramohan and Suresh (2012) Jhansi and Satyanarayana (2015)	Banumathy *et al.* (2003) Swamy *et al.* (2003) Panwar (2005) Jayasudha and Deepak (2009) Nadali and Babaeian (2010) Saidaiah *et al.* (2011) Selvaraj *et al.* (2011) Ghara *et al.* (2012) Ghosh *et al.* (2012) Satheeshkumar and Saravanan (2013) Shivam and Harish (2013) Mallikarjuna *et al* (2014) Bineeta and Lal (2015) Savita *et al.* (2015) Sathya and Jebaraj (2015)	Faiz *et al.* (2006) Chakraborty *et al.* (2008) Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013) Adilakshmi *et al.* (2013)

Days to Maturity

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ganesan and Rangaswamy (1998) Rosamma and Vijayakumar (2005) Anand *et al.* (2006) Gnanasekaran *et al.* (2006) Dalvi and Patel (2009)	Bhave *et al.* (2003) Swamy *et al.* (2003) Panwar (2005) Jayasudha and Deepak (2009) Akter *et al.* (2010) Nadali and Babaeian (2010) Saidaiah *et al.* (2011) Onyia (2011) Ghara *et al.* (2012) Srivastava and Jaiswal (2012) Satheeshkumar and Saravanan (2013) Shivam and Harish (2013)	Chakraborty *et al.* (2008) Rahimi *et al.* (2010) Najeeb *et al.* (2011) Ramalingam and Jebaraj (2013) Adilakshmi *et al.* (2013)

Table 2.3 (contd.)

Plant height (cm)

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ganesan and Rangaswamy (1998) Lavanya (2000) Vanaja *et al.* (2003) Anand *et al.* (2006) Gnanasekaran *et al.* (2006) Senguttuvel and Kannan (2007) Nadali and Babaeian (2010) Tushara *et al.* (2013)	Bhave *et al.* (2003) Hariprasanna *et al.* (2006) Akarsh and Pathak (2008) Ahmadikhah *et al.* (2008) Dalvi and Patel (2009) Jayasudha and Deepak (2009) Saidaiah *et al.* (2011) Selvaraj *et al.* (2011) Ghosh *et al.* (2012) Satheeshkumar and Saravanan (2013) Utharasu and Anandakumar (2013) Mallikarjuna *et al.* (2014) Ali *et al.* (2014) Jhansi and Satyanarayana (2015) Savita *et al.* (2015) Sathya and Jebaraj (2015)	Swamy *et al.* (2003) Singh (2005) Sharma *et al.* (2005) Sawant *et al.* (2006) Faiz *et al.* (2006) Rashid *et al.* (2007) Zhao *et al.* (2008) Chakraborty *et al.* (2008) Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013) Adilakshmi *et al.* (2013)

Number of effective tillers per plant

Gene action		
Additive	**Non additive**	**Additive and non additive**
Rosamma and Vijayakumar (2005) Gnanasekaran *et al.* (2006) Dalvi and Patel (2009) Chandramohan and Suresh (2012) Tushara *et al.* (2013)	Banumathy *et al.* (2003) Bhave *et al.* (2003) Panwar (2005) Singh *et al.* (2005) Anand *et al.* (2006) Jayasudha and Deepak (2009) Nadali and Babaeian (2010) Saidaiah *et al.* (2011) Selvaraj *et al.* (2011) Ghara *et al.* (2012) Satheeshkumar and Saravanan (2013)	Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013)

Table 2.3 (contd.)

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Utharasu and Anandakumar (2013) Ali *et al.* (2014) Montazeri *et al.* (2014) Jhansi and Satyanarayana (2015) Bineeta and Lal (2015) Savita *et al.* (2015) Sathya and Jebaraj (2015)	

Panicle length (cm)

Gene action		
Additive	**Non additive**	**Additive and non additive**
Chandramohan and Suresh (2012) Veeresha *et al.* (2013)	Shanthi *et al.* (2003) Veni and Rani (2003) Panwar (2005) Gnanasekaran *et al.* (2006) Hariprasanna *et al.* (2006) Ahmadikhah *et al.* (2008) Dalvi and Patel (2009) Jayasudha and Deepak (2009) Saidaiah *et al.* (2011) Pradeep and Reddy (2011) Ghara *et al.* (2012) Ghosh *et al.* (2012) Shivam and Harish (2013) Utharasu and Anandakumar (2013) Ali *et al.* (2014) Montazeri *et al.* (2014) Jhansi and Satyanarayana (2015) Sathya and Jebaraj (2015)	Sharma *et al.* (2005) Singh (2005) Sawant *et al.* (2006) Anand *et al.* (2006) Zhao *et al.* (2008) Chakraborty *et al.* (2008) Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013)

Table 2.3 (contd.)

Number of filled grains per panicle

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ganesan and Rangaswamy (1998) Rosamma and Vijayakumar (2005)	Banumathy *et al.* (2003) Panwar (2005) Gnanasekaran *et al.* (2006) Dalvi and Patel (2009) Nadali and Babaeian (2010) Saidaiah *et al.* (2011) Selvaraj *et al.* (2011) Ghara *et al.* (2012) Ghosh *et al.* (2012) Satheeshkumar and Saravanan (2013) Shivam and Harish (2013) Ali *et al.* (2014) Jhansi and Satyanarayana (2015) Sathya and Jebaraj (2015)	Anand *et al.* (2006) Chakraborty *et al.* (2008) Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013)

Number of ill-filled grains per panicle

Gene action		
Additive	**Non additive**	**Additive and non additive**
		Vanaja *et al.* (2003) Faiz *et al.* (2006) Akram *et al.* (2007) Gulzar and Wassem (2012)

1000 grain weight (g)

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ganesan and Rangaswamy (1998) Lavanya (2000) Vanaja *et al.* (2003) Rosamma and Vijayakumar (2005) Gnanasekaran *et al.* (2006) Senguttuvel and Kannan (2007) Tushara *et al.* (2013) Ali *et al.* (2014)	Veni and Rani (2003) Anand *et al.* (2006) Hariprasanna *et al.* (2006) Akarsh and Pathak (2008) Pradeep and Reddy (2011) Chandramohan and Suresh (2012)	Sharma *et al.* (2005) Singh (2005) Panwar (2005) Sawant *et al.* (2006) Zhao *et al.* (2008) Rahimi *et al.* (2010) Ramalingam and Jebaraj (2013)

Table 2.3 (contd.)

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Mallikarjuna *et al* (2014) Dorosti and Monajjem (2014) Jhansi and Satyanarayana (2015) Bineeta and Lal (2015)	

Grain yield per plant (g)

Gene action		
Additive	**Non additive**	**Additive and non additive**
Veni and Rani (2003) Senguttuvel and Kannan (2007) Tushara *et al.* (2013)	Vanaja *et al.* (2003) Hariprasanna *et al.* (2006) Akarsh and Pathak (2008) Pradeep and Reddy (2011) Kumar *et al.* (2010) Selvaraj *et al.* (2011) Ghara *et al.* (2012) Ghosh *et al.* (2012) Chandramohan and Suresh (2012) Satheeshkumar and Saravanan (2013) Shivam and Harish (2013) Adilakshmi *et al.* (2013) Mallikarjuna *et al.* (2014) Dorosti and Monajjem (2014) Jhansi and Satyanarayana (2015) Bineeta and Lal (2015) Savita *et al.* (2015)	Swamy *et al.* (2003) Panwar (2005) Sharma *et al.* (2005) Singh (2005) Faiz *et al.* (2006) Sawant *et al.* (2006) Zhao *et al.* (2008) Rahimi *et al.* (2010) Veeresha *et al.* (2013)

Leaf area duration

Gene action		
Additive	**Non additive**	**Additive and non additive**
		Murthy (1994)

Table 2.3 (contd.)

Spad chlorophyll meter readings

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Gopikannan and Ganesh (2013a) Sathya and Jebaraj (2015)	Khaleda (2004) Malarvizhi *et al.* (2011) Adilakshmi and Raghavareddy (2012)

Specific leaf weight (g/cm^2)

Gene action		
Additive	**Non additive**	**Additive and non additive**
Ali *et al.* (2010)	John *et al.* (2011)	Liang *et al.* (1999) Khaleda (2004) Adilakshmi and Raghavareddy (2012)

Specific leaf area (cm^2/g)

Gene action		
Additive	**Non additive**	**Additive and non additive**
		Ali *et al.* (2010) John *et al.* (2011)

Harvest index

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Singh *et al.* (2005) Panwar (2005) Sharma *et al.* (2005) Gnanasekaran *et al.* (2006) Pradhan and Singh (2008) Ram *et al.* (2010) Adilakshmi and Raghavareddy (2012) Patil *et al.* (2012) Utharasu and Anandakumar (2013)	Gulzar and Wassem (2012) Chandramohan and Suresh (2012) Bineeta and Lal (2015)

Shoot dry weight (g)

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Sathya and Jebaraj (2015)	Han and Koh (2000) Malarvizhi *et al.* (2011)

Table 2.3 (contd.)

Root dry weight (g)

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Mishra *et al.* (1989) Sathya and Jebaraj (2015)	Amudha and Thiyagarajan (2011) Malarvizhi *et al.* (2011) Utharasu and Anandakumar (2013)

Root shoot ratio

Gene action		
Additive	**Non additive**	**Additive and non additive**
	Sathya and Jebaraj (2015)	Malarvizhi *et al.* (2011) Utharasu and Anandakumar (2013)

Table 2.4. Review of literature on heterosis over standard parent for yield, yield components and physiological raits in rice (*Oryza sativa* L.)

Character	Range	Reference
1. Days to 50% flowering	-20.19 to -0.39 -21.00 to 14.00 -2 to -2.67 -21.89 to 14.35 -16.57 to 12.65 -7.94 to 14.95 -10.44 to 13.17 -7.66 to 11.19 22.88 to 2.45 8.87 to -5.12 -6.42 to 9.40	Pandya and Tripathi (2006) Singh *et al.* (2006) Eradasappa *et al.* (2007a) Gouri *et al.* (2010) Tiwari *et al.* (2011) Aditya *et al.* (2012) Latha *et al.* (2013) Dar *et al.* (2014) Sasikala *et al.* (2015) Savita *et al.* (2015) Dar *et al.* (2015)
2. Days to maturity	-4.17 to 18.33 -10.46 to 10.64 -5.92 to 10.35	Akarsh and Pathak (2008) Sanjeev *et al.* (2010) Dar *et al.* (2014)
3.Plant height (cm)	-11.20 to 34.40 -35.40 to -15.08 -25.00 to 21.00 -4.71 to -1.77 -16.32 to -12.60 -16.40 to 0.18 -22.41 to 35.69 -6.06 to 30.12 5.54 to 44.85 0.46 to 7.95 -16.41 to 24 -25.73 to 64.34 17.58 to 32.85 1.94 to 32.41	Rosamma and Vijayakumar (2005) Pandya and Tripathi (2006) Singh *et al.* (2006) Eradasappa *et al.* (2007a) Chandirakala *et al.* (2010) Tiwari *et al.* (2011) Aditya *et al.* (2012) Venkatasubbaiah *et al.* (2013) Adilakshmi *et al.* (2013) Ali *et al.* (2014) Dar *et al.* (2014) Sasikala *et al.* (2015) Savita *et al.* (2015) Dar *et al.* (2015)
4. Number of effective tillers per plant	-18.1 to 131.9 -45.00 to 105.00 34.54 to 38.55 -25.37 to 34.23 -8.33 to 75.00 -14.58 to 48.37 -10.07 to 41.35	Rosamma and Vijayakumar (2005) Singh *et al.* (2006) Eradasappa *et al.* (2007a) Gouri *et al.* (2010) Tiwari *et al.* (2011) Adilakshmi *et al.* (2013) Dar *et al.* (2014)
5. Panicle length (cm)	-24.00 to 19.00 38.92 to 40.37 -31.98 to 70.67 -4.04 to 21.62	Singh *et al.* (2006) Eradasappa *et al.* (2007a) Singh *et al.* (2007b) Kumar *et al.* (2010)

Table 2.4 (contd.)

Character	Range	Reference
	-40.63 to 23.20 -6.75 to 14.89 -7.21 to 22.81 3.22 to 22.44 4.66 to 24.23 -17.22 to 31.29	Tiwari *et al.* (2011) Aditya *et al.* (2012) Venkatasubbaiah *et al.* (2013) Adilakshmi *et al.* (2013) Ali *et al.* (2014) Dar *et al.* (2014)
6. Number of filled grains per panicle	4.13 to 14.38 -91.00 to 63.00 -28.85 to 11.86 42.3` to 45.11 36.40 to 76.96 -43.69 to 19.04 -33.58 to 12.08 -45.66 to 18.60 -22.1 to 22.37	Pandya and Tripathi (2006) Singh *et al.* (2006) Singh *et al.* (2007b) Eradasappa *et al.* (2007a) Chandirakala *et al.* (2010) Gouri *et al.* (2010) Tiwari *et al.* (2011) Adilakshmi *et al.* (2013) Dar *et al.* (2014)
7. Number of ill-filled grains per panicle	-38.42 to -13.38 -88.00 to 69.00 -28.08 to 11.07 28.81 to 34.34 -11.27 to 8.06 -0.81 to 16.31	Pandya and Tripathi (2006) Singh *et al.* (2006) Singh *et al.* (2007b) Chandirakala *et al.* (2010) Gouri *et al.* (2010) Tiwari *et al.* (2011)
8. 1000 grain weight (g)	-28.3 to -0.70 0.00 to 26.00 -23.00 to 30.53 -28.62 to 42.48 -4.6 to 18.1 -43.47 to 41.25 -14.92 to 29.31 -3.91 to 53.31	Rosamma and Vijayakumar (2005) Pandya and Tripathi (2006) Singh *et al.* (2006) Singh *et al.* (2007b) Rahimi *et al.* (2010) Tiwari *et al.* (2011) Aditya *et al.* (2012) Ali *et al.* (2014)
9. Grain yield per plant (g)	1.36 to 47.88 -74.00 to 80.00 65.3 to 211.00 51.57 to 57.94 -60.35 to 22.64 24.05 to 28.97 -29.19 to 20.14 -28.57 to 71.56	Pandya and Tripathi (2006) Singh *et al.* (2006) Chaudhry *et al.* (2007) Eradasappa *et al.* (2007a) Singh *et al.* (2007b) Chandirakala *et al.* (2010) Chandramohan and Suresh (2012) Gouri *et al.* (2010) Tiwari *et al.* (2011)

Table 2.4 (contd.)

Character	Range	Reference
10. SCMR	-	Sathya and Jebaraj (2015)
11. Harvest Index	-17.24 to 4.05 -27.94 to 33.29 -13.39 to 58.59 -26.54 to 12.12 -53.53 to 14.19 -49.69 to 40.97 -1.80 to .57	Akarsh and Pathak (2008) Sanjeev *et al.* (2010) Aditya *et al.* (2012) Adilakshmi *et al.* (2013) Venkatasubbaiah *et al.* (2013) Dar *et al.* (2014) Singh *et al.* (2015)
12. RDW (g)	-	Sathya and Jebaraj (2015)
13. SDW (g)	-	Sathya and Jebaraj (2015)
14. RSR	-	Sathya and Jebaraj (2015)

Table 2.5. Review of literature on heterosis over better parent for yield, yield components and physiological raits in rice (*Oryza sativa* L.)

Character	Range	Reference
1. Days to 50% flowering	-24.06 to 4.58	Raju *et al.* (2006)
	-8.00 to 18.0	Singh *et al.* (2006)
	-10.95 to 19.35	Deo *et al.* (2007)
	24.35 to 8.16	Akarsh and Pathak (2008)
	8.64 to 32.1	EL- Namaky *et al.* (2010)
	-13.91 to 16.57	Tiwari *et al.* (2011)
	-0.42 to -0.16	Muhammad *et al.* (2012)
	-8.82 to 44.83	Sharma *et al.* (2013)
	14.67 to 1.25	Latha *et al.* (2013)
	-19.50 to 0.58	Rukmini *et al.* (2014)
	-7.83 to 11.76	Shafina *et al.* (2014)
	-21.0 to 5.6	Bhati *et al.* (2015)
	-17.48 to 2.78	Balakrishna and Satyanarayana (2015)
2. Days to maturity	-14.12 to 6.21	Bhandarkar *et al.* (2005)
	-17.86 to 7.69	Akarsh and Pathak (2008)
	-10.88 to 16.08	Sanjeev *et al.* (2010)
3. Plant height (cm)	-29.01 to 65.28	Bhandarkar *et al.* (2005)
	-26.98 to 27.70	Raju *et al.* (2006)
	-33.33 to 97.05	Deo *et al.* (2007)
	34.08 to 3.29	Akarsh and Pathak (2008)
	-1.03 to 29.43	EL- Namaky *et al.* (2010)
	-35.38 to 5.08	Palaniraja *et al.* (2010)
	-16.74 to 12.50	Tiwari *et al.* (2011)
	0.03 to 0.14	Muhammad *et al.* (2012)
	-5.95 to 158.65	Sharma *et al.* (2013)
	-11.43 to 8.88	Latha *et al.* (2013)
	-0.77 to 9.07	Anil and Mani (2013)
	0.98 to 21.61	Montazeri *et al.* (2014)
	-15.85 to 20.10	Rukmini *et al.* (2014)
	17.58 to 32.85	Savita *et al.* (2015)
	-11.60 to 11.39	Balakrishna and Satyanarayana (2015)
4. Number of effective tillers per plant	-26.98 to 31.58	Raju *et al.* (2006)
	-28.57 to 97.05	Deo *et al.* (2007)
	-1.21 to 147.52	Mehrajuddin and Salgotra (2009)
	-34 to 39.53	Tiwari *et al.* (2011)
	-0.76 to 0.06	Muhammad *et al.* (2012)
	-58.63 to 36.71	Sharma *et al.* (2013)
	-39.7 to 42.50	Anil and Mani (2013)
	-20.0 to 35.70	Rukmini *et al.* (2014)
	-56.4 to 29.9	Bhati *et al.* (2015)
	-21.45 to 29.63	Balakrishna and Satyanarayana (2015)

Table 2.5 (contd.)

Character	Range	Reference
5. Panicle length (cm)	22.02 to 3.20	Bhandarkar *et al.* (2005)
	-16.69 to 3.67	Raju *et al.* (2006)
	-18.42 to 31.58	Deo *et al.* (2007)
	-43.88 to 30.56	Singh *et al.* (2007b)
	-31.73 to 43.21	Akarsh and Pathak (2008)
	-15 to 23.81	EL- Namaky *et al.* (2010)
	-9.54 to 25.85	Vanishree *et al.* (2011)
	-0.08 to 0.19	Muhammad *et al.* (2012)
	-13.65 to 29.10	Sharma *et al.* (2013)
	-7.75 to 18.50	Latha *et al.* (2013)
	0.47 to 13.40	Montazeri *et al.* (2014)
	-16.39 to 13.48	Shafina *et al.* (2014)
	-4.6 to 20.96	Dar *et al.* (2015)
	-15.33 to 26.11	Balakrishna and Satyanarayana (2015)
6. Number of filled grains per panicle	0.34 to 147	Mehrajuddin and Salgotra (2009)
	-32.71 to 54.66	EL- Namaky *et al.* (2010)
	-20.66 to 46.61	Tiwari *et al.* (2011)
	-58.32 to 28.85	Vanishree *et al.* (2011)
	-0.7 to 1.16	Muhammad *et al.* (2012)
	-48.34 to 32.39	Sharma *et al.* (2013)
	-2.17 to 18.51	Montazeri *et al.* (2014)
	-1.01 to 51.52	Dar *et al.* (2015)
	-21.1 to -6.5	Elixon et al. (2015)
7. Number of ill-filled grains per panicle	-30.94 to 49.44	Singh *et al.* (2007b)
8. 1000 grain weight (g)	3.0 to 14.30	Krishnaveni *et al.* (2005b)
	-27.56 to 29.12	Tirkey *et al.* (2006)
	-22.64 to 12.48	Raju *et al.* (2006)
	-44.00 to 20.19	Deo *et al.* (2007)
	-29.12 to 13.12	Akarsh and Pathak (2008)
	-24.40 to 4.89	EL- Namaky *et al.* (2010)
	-19.97 to 7.01	Vanishree *et al.* (2011)
	-0.06 to 0.22	Muhammad *et al.* (2012)
	-39.93 to 1.76	Sharma *et al.* (2013)
	-27.45 to 4.0	Latha *et al.* (2013)
	-33.4 to 27.4	Bhati *et al.* (2015)
	-22.28 to 4.93	Balakrishna and Satyanarayana (2015)
9.Grain yield per plant (g)	-65.1 to 235.2	Krishnaveni *et al.* (2005b)
	-29.3 to 43.47	Raju *et al.* (2006)
	-54.69 to 69	Singh *et al.* (2007b)
	-41.91 to 23.75	Mehrajuddin and Salgotra (2009)
	13.88 to 16.28	Palaniraja *et al.* (2010)

Table 2.5 (contd.)

Character	Range	Reference
	-23.33 to 82.15 -36.05 to 113.04 -66.98 to 104.19 -38.35 to 66.35 -70.59 to 68.37 -28.93 to 37.32 -38.4 to 93.3 -26.05 to 13.33	EL- Namaky *et al.* (2010) Tiwari *et al.* (2011) Vanishree *et al.* (2011) Sharma *et al.* (2013) Latha *et al.* (2013) Dar *et al.* (2015) Bhati *et al.* (2015) Balakrishna and Satyanarayana (2015)
10. SCMR	-14.21 to 76.98 -17.65 to 13.1	Adilakshmi and Raghavareddy (2012) El-Namaky *et al.* (2010)
11. SLW (g/cm^2)	-17.1 to 7.66	Adilakshmi and Raghavareddy (2012)
12. Harvest Index	-56.38 to 29.54 -11.85 to 8.15 -16.40 to 14.58 -43.34 to 36.54 -17.08 to 13.95 -0.47 to 1.27	Sarawagi *et al.* (2000) Akarsh and Pathak (2008) Adilakshmi and Raghavareddy (2012) Sanjeev *et al.* (2010) Vanishree *et al.* (2011) Singh *et al.* (2015)

Table 2.6. Review of literature on heterosis over mid parent for yield, yield components and physiological raits in rice (*Oryza sativa* L.)

Character	Range	Reference
1.Days to 50% flowering	-17.06 to 5.32	Raju *et al*. (2005)
	-17.06 to 5.32	Raju *et al.* (2006)
	-11.59 to 17.74	Deo *et al.* (2007)
	-7.74 to -12.27	Venkatesan *et al.* (2008)
	-13.38 to 20.28	Panwar and Ali (2010)
	-10.27 to 7.12	Vanishree *et al.* (2011)
	-0.4 to -0.04	Muhammad *et al.* (2012)
	-22.76 to 16.49	Sharma *et al.* (2013)
	-10.51 to 6.28	Latha *et al.* (2013)
	-18.48 to 11.94	Rukmini *et al.* (2014)
	-19.9 to 4.7	Shafina *et al.* (2014)
	-9.39 to 7.83	Balakrishna and Satyanarayana (2015)
2. Days to maturity	-3.42 to 13.83	Srivastava and Jaiswal (2016)
3. Plant height (cm)	-14.9 to 8.1	Krishnaveni *et al*. (2005a)
	-14.9 to 1	Krishnaveni *et al*. (2005b)
	-19.53 to 16.94	Raju *et al.* (2006)
	-23.14 to 53.31	Deo *et al.* (2007)
	-1.74 to-14.18	Venkatesan *et al*. (2008)
	-17.02 to 17.69	Panwar and Ali (2010)
	0.05 to 0.29	Muhammad *et al.* (2012)
	-31.48 to 25.58	Sharma *et al.* (2013)
	-10.43 to 12.35	Latha *et al.* (2013)
	2.63 to 23.48	Montazeri *et al.* (2014)
	-15.82 to 27.82	Rukmini *et al.* (2014)
	-13.8 to 0.5	Dorosti *et al.* (2014)
	-0.35 to 21.41	Balakrishna and Satyanarayana (2015)
4. Number of effective tillers per plant	-13.91 to 51.84	Raju *et al*. (2005)
	-13.91 to 51.84	Raju *et al.* (2006)
	-27.87 to 96.5	Deo *et al.* (2007)
	9.56 to 85.36	Venkatesan *et al*. (2008)
	-3.45 to 84.01	Panwar and Ali (2010)
	-31.93 to 78.43	Vanishree *et al.* (2011)
	-0.07 to 0.3	Muhammad *et al.* (2012)
	-52.01 to 23.33	Sharma *et al.* (2013)
	-24.50 to 23.10	Latha *et al.* (2013)
	24.62 to 107.41	Montazeri *et al.* (2014)
	-15.79 to 60.06	Rukmini *et al.* (2014)
	-10.37 to 40.00	Balakrishna and Satyanarayana (2015)

Table 2.6 (contd.)

Character	Range	Reference
5. Panicle length (cm)	-2.3 to 26.9 1.2 to 15.7 -7.60 to 6.21 -10.09 to 37.28 -6.79 to 4.47 -23.66 to 29.10 -8.81 to 29.77 -0.05 to 0.32 -33.31 to 6.19 -2.05 to 18.88 7.50 to 16.08 -11.9 to 1.2 -12.21 to 18.64 -10.84 to 31.16	Krishnaveni *et al*. (2005a) Krishnaveni *et al*. (2005b) Raju *et al*. (2006) Deo *et al*. (2007) Venkatesan *et al*. (2008) Panwar and Ali (2010) Vanishree *et al*. (2011) Muhammad *et al*. (2012) Sharma *et al*. (2013) Latha *et al*. (2013) Montazeri *et al*. (2014) Dorosti *et al*. (2014) Shafina *et al*. (2014) Balakrishna and Satyanarayana (2015)
6. Number of filled grains per panicle	-89.3 to 67.9 -41.83 to 20.18 -17.76 to 33.37 -49.43 to 52.87 -0.25 to 1.5 -57.96 to 14.58 5.43 to 22.97	Krishnaveni *et al*. (2005b) Raju *et al*. (2005) Panwar and Ali (2010) Vanishree *et al*. (2011) Muhammad *et al*. (2012) Sharma *et al*. (2013) Montazeri *et al*. (2014)
7. Grain yield per plant (g)	-60.2 to 297.9 -60.2 to 297.9 -6.22 to 64.08 -31.90 to 121.3 -16.82 to 75.72 -32.28 to 102.7 -63.69 to 122.5 -47.63 to 20.60 -57.52 to 82.37 27.73 to 245.8 15 to 38.9 -11.41 to 34.41	Krishnaveni *et al*. (2005a) Krishnaveni *et al*. (2005b) Pandya and Tripathi (2006) Deo *et al*. (2007) Venkatesan *et al*. (2008) Panwar and Ali (2010) Vanishree *et al*. (2011) Sharma *et al*. (2013) Latha *et al*. (2013) Rukmini *et al*. (2014) Dorosti *et al*. (2014) Balakrishna and Satyanarayana (2015)
8. 1000 grain weight (g)	-1.0 to 18.1 -1 to 15.3 -6.19 to 20.13 -4.14 to 16.73 -22.18 to 41.11 1.17 to 5.47	Krishnaveni *et al*. (2005a) Krishnaveni *et al*. (2005b) Pandya and Tripathi (2006) Raju *et al*. (2006) Deo *et al*. (2007) Venkatesan *et al*. (2008)

Table 2.6 (contd.)

Character	Range	Reference
	-21.33 to 20.64 -3.84 to 30.79 -0.01 to 0.23 -24.11 to 22.41 -21.40 to 13.91 1.3 to 26.3 -7.28 to 2.30 -13.44 to 24.40	Panwar and Ali (2010) Vanishree *et al.* (2011) Muhammad *et al.* (2012) Sharma *et al.* (2013) Latha *et al.* (2013) Dorosti *et al.* (2014) Rukmini *et al.* (2014) Balakrishna and Satyanarayana (2015)
9. SCMR	-34.78 to 88.27	Adilakshmi and Raghavareddy (2012)
10. SLW (g/cm^2)	-15.46 to 13.71	Adilakshmi and Raghavareddy (2012)
11. Harvest Index	-15.58 to 18.20	Adilakshmi and Raghavareddy (2012)
12. RDW	-90.7 to 31.3 -90.7 to 22.6 -14.91 to 21.44	John *et al.* (2001) Vanishree *et al.* (2011)

Table 2.7. Review of literature on association of component characters with grain yield per plant in rice (*Oryza sativa* L.)

S.No.	Character	Correlation	S/NS	P/G	Reference
1.	Days to 50% flowering	Positive	S	G	Swain and Reddy (2006)
				G	Reddy *et al.* (2013)
				G	Khare *et al.* (2014)
				G	Islam *et al.* (2015)
			NS	G	Rangare *et al.* (2012)
				G	Sudharani *et al.* (2012)
				G	Nagaraju *et al.* (2013)
				G	Dhurai *et al.* (2014a)
				G	Ratna *et al.* (2015)
				G	Sarwar *et al.* (2015)
		Negative	S	G	Eradasappa *et al.* (2007b)
				G	Gangashetty (2013)
				G	Bornare *et al.* (2014)
				G	Saikumar *et al.* (2014)
				G	Prasad *et al.* (2015)
			NS	G	Borbora *et al.* (2005)
				G	Kumar and Bapu (2005)
				G	Panwar and Ali (2007)
				G	Bhadru *et al.* (2012b)
				G	Gopikannan and Ganesh (2013b)
				G	Kishore *et al.* (2015)
2.	Days to maturity	Positive	S	G	Reddy *et al.* (2013)
				G	Dhurai *et al.* (2014a)
				G	Khare *et al.* (2014)
				G	Sarwar *et al.* (2015)
				G	Islam *et al.* (2015)
			NS	G	Nagaraju *et al.* (2013)
				-	Madakemohekar *et al.* (2015)
		Negative	S	G	Nilanjaya and Kumar (2015)
				G	Prasad *et al.* (2015)
3.	Plant height (cm)	Positive	S	G	Shashidhar *et al.* (2005)
				G	Eradasappa *et al.* (2007b)
				G	Chakraborty *et al.* (2010)
				G	Sudharani *et al.* (2012)
				G	Bhadru *et al.* (2012b)
				G	Reddy *et al.* (2013)
				G	Nagaraju *et al.* (2013)
				G	Khare *et al.* (2014)
				G	Ramanjaneyulu *et al.* (2014)

Table 2.7 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				G	Hossain *et al.* (2015)
				G	Prasad *et al.* (2015)
			NS	G	Kumar and Bapu (2005)
				G	Swain and Reddy (2006)
				G	Sharma and Sharma (2007)
				G	Rangare *et al.* (2012)
				G	Gopikannan and Ganesh (2013b)
				-	Uday *et al.* (2014)
				G	Kishore *et al.* (2015)
				G	Sarwar *et al.* (2015)
		Negative	S	G	Borbora *et al.* (2005)
				G	Panwar and Ali (2007)
				G	Gangashetty (2013)
				G	Rashid *et al.* (2014)
				G	Dhurai *et al.* (2014a)
				G	Ratna *et al.* (2015)
				G	Roy *et al.* (2015)
			NS	G	Manna *et al.* (2006)
				G	Panwar (2006)
				G	Dey *et al.* (2010)
				G	Akhtar *et al.* (2011)
				G	Laxuman *et al.* (2010)
				G	Seyoum *et al.* (2012)
				G	Malath and Gomathinayagam (2013)
4.	Number of effective tillers per plant	Positive	S	G	Shashidhar *et al.* (2005)
				G	Swain and Reddy (2006)
				G	Panwar (2006)
				G	Panwar and Ali (2007)
				G	Eradasappa *et al.* (2007b)
				G	Sudharani *et al.* (2012)
				G	Bhadru *et al.* (2012b)
				G	Nagaraju *et al.* (2013)
				G	Malath and Gomathinayagam (2013)
				G	Rashid *et al.* (2014)
				G	Neha *et al.* (2014)
				G	Bornare *et al.* (2014)
				G	Ratna *et al.* (2015)
				G	Kishore *et al.* (2015)
			NS	G	Sharma and Sharma (2007)
				G	Rani and Reddy (2010)
				G	Dhurai *et al.* (2014a)
				G	Hossain *et al.* (2015)
		Negative	NS	G	Khare *et al.* (2014)

Table 2.7 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
5.	Panicle length (cm)	Positive	S	G	Hasib (2005)
				G	Kumar and Bapu (2005)
				G	Eradasappa *et al.* (2007b)
				G	Chakraborty *et al.* (2010)
				G	Laxuman *et al.* (2010)
				G	Rangare *et al.* (2012)
				-	Adilakshmi and Ragahavreddy (2012)
				G	Ashim and Gosh (2013)
				G	Gopikannan and Ganesh (2013b)
				G	Bornare *et al.* (2014)
				G	Saikumar *et al.* (2014)
				G	Prasad *et al.* (2015)
			NS	G	Borbora *et al.* (2005)
				G	Panwar (2006)
				G	Seyoum *et al.* (2012)
				G	Malath and Gomathinayagam (2013)
				G	Dhurai *et al.* (2014a)
				G	Kishore *et al.* (2015)
				G	Hossain *et al.* (2015)
		Negative	S	G	Rashid *et al.* (2014)
				G	Ratna *et al.* (2015)
			NS	G	Sarwar *et al.* (2015)
6.	Number of filled grains per panicle	Positive	S	G	Chakraborty *et al.* (2010)
				G	Sudharani *et al.* (2012)
				G	Bhadru *et al.* (2012b)
				G	Gopikannan and Ganesh (2013b)
				G	Khare *et al.* (2014)
				G	Saikumar *et al.* (2014)
				G	Kishore *et al.* (2015)
				G	Prasad *et al.* (2015)
			NS	G	Hossain *et al.* (2015)
				G	Sarwar *et al.* (2015)
7.	Number of ill-filled grains per panicle	Positive	S	G	Hossain *et al.* (2015)
		Negative	S	G	Sarwar *et al.* (2015)
				G	Prasad *et al.* (2015)
			NS	G	Ratna *et al.* (2015)
8.	1000 grain weight (g)	Positive	S	G	Kumar and Bapu (2005)
				G	Sharma and Sharma (2007)
				G	Sudharani *et al.* (2012)
				G	Bhadru *et al.* (2012b)
				G	Sudharani *et al.* (2012)
				G	Reddy *et al.* (2013)
				G	Ramanjaneyulu *et al.* (2014)
				G	Saikumar *et al.* (2014)

Table 2.7 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				G G	Prasad *et al.* (2015) Roy *et al.* (2015)
			NS	G G G G G G	Borbora *et al.* (2005) Eradasappa *et al.* (2007b) Garg *et al.* (2010) Gopikannan and Ganesh (2013b) Hossain *et al.* (2015) Sarwar *et al.* (2015)
		Negative	S	G G G	Swain and Reddy (2006) Khare *et al.* (2014) Islam *et al.* (2015)
			NS	G G G G G G G G	Hasib (2005) Panwar and Ali (2007) Babu *et al.* (2012) Seyoum *et al.* (2012) Malath and Gomathinayagam (2013) Dhurai *et al.* (2014a) Ratna *et al.* (2015) Kumar and Verma (2015)
9.	LAD	Positive	S	-	Caglar *et al.* (2010)
			NS	G	Rajnish *et al.* (2015)
10.	SCMR	Positive	S	- G	Adilakshmi and Raghavareddy (2012) Gopikannan and Ganesh (2013b)
			NS	G -	Malath and Gomathinayagam (2013) Madakemohekar *et al.* (2015)
		Negative	NS	G	Sudharani *et al.* (2012) Khaleda (2004)
11.	SLA (cm^2/g)	Positive	NS	G	Rajnish *et al.* (2015)
		Negative	NS	G - G	Mohankumar *et al.* (2011) Elango *et al.* (2012) Rajnish *et al.* (2015)
12.	SLW (g/cm^2)	Positive	NS	P	Ali *et al.* (2010)
		Negative	NS	G -	Khaleda (2004) Adilakshmi and Raghavareddy (2012)
13.	Harvest Index	Positive	S	G G - G G G G G	Chakraborty *et al.* (2010) Sudharani *et al.* (2012) Adilakshmi and Raghavareddy (2012) Reddy *et al.* (2013) Nagaraju *et al.* (2013) Dhurai *et al.* (2014a) Ramanjaneyulu *et al.* (2014) Saikumar *et al.* (2014)

Table 2.7 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				-	Madakemohekar *et al.* (2015)
				G	Roy *et al.* (2015)
			NS	G	Reddy *et al.* (2013)
				G	Kumar and Verma (2015)
14.	RDW (g)	Positive	NS	G	Shajedur *et al.* (2015)
		Negative	NS	G	Malath and Gomathinayagam (2013)
15.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
16.	RSR	Positive	S	G	Haider *et al.* (2012)
				G	Sudharani *et al.* (2012)
		Negative	S	G	Malath and Gomathinayagam (2013)
			NS	P	Sathya and Jebaraj (2015)

Table 2.8. Review of literature on association of component characters among themselves in rice (*Oryza sativa* L.)

S.No.	Character	Correlation	S/NS	P/G	Reference
Association of days to 50% flowering with					
1.	Days to maturity	Positive	S	G G G	Reddy *et al.* (2013) Dhurai *et al.* (2014a) Prasad *et al.* (2015)
			NS	G	Sarwar *et al.* (2015)
2.	Plant height (cm)	Positive	S	G G G G G G G G	Kumar and Bapu (2005) Borbora *et al.* (2005) Panwar (2006) Panwar and Ali (2007) Babu *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)
			NS	G G G G	Sharma and Sharma (2007) Sudharani *et al.* (2012) Gopikannan and Ganesh (2013b) Prasad *et al.* (2015)
		Negative	S	P	Sathya and Jebaraj (2015)
			NS	G G G G G G	Swain and Reddy (2006) Eradasappa *et al.* (2007b) Malath and Gomathinayagam (2013) Nagaraju *et al.* (2013) Dhurai *et al.* (2014a) Kumar and Verma (2015)
3.	Number of effective tillers per plant	Positive	S	G G	Sudharani *et al.* (2012) Sarwar *et al.* (2015)
			NS	G G	Bhadru *et al.* (2012b) Malath and Gomathinayagam (2013)
		Negative	S	G G	Khare *et al.* (2014) Prasad *et al.* (2015)
			NS	- G G G G	Adilakshmi and Raghavareddy (2012) Nagaraju *et al.* (2013) Dhurai *et al.* (2014a) Saikumar *et al.* (2014) Ratna *et al.* (2015)
4.	Panicle length (cm)	Positive	S	G G G	Kumar and Bapu (2005) Swain and Reddy (2006) Panwar (2006)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				G G G G	Bhadru *et al*. (2012b) Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)
			NS	G G - G	Panwar and Ali (2007) Nagaraju *et al.* (2013) Uday *et al.* (2014) Kishore *et al.* (2015)
		Negative	S	G G G	Binse *et al.* (2006) Eradasappa *et al.* (2007b) Saikumar *et al.* (2014)
			NS	G G G G - G G G	Borbora *et al.* (2005) Panwar (2006) Eradasappa *et al.* (2007b) Sharma and Sharma (2007) Adilakshmi and Raghavareddy (2012) Gopikannan and Ganesh (2013b) Prasad *et al.* (2015) Kumar and Verma (2015)
5.	Number of filled grains per panicle	Positive	S	G G G	Khare *et al.* (2014) Ratna *et al.* (2015) Islam *et al.* (2015)
			NS	-	Adilakshmi and Raghavareddy (2012)
		Negative	S	P	Saikumar *et al.* (2014)
			NS	G G G	Gopikannan and Ganesh (2013b) Saikumar *et al.* (2014) Sarwar *et al.* (2015)
6.	Number of ill-filled grains per panicle	Positive	NS	G G	Ratna *et al.* (2015) Kishore *et al.* (2015)
7.	1000 grain weight (g)	Positive	S	G G	Panwar (2006) Nilanjaya and Kumar (2015)
			NS	G G G G G G G	Borbora *et al.* (2005) Panwar and Ali (2007) Adilakshmi and Raghavareddy (2012) Bhadru *et al*. (2012b) Reddy *et al.* (2013) Kumar and Verma (2015) Islam *et al.* (2015)
		Negative	S	G G G G	Swain and Reddy (2006) Nagaraju *et al.* (2013) Saikumar *et al.* (2014) Islam *et al.* (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
			NS	G G G G G G G G G	Kumar and Bapu (2005) Binse *et al.* (2006) Eradasappa *et al.* (2007b) Garg *et al.* (2010) Sudharani *et al.* (2012) Malath and Gomathinayagam (2013) Khare *et al.* (2014) Dhurai *et al.* (2014a) Ratna *et al.* (2015)
9.	SCMR	Positive	S	G	Sudharani *et al.* (2012)
		Negative	S	G	Nilanjaya and Kumar (2015)
			NS	- G G	Adilakshmi and Raghavareddy (2012) Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013b)
10.	SLA (cm^2/g)	Positive	NS	P	Ali *et al.* (2010)
11.	SLW (g/cm^2)	Negative	NS	P -	Ali *et al.* (2010) Adilakshmi and Raghavareddy (2012)
12.	Harvest Index	Positive	S	G G	Sudharani *et al.* (2012) Nagaraju *et al.* (2013)
			NS	P	Reddy *et al.* (2013)
		Negative	S	G	Saikumar *et al.* (2014)
			NS	- G G G	Adilakshmi and Raghavareddy (2012) Reddy *et al.* (2013) Dhurai *et al.* (2014a) Kumar and Verma (2015)
13.	RDW (g)	Positive	NS	P	Sathya and Jebaraj (2015)
		Negative	NS	G	Malath and Gomathinayagam (2013)
14.	SDW (g)	Positive	NS	P	Sathya and Jebaraj (2015)
		Negative	NS	G	Shajedur *et al.* (2015)
15.	RSR	Positive	NS	G	Sudharani *et al.* (2012)
		Negative	NS	G	Malath and Gomathinayagam (2013)
Association of days to maturity with					
1.	Plant height (cm)	Positive	S	G G	Nilanjaya and Kumar (2015) Islam *et al.* (2015)
			NS	G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Prasad *et al.* (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
		Negative	S	G	Dhurai *et al.* (2014a)
			NS	G	Nagaraju *et al.* (2013)
				-	Uday *et al.* (2014)
				G	Sarwar *et al.* (2015)
				G	Kumar and Verma (2015)
2.	Number of effective tillers per plant	Positive	NS	G	Nagaraju *et al.* (2013)
				G	Sarwar *et al.* (2015)
		Negative	S	-	Uday *et al.* (2014)
				G	Khare *et al.* (2014)
				G	Nilanjaya and Kumar (2015)
				G	Prasad *et al.* (2015)
			NS	G	Dhurai *et al.* (2014a)
3.	Panicle length (cm)	Positive	S	G	Reddy *et al.* (2013)
				G	Khare *et al.* (2014)
				G	Nilanjaya and Kumar (2015)
			NS	G	Nagaraju *et al.* (2013)
				G	Dhurai *et al.* (2014a)
				-	Uday *et al.* (2014)
				G	Prasad *et al.* (2015)
		Negative	S	P	Kumar and Verma (2015)
			NS	G	Sarwar *et al.* (2015)
				G	Kumar and Verma (2015)
4.	Number of filled grains per panicle	Positive	S	G	Khare *et al.* (2014)
				G	Islam *et al.* (2015)
			NS	G	Sarwar *et al.* (2015)
		Negative	NS	G	Prasad *et al.* (2015)
5.	Number of ill-filled grains per panicle	Positive	NS	G	Sarwar *et al.* (2015)
				G	Prasad *et al.* (2015)
6.	1000 grain weight (g)	Positive	S	G	Nilanjaya and Kumar (2015)
			NS	G	Reddy *et al.* (2013)
				G	Sarwar *et al.* (2015)
		Negative	S	G	Islam *et al.* (2015)
			NS	G	Nagaraju *et al.* (2013)
				G	Khare *et al.* (2014)
				-	Madakemohekar *et al.* (2015)
8.	SCMR	Positive	NS	-	Madakemohekar *et al.* (2015)
		Negative	S	G	Nilanjaya and Kumar (2015)
9.	SLA (cm^2/g)	Negative	NS	P	Ali *et al.* (2010)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
10.	SLW (g/cm^2)	Positive	NS	P	Ali *et al.* (2010)
11.	Harvest Index	Positive	NS	G G G	Nagaraju *et al.* (2013) Dhurai *et al.* (2014a) Kumar and Verma (2015)
		Negative	S	P	Nagaraju *et al.* (2013)
			NS	G -	Reddy *et al.* (2013) Madakemohekar *et al.* (2015)
Association of plant height with					
1	Number of effective tillers per plant	Positive	S	G G	Sudharani *et al.* (2012) Prasad *et al.* (2015)
			NS	G G G G G G G G	Shashidhar *et al.* (2005) Swain and Reddy (2006) Panwar (2006) Eradasappa *et al.* (2007b) Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013b) Ramanjaneyulu *et al.* (2014) Hossain *et al.* (2015)
		Negative	S	G G G G	Binse *et al.* (2006) Khare *et al.* (2014) Saikumar *et al.* (2014) Nilanjaya and Kumar (2015)
			NS	G G G G	Borbora *et al.* (2005) Manna *et al.* (2006) Krishna *et al.* (2008) Bhadru *et al.* (2012b)
2.	Panicle length (cm)	Positive	S	G G G G G G G G	Garg *et al.* (2010) Babu *et al.* (2012) Datt *et al.* (2012) Minnie *et al.* (2013) Khare *et al.* (2014) Saikumar *et al.* (2014) Ratna *et al.* (2015) Prasad *et al.* (2015)
			NS	G G G G G G G G G	Borbora *et al.* (2005) Manna *et al.* (2006) Panwar (2006) Sharma and Sharma (2007) Eradasappa *et al.* (2007b) Rani and Reddy (2010) Chakraborty *et al.* (2010) Bhadru *et al.* (2012b) Nagaraju *et al.* (2013)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				G	Dhurai *et al.* (2014a)
				-	Uday *et al.* (2014)
				G	Kumar and Verma (2015)
		Negative	NS	G	Gopikannan and Ganesh (2013b)
3.	Number of filled grains per panicle	Positive	S	G	Chakraborty *et al.* (2010)
				-	Adilakshmi and Raghavareddy (2012)
				G	Sudharani *et al.* (2012)
				G	Bhadru *et al.* (2012b)
				G	Khare *et al.* (2014)
				G	Prasad *et al.* (2015)
				G	Islam *et al.* (2015)
			NS	G	Kishore *et al.* (2015)
		Negative	S	G	Malath and Gomathinayagam (2013)
			NS	G	Saikumar *et al.* (2014)
				G	Ratna *et al.* (2015)
				G	Hossain *et al.* (2015)
4.	Number of ill-filled grains per panicle	Positive	S	G	Ratna *et al.* (2015)
				G	Sarwar *et al.* (2015)
			NS	G	Gopikannan and Ganesh (2013b)
		Negative	S	G	Prasad *et al.* (2015)
			NS	G	Hossain *et al.* (2015)
5.	1000 grain weight (g)	Positive	S	G	Sudharani *et al.* (2012)
				G	Nagaraju *et al.* (2013)
				G	Nilanjaya and Kumar (2015)
			NS	-	Adilakshmi and Raghavareddy (2012)
				G	Malath and Gomathinayagam (2013)
				G	Gopikannan and Ganesh (2013b)
				G	Dhurai *et al.* (2014a)
				G	Ramanjaneyulu *et al.* (2014)
				G	Kishore *et al.* (2015)
				G	Hossain *et al.* (2015)
		Negative	S	G	Ratna *et al.* (2015)
				G	Islam *et al.* (2015)
			NS	G	Bhadru *et al.* (2012b)
				G	Khare *et al.* (2014)
				G	Saikumar *et al.* (2014)
7.	SCMR	Positive	S	-	Adilakshmi and Raghavareddy (2012)
				G	Sudharani *et al.* (2012)
			NS	G	Ullah *et al.* (2011)
				G	Malath and Gomathinayagam (2013)
				-	Madakemohekar *et al.* (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
		Negative	S	G	Nilanjaya and Kumar (2015)
			NS	G	Gopikannan and Ganesh (2013b)
8.	SLA (cm^2/g)	Negative	NS	P	Ali *et al.* (2010)
9.	SLW (g/cm^2)	Positive	NS	P	Ali *et al.* (2010)
		Negative	S	-	Adilakshmi and Raghavareddy (2012)
10.	Harvest Index	Positive	S	G G	Sudharani *et al.* (2012) Ramanjaneyulu *et al.* (2014)
			NS	- G -	Adilakshmi and Raghavareddy (2012) Nagaraju *et al.* (2013) Madakemohekar *et al.* (2015)
		Negative	S	G -	Ullah *et al.* (2011) Moosavi *et al.* (2015)
			NS	P	Ullah *et al.* (2011)
11.	RDW (g)	Positive	NS	G G	Malath and Gomathinayagam (2013) Shajedur *et al.* (2015)
12.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
13.	RSR	Positive	S	G	Sudharani *et al.* (2012)
			NS	G	Malath and Gomathinayagam (2013)
Association of number of effective tillers per plant with					
1.	Panicle length (cm)	Positive	S	G G G G	Eradasappa *et al.* (2007b) Sudharani *et al.* (2012) Nagaraju *et al.* (2013) Gopikannan and Ganesh (2013b)
			NS	G G G - G G G G	Panwar and Ali (2007) Rani and Reddy (2010) Ullah *et al.* (2011) Adilakshmi and Raghavareddy (2012) Bhadru *et al.* (2012b) Nagaraju *et al.* (2013) Prasad *et al.* (2015) Kumar and Verma (2015)
		Negative	S	G G G G	Malath and Gomathinayagam (2013) Khare *et al.* (2014) Hossain *et al.* (2015) Nilanjaya and Kumar (2015)

Table 2.8 (contd.)

S.No	Character	Correlation	S/NS	P/G	Reference
			NS	G G G G	Borbora *et al.* (2005) Binse *et al.* (2006) Panwar (2006) Sharma and Sharma (2007)
2.	Number of filled grains per panicle	Positive	S	G G G	Sudharani *et al.* (2012) Gopikannan and Ganesh (2013b) Prasad *et al.* (2015)
			NS	- G	Adilakshmi and Raghavareddy (2012) Ratna *et al.* (2015)
		Negative	S	G G G G	Bhadru *et al.* (2012b) Khare *et al.* (2014) Kishore *et al.* (2015) Hossain *et al.* (2015)
			NS	G G G	Malath and Gomathinayagam (2013) Saikumar *et al.* (2014) Sarwar *et al.* (2015)
3.	Number of ill-filled grains per panicle	Positive	NS	G	Hossain *et al.* (2015)
		Negative	S	G G	Ratna *et al.* (2015) Prasad *et al.* (2015)
			NS	G	Sarwar *et al.* (2015)
4.	1000 grain weight (g)	Positive	S	G G G	Sudharani *et al.* (2012) Saikumar *et al.* (2014) Prasad *et al.* (2015)
			NS	G G G G G G G G	Panwar (2006) Panwar and Ali (2007) Rani and Reddy (2010) Garg *et al.* (2010) Bhadru *et al.* (2012b) Gopikannan and Ganesh (2013b) Nagaraju *et al.* (2013) Dhurai *et al.* (2014a)
		Negative	S	G G G G G -	Borbora *et al.* (2005) Swain and Reddy (2006) Eradasappa *et al.* (2007b) Ullah *et al.* (2011) Nilanjaya and Kumar (2015) Moosavi *et al.* (2015)
			NS	G G	Binse *et al.* (2006) Bhattacharyya *et al.* (2007)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
				G G	Sharma and Sharma (2007) Malath and Gomathinayagam (2013)
5.	LAD	Negative	NS	G	Sudharani *et al.* (2012)
6.	SCMR	Positive	S	G G	Gopikannan and Ganesh (2013b) Nilanjaya and Kumar (2015)
			NS	P	Sathya and Jebaraj (2015)
		Negative	NS	G - G	Ullah *et al*. (2011) Adilakshmi and Raghavareddy (2012) Malath and Gomathinayagam (2013)
7.	SLW (g/cm^2)	Positive	NS	-	Adilakshmi and Raghavareddy (2012)
8.	Harvest Index	Positive	S	- G G G	Adilakshmi and Raghavareddy (2012) Ullah *et al*. (2011) Sudharani *et al.* (2012) Ramanjaneyulu *et al.* (2014)
			NS	G G G	Nagaraju *et al*. (2013) Dhurai *et al.* (2014a) Kumar and Verma (2015)
		Negative	NS	-	Moosavi *et al.* (2015)
9.	RDW (g)	Positive	NS	G	Shajedur *et al.* (2015)
		Negative	NS	G	Malath and Gomathinayagam (2013)
10.	SDW (g)	Positive	NS	P	Sathya and Jebaraj (2015)
11.	RSR	Negative	NS	G G	Sudharani *et al.* (2012) Malath and Gomathinayagam (2013)
Association of panicle length with					
1.	Number of filled grains per panicle	Positive	S	G G G G G G	Sudharani *et al.* (2012) Bhadru *et al*. (2012b) Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013b) Khare *et al.* (2014) Sarwar *et al.* (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
			NS	- G G G	Adilakshmi and Raghavareddy (2012) Saikumar *et al.* (2014) Kishore *et al.* (2015) Prasad *et al.* (2015)
		Negative	NS	G G	Ratna *et al.* (2015) Hossain *et al.* (2015)
2.	Number of ill-filled grains per panicle	Positive	S	G	Hossain *et al.* (2015)
			NS	G G	Ratna *et al.* (2015) Sarwar *et al.* (2015)
		Negative	S	G	Prasad *et al.* (2015)
			NS	P	Ratna *et al.* (2015)
3.	1000 grain weight (g)	Positive	S	G G G G G G	Hasib (2005) Babu *et al.* (2012) Minnie *et al.* (2013) Saikumar *et al.* (2014) Nilanjaya and Kumar (2015) Prasad *et al.* (2015)
			NS	G G G G G G G G	Borbora *et al.* (2005) Binse *et al.* (2006) Panwar and Ali (2007) Rani and Reddy (2010) Gopikannan and Ganesh (2013b) Khare *et al.* (2014) Kishore *et al.* (2015) Hossain *et al.* (2015)
		Negative	S	G	Ratna *et al.* (2015)
			NS	G G G G G G	Kumar and Bapu (2005) Panwar (2006) Garg *et al.* (2010) Ullah *et al.* (2011) Malath and Gomathinayagam (2013) Dhurai *et al.* (2014a)
5.	SCMR	Positive	S	G G G	Sudharani *et al.* (2012) Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013b)
			NS	-	Adilakshmi and Raghavareddy (2012)
		Negative	S	G G	Ullah *et al.* (2011) Nilanjaya and Kumar (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
			NS	P	Ullah *et al.* (2011)
6.	SLW (g/cm^2)	Negative	NS	-	Adilakshmi and Raghavareddy (2012)
7.	Harvest Index	Positive	S	G G - G	Chakraborty *et al.* (2010) Sudharani *et al.* (2012) Adilakshmi and Raghavareddy (2012) Saikumar *et al.* (2014)
			NS	G G	Nagaraju *et al.* (2013) Dhurai *et al.* (2014)
		Negative	S	P	Kumar and Verma (2015)
			NS	G G	Reddy *et al.* (2013) Kumar and Verma (2015)
8.	RDW (g)	Positive	S	P G	Sathya and Jebaraj (2015) Shajedur *et al.* (2015)
			NS	G	Malath and Gomathinayagam (2013)
9.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
10.	RSR	Positive	S	G	Sudharani *et al.* (2012)
			NS	P G	Sudharani *et al.* (2012) Malath and Gomathinayagam (2013)
Association of Number of filled grains per panicle with					
1.	Number of ill-filled grains per panicle	Positive	S	G	Sarwar *et al.* (2015)
		Negative	NS	G G G	Ratna *et al.* (2015) Hossain *et al.* (2015) Prasad *et al.* (2015)
2.	1000 grain weight (g)	Positive	S	G G G	Sudharani *et al.* (2012) Saikumar *et al.* (2014) Hossain *et al.* (2015)
			NS	G G	Bhadru *et al.* (2012b) Gopikannan and Ganesh (2013b)
		Negative	S	- G G G	Adilakshmi and Raghavareddy (2012) Khare *et al.* (2014) Ratna *et al.* (2015) Kishore *et al.* (2015)
			NS	G G	Malath and Gomathinayagam (2013) Sarwar *et al.* (2015)
3.	SCMR	Positive	S	G G	Sudharani *et al.* (2012) Gopikannan and Ganesh (2013b)
			NS	P	Sudharani *et al.* (2012)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
		Negative	S	P	Sathya and Jebaraj (2015)
			NS	- G	Adilakshmi and Raghavareddy (2012) Malath and Gomathinayagam (2013)
4.	SLW (g/cm^2)	Negative	NS	-	Adilakshmi and Raghavareddy (2012)
5.	Harvest Index	Positive	S	G G G	Chakraborty *et al.* (2010) Sudharani *et al.* (2012) Saikumar *et al.* (2014)
			NS	-	Adilakshmi and Raghavareddy (2012)
6.	RDW (g)	Positive	NS	G	Malath and Gomathinayagam (2013)
		Negative	NS	G	Shajedur *et al.* (2015)
7.	SDW (g)	Positive	NS	P	Sathya and Jebaraj (2015)
8.	RSR	Positive	S	G	Sudharani *et al.* (2012)
			NS	G	Malath and Gomathinayagam (2013)
Association of Number of ill-filled grains per panicle with					
1.	1000 grain weight (g)	Positive	S	G	Hossain *et al.* (2015)
			NS	G	Ratna *et al.* (2015)
		Negative	S	G	Prasad *et al.* (2015)
			NS	G	Sarwar *et al.* (2015)
2.	RDW (g)	Positive	NS	G	Shajedur *et al.* (2015)
Association of 1000 grain weight with					
1.	SCMR	Positive	S	G	Ullah *et al.* (2011)
			NS	- G G -	Adilakshmi and Raghavareddy (2012) Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013b) Madakemohekar *et al.* (2015)
		Negative	S	G	Sudharani *et al.* (2012)
			NS	P	Sathya and Jebaraj (2015)
2.	SLA (cm^2/g)	Negative	S	P	Ali *et al.* (2010)
3.	SLW (g/cm^2)	Positive	S	P	Ali *et al.* (2010)
		Negative	NS	-	Adilakshmi and Raghavareddy (2012)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
4.	Harvest Index	Positive	S	G G G G	Ullah *et al.* (2011) Sudharani *et al.* (2012) Ramanjaneyulu *et al.* (2014) Saikumar *et al.* (2014)
			NS	- G G -	Adilakshmi and Raghavareddy (2012) Nagaraju *et al.* (2013) Dhurai *et al.* (2014a) Madakemohekar *et al.* (2015)
		Negative	S	G	Ullah *et al.* (2011)
			NS	G - G	Reddy *et al.* (2013) Moosavi *et al.* (2015) Madakemohekar *et al.* (2015)
5.	RDW (g)	Positive	NS	G	Malath and Gomathinayagam (2013)
		Negative	NS	G	Shajedur *et al.* (2015)
6.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
7.	RSR	Positive	S	G	Haider *et al.* (2012)
		Negative	NS	G G	Sudharani *et al.* (2012) Malath and Gomathinayagam (2013)
			NS	P	Sathya and Jebaraj (2015)
Association of leaf area duration with					
1.	SLA (cm^2/g)	Positive	NS	- G	Hajimobin *et al.* (2011) Rajnish *et al.* (2015)
2.	SLW (g/cm^2)	Negative	NS	- G	Hajimobin *et al.* (2011) Rajnish *et al.* (2015)
Association of SCMR with					
1.	SLW (g/cm^2)	Positive	S	G	Khaleda (2004)
			NS	-	Adilakshmi and Raghavareddy (2012)
2.	Harvest Index	Positive	S	G	Ullah *et al.* (2011)
			NS	G	Sudharani *et al.* (2012)
		Negative	NS	- -	Adilakshmi and Raghavareddy (2012) Madakemohekar *et al.* (2015)
3.	RDW (g)	Positive	S	G	Malath and Gomathinayagam (2013)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
Association of SCMR with					
1.	SLW (g/cm^2)	Positive	S	G	Khaleda (2004)
			NS	-	Adilakshmi and Raghavareddy (2012)
2.	Harvest Index	Positive	S	G	Ullah *et al.* (2011)
			NS	G	Sudharani *et al.* (2012)
		Negative	NS	- -	Adilakshmi and Raghavareddy (2012) Madakemohekar *et al.* (2015)
3.	RDW (g)	Positive	S	G	Malath and Gomathinayagam (2013)
		Negative	S	P	Sathya and Jebaraj (2015)
4.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
5.	RSR	Positive	NS	G	Sudharani *et al.* (2012)
		Negative	NS	G	Malath and Gomathinayagam (2013)
Association of specific leaf area with					
1.	SLW (g/cm^2)	Negative	S	P P	Ali *et al.* (2010) Rajnish *et al.* (2015)
			NS	- G	Hajimobin *et al.* (2011) Rajnish *et al.* (2015)
Association of specific leaf weight with					
1.	Harvest Index	Negative	NS	-	Adilakshmi and Raghavareddy (2012)
Association of harvest index with					
1.	RDW (g)	Positive	NS	P	Sathya and Jebaraj (2015)
2.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
3.	RSR	Positive	S	G	Sudharani *et al.* (2012)
		Negative	NS	P	Sathya and Jebaraj (2015)
Association of root dry weight with					
1.	SDW (g)	Negative	NS	P	Sathya and Jebaraj (2015)
2.	RSR	Positive	S	P	Sathya and Jebaraj (2015)
		Negative	NS	G	Malath and Gomathinayagam (2013)
Association of shoot dry weight with					
1.	RSR	Negative	NS	P	Sathya and Jebaraj (2015)

Table 2.8 (contd.)

S.No.	Character	Correlation	S/NS	P/G	Reference
Association of root shoot ratio with					
1.	Grain yield per plant (g)	Positive	S	G G	Haider *et al.* (2012) Sudharani *et al.* (2012)
		Negative	S	G	Malath and Gomathinayagam (2013)
			NS	P	Sathya and Jebaraj (2015)

Table 2.9. Review of literature on direct effects of component characters on grain yield in rice (*Oryza sativa* L.)

S.No.	Character	P/G	Positive direct effect	P/G	Negative direct effect
1	Days to 50% flowering	G G - G - G	Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Gopikannan and Ganesh (2013b) Saikumar *et al.* (2014) Ratna *et al.* (2015) Pradhan *et al.* (2015)	G G G G G G G G - G	Borbora *et al.* (2005) Swain and Reddy (2006) Girolkar *et al.* (2008) Garg *et al.* (2010) Babu *et al.* (2012) Reddy *et al.* (2013) Dhurai *et al.* (2014a) Khare *et al.* (2014) Sarwar *et al.* (2015) Kumar and Verma (2015)
2	Days to maturity	G G G - G	Reddy *et al.* (2013) Dhurai *et al.* (2014a) Khare *et al.* (2014) Sarwar *et al.* (2015) Kumar and Verma (2015)	- G G G	Madakemohekar *et al.* (2015) Nilanjaya and Kumar (2015) Kahani and Hittalmani (2015) Prasad *et al.* (2015)
3	Plant height (cm)	G G G G G G G G G G G G G	Shashidhar *et al.* (2005) Swain and Reddy (2006) Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Rangare *et al.* (2012) Sudharani *et al.* (2012) Bhadru *et al.* (2012) Reddy *et al.* (2013) Dhurai *et al.* (2014a) Khare *et al.* (2014) Pradhan *et al.* (2015) Kishore *et al.* (2015) Kumar and Verma (2015)	G G P P - G P G	Manna *et al.* (2006) Rani and Reddy (2010) Kumar and Saravanan (2012) Babu *et al.* (2012) Gopikannan and Ganesh (2013b) Nilanjaya and Kumar (2015) Kumar and Verma (2015) Kahani and Hittalmani (2015)
4	Number of effective tillers per plant	G G G G G G G G G G G	Manna *et al.* (2006) Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Babu *et al.* (2012) Bhadru *et al.* (2012b) Kumar *et al.* (2013) Nagaraju *et al.* (2013) Khare *et al.* (2014) Pradhan *et al.* (2015) Kishore *et al.* (2015) Nilanjaya and Kumar (2015)	G G G G	Rani and Reddy (2010) Sudharani *et al.* (2012) Dhurai *et al.* (2014a) Kumar and Verma (2015)

Table 2.9 (contd.)

S.No.	Character	P/G	Positive direct effect	P/G	Negative direct effect
5	Panicle length (cm)	G G G G G G - G G	Borbora *et al.* (2005) Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Rangare *et al.* (2012) Babu *et al.* (2012) Bhadru *et al.* (2012) Gopikannan and Ganesh (2013b) Nilanjaya and Kumar (2015) Kahani and Hittalmani (2015)	G G G G G G G G G G	Borbora *et al.* (2005) Manna *et al.* (2006) Rani and Reddy (2010) Sudharani *et al.* (2012) Reddy *et al.* (2013) Nagaraju *et al.* (2013) Khare *et al.* (2014) Pradhan *et al.* (2015) Kishore *et al.* (2015) Kumar and Verma (2015)
6	Number of filled grains per panicle	G - G G - G	Sudharani *et al.* (2012) Gopikannan and Ganesh (2013b) Saikumar *et al.* (2014) Khare *et al.* (2014) Ratna *et al.* (2015) Kishore *et al.* (2015)	G G G G - G	Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Babu *et al.* (2012) Bhadru *et al.* (2012b) Sarwar *et al.* (2015) Pradhan *et al.* (2015)
7	Number of ill-filled grains per panicle	-	Sarwar *et al.* (2015)	G G - G	Girolkar *et al.* (2008) Babu *et al.* (2012) Ratna *et al.* (2015) Pradhan *et al.* (2015)
8	1000 grain weight (g)	G G G G G G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Rangare *et al.* (2012) Kumar *et al.* (2013) Reddy *et al.* (2013) Saikumar *et al.* (2014) Kishore *et al.* (2015) Nilanjaya and Kumar (2015)	G G G G G G G G G G	Swain and Reddy (2006) Rani and Reddy (2010) Garg *et al.* (2010) Babu *et al.* (2012) Sudharani *et al.* (2012) Dhurai *et al.* (2014a) Khare *et al.* (2014) Pradhan *et al.* (2015) Kumar and Verma (2015) Bhadru *et al.* (2012b)
9	SCMR	- - G	Adilakshmi and Raghavareddy (2012) Madakemohekar *et al.* (2015) Nilanjaya and Kumar (2015)	G -	Sudharani *et al.* (2012) Gopikannan and Ganesh (2013)
10	SLA (cm^2/g)	-	Mohankumar *et al.* (2011)	-	Elango *et al.* (2012)

Table 2.8 (contd.)

S.No.	Character	P/G	Positive direct effect	P/G	Negative direct effect
11	SLW (g/cm^2)			-	Adilakshmi and Raghavareddy (2012)
12	Harvest index	G G - G G G G G - G	Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Adilakshmi and Raghavareddy (2012) Sudharani *et al.* (2012) Reddy *et al.* (2013) Dhurai *et al.* (2014a) Saikumar *et al.* (2014) Pradhan *et al.* (2015) Madakemohekar *et al.* (2015) Kumar and Verma (2015)	G	Nagaraju *et al.* (2013)
13	RDW (g)	G	Shajedur *et al.* (2015)		
14	RSR	G	Sudharani *et al.* (2012)		

Table 2.10. Review of literature on indirect effects of component characters on grain yield in rice (*Oryza sativa* L.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
1.	**Days to 50% flowering on grain yield through**				
	Days to maturity	G G G - G	Reddy *et al.* (2013) Dhurai *et al.* (2014a) Khare *et al.* (2014) Sarwar *et al.* (2015) Nilanjaya and Kumar (2015)	G G	Kumar and Verma (2015) Prasad *et al.* (2015)
2.	Plant height (cm)	G G G G G G G G G	Panwar and Ali (2007) Garg *et al.* (2010) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015) Kumar and Verma (2015) Pradhan *et al.*(2015)	G G - G - G	Borbora *et al.* (2005) Babu *et al.* (2012) Gopikannan and Ganesh (2013b) Dhurai *et al.* (2014a) Ratna *et al.* (2015) Kishore *et al.* (2015)
3.	Number of effective tillers per plant	G G G G - G G	Binse *et al.* (2006) Babu *et al.* (2012) Bhadru *et al.* (2012b) Dhurai *et al.* (2014a) Sarwar *et al.* (2015) Kumar and Verma (2015) Pradhan *et al.* (2015)	G G - G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Gopikannan and Ganesh (2013b) Khare *et al.* (2014) Kishore *et al.* (2015) Nilanjaya and Kumar (2015)
4.	Panicle length (cm)	G G G G G G G	Binse *et al.* (2006) Sudharani *et al.* (2012) Bhadru *et al.* (2012) Dhurai *et al.* (2014a) Kishore *et al.* (2015) Kumar and Verma (2015) Pradhan *et al.* (2015)	G G G G G G - G	Borbora *et al.* (2005) Binse *et al.* (2006) Girolkar *et al.* (2008) Babu *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Ratna *et al.* (2015) Prasad *et al.* (2015)
5.	Number of filled grains per panicle	G G G -	Girolkar *et al.* (2008) Bhadru *et al.* (2012) Khare *et al.* (2014) Ratna *et al.* (2015)	G G -	Babu *et al.* (2012) Sudharani *et al.* (2012) Gopikannan and Ganesh (2013b)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
				G G G	Saikumar *et al.* (2014) Kishore *et al.* (2015) Pradhan *et al.* (2015)
6.	Number of ill-filled grains per panicle			G G G - - G	Girolkar *et al.* (2008) Babu *et al.* (2012) Saikumar *et al.* (2014) Sarwar *et al.* (2015) Ratna *et al.* (2015) Prasad *et al.* (2015)
7.	1000 grain weight (g)	G G G G G G	Binse *et al.* (2006) Garg *et al.* (2010) Reddy *et al.* (2013) Dhurai *et al.* (2014) Nilanjaya and Kumar (2015) Pradhan *et al.* (2015)	G G G G G - G G G G	Borbora *et al.* (2005) Binse *et al.* (2006) Girolkar *et al.* (2008) Sudharani *et al.* (2012) Bhadru *et al.* (2012) Gopikannan and Ganesh (2013b) Khare *et al.* (2014) Saikumar *et al.* (2014) Kishore *et al.* (2015) Kumar and Verma (2015)
8.	SCMR	G	Sudharani *et al.* (2012)	G	Nilanjaya and Kumar (2015)
9.	Harvest index	G G G	Sudharani *et al.* (2012) Reddy *et al.* (2013) Kumar and Verma (2015)	G G G G	Girolkar *et al.* (2008) Dhurai *et al.* (2014a) Saikumar *et al.* (2014) Pradhan *et al.* (2015)
10.	RDW (g)			G	Shajedur *et al.* (2015)
11.	RSR			G	Sudharani *et al.* (2012)
2. Days to maturity on grain yield through					
1.	Days to 50% flowering	- G G	Sarwar *et al.* (2015) Kumar and Verma (2015) Prasad *et al.* (2015)	G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)
2.	Plant height (cm)	G G - G	Reddy *et al.* (2013) Khare *et al.* (2014) Madakemohekar *et al.* (2015) Prasad *et al.* (2015)	G - G G	Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Nilanjaya and Kumar (2015) Kumar and Verma (2015)

Table 2.8 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
3.	Number of effective tillers per plant	G - G	Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Nilanjaya and Kumar (2015)	G - G	Khare *et al.* (2014) Madakemohekar *et al.* (2015) Prasad *et al.* (2015)
4.	Panicle length (cm)	G - G	Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Prasad *et al.* (2015)	G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)
5.	Number of filled grains per panicle	G -	Khare *et al.* (2014) Sarwar *et al.* (2015)	G	Prasad *et al.* (2015)
6.	Number of ill-filled grains per panicle			- G	Sarwar *et al.* (2015) Prasad *et al.* (2015)
7.	1000 grain weight (g)	G G G - -	Reddy *et al.* (2013) Khare *et al.* (2014) Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Madakemohekar *et al.* (2015)	G G	Nilanjaya and Kumar (2015) Prasad *et al.* (2015)
8.	SCMR	G	Nilanjaya and Kumar (2015)	-	Madakemohekar *et al.* (2015)
9.	Harvest index	G -	Reddy *et al.* (2013) Madakemohekar *et al.* (2015)		
3. Plant height on grain yield through					
1.	Days to 50% flowering	G G G G G	Babu *et al.* (2012) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Kishore *et al.* (2015) Pradhan *et al.* (2015)	G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)
2.	Days to maturity	G G -	Reddy *et al.* (2013) Khare *et al.* (2014) Madakemohekar *et al.* (2015)	G - G	Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Nilanjaya and Kumar (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
3.	Number of effective tillers per plant	G G G G G G	Shashidhar *et al.* (2005) Chakraborty *et al.* (2010) Sudharani *et al.* (2012) Hossain *et al.* (2015) Kahani and Hittalmani (2015) Nilanjaya and Kumar (2015)	G G G G G - - -	Girolkar *et al.* (2008) Babu *et al.* (2012) Bhadru *et al.* (2012b) Nagaraju *et al.* (2013) Khare *et al.* (2014) Sarwar *et al.* (2015) Madakemohekar *et al.* (2015) Ratna *et al.* (2015)
4.	Panicle length (cm)	G G G G G G G G	Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Babu *et al.* (2012) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Nagaraju *et al.* (2013) Kishore *et al.* (2015) Prasad *et al.* (2015)	G G G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Kahani and Hittalmani (2015) Nilanjaya and Kumar (2015) Pradhan *et al.* (2015)
5.	Number of filled grains per panicle	G G G G G G	Rani and Reddy (2010) Garg *et al.* (2010) Sudharani *et al.* (2012) Khare *et al.* (2014) Hossain *et al.* (2015) Prasad *et al.* (2015)	G G G - G	Girolkar *et al.* (2008) Chakraborty *et al.* (2010) Bhadru *et al.* (2012b) Ratna *et al.* (2015) Pradhan *et al.* (2015)
6.	Number of ill -filled grains per panicle	G G G G	Girolkar *et al.* (2008) Babu *et al.* (2012) Hossain *et al.* (2015) Prasad *et al.* (2015)	- -	Sarwar *et al.* (2015) Ratna *et al.* (2015)
7.	1000 grain weight (g)	G G G G G G G	Girolkar *et al.* (2008) Rani and Reddy (2010) Babu *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Kishore *et al.* (2015) Pradhan *et al.* (2015)	P G	Kishore *et al.* (2015) Hossain *et al.* (2015)
8.	SLA (cm^2/g)			G	Rajnish *et al.* (2015)
9.	SLW (g/cm^2)	P	Rajnish *et al.* (2015)	G	Rajnish *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
10.	Harvest index	G G	Sudharani *et al.* (2012) Girolkar *et al.* (2008)	G G - G	Reddy *et al.* (2013) Nagaraju *et al.* (2013) Madakemohekar *et al.* (2015) Pradhan *et al.* (2015)
11.	RDW	G	Shajedur *et al.* (2015)		
12.	RSR	G	Sudharani *et al.* (2012)		
4. Number of effective tillers per plant on grain yield through					
1.	Days to 50% flowering	G G G G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Babu *et al.* (2012) Bhadru *et al.* (2012b) Khare *et al.* (2014) Kishore *et al.* (2015) Prasad *et al.* (2015)	G G G G	Sudharani *et al.* (2012) Babu *et al.* (2012) Nilanjaya and Kumar (2015) Prasad *et al.* (2015)
2.	Days to maturity	G G	Kahani and Hittalmani (2015) Prasad *et al.* (2015)	G G	Khare *et al.* (2014) Nilanjaya and Kumar (2015)
3.	Plant height (cm)	G G G G G	Shashidhar *et al.* (2005) Hossain *et al.* (2015) Kahani and Hittalmani (2015) Pradhan *et al.* (2015) Prasad *et al.* (2015)	G G G G G G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Babu *et al.* (2012) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Nagaraju *et al.* (2013) Khare *et al.* (2014) Kishore *et al.* (2015) Nilanjaya and Kumar (2015)
4.	Panicle length (cm)	G G G G G - G	Bhadru *et al.* (2012b) Nagaraju *et al.* (2013) Khare *et al.* (2014) Hossain *et al.* (2015) Kahani and Hittalmani (2015) Sarwar *et al.* (2015) Prasad *et al.* (2015)	G G G G G G - G	Binse *et al.* (2006) Girolkar *et al.* (2008) Sudharani *et al.* (2012) Babu *et al.*(2012) Kishore *et al.*(2015) Nilanjaya and Kumar (2015) Ratna *et al.* (2015) Pradhan *et al.*(2015)
5.	Number of filled grains per panicle	G P G G G	Girolkar *et al.* (2008) Babu *et al.* (2012) Bhadru *et al.* (2012b) Kishore *et al.* (2015) Pradhan *et al.* (2015)	G G G G	Babu *et al.* (2012) Sudharani *et al.* (2012) Khare *et al.* (2014) Hossain *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
6.	Number of ill-filled grains per panicle	G -	Hossain *et al.* (2015) Sarwar *et al.* (2015)	G G	Girolkar *et al.* (2008) Babu *et al.* (2012)
7.	1000 grain weight (g)	G G G	Kishore *et al.* (2015) Pradhan *et al.* (2015) Prasad *et al.* (2015)	G G G G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Khare *et al.* (2014) Hossain *et al.* (2015) Nilanjaya and Kumar (2015)
8.	SCMR	- G	Madakemohekar *et al.* (2015) Nilanjaya and Kumar (2015)	G	Sudharani *et al.* (2012)
9.	Harvest index	G	Pradhan *et al.* (2015)	G G G -	Girolkar *et al.* (2008) Sudharani *et al.* (2012) Nagaraju *et al.* (2013) Madakemohekar *et al.* (2015)
10.	RDW (g)	G	Shajedur *et al.* (2015)		
11.	RSR	G	Sudharani *et al.* (2012)		
5. Panicle length on grain yield through					
1.	Days to 50% flowering	G G G	Girolkar *et al.* (2008) Bhadru *et al.* (2012b) Kishore *et al.* (2015)	G G G G G	Sudharani *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Pradhan *et al.* (2015) Prasad *et al.* (2015)
2.	Days to maturity	G G G	Reddy *et al.* (2013) Khare *et al.* (2014) Nilanjaya and Kumar (2015)	- G	Sarwar *et al.* (2015) Prasad *et al.* (2015)
3.	Plant height (cm)	G G G G G G G G G G	Girolkar *et al.*(2008) Rani and Reddy (2010) Babu *et al.* (2012) Bhadru *et al.* (2012b) Reddy *et al.* (2013) Khare *et al.* (2014) Kishore *et al.* (2015) Hossain *et al.* (2015) Nilanjaya and Kumar (2015) Pradhan *et al.* (2015)	G G -	Sudharani *et al.* (2012) Nagaraju *et al.* (2013) Ratna *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
4.	Number of effective tillers per plant	G G G	Garg *et al.* (2010) Bhadru *et al*. (2012b) Pradhan *et al.* (2015)	G G G G G G G	Girolkar *et al.* (2008) Rani and Reddy (2010) Babu *et al.* (2012) Nagaraju *et al*. (2013) Khare *et al*. (2014) Kishore *et al.* (2015) Hossain *et al*. (2015)
5.	Number of filled grains per panicle	G G G G - G	Manna *et al.* (2006) Girolkar *et al.* (2008) Babu *et al.* (2012) Khare *et al*. (2014) Sarwar *et al.* (2015) Prasad *et al.* (2015)	G G G G G G	Rani and Reddy (2010) Sudharani *et al.* (2012) Bhadru *et al*. (2012b) Kishore *et al.* (2015) Hossain *et al*. (2015) Pradhan *et al.* (2015)
6.	Number of ill-filled grains per panicle	G G G	Babu *et al.* (2012) Hossain *et al*. (2015) Prasad *et al.* (2015)	G - -	Girolkar *et al.* (2008) Sarwar *et al.* (2015) Ratna *et al.* (2015)
7.	1000 grain weight (g)	G G G G G G	Girolkar *et al.* (2008) Garg *et al.* (2010) Babu *et al.* (2012) Reddy *et al.* (2013) Kishore *et al.* (2015) Nilanjaya and Kumar (2015)	G G G G G	Sudharani *et al.* (2012) Bhadru *et al*. (2012b) Khare *et al*. (2014) Hossain *et al*. (2015) Pradhan *et al.* (2015)
8.	SCMR	P	Sudharani *et al.* (2012)	G G	Sudharani *et al.* (2012) Nilanjaya and Kumar (2015)
9.	Harvest index	P	Sudharani *et al.* (2012)	G G G G G	Girolkar *et al.* (2008) Sudharani *et al.* (2012) Reddy *et al.* (2013) Nagaraju *et al*. (2013) Pradhan *et al.* (2015)
10.	RDW (g)	G	Shajedur *et al.* (2015)		
11.	RSR	P	Sudharani *et al.* (2012)	G	Sudharani *et al.* (2012)
6. Number of filled grains per panicle on grain yield through					
1.	Days to 50% flowering	G G	Girolkar *et al.* (2008) Pradhan *et al.* (2015)	G G G G - G G	Babu *et al.* (2012) Sudharani *et al.* (2012) Saikumar *et al*. (2014) Khare *et al*. (2014) Sarwar *et al.* (2015) Prasad *et al.* (2015) Kishore *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
2.	Days to maturity	G - G	Khare *et al*. (2014) Sarwar *et al*. (2015) Prasad *et al.* (2015)		-
3.	Plant height (cm)	G G G G	Girolkar *et al.* (2008) Bhadru *et al*. (2012b) Ratna *et al*. (2015) Prasad *et al.* (2015)	G G	Babu *et al*. (2012) Hossain *et al*. (2015)
4.	Number of effective tillers per plant	G G G G	Sudharani *et al*. (2012) Babu *et al*. (2012) Hossain *et al*. (2015) Prasad *et al.* (2015)	G P G G G	Girolkar *et al.* (2008) Babu *et al*. (2012) Bhadru *et al*. (2012b) Khare *et al*. (2014) Pradhan *et al*. (2015)
5.	Panicle length(cm)	G G G G	Sudharani *et al*. (2012) Bhadru *et al*. (2012b) Hossain *et al*. (2015) Prasad *et al.* (2015)	G G G G	Girolkar *et al.* (2008) Babu *et al*. (2012) Khare *et al*. (2014) Pradhan *et al*. (2015)
6.	Number of ill-filled grains per panicle	G - G	Girolkar *et al.* (2008) Ratna *et al*. (2015) Prasad *et al.* (2015)	G G -	Babu *et al*. (2012) Hossain *et al*. (2015) Sarwar *et al*. (2015)
7.	1000 grain weight (g)	G G G G	Girolkar *et al.* (2008) Sudharani *et al*. (2012) Khare *et al*. (2014) Pradhan *et al*. (2015)	G G G G	Babu *et al*. (2012) Bhadru *et al*. (2012b) Hossain *et al*. (2015) Prasad *et al.* (2015)
8.	SCMR	G	Sudharani *et al*. (2012)		
9.	Harvest index	G G G G	Girolkar *et al.* (2008) Sudharani *et al*. (2012) Saikumar *et al*. (2014) Pradhan *et al*. (2015)		
10.	RDW (g)		-	G	Shajedur *et al*. (2015)
11.	RSR	G	Sudharani *et al*. (2012)		
7. Number of ill-filled grains per panicle on grain yield through					
1.	Days to 50% flowering	- G	Sarwar *et al*. (2015) Prasad *et al.* (2015)	G G G	Girolkar *et al.* (2008) Babu *et al*.(2012) Saikumar *et al*. (2014)
2.	Days to maturity	-	Sarwar *et al*. (2015)	G	Prasad *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
3.	Plant height (cm)	-	Sarwar *et al.* (2015)	G G G - G	Girolkar *et al.* (2008) Babu *et al.* (2012) Hossain *et al.* (2015) Ratna *et al.* (2015) Prasad *et al.* (2015)
4.	Number of effective tillers per plant	G G G	Girolkar *et al.* (2008) Babu *et al.* (2012) Hossain *et al.* (2015)	G	Prasad *et al.* (2015)
5.	Panicle length (cm)	G -	Girolkar *et al.* (2008) Ratna *et al.* (2015)	G G G	Babu *et al.* (2012) Hossain *et al.* (2015) Prasad *et al.* (2015)
6.	Number of filled grains per panicle	G	Girolkar *et al.* (2008)	G G G	Babu *et al.* (2012) Hossain *et al.* (2015) Prasad *et al.* (2015)
7.	1000 grain weight (g)	-	Ratna *et al.* (2015)	G G G G	Girolkar *et al.* (2008) Babu *et al.* (2012) Hossain *et al.* (2015) Prasad *et al.* (2015)
8.	Harvest index	G	Saikumar *et al.* (2014)	G	Girolkar *et al.*(2008)
9.	RDW (g)			G	Shajedur *et al.* (2015)
8. 1000 grain weight on grain yield through					
1.	Days to 50% flowering	G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Sudharani *et al.* (2012) Bhadru *et al.* (2012b)	G G G G G	Babu *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Pradhan *et al.* (2015) Prasad *et al.* (2015)
2.	Days to maturity	G G G	Reddy *et al.* (2013) Nilanjaya and Kumar (2015) Prasad *et al.* (2015)	G G	Khare *et al.* (2014) Kahani and Hittalmani (2015)
3.	Plant height (cm)	G G G G G G G	Binse *et al.* (2006) Girolkar *et al.* (2008) Rani and Reddy (2010) Babu *et al.* (2012) Hossain *et al.* (2015) Nilanjaya and Kumar (2015) Prasad *et al.* (2015)	G G G G G G G	Garg *et al.* (2010) Sudharani *et al.* (2012) Bhadru *et al.* (2012b) Reddy *et al.* (2013) Khare *et al.* (2014) Kahani and Hittalmani (2015) Pradhan *et al.* (2015)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
4.	Number of effective tillers per plant	G G G G G G	Girolkar *et al.* (2008) Garg *et al.* (2010) Bhadru *et al.* (2012b) Khare *et al.* (2014) Hossain *et al.* (2015) Prasad *et al.* (2015)	G G G G G G	Binse *et al.* (2006) Rani and Reddy (2010) Sudharani *et al.* (2012) Babu *et al.* (2012) Nilanjaya and Kumar (2015) Pradhan *et al.*(2015)
5.	Panicle length (cm)	G G G G G	Binse *et al.* (2006) Garg *et al.* (2010) Bhadru *et al.* (2012b) Kahani and Hittalmani (2015) Prasad *et al.* (2015)	G G G G G G G G G	Girolkar *et al.* (2008) Rani and Reddy (2010) Garg *et al.* (2010) Sudharani *et al.* (2012) Babu *et al.* (2012) Reddy *et al.* (2013) Khare *et al.* (2014) Hossain *et al.* (2015) Pradhan *et al.* (2015)
6.	Number of filled grains per panicle	G G G G G	Babu *et al.* (2012) Bhadru *et al.* (2012) Saikumar *et al.* (2014) Hossain *et al.* (2015) Pradhan *et al.* (2015)	G G G G G	Girolkar *et al.* (2008) Garg *et al.* (2010) Sudharani *et al.* (2012) Khare *et al.* (2014) Prasad *et al.* (2015)
7.	Number of ill-filled grains per panicle	G G G	Girolkar *et al.*(2008) Hossain *et al.* (2015) Prasad *et al.* (2015)	G -	Babu *et al.*(2012) Ratna *et al.* (2015)
8.	SCMR	-	Madakemohekar *et al.* (2015)	G G	Sudharani *et al.* (2012) Nilanjaya and Kumar (2015)
9.	Harvest index	G G G - G	Girolkar *et al.* (2008) Reddy *et al.* (2013) Saikumar *et al.* (2014) Madakemohekar *et al.* (2015) Pradhan *et al.* (2015)	G	Sudharani *et al.* (2012)
10.	RDW (g)			G	Shajedur *et al.* (2015)
11.	RSR			G	Sudharani *et al.* (2012)
9. Leaf area duration on grain yield through					
1.	SLA (cm^2/g)			G	Rajnish *et al.* (2015)
2.	SLW (g/cm^2)	G	Rajnish *et al.* (2015)		

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
10. SCMR on grain yield through					
1.	Days to 50% flowering			G G	Sudharani *et al.* (2012) Nilanjaya and Kumar (2015)
2.	Days to maturity	-	Madakemohekar *et al.* (2015)	G	Nilanjaya and Kumar (2015)
3.	Plant height (cm)	G -	Sudharani *et al.* (2012) Madakemohekar *et al.* (2015)	G	Nilanjaya and Kumar (2015)
4.	Number of effective tillers per plant	- G	Madakemohekar *et al.* (2015) Nilanjaya and Kumar (2015)	G	Sudharani *et al.* (2012)
5.	Panicle length (cm)	P	Sudharani *et al.* (2012)	G G	Sudharani *et al.* (2012) Nilanjaya and Kumar (2015)
6.	Number of filled grains per panicle	G	Sudharani *et al.* (2012)		
7.	1000 grain weight g)	-	Madakemohekar *et al.* (2015)	G G	Sudharani *et al.* (2012) Nilanjaya and Kumar (2015)
8.	SLW (g/cm^2)	-	Adilakshmi and Raghavareddy (2012)		
9.	Harvest index	- G	Adilakshmi and Raghavareddy (2012) Sudharani *et al.* (2012)	-	Madakemohekar *et al.* (2015)
10.	RSR	P	Sudharani *et al.* (2012)	G	Sudharani *et al.* (2012)
11. Specific leaf area on grain yield through					
1.	LAD			G	Rajnish *et al.* (2015)
2.	SLW (g/cm^2)	G	Rajnish *et al.* (2015)	P	Rajnish *et al.* (2015)
12. Specific leaf weight on grain yield through					
1.	LAD	G	Rajnish *et al.* (2015)		
2.	SCMR			-	Adilakshmi and Raghavareddy (2012)
3.	SLA (cm^2/g)	G	Rajnish *et al.* (2015)		
4.	Harvest index			-	Adilakshmi and Raghavareddy (2012)

Table 2.10 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
13. Harvest index on grain yield through					
1.	Days to 50% flowering	G G	Girolkar *et al.* (2008) Sudharani *et al.* (2012)	G G G	Reddy *et al.* (2013) Saikumar *et al.* (2014) Pradhan *et al.* (2015)
2.	Days to matirity	G	Reddy *et al.* (2013)	-	Madakemohekar *et al.* (2015)
3.	Plant height (cm)	G G G -	Girolkar *et al.* (2008) Sudharani *et al.* (2012) Nagaraju *et al.* (2013) Madakemohekar *et al.* (2015)	G G	Reddy *et al.* (2013) Pradhan *et al.* (2015)
4.	SCMR	- G	Adilakshmi and Raghavareddy (2012) Sudharani *et al.* (2012)	-	Madakemohekar *et al.* (2015)
5.	SLW (g/cm^2)	-	Adilakshmi and Raghavareddy (2012)		
6.	RSR	G	Sudarani *et al.* (2012)		
14. Root dry weight on grain yield through					
1.	Days to 50% flowering			G	Shajedur *et al.* (2015)
2.	Plant height (cm)	G	Shajedur *et al.* (2015)		
3.	Number of effective tillers per plant	G	Shajedur *et al.* (2015)		
4.	Panicle length (cm)	G	Shajedur *et al.* (2015)	P	Shajedur *et al.* (2015)
5.	Number of filled grains per panicle			G	Shajedur *et al.* (2015)
6.	Number of ill-filled grains per panicle	G	Shajedur *et al.* (2015)		
7.	1000 grain weight (g)	G	Shajedur *et al.* (2015)		

Table 2.8 (contd.)

S.No.	Character	P/G	Positive indirect effect	P/G	Negative indirect effect
15. Root shoot ratio on grain yield through					
1.	Days to 50% flowering			G	Sudharani *et al.* (2012)
2.	Plant height (cm)	G	Sudharani *et al.* (2012)		
3.	Number of effective tillers per plant			G	Sudharani *et al.* (2012)
4.	Panicle length (cm)	G	Sudharani *et al.* (2012)		
5.	Number of filled grains per panicle	G	Sudharani *et al.* (2012)		
6.	1000 grain weight (g)	G	Sudharani *et al.* (2012)		
7.	SCMR	G	Sudharani *et al.* (2012)		
8.	Harvest index	G	Sudharani *et al.* (2012)		

Chapter V

SUMMARY AND CONCLUSION

The present investigation was carried out with an objective to test combining ability and to know the gene actions involved in inheritance of different yield, yield contributing and physiological traits (days to 50 % flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, leaf area duration at 60-80 DAT, SPAD chlorophyll meter reading at 80 DAT, specific leaf area at 80 DAT, specific leaf weight at 80 DAT, harvest index, shoot dry weight, root dry weight, root shoot ratio and grain yield per plant) along with variability, heritability, heterosis, correlation and path analysis in rice using 5 lines and 4 testers mated in L x T fashion. Evaluation of 20 crosses, nine parents along with two checks for different traits was carried out at Agricultural Research Station, Nellore during *kharif* 2015 and *rabi* 2015-16.

The analysis of variance indicated significant differences among the 31 genotypes for majority of the characters studied. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation indicating the influence of environment in the expression of the traits.

The estimates of PCV and GCV were high for characters viz., Number of ill-filled grains per panicle, root dry weight, shoot dry weight and root shoot ratio phenotypic co-efficient of variation for these characters was noticed to be closely and essentially associated with high genotypic co-efficient of variation, indicating the minimal influence of environment and presence of high genetic variability for these traits in the experimental material. Hence, selection on the basis of phenotype for these traits can be effective. High PCV and moderate GCV were observed for number of effective tillers per plant, harvest index and grain yield per plant. Moderate PCV and GCV were observed for number of filled grains per panicle, 1000 grain weight and LAD at 60-80 DAT. Moderate PCV and low GCV were observed for panicle length, SLA at 80 DAT. While, low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, SCMR at 80 DAT and SLW at 80 DAT indicating low variability for these characters in the present experimental material and therefore little scope for improvement of these traits.

The estimates of heritability and genetic advance as per cent of means were high for the characters viz., number of effective tillers per plant, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT, root dry weight, shoot dry weight, root shoot ratio and grain yield per plant indicating the involvement of additive gene action in the inheritance of these traits hence simple selection would be rewarding. High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, high heritability coupled with low genetic advance as per cent of mean was observed for days to maturity, plant height and SCMR at 80 DAT, moderate heritability coupled with high genetic advance as per cent of mean was observed for harvest index, moderate heritability coupled with low genetic advance as per cent of mean was observed for panicle length indicating involvement of both additive and non additive gene action in the inheritance of these traits thus simple selection may not be effective instead population improvement for these traits would be desirable. While low heritability coupled with low genetic advance as per cent of mean was observed for SLA at 80 DAT and SLW at 80 DAT thus proposing the preponderance of non additive gene action in the inheritance of these traits thus heterosis breeding would be more desirable for these traits.

The analysis of variance for combining ability revealed the existence of significant amount of variability among parents and different cross combinations for majority of the characters studied. The per cent contribution towards the total variance was maximum due to the interaction of lines and testers for the traits, days to 50% flowering, plant height, number of effective tillers per plant, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, SCMR at 80 DAT, harvest index and grain yield per plant. The contribution of lines alone towards the total variance was maximum for days to maturity, panicle length, SLA at 80 DAT, SLW at 80 DAT and shoot dry weight. While contribution of testers alone towards the total variance was maximum for LAD at 60-80 DAT, root dry weight and root shoot ratio.

The component of variance due to both *gca* and *sca* were significant for the characters, days to 50% flowering, days to maturity, number of filled grains per panicle, number of ill-filled grains per panicle, LAD at 60-80 DAT, shoot dry weight, root dry weight, root shoot ratio and grain yield per plant indicating the role of both additive and non additive gene action in the inheritance of these characters, while *gca* component of variance was high for the characters, panicle length, SLW at 80 DAT, indicating the predominance of additive gene action in the inheritance of this trait, but the ratio *gca* component of variance to total genetic variance was intermediate to near unity and heritability narrow sense was low to intermediate indicating the presence both additive and non additive gene action. Since both additive and non-additive genes are involved in the inheritance of these traits they can be improved either by population improvement methods or even by heterosis breeding methods like production of hybrids, synthetics and composites.

sca variance was significant for the characters, plant height, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT and harvest index proposing the role of non-additive gene action in the inheritance of these traits. As non-additive gene action was predominant, breeding methods involving selection, inter mating among selected ones and reselection may help to improve this trait besides exploiting the methods of heterosis breeding involving production of hybrids and synthetics.

Among five lines tested for their combining abilities pertaining to different character under study, the line JGL 11118, recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, LAD at 60-80 DAT and SCMR at 80 DAT followed by RNR 2465, for days to 50 % flowering, days to maturity, number of ill-filled grains per panicle, 1000 grain weight, SLW at 80 DAT and shoot dry weight, Kavya, for number of filled grains per panicle, SLA at 80 DAT, SLW at 80 DAT and root dry weight and BPT 5204, for number of ill-filled grains per panicle, root dry weight, shoot dry weight and grain yield per plant and among testers, IR 64 recorded significant *gca* effects in desirable direction for majority of the traits viz., days to 50% flowering, days to maturity, number of ill-filled grains per panicle, 1000-grain weight followed by NLR 34449 for days to 50% flowering, days to maturity, number of filled grains per panicle and number of ill-filled grains per panicle.

Among the twenty crosses tested for specific combining ability for seventeen different characters, the cross, NLR 3041 x IR 36 viz., days to 50% flowering, days to maturity, number of effective tillers per plant, number of ill-filled grains and root dry weight and root shoot ratio recorded significant *sca* effects in desirable direction for majority of the traits, followed by RNR 2465 x IR 64, for number of effective tillers per plant, shoot dry weight and grain yield per plant, BPT 5204 x NLR 34449 for days to 50% flowering, days to maturity, 1000 grain weight, and JGL 11118 x IR 36 for 1000 grain weight, harvest index and shoot dry weight.

Heterosis studies revealed that five out of 20 crosses registered significant positive heterosis over mid parent and two out of 20 exhibited significant positive heterobeltiosis for grain yield per plant. Out of 20 cross combinations, the crosses, BPT 5204 x IR 36 and JGL 11118 x IR 36, recorded highest significant relative heterosis and heterobeltiosis for grain yield per plant. Further heterotic studies also revealed that the cross, RNR 2465 x IR 64, registered highest significant positive heterosis for grain yield over both the checks (NLR 40024 and NLR 30491.). Though the *per se* performance of the parents involved in the above heterotic crosses are relatively low, the crosses are heterotic indicating better nicking ability of the parents involved in producing a high heterotic hybrid.

Correlation studies revealed that the traits plant height, panicle length, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT, SLA at 80 DAT, SLW at 80 DAT, harvest index and shoot dry weight and root shoot ratio were found to possess significant association in desirable direction with grain yield per plant. The association studied indicating grain yield of rice can be improved by selecting genotypes having higher performances for these traits.

Path analysis revealed that plant height, number of effective tillers per plant 1000 grain weight, SCMR at 80 DAT, SLW at 80 DAT and shoot dry weight showed true relationship by establishing positive association and positive direct effect on grain yield per plant. Hence, these traits should be considered as important selection criteria in all rice improvement programmes and direct selection for these traits is recommended for yield improvement.

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 plant height, number of effective tillers per plant, 1000 grain weight, SCMR at 80 DAT, SLW at 80 DAT and shoot dry weight.

Table 4.1. Mean performance of hybrids, lines, testers and checks in rice (*Oryza sativa* L.)

Hybrids, Parents and Checks	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
Hybrids									
RNR 2465 x IR 36	82.50	115.50	78.30	13.40	23.40	158.60	27.60	16.51	640.70
RNR 2465 x IR 64	85.50	118.00	82.90	16.95	23.00	151.50	14.60	16.79	676.80
RNR 2465 x NLR 34449	88.50	119.50	81.70	13.27	21.70	169.55	12.50	16.07	721.92
RNR 2465 x NLR 145	92.50	124.00	68.20	12.00	21.40	140.20	13.80	13.59	756.63
JGL 11118 x IR 36	84.00	118.00	83.50	10.88	25.20	179.20	33.40	20.19	693.30
JGL 11118 x IR 64	87.00	118.50	72.88	12.37	22.63	165.20	18.40	15.06	683.50
JGL 11118 x NLR 34449	85.00	116.50	73.80	12.99	21.20	161.30	15.00	15.25	638.75
JGL 11118 x NLR 145	89.50	120.50	71.60	10.11	23.00	188.30	31.20	16.76	871.93
BPT 5204 x IR 36	98.00	131.00	66.88	15.88	19.67	186.00	24.90	13.38	624.22
BPT 5204 x IR 64	89.00	121.50	71.20	13.60	18.10	154.60	25.50	15.28	649.88
BPT 5204 x NLR 34449	86.50	119.00	76.90	13.70	21.10	161.40	17.50	16.26	637.82
BPT 5204 x NLR 145	99.00	130.50	80.60	13.68	20.70	180.30	39.30	15.47	767.05
Kavya x IR 36	89.00	120.50	71.60	9.85	20.30	218.30	35.60	13.70	613.65
Kavya x IR 64	90.00	122.50	75.30	12.00	23.30	175.50	42.40	18.26	719.93
Kavya x NLR 34449	91.00	124.00	72.50	14.32	23.17	200.00	47.10	12.24	675.30
Kavya x NLR 145	89.00	121.50	74.10	13.20	22.30	159.20	43.10	14.50	741.55
NLR 3041 x IR 36	89.00	122.00	73.67	19.83	21.83	114.80	27.70	13.56	671.13
NLR 3041 x IR 64	90.50	122.50	76.40	13.52	21.40	105.05	19.10	17.72	666.45
NLR 3041 x NLR 34449	92.00	125.00	75.40	10.85	20.80	197.20	24.80	11.33	671.95
NLR 3041 x NLR 145	107.50	136.00	76.40	11.39	20.80	162.60	82.70	13.34	697.45
Lines									
RNR 2465	94.00	124.50	78.10	14.96	21.10	133.40	19.60	16.59	558.55
JGL 11118	86.00	116.50	74.90	8.09	19.80	166.00	23.80	16.07	737.15
BPT 5204	106.00	136.50	73.10	11.33	17.20	151.10	15.60	13.36	527.88
Kavya	91.00	124.50	75.80	8.10	20.30	180.10	47.30	15.84	664.28
NLR 3041	109.00	139.50	71.30	14.00	17.60	183.10	33.40	13.50	526.28

Table 4.1 (Contd.)

Hybrids, Parents and Checks	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
Testers									
IR 36	88.50	120.50	73.50	9.51	21.30	139.20	20.90	21.56	641.85
IR 64	92.00	124.50	71.60	9.68	20.10	120.50	14.80	23.05	534.85
NLR 34449	92.50	124.50	68.90	11.79	18.90	176.90	19.70	13.76	664.65
NLR 145	105.00	137.00	78.60	10.05	22.70	138.50	36.90	22.72	677.78
Checks									
NLR 40024	91.00	122.50	67.50	16.05	18.10	110.90	9.00	18.60	480.50
NLR 30491	90.50	121.50	68.30	10.30	18.10	109.60	14.60	18.30	554.75
Mean	**91.95**	**123.82**	**74.37**	**12.51**	**20.97**	**159.29**	**27.48**	**16.08**	**657.69**
CV%	2.2549	1.7616	4.1228	11.375	8.1371	8.9469	14.241	2.9566	6.2722
Sem	1.4661	1.5424	2.1680	1.0058	1.2068	10.077	2.7669	0.3363	29.1695
CD at 5% LOS	4.2344	4.4548	6.2617	2.9051	3.4854	29.106	7.9912	0.9712	84.2472

Table 4.1 (Contd.)

S.No.	Hybrids, Parents and Checks	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
	Hybrids								
1.	RNR 2465 x IR 36	49.05	64.75	0.0155	42.69	6.82	90.10	0.08	32.90
2.	RNR 2465 x IR 64	48.30	66.63	0.0150	52.71	6.03	91.10	0.07	42.00
3.	RNR 2465 x NLR 34449	42.10	62.90	0.0160	49.22	5.60	89.53	0.06	35.70
4.	RNR 2465 x NLR 145	45.00	75.76	0.0133	32.62	7.91	56.19	0.14	21.00
5.	JGL 11118 x IR 36	44.60	64.12	0.0157	68.03	4.99	92.76	0.05	37.80
6.	JGL 11118 x IR 64	45.90	62.93	0.0159	43.90	5.13	60.44	0.09	29.88
7.	JGL 11118 x NLR 34449	49.45	67.31	0.0149	47.80	5.05	61.28	0.08	30.10
8.	JGL 11118 x NLR 145	50.00	66.19	0.0151	42.07	7.43	74.15	0.10	30.80
9.	BPT 5204 x IR 36	45.65	56.26	0.0178	49.93	6.64	84.35	0.08	39.17
10.	BPT 5204 x IR 64	46.60	63.23	0.0158	40.23	8.70	73.40	0.12	31.33
11.	BPT 5204 x NLR 34449	43.15	63.30	0.0159	49.29	6.26	82.55	0.08	35.50
12.	BPT 5204 x NLR 145	44.40	60.22	0.0167	54.10	10.01	80.72	0.12	36.00
13.	Kavya x IR 36	47.60	59.71	0.0167	43.65	7.10	77.46	0.09	27.20
14.	Kavya x IR 64	46.15	52.36	0.0191	45.13	7.97	82.72	0.10	37.33
15.	Kavya x NLR 34449	46.00	57.49	0.0174	38.68	7.17	78.54	0.09	33.80
16.	Kavya x NLR 145	43.10	60.07	0.0166	39.76	8.99	70.81	0.13	29.50
17.	NLR 3041 x IR 36	45.20	66.38	0.0151	52.53	9.51	69.76	0.14	27.67
18.	NLR 3041 x IR 64	45.60	65.60	0.0153	49.54	4.93	46.39	0.11	24.83
19.	NLR 3041 x NLR 34449	47.65	61.34	0.0164	41.44	4.61	49.76	0.09	23.00
20.	NLR 3041 x NLR 145	41.00	61.23	0.0163	38.00	9.02	54.03	0.17	23.50
	Lines								
21.	RNR 2465	43.50	58.44	0.0171	45.14	12.69	98.69	0.13	40.17
22.	JGL 11118	41.60	71.36	0.0141	47.22	9.93	60.54	0.16	21.50
23.	BPT 5204	42.35	62.07	0.0161	27.08	6.28	54.63	0.11	20.33
24.	Kavya	40.70	65.11	0.0154	25.45	3.90	45.52	0.09	17.33
25.	NLR 3041	44.40	63.56	0.0158	50.73	6.11	71.69	0.08	34.33

Table 4.1 (Contd.)

S.No	Hybrids, Parents and Checks	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
	Testers								
26.	IR 36	45.65	58.22	0.0172	43.56	8.18	65.91	0.12	28.17
27.	IR 64	42.70	68.14	0.0147	35.65	6.23	68.18	0.09	29.83
28.	NLR 34449	47.40	57.03	0.0175	44.45	5.64	73.49	0.08	28.20
29.	NLR 145	44.30	67.58	0.0149	45.31	9.49	101.04	0.09	38.83
	Checks								
30.	NLR 40024	41.35	69.24	0.0156	53.51	6.18	60.02	0.10	32.50
31.	NLR 30491	42.65	60.28	0.0166	35.82	4.89	51.16	0.10	20.33
	Mean	**44.94**	**63.19**	**0.0160**	**44.36**	**7.08**	**71.51**	**0.10**	**30.34**
	CV%	3.7524	10.3406	9.4110	13.9396	13.8526	10.0559	11.2239	14.0917
	Sem	1.1924	4.6202	0.0011	4.3728	0.6932	5.0850	0.0080	3.0232
	CD at 5% LOS	3.4438	13.3442	0.0031	12.6294	2.0021	14.6865	0.0232	8.7316

DFF- days to 50% flowering, DM- days to maturity, PH- plant height, NEPT- number of effective tillers per plant, PL- panicle length, NFGP- number of filled grains per panicle, NIFGP- number of ill-filled grains per panicle, 1000 GW-1000 grain weight, LAD- leaf area duration, SCMR- spad chlorophyll meter reading, SLA- specific leaf area, SLW- specific leaf weight, HI- harvest index, RDW- root dry weight, SDW- shoot dry weight, RSR- root shoot ratio, GYP- grain yield per plant

Table 4.2. Analysis of variance for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

Source of variations	d.f.	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
Mean sum of squares										
Replications	1	8.5323	19.7581	9.6577	1.1138	0.1310	0.7458	20.2123	0.1756	3510.035
Entries	30	93.2452**	80.0183**	38.3000**	13.645**	7.4032**	1600.299**	444.267**	16.9903**	13305.53**
Error	30	4.2989	4.7581	9.4006	2.0235	2.9126	203.1161	15.3109	0.2261	1701.7217

Source of variations	d.f.	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
Mean sum of squares									
Replications	1	2.2458	80.3929	0.0000043	12.9907	0.2633	78.6489	0.0000	2.3265
Entries	30	12.982**	46.4510	0.0000027	141.03**	8.0001**	483.89**	0.0015**	87.2264**
Error	30	2.8435	42.6933	0.0000023	38.2423	0.9610	51.7144	0.0001	18.2795

** Significant at 1% level

DFF- days to 50% flowering, DM- days to maturity, PH- plant height, NEPT- number of effective tillers per plant, PL- panicle length, NFGP- number of filled grains per panicle, NIFGP- number of ill-filled grains per panicle, 1000GW-1000 grain weight, LAD- leaf area duration, SCMR- spad chlorophyll meter reading, SLA- specific leaf area, SLW- specific leaf weight, HI- harvest index, RDW- root dry weight, SDW- shoot dry weight, RSR- root shoot ratio, GYP- grain yield per plant

Table 4.3. Estimates of variability, heritability and genetic advance as per cent mean for grain yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S. No.	Character	Mean	Range		Coefficient of variation		Heritability % (broad sense)	Genetic advance as per cent of mean
			Minimum	Maximum	GCV% (%)	PCV% (%)		
1.	DFF	91.95	82.50	109.00	7.25	7.59	91	14.27
2.	DM	123.82	115.50	139.50	4.95	5.26	89	9.62
3.	PH (cm)	74.37	66.88	83.50	5.11	6.57	61	8.26
4.	NETP	12.51	8.09	19.83	19.28	22.38	74	34.29
5.	PL (cm)	20.97	17.20	25.20	7.14	10.83	44	9.71
6.	NFGP	159.29	105.05	218.30	16.59	18.85	77	30.10
7.	NIFGP	27.48	9.00	82.70	53.30	55.17	93	106.10
8.	1000 GW (g)	16.08	11.33	23.05	18.00	18.24	97	36.59
9.	LAD at 60-80 DAT	657.69	480.50	871.93	11.58	13.17	77	20.97
10.	SCMR at 80 DAT	44.94	40.70	50.00	5.01	6.26	64	8.26
11.	SLA at 80 DAT (cm^2/g)	63.19	52.36	75.76	2.17	10.57	04	01
12.	SLW at 80 DAT (g/cm^2)	0.0160	0.0133	0.0191	3.04	9.89	09	1.92
13.	HI	44.36	25.45	68.03	16.16	21.34	57	25.20
14.	RDW (g)	7.08	3.90	12.69	26.51	29.91	79	48.40
15.	SDW (g)	71.51	45.52	101.04	20.55	22.88	81	38.03
16.	RSR	0.10	0.054	0.17	26.27	28.56	85	49.75
17.	GYP (g)	30.34	17.33	42.00	19.35	23.94	65	32.23

DFF- days to 50% flowering, DM- days to maturity, PH- plant height, NEPT- number of effective tillers per plant, PL- panicle length, NFGP- number of filled grains per panicle, NIFGP- number of ill-filled grains per panicle, 1000GW-1000 grain weight, LAD- leaf area duration, SCMR- spad chlorophyll meter reading, SLA- specific leaf area, SLW- specific leaf weight, HI- harvest index, RDW- root dry weight, SDW- shoot dry weight, RSR- root shoot ratio, GYP- grain yield per plant

Tale 4.4. Analysis of variance for combining ability for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

Source of variations	d.f.	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
Replications	1	6.8966	14.5000	2.8558	1.9409	0.0000	0.5800	20.1662	0.1086	1965.064
Treatments	28	99.6761**	85.1909**	34.629**	13.3707**	6.6709*	1347.238**	437.3465**	17.3440**	11063.12**
Parents	8	140.875**	130.306**	20.5339	11.7278**	6.2572	1052.467**	242.9789**	31.7900**	12387.15**
Lines	4	195.400**	180.400**	13.4560	20.6153**	5.8700	861.4260**	321.7960**	4.6481**	17628.50**
Testers	3	104.333**	102.792**	33.5267*	2.1892	5.3000	1125.165**	183.8184**	38.5090**	8451.217**
Lines *vs.* Testers	1	32.4000*	12.4694	9.8671	4.7933	10.6778	1598.5386*	105.1921*	120.2009**	3229.509
Parents *vs.* Hybrids	1	410.431**	339.625**	18.2644	68.8943**	42.963**	1826.193**	201.8335**	55.8233**	72059.98**
Crosses	19	65.9737**	52.8039**	41.417**	11.1401**	4.9349	1446.145**	531.5809**	9.2363**	7295.289**
Line effect	4	105.5625	103.1625*	23.5948	10.6964	11.9691	2275.5684	849.6165	9.2933	3367.333
Tester effect	3	122.5667	78.6250	7.4521	7.0529	0.4974	1379.5112	747.2867	10.7890	27252.29**
Lines x Testers	12	38.6292**	29.5625**	55.849**	12.3098**	3.6995	1186.328**	371.6425**	8.8291**	3615.357*
Error	28	4.5751	4.9643	9.0222	2.0904	2.9125	209.5096	16.3234	0.2346	1601.315
Total	57	51.3321	44.5411	21.4902	7.6290	4.7076	764.7285	223.2091	8.6370	6255.606

Source of variations	d.f.	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
Replications	1	3.2834	22.5938	0.0000013	18.6850	0.7510	162.9944	0.0000	0.0176
Treatments	28	12.5300**	46.5242*	0.0000029*	139.905**	8.1514**	476.834**	0.0017**	85.815**
Parents	8	8.6401**	49.9894*	0.0000030*	162.347**	14.6430**	683.960**	0.0016**	129.69**
Lines	4	4.3410	45.1029	0.0000025	284.178**	24.4004**	839.623**	0.0022**	197.47**
Testers	3	7.9746*	70.4155*	0.0000045*	39.6325	6.2818**	527.209**	0.0008**	52.2248
Lines *vs.* Testers	1	27.8334**	8.2568	0.0000006	43.1601	0.6970	531.563**	0.0016**	91.0329*
Parents *vs.* Hybrids	1	60.2346**	4.6681	0.0000003	383.341**	4.6533*	61.5221	0.0009*	90.9197*
Crosses	19	11.6571**	47.2682*	0.0000030*	117.644**	5.6022**	411.481**	0.0017**	67.068**
Line effect	4	9.1025	123.174*	0.0000080*	92.6387	6.8988	945.8068*	0.0025*	128.2905
Tester effect	3	7.0430	14.6269	0.0000007	171.1717	15.2996*	454.9012	0.0052**	52.4596
Lines x Testers	12	13.6622**	30.1265	0.0000019	112.5975*	2.7457*	222.517**	0.0006**	50.3124*
Error	28	2.6734	21.6410	0.0000012	40.4493	0.9488	45.4476	0.0001	18.5784
Total	57	7.5260	33.8811	0.0000020	88.9231	4.4835	259.4187	0.0009	51.2810

** Significant at 1%   * Significant at 5%

Table 4.5. Estimates of general combining ability (*gca*) effects of lines and testers for different characters in rice (*Oryza sativa* L.)

S.No.	Parents	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
	Lines									
1.	RNR 2465	-3.00**	-3.08**	2.58*	0.72	0.63	-11.48*	-12.68**	0.48*	8.02
2.	JGL 11118	-3.88**	-3.95**	0.25	-1.60**	1.26	7.06	-5.31**	1.55**	30.87*
3.	BPT 5204	2.88**	3.17**	-1.30	1.02	-1.86**	4.13	-3.01*	-0.16	-21.25
4.	Kavya	-0.50	-0.20	-1.82	-0.85	0.52	21.81**	12.24**	-0.59**	-3.39
5.	NLR 3041	4.50**	4.05**	0.28	0.71	0.63	-21.53**	8.76**	-1.28**	-14.25
	SE	0.7562	0.7877	1.0620	0.5112	0.6034	5.1175	1.4284	0.1713	14.1479
	C D at 5%	1.5828	1.6488	2.2227	1.0699	1.2629	10.7110	2.9897	0.3584	29.6119
	Testers									
6.	IR 36	-1.75*	-0.93	-0.40	0.78	-0.54	4.94	0.03	0.21	-42.40**
7.	IR 64	-1.85*	-1.73*	0.54	0.50	0.33	-16.07**	-5.81**	1.36**	-11.68
8.	NLR 34449	-1.65*	-1.52*	0.87	-0.16	-0.06	11.45*	-6.43**	-1.03**	-21.85
9.	NLR 145	5.25**	4.18**	-1.01	-1.11*	-0.16	-0.32	12.21**	-0.53**	75.93**
	SE	0.6764	0.7046	0.9499	0.4572	0.5397	4.5772	1.2776	0.1532	12.6543
	CD at 5%	1.4157	1.4747	1.9881	0.9569	1.1296	9.5802	2.6741	0.3206	26.4857

Table 4.5 (Contd.)

S. No	Parents	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
	Lines								
1.	RNR 2465	0.29	4.62*	-0.00108*	-1.76	-0.41	8.43**	-0.0128**	1.45
2.	JGL 11118	1.66**	2.25	-0.00064	4.38	-1.34**	-1.15	-0.0181**	0.69
3.	BPT 5204	-0.88	-2.14	0.00054	2.32	0.91*	6.95**	0.0007	4.05*
4.	Kavya	-0.11	-5.48**	0.00144**	-4.26	0.81*	4.08	0.0028	0.51
5.	NLR 3041	-0.96	0.75	-0.00026	-0.69	0.03	-18.32**	0.0274**	-6.7**
	SE	0.5781	1.6447	0.00039	2.2486	0.3444	2.3835	0.0042	1.5239
	C D at 5%	1.2099	3.4424	0.00081	4.7063	0.7208	4.9887	0.0087	3.1896
	Testers								
6.	IR 36	0.60	-0.64	0.00012	5.30*	0.02	9.58**	-0.0117**	1.50
7.	IR 64	0.69	-0.74	0.00019	0.24	-0.44	-2.49	-0.0035	1.63
8.	NLR 34449	-0.16	-0.42	0.00009	-0.78	-1.26**	-0.97	-0.0180*	0.17
9.	NLR 145	-1.13*	1.80	-0.00039	-4.76*	1.68**	-6.12**	0.0332**	-3.29*
	SE	0.5171	1.4711	0.00035	2.0112	0.3080	2.1318	0.0037	1.3630
	CD at 5%	1.0822	3.0790	0.00072	4.2095	0.6447	4.4620	0.0078	2.8528

** Significant at 1% level

* Significant at 5% level

Table 4.6. Estimates of specific combining ability (*sca*) effects of hybrids for different characters in rice (*Oryza sativa* L.)

SL. No.	Hybrids, Parents and Checks	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
	Hybrids									
1.	RNR 2465 x IR 36	-3.00	-2.83	0.93	-1.28	0.70	-1.30	10.45**	0.56	-15.92
2.	RNR 2465 x IR 64	0.10	0.47	4.58*	2.54*	0.69	12.61	3.28	-0.31	-10.53
3.	RNR 2465 x NLR 34449	2.90	1.77	3.06	-0.47	-0.52	3.14	1.81	1.36**	44.76
4.	RNR 2465 x NLR 145	0.00	0.57	-8.56**	-0.79	-0.87	-14.44	-15.53**	-1.61**	-18.31
5.	JGL 11118 x IR 36	-0.63	0.55	8.46**	-1.48	1.86	0.76	8.87**	3.17**	13.83
6.	JGL 11118 x IR 64	2.47	1.85	-3.11	0.28	-0.32	7.77	-0.29	-3.11**	-26.68
7.	JGL 11118 x NLR 34449	0.28	-0.35	-2.51	1.57	-1.65	-23.65*	-3.07	-0.53	-61.27*
8.	JGL 11118 x NLR 145	-2.13	-2.05	-2.83	-0.37	0.10	15.12	-5.51	0.48	74.13
9.	BPT 5204 x IR 36	6.63**	6.43**	-6.62**	0.88	-0.56	10.48	-1.93	-1.93**	-3.12*
10.	BPT 5204 x IR 64	-2.28	-2.28	-3.24	-1.11	-1.73	0.10	4.51	-1.18**	-8.18
11.	BPT 5204 x NLR 34449	-4.97**	-4.97**	2.14	-0.35	1.37	-20.62	-2.87	2.20**	-10.07
12.	BPT 5204 x NLR 145	0.63	0.82	7.72**	0.58	0.92	10.04	0.29	0.90*	21.38
13.	Kavya x IR 36	1.00	-0.70	-1.37	-3.27**	-2.30	25.11*	-6.48*	-1.18**	-31.56
14.	Kavya x IR 64	2.10	2.10	1.38	-0.84	1.10	3.32	6.16*	2.23**	44.00
15.	Kavya x NLR 34449	2.90	3.40*	-1.74	2.14*	1.05	0.30	11.48**	-1.40**	9.54
16.	Kavya x NLR 145	-6.00**	-4.80**	1.74	1.97	0.14	-28.73*	-11.16**	0.35	-21.98
17.	NLR 3041 x IR 36	-4.00*	-3.45*	-1.40	5.16**	0.29	-35.05**	-10.90**	-0.63	36.78
18.	NLR 3041 x IR 64	-2.40	-2.15	0.39	-0.87	0.26	-23.79*	-13.67**	2.37**	1.39
19.	NLR 3041 x NLR 34449	-1.10	0.15	-0.94	-2.89*	-0.25	40.84**	-7.35*	-1.63**	17.05
20.	NLR 3041 x NLR 145	7.50**	5.45**	1.94	-1.40	-0.30	18.01	31.92**	-0.12	-55.22
	SE	1.5125	1.5755	2.1239	1.0224	1.2068	10.2350	2.8569	0.3425	28.2959
	CD at 5% LOS	3.1656	3.2975	4.4454	2.1398	2.5258	21.4220	5.9795	0.7169	59.2238

Table 4.6 (Contd.)

SL.No.	Hybrids, Parents and Checks	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
	Hybrids								
1.	RNR 2465 x IR 36	2.34	-2.12	0.00040	-6.92	0.22	-1.22	0.0010	-1.50
2.	RNR 2465 x IR 64	1.50	-0.14	-0.00012	8.16	-0.12	11.87*	-0.0165	7.47*
3.	RNR 2465 x NLR 34449	-3.86**	-4.19	0.00094	5.69	0.26	8.77	-0.0058	2.63
4.	RNR 2465 x NLR 145	0.01	6.44	-0.00122	-6.94	-0.36	-19.41**	0.0213*	-8.61*
5.	JGL 11118 x IR 36	-3.48**	-0.38	0.00016	12.28*	-0.68	11.02*	-0.0152	4.16
6.	JGL 11118 x IR 64	-2.27	-1.47	0.00031	-6.79	-0.08	-9.23	0.0089	-3.89
7.	JGL 11118 x NLR 34449	2.12	2.59	-0.00062	-1.87	0.65	-9.91	0.0196*	-2.21
8.	JGL 11118 x NLR 145	3.64**	-0.75	0.00015	-3.62	0.11	8.12	-0.0132	1.95
9.	BPT 5204 x IR 36	0.10	-3.84	0.00109	-3.76	-1.28	-5.49	-0.0092	2.17
10.	BPT 5204 x IR 64	0.96	3.22	-0.00091	-8.39	1.24	-4.37	0.0232*	-5.79
11.	BPT 5204 x NLR 34449	-1.64	2.97	-0.00074	1.68	-0.39	3.26	-0.0060	-0.17
12.	BPT 5204 x NLR 145	0.57	-2.34	0.00056	10.47*	0.43	6.59	-0.0081	3.79
13.	Kavya x IR 36	1.29	2.95	-0.00084	-3.46	-0.73	-9.50	0.0016	-6.26
14.	Kavya x IR 64	-0.25	-4.31	0.00144	3.09	0.61	7.83	-0.0014	3.75
15.	Kavya x NLR 34449	0.44	0.50	-0.00016	-2.35	0.62	2.13	0.0076	1.67
16.	Kavya x NLR 145	-1.49	0.86	-0.00043	2.71	-0.50	-0.45	-0.0078	0.83
17.	NLR 3041 x IR 36	-0.26	3.39	-0.00081	1.86	2.47**	5.19	0.0218*	1.42
18.	NLR 3041 x IR 64	0.05	2.70	-0.00071	3.92	-1.65*	-6.10	-0.0142	-1.54
19.	NLR 3041 x NLR 34449	2.94*	-1.88	0.00057	-3.16	-1.15	-4.25	-0.0154	-1.92
20.	NLR 3041 x NLR 145	-2.74*	-4.21	0.00095	-2.62	0.33	5.16	0.0078	2.04
	SE	1.1562	3.2895	0.00077	4.4972	0.6888	4.7669	0.0083	3.0478
	CD at 5% LOS	2.4199	6.8849	0.00162	9.4127	1.4416	9.9773	0.0174	6.3791

** Significant at 1% level

* Significant at 5% level

Table 4.7. Estimates of genetic components of variance and proportional contribution of lines, testers and line x tester interactions to total variance for different characters in rice (*Oryza sativa* L.)

Source of variance	DFF	DM	PH (cm)	NETP	PL (cm)	NFGP	NIFGP	1000 GW (g)	LAD at 60-80 DAT
gca	12.1655**	9.5477**	0.7224	0.7538	0.3690*	179.7811*	86.9031*	1.0896	1523.1664**
sca	17.0270**	12.2991**	23.4137**	5.1097**	0.3935	488.4093**	177.6596 **	4.2972**	1007.0209**
2*gca*/2*gca*+*sca*	0.59	0.61	0.06	0.23	0.65	0.42	0.49	0.34	0.75
h^2 (n)	55.75	56.36	4.92	19.67	28.52	37.74	48.33	33.04	62.76
Contribution (%)									
Lines	33.6857	41.1303	11.9933	20.2141	51.0612	33.1272	33.6481	21.1826	9.7174
Testers	29.3339	23.5105	2.8409	9.9964	1.5914	15.0620	22.1966	18.4439	58.9832
Line x Tester	36.9805	35.3592	85.1657	69.7894	47.3474	51.8109	44.1554	60.3734	31.2994

Source of variance	SCMR at 80 DAT	SLA at 80 DAT (cm^2/g)	SLW at 80 DAT (g/cm^2)	HI	RDW (g)	SDW (g)	RSR	GYP (g)
gca	0.5999	5.2511*	0.000021*	10.1618	1.1278**	72.7674**	0.0004**	7.9774*
sca	5.4944**	4.2427	0.000015	36.0741*	0.8984**	88.5348**	0.0002**	15.8670*
2*gca*/2*gca*+*sca*	0.18	0.71	0.73	0.36	0.72	0.62	0.80	0.50
h^2 (n)	14.94	41.07	42.52	26.52	62.16	56.67	74.24	38.80
Contribution (%)								
Lines	16.4390	54.8602	56.262	16.5779	25.9251	48.3904	30.6256	40.2704
Testers	9.5397	4.8860	3.7239	22.9736	43.1207	17.4556	48.2123	12.3503
Line x Tester	74.0213	40.2539	40.014	60.4485	30.9543	34.1540	21.1622	47.3793

** Significant at 1% level   * Significant at 5% level

DFF- days to 50% flowering, DM- days to maturity, PH- plant height, NEPT- number of effective tillers per plant, PL- panicle length, NFGP- number of filled grains per panicle, NIFGP- number of ill-filled grains per panicle, 1000 GW- 1000 grain weight, LAD- leaf area duration, SCMR- spad chlorophyll meter reading, SLA- specific leaf area, SLW- specific leaf weight, HI- harvest index, RDW- root dry weight, SDW- shoot dry weight, RSR- root shoot ratio, GYP- grain yield per plant

Table 4.8. Good general combiners among lines and testers for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S. No.	Traits	Lines					Testers			
		RNR 2465	JGL 11118	BPT 5204	Kavya	NLR 3041	IR 36	IR 64	NLR 34449	NLR 145
1.	DFF	+1	+1	-1	0	-1	+1	+1	+1	-1
2.	DM	+1	+1	-1	0	-1	0	+1	+1	-1
3.	PH (cm)	-1	0	0	0	0	0	0	0	0
4.	NETP	0	-1	0	0	0	0	0	0	-1
5.	PL (cm)	0	0	-1	0	0	0	0	0	0
6.	NFGP	-1	0	0	+1	-1	0	-1	+1	0
7.	NIFGP	+1	+1	+1	-1	-1	0	+1	+1	-1
8.	1000 GW (g)	+1	+1	0	-1	-1	0	+1	-1	-1
9.	LAD at 60-80 DAT	0	+1	0	0	0	-1	0	0	+1
10.	SCMR at 80 DAT	0	+1	0	0	0	0	0	0	-1
11.	SLA at 80DAT (cm^2/g)	-1	0	0	+1	0	0	0	0	0
12.	SLW at 80DAT (g/cm^2)	-1	0	0	+1	0	0	0	0	0
13.	HI	0	0	0	0	0	+1	0	0	-1
14.	RDW (g)	0	-1	+1	+1	0	0	0	-1	+1
15.	SDW (g)	+1	0	+1	0	-1	+1	0	0	-1
16.	RSR	-1	-1	0	0	+1	-1	0	-1	+1
17.	GYP (g)	0	0	+1	0	-1	0	0	0	-1
	Overall score	0	3	1	2	-6	1	3	1	-6
	Rank	4	1	3	2	5	3	1	3	5

+1 indicates significant *gca* in desirable direction
-1 indicates significant *gca* in undesirable direction
0 indicates non significant *gca*

DFF- days to 50% flowering, DM- days to maturity, PH- plant height, NEPT- number of effective tillers per plant, PL- panicle length, NFGP- number of filled grains per panicle, NIFGP- number of ill-filled grains per panicle, 1000 GW-1000grain weight, LAD- leaf area duration, SCMR- spad chlorophyll meter reading, SLA- specific leaf area, SLW- specific leaf weight, HI- harvest index, RDW- root dry weight, SDW- shoot dry weight, RSR- root shoot ratio, GYP- grain yield per plant

Table 4.9. Average heterosis, heterobeltiosis and standard hetrosis for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

Crosses	Days to 50 % flowering				Days to maturity			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	-9.59 **	-12.23**	-9.34 **	-8.84 **	-5.71**	-7.23**	-5.71 **	-4.94*
RNR 2465 x IR 64	-8.06**	-9.04**	-6.04*	-5.52 *	-5.22**	-5.22**	-3.67	-2.88
RNR 2465 x NLR 34449	-5.09*	-5.85*	-2.75	-2.21	-4.02 *	-4.02*	-2.45	-1.65
RNR 2465 x NLR 145	-7.04**	-11.90 **	1.65	2.21	-5.16 **	-9.49 **	1.22	2.06
JGL 11118 x IR 36	-3.72	-5.08*	-7.69**	-7.18 **	-0.42	-2.07	-3.67	-2.88
JGL 11118 x IR 64	-2.25	-5.43*	-4.40	-3.87	-1.66	-4.82*	-3.27	-2.47
JGL 11118 x NLR 34449	-4.76*	-8.11**	-6.59*	-6.08 *	-3.32	-6.43**	-4.90*	-4.12*
JGL 11118 x NLR 145	-6.28 **	-14.76 **	-1.65	-1.10	-4.93**	-12.04 **	-1.63	-0.82
BPT 5204 x IR 36	0.77	-7.55**	7.69 **	8.29 **	1.95	-4.03 *	6.94**	7.82**
BPT 5204 x IR 64	-10.1 **	-16.04 **	-2.20	-1.66	-6.90 **	-10.99 **	-0.82	0.00
BPT 5204 x NLR 34449	-12.85 **	-18.40**	-4.95*	-4.42	-8.81**	-12.82**	-2.86	-2.06
BPT 5204 x NLR 145	-6.16 **	-6.60 **	8.79 **	9.39 **	-4.57**	-4.74**	6.53**	7.41**
Kavya x IR 36	-0.84	-2.20	-2.20	-1.66	-1.63	-3.21	-1.63	-0.82
Kavya x IR 64	-1.64	-2.17	-1.10	-0.55	-1.61	-1.61	0.00	0.82
Kavya x NLR 34449	-0.82	-1.62	0.00	0.55	-0.40	-0.40	1.22	2.06
Kavya x NLR 145	-9.18**	-15.24 **	-2.20	-1.66	-7.07**	-11.31**	-0.82	0.00
NLR 3041 x IR 36	-9.87**	-18.35 **	-2.20	-1.66	-6.15**	-12.54**	-0.41	0.41
NLR 3041 x IR 64	-9.95 **	-16.97**	-0.55	0.00	-7.20**	-12.19**	0.00	0.82
NLR 3041 x NLR 34449	-8.68 **	-15.60 **	1.10	1.66	-5.30**	-10.39**	2.04	2.88
NLR 3041 x NLR 145	0.47	-1.38	18.13 **	18.78 **	-1.63	-2.51	11.02 **	11.93*
Range	-12.85 to 0.77	-18.40 to -1.38	-9.34 to 18.13	-8.84 to 18.78	-8.81 to 1.95	-12.82 to -0.40	-5.71 to 11.02	-4.94 to 11.93

Table 4.9 (Contd.)

Crosses	Plant height (cm)				Number of effective tillers per plant			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	3.30	0.26	16.00**	14.64**	9.52	-10.43	-16.51	30.10*
RNR 2465 x IR 64	10.75**	6.15	22.81 **	21.38**	37.58 **	13.30	5.61	64.56**
RNR 2465 x NLR 34449	11.16**	4.61	21.04**	19.62**	-0.75	-11.26	-17.29	28.88
RNR 2465 x NLR 145	-12.95**	-13.23**	1.04	-0.15	-4.04	-19.79	-25.23*	16.50
JGL 11118 x IR 36	12.53**	11.48**	23.70**	22.25 **	23.64	14.41	-32.21**	5.63
JGL 11118 x IR 64	-0.51	-2.70	7.96	6.70	39.22*	27.79	-22.93*	20.10
JGL 11118 x NLR 34449	2.64	-1.47	9.33*	8.05	30.73*	10.22	-19.03*	26.17
JGL 11118 x NLR 145	-6.71	-8.91*	6.07	4.83	11.47	0.60	-37.01 **	-1.84
BPT 5204 x IR 36	-8.77*	-9.01 *	-0.93	-2.09	52.35**	40.11**	-1.09	54.13**
BPT 5204 x IR 64	-1.59	-2.60	5.48	4.25	29.46*	20.04	-15.26	32.04*
BPT 5204 x NLR 34449	8.31*	5.20	13.93**	12.59**	18.51	16.20	-14.64	33.01*
BPT 5204 x NLR 145	6.26	2.54	19.41**	18.01**	28.02 *	20.79	-14.74	32.86*
Kavya x IR 36	-4.09	-5.54	6.07	4.83	11.81	3.52	-38.66**	-4.42
Kavya x IR 64	2.17	-0.66	11.56*	10.25 *	34.98 *	23.97	-25.23 *	16.50
Kavya x NLR 34449	0.21	-4.35	7.41	6.15	44.04 **	21.50	-10.75	39.08*
Kavya x NLR 145	-4.02	-5.73	9.78*	8.49	45.45 **	31.34 *	-17.76	28.16
NLR 3041 x IR 36	1.75	0.22	9.13	7.86	68.69**	41.64**	23.55*	92.52**
NLR 3041 x IR 64	6.93	6.70	13.19**	11.86*	14.23	-3.39	-15.73	31.31*
NLR 3041 x NLR 34449	7.56	5.75	11.70*	10.40 *	-15.86	-22.50 *	-32.40 **	5.34
NLR 3041 x NLR 145	1.93	-2.80	13.19 **	11.86*	-5.28	-18.64	-29.03 **	10.58
Range	-12.95 to 12.53	-13.23 to 11.48	-0.93 to 23.70	-2.09 to 22.25	-15.86 to 68.69	-22.50 to 41.64	-38.66 to 23.55	-4.42 to 92.52

Table 4.9 (Contd.)

Crosses	Panicle length (cm)				Number of filled grains per panicle			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	10.38	9.86	29.28**	29.28 **	16.36	13.94	43.01 **	44.71**
RNR 2465 x IR 64	11.65	9.00	27.07 **	27.07**	19.34	13.57	36.61 *	38.23**
RNR 2465 x NLR 34449	8.50	2.84	19.89*	19.89*	9.28	-4.15	52.89**	54.70**
RNR 2465 x NLR 145	-2.28	-5.73	18.23	18.23	3.13	1.23	26.42	27.92*
JGL 11118 x IR 36	22.63**	18.31*	39.23**	39.23**	17.43*	7.95	61.59**	63.50**
JGL 11118 x IR 64	13.41	12.56	25.00*	25.00*	15.32	-0.48	48.96**	50.73**
JGL 11118 x NLR 34449	9.56	7.07	17.13	17.13	-5.92	-8.82	45.45**	47.17**
JGL 11118 x NLR 145	8.24	1.32	27.07**	27.07**	23.68**	13.43	69.79 **	71.81**
BPT 5204 x IR 36	2.16	-7.68	8.65	8.65	28.14**	23.10*	67.72**	69.71**
BPT 5204 x IR 64	-2.95	-9.95	0.00	0.00	13.84	2.32	39.40 **	41.06**
BPT 5204 x NLR 34449	16.90	11.64	16.57	16.57	-1.59	-8.76	45.54**	47.26**
BPT 5204 x NLR 145	3.76	-8.81	14.36	14.36	24.52 *	19.32	62.58 **	64.51**
Kavya x IR 36	-2.40	-4.69	12.15	12.15	36.74**	21.21*	96.84**	99.18**
Kavya x IR 64	15.35*	14.78	28.73**	28.73 **	16.77	-2.55	58.25**	60.13**
Kavya x NLR 34449	18.19*	14.11	27.98**	27.98**	12.04	11.05	80.34 **	82.48**
Kavya x NLR 145	3.72	-1.76	23.20*	23.20*	-0.06	-11.60	43.55**	45.26**
NLR 3041 x IR 36	12.24	2.49	20.61*	20.61 *	-28.76**	-37.30**	3.52	4.74
NLR 3041 x IR 64	13.53	6.47	18.23	18.23	-30.80**	-42.63**	-5.28	-4.15
NLR 3041 x NLR 34449	13.97	10.05	14.92	14.92	9.56	7.70	77.82 **	79.93**
NLR 3041 x NLR 145	3.23	-8.37	14.92	14.92	1.12	-11.20	46.62**	48.36**
Range	-2.40 to 22.63	-8.81 to18.31	0.00 to 39.23	0.00 to 39.23	-30.80 to 36.74	-42.63 to 23.10	-5.28 to 96.84	-4.15 to 99.18

Table 4.9 (Contd.)

Crosses	Number of ill-filled grains per panicle				1000 GW (g)			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	36.30*	32.06	206.67**	89.04 **	-13.50**	-23.46**	-11.29 **	-9.81**
RNR 2465 x IR 64	-15.12	-25.51	62.22	0.00	-15.30**	-27.16**	-9.76**	-8.25**
RNR 2465 x NLR 34449	-36.39	-36.55	38.89	-14.38	5.85*	-3.19	-13.65**	-12.21**
RNR 2465 x NLR 145	-51.15**	-62.60**	53.33	-5.48	-30.83**	-40.15 **	-26.93**	-25.71**
JGL 11118 x IR 36	49.44**	40.34*	271.11 **	128.77**	7.33 **	-6.35*	8.55**	10.36**
JGL 11118 x IR 64	-4.66	-22.69	104.44*	26.03	-23.00**	-34.66**	-19.05**	-17.70**
JGL 11118 x NLR 34449	-31.03	-36.97*	66.67	2.74	2.26	-5.07	-18.03**	-16.67**
JGL 11118 x NLR 145	2.80	-15.45	246.67 **	113.70 **	-13.56**	-26.22**	-9.92**	-8.42**
BPT 5204 x IR 36	36.44	19.14	176.67 **	70.55 *	-23.39 **	-37.96**	-28.08**	-26.89**
BPT 5204 x IR 64	67.76 **	63.46*	183.33**	74.66 *	-16.08 **	-33.71 **	-17.87**	-16.50**
BPT 5204 x NLR 34449	-0.85	-11.17	94.44*	19.86	19.93 **	18.20 **	-12.58**	-11.12**
BPT 5204 x NLR 145	49.71**	6.50	336.67 **	169.18 **	-14.25 **	-31.90**	-16.85**	-15.46**
Kavya x IR 36	4.40	-24.74**	295.56 **	143.84 **	-26.72**	-36.45**	-26.34**	-25.11**
Kavya x IR 64	36.55**	-10.36	371.11 **	190.41 **	-6.09*	-20.78**	-1.85	-0.22
Kavya x NLR 34449	40.60**	-0.42	423.33**	222.60**	-17.26**	-22.70 **	-34.18**	-33.09**
Kavya x NLR 145	2.38	-8.88	378.89**	195.21 **	-24.81**	-36.19**	-22.09**	-20.79**
NLR 3041 x IR 36	2.03	-17.07	207.78**	89.73**	-22.65**	-37.12**	-27.12**	-25.90**
NLR 3041 x IR 64	-20.75	-42.81 **	112.22*	30.82	-3.05	-23.15**	-4.78	-3.20
NLR 3041 x NLR 34449	-6.59	-25.75*	175.56 **	69.86*	-16.90**	-17.70**	-39.13**	-38.11**
NLR 3041 x NLR 145	135.28**	124.12 **	818.89**	466.44**	-26.35 **	-41.29 **	-28.33**	-27.13**
Range	-51.15 to 135.28	-62.60 to 124.12	38.89 to 818.89	-14.38 to 466.44	-30.83 to 19.93	-41.29 to -18.20	-39.13 to 8.55	-38.11 to 10.36

Table 4.9 (Contd.)

Crosses	LAD at 60-80 DAT				SCMR at 80 DAT			
	Mid parent heterosis	**Better parent heterosis**	**Standard heterosis (NLR 40024)**	**Standard heterosis (NLR 30491)**	**Mid parent heterosis**	**Better parent heterosis**	**Standard heterosis (NLR 40024)**	**Standard heterosis (NLR 30491)**
RNR 2465 x IR 36	6.75	-0.18	33.34 **	15.49*	10.04 **	7.45	18.62**	15.01**
RNR 2465 x IR 64	23.80 **	21.17**	40.85 **	22.00**	12.06**	11.03 **	16.81**	13.25**
RNR 2465 x NLR 34449	18.04**	8.62	50.24**	30.14 **	-7.37 *	-11.18**	1.81	-1.29
RNR 2465 x NLR 145	22.40 **	11.63	57.47 **	36.39 **	2.51	1.58	8.83*	5.51
JGL 11118 x IR 36	0.55	-5.95	44.29 **	24.98**	2.23	-2.30	7.86	4.57
JGL 11118 x IR 64	7.47	-7.28	42.25 **	23.21 **	8.90*	7.49	11.00 *	7.62
JGL 11118 x NLR 34449	-8.87	-13.35 *	32.93 **	15.14 *	11.12**	4.32	19.59**	15.94**
JGL 11118 x NLR 145	23.25 **	18.28**	81.46 **	57.17**	16.41**	12.87**	20.92 **	17.23**
BPT 5204 x IR 36	6.73	-2.75	29.91 **	12.52	3.75	0.00	10.40 *	7.03
BPT 5204 x IR 64	22.30**	21.51 **	35.25**	17.15*	9.58 **	9.13 *	12.70 **	9.26 *
BPT 5204 x NLR 34449	6.97	-4.04	32.74 **	14.98	-3.84	-8.97*	4.35	1.17
BPT 5204 x NLR 145	27.24 **	13.17 *	59.64**	38.27**	2.48	0.23	7.38	4.10
Kavya x IR 36	-6.04	-7.62	27.71 **	10.62	10.25**	4.27	15.11 **	11.61 **
Kavya x IR 64	20.08**	8.38	49.83 **	29.77**	10.67**	8.08*	11.61**	8.21 *
Kavya x NLR 34449	1.63	1.60	40.54**	21.73 **	4.43	-2.95	11.25*	7.85
Kavya x NLR 145	10.51	9.41	54.33 **	33.67**	1.41	-2.71	4.23	1.06
NLR 3041 x IR 36	14.91*	4.56	39.67 **	20.98**	0.39	-0.99	9.31 *	5.98
NLR 3041 x IR 64	25.61**	24.61 **	38.70**	20.14*	4.71	2.70	10.28 *	6.92
NLR 3041 x NLR 34449	12.85*	1.10	39.84**	21.13**	3.81	0.53	15.24 **	11.72**
NLR 3041 x NLR 145	15.85 *	2.90	45.15**	25.72**	-7.55*	-7.66	-0.85	-3.87
Range	-8.87 to 27.24	-13.35 to 24.61	27.71 to 81.46	10.62 to 57.17	-7.37 to 16.41	-11.18 to 12.87	-0.85 to 20.92	-1.29 to 17.23

Table 4.9 (Contd.)

Crosses	SLA at 80 DAT (cm^2/g)				SLW at 80 DAT (g/cm^2)			
	Mid parent heterosis	**Better parent heterosis**	**Standard heterosis (NLR 40024)**	**Standard heterosis (NLR 30491)**	**Mid parent heterosis**	**Better parent heterosis**	**Standard heterosis (NLR 40024)**	**Standard heterosis (NLR 30491)**
RNR 2465 x IR 36	11.00	10.80	-6.48	7.42	-9.73	-9.90	-0.97	-6.81
RNR 2465 x IR 64	5.29	-2.21	-3.76	10.54	-5.47	-12.20	-3.85	-9.52
RNR 2465 x NLR 34449	8.95	7.64	-9.15	4.35	-7.72	-8.84	2.31	-3.72
RNR 2465 x NLR 145	20.22**	12.09	9.41	25.67 **	-16.62 *	-22.05**	-14.64 *	-19.68**
JGL 11118 x IR 36	-1.05	-10.15	-7.40	6.36	0.35	-8.76	0.29	-5.63
JGL 11118 x IR 64	-9.78	-11.81	-9.11	4.40	10.64	8.31	1.73	-4.27
JGL 11118 x NLR 34449	4.85	-5.68	-2.79	11.66	-5.92	-15.25*	-4.89	-10.49
JGL 11118 x NLR 145	-4.72	-7.24	-4.40	9.80	4.69	1.79	-3.07	-8.78
BPT 5204 x IR 36	-6.45	-9.35	-18.74 *	-6.66	6.71	3.50	13.76	7.05
BPT 5204 x IR 64	-2.88	-7.21	-8.68	4.89	2.81	-1.85	1.39	-4.59
BPT 5204 x NLR 34449	6.30	1.99	-8.58	5.01	-5.47	-9.23	1.87	-4.14
BPT 5204 x NLR 145	-7.11	-10.90	-13.03	-0.11	7.89	3.67	7.09	0.78
Kavya x IR 36	-3.18	-8.30	-13.76	-0.95	2.70	-2.49	7.18	0.86
Kavya x IR 64	-21.41**	-23.16**	-24.38 **	-13.14	26.84 **	23.71**	22.23**	15.02 *
Kavya x NLR 34449	-5.87	-11.71	-16.97 *	-4.63	5.50	-0.81	11.32	4.76
Kavya x NLR 145	-9.46	-11.12	-13.24	-0.35	9.82	7.83	6.54	0.25
NLR 3041 x IR 36	9.02	4.44	-4.12	10.13	-8.52	-12.21	-3.51	-9.20
NLR 3041 x IR 64	-0.39	-3.73	-5.26	8.82	0.11	-3.42	-2.40	-8.16
NLR 3041 x NLR 34449	1.73	-3.49	-11.41	1.76	-1.39	-6.31	5.15	-1.05
NLR 3041 x NLR 145	-6.62	-9.40	-11.57	1.58	6.50	3.43	4.52	-1.65
Range	-21.41 to 20.22	-23.16 to 12.09	-24.38 to 9.41	-13.14 to 25.67	-16.62 to 26.84	-22.05 to 23.71	-14.64 to 22.23	-19.68 to 15.02

Table 4.9 (Contd.)

Crosses	Harvest index				Root dry weight (g)			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	-3.75	-5.43	-20.24	19.18	-34.58 **	-46.22**	10.35	39.43
RNR 2465 x IR 64	30.49*	16.78	-1.50	47.17*	-36.33 **	-52.52**	-2.59	23.08
RNR 2465 x NLR 34449	9.90	9.06	-8.02	37.44*	-38.95 **	-55.91 **	-9.54	14.30
RNR 2465 x NLR 145	-27.86*	-28.00	-39.05**	-8.92	-28.72 **	-37.71**	27.81	61.49 **
JGL 11118 x IR 36	49.87 **	44.06**	27.12*	89.95**	-44.86**	-49.72 **	-19.32	1.94
JGL 11118 x IR 64	5.94	-7.04	-17.97	22.57	-36.51 **	-48.31 **	-17.06	4.80
JGL 11118 x NLR 34449	4.28	1.22	-10.68	33.46	-35.11 **	-49.12 **	-18.35	3.17
JGL 11118 x NLR 145	-9.06	-10.91	-21.38	17.48	-23.41*	-25.09*	20.21	51.89 *
BPT 5204 x IR 36	41.36 *	14.62	-6.70	39.41*	-8.10	-18.78	7.36	35.65
BPT 5204 x IR 64	28.26	12.85	-24.82	12.33	39.09**	38.65*	40.66 *	77.73**
BPT 5204 x NLR 34449	37.82 *	10.89	-7.89	37.62*	4.99	-0.32	1.13	27.78
BPT 5204 x NLR 145	49.48**	19.41	1.09	51.05**	26.93 *	5.43	61.76 **	104.39**
Kavya x IR 36	26.49	0.21	-18.43	21.88	17.60	-13.15	14.79	45.05*
Kavya x IR 64	47.71 *	26.59	-15.67	26.01	57.28 **	27.83	28.86	62.82 **
Kavya x NLR 34449	10.66	-12.98	-27.72*	8.00	50.31 *	27.13	15.93	46.48 *
Kavya x NLR 145	12.39	-12.23	-25.69*	11.03	34.20*	-5.32	45.27**	83.55**
NLR 3041 x IR 36	11.43	3.56	-1.83	46.68*	33.10*	16.33	53.76**	94.28 **
NLR 3041 x IR 64	14.70	-2.35	-7.43	38.32*	-20.24	-21.01	-20.37	0.61
NLR 3041 x NLR 34449	-12.91	-18.30	-22.55	15.72	-21.48	-24.53	-25.38	-5.72
NLR 3041 x NLR 145	-20.86	-25.09	-28.99 *	6.10	15.67	-4.90	45.92**	84.37 **
Range	-27.86 to 49.87	-28.00 to 44.06	-39.05 to 27.12	-8.92 to 89.95	-44.86 to 57.28	-55.91 to 38.65	-25.38 to 61.76	-5.72 to 104.39

Table 4.9 (Contd.)

Crosses	Shoot dry weight (g)				Root shoot ratio			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	9.47	-8.71	50.11 **	76.10**	-40.44**	-41.41**	-27.06 *	-21.15
RNR 2465 x IR 64	9.19	-7.69	51.78 **	78.07**	-39.68**	-48.64**	-36.06**	-30.88 *
RNR 2465 x NLR 34449	3.99	-9.29	49.16**	74.99**	-39.41**	-51.62**	-39.77 **	-34.89 *
RNR 2465 x NLR 145	-43.73**	-44.38 **	-6.37	9.84	25.72*	9.23	35.98**	47.00 **
JGL 11118 x IR 36	46.71 **	40.74 **	54.55**	81.31**	-62.73**	-67.25**	-47.90**	-43.68**
JGL 11118 x IR 64	-6.10	-11.35	0.69	18.13	-32.45**	-47.64**	-16.71	-9.96
JGL 11118 x NLR 34449	-8.57	-16.62	2.09	19.77**	-31.75 **	-49.93 **	-20.36	-13.90
JGL 11118 x NLR 145	-8.21	-26.60 **	23.55 *	44.95**	-22.37*	-38.78**	-2.61	5.28
BPT 5204 x IR 36	39.96**	27.99*	40.54**	64.88**	-34.27 **	-36.81 **	-23.89 *	-17.72
BPT 5204 x IR 64	19.53	7.66	22.28	43.46**	16.15	3.80	15.37	24.72
BPT 5204 x NLR 34449	28.87**	12.34	37.54**	61.36**	-21.17	-34.23**	-26.90 *	-20.98
BPT 5204 x NLR 145	3.72	-20.10 **	34.50 **	57.79**	18.78	8.46	20.55	30.32 *
Kavya x IR 36	39.04 **	17.53	29.07*	51.42**	-12.95	-26.45*	-11.40	-4.22
Kavya x IR 64	45.51**	21.33*	37.82**	61.69**	9.64	6.88	-6.47	1.11
Kavya x NLR 34449	31.99 **	6.88	30.86*	53.52**	12.16	6.23	-11.72	-4.57
Kavya x NLR 145	-3.37	-29.92**	17.98	38.41**	40.51**	33.83 *	22.90	32.86*
NLR 3041 x IR 36	1.39	-2.70	16.22	36.35*	30.13 **	9.52	31.92*	42.61 **
NLR 3041 x IR 64	-33.66**	-35.29**	-22.71	-9.32	23.64	19.95	4.97	13.48
NLR 3041 x NLR 34449	-31.44 **	-32.28 **	-17.09	-2.73	14.69	9.13	-10.20	-2.92
NLR 3041 x NLR 145	-37.44 **	-46.53 **	-9.99	5.60	85.87**	76.21**	61.82**	74.94**
Range	-43.73 to 46.71	-46.53 to 40.74	-22.71 to 54.55	-9.32 to 81.31	-62.73 to 85.87	-67.25 to 76.21	-47.90 to 61.82	-43.68 to 74.94

Table 4.9 (Contd.)

Crosses	Grain yield (g)			
	Mid parent heterosis	Better parent heterosis	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
RNR 2465 x IR 36	-3.71	-18.09	1.23	61.83**
RNR 2465 x IR 64	20.01	4.57	29.23*	106.59**
RNR 2465 x NLR 34449	4.44	-11.12	9.85	75.60**
RNR 2465 x NLR 145	-46.84**	-47.72 **	-35.38 *	3.30
JGL 11118 x IR 36	52.20 **	34.19*	16.31	85.93**
JGL 11118 x IR 64	16.40	0.15	-8.08	46.95*
JGL 11118 x NLR 34449	21.13	6.74	-7.38	48.06*
JGL 11118 x NLR 145	2.10	-20.69	-5.23	51.50*
BPT 5204 x IR 36	61.51 **	39.05*	20.52	92.67**
BPT 5204 x IR 64	24.93	5.05	-3.58	54.13*
BPT 5204 x NLR 34449	46.29**	25.89	9.23	74.62**
BPT 5204 x NLR 145	21.68	-7.30	10.77	77.08**
Kavya x IR 36	19.56	-3.44	-16.31	33.79
Kavya x IR 64	58.33**	25.16	14.88	83.64**
Kavya x NLR 34449	48.47 **	19.86	4.00	66.26**
Kavya x NLR 145	5.05	-24.04*	-9.23	45.11*
NLR 3041 x IR 36	-11.48	-19.43	-14.88	36.08
NLR 3041 x IR 64	-22.59	-27.67 *	-23.58	22.16
NLR 3041 x NLR 34449	-26.44 *	-33.01*	-29.23 *	13.13
NLR 3041 x NLR 145	-35.77**	-39.49 **	-27.69	15.59
Range	-46.84 to 61.51	-47.72 to 39.05	-35.38 to 29.23	3.30 to 106.59

** Significant at 1% level

* Significant at 5% level

Table 4.10. The best cross combinations identified for yield, yield components and physiological traits in rice (*Oryza sativa* L.) based on *per se* performance, *sca* effect and heterosis.

S.No.	Traits	Cross combination	*Per se* performance	*sca* effect	Standard heterosis (NLR 40024)	Standard heterosis (NLR 30491)
1.	**DFF**	BPT-5204 x NLR-34449	86.50	-4.97**	-4.95*	-
2.	**NETP**	RNR-2465 x IR-64	18.95	2.54*	-	64.56**
3.	**PL (cm)**	NLR-3041 x IR-36 Kavya x IR-36	19.83 28.30	5.16 25.11**	3.55** 96.84**	92.52** 99.18*
4.	**NFGP**	NLR -3041 x NLR-34449	197.20	40.84**	77.82**	99.93**
5.	**1000 GW (g)**	JGL-1118 x IR-36	20.19	3.17**	8.55**	10.36**
7.	**SCMR at 80 DAT**	JGL-11118 x NLR-145 NLR-3041 x NLR-34449	50.10 47.65	36.4** 2.94*	20.92** 15.24**	17.23** 17.23**
9.	**SLW at 80 DAT (g/cm^2)**	RNR-2465 x IR-64	0.0198	0.003*	-	20.70*
10.	**HI**	JGL-11118 x IR-36	68.03	12.28*	27.12*	89.95**
11.	**RDW (g)**	NLR-3041 x IR-36	9.51	2.47*	53.76**	94.28**
12.	**SDW (g)**	RNR-2465 x IR-64 JGL-11118 x IR-36	91.10 92.76	11.87* 11.02*	51.78** 54.55**	78.07** 81.31**
13.	**RSR**	RNR-2465 x NLR-145 NLR-3041 x IR-36	0.14 0.14	0.02* 0.022*	35.98** 31.92*	47.00** 42.60**
14.	**Grain yield per plant (g)**	RNR-2465 x IR-64	42.00	7.47*	29.25*	106.59**

** Significant at 1% level   * Significant at 5% level

Table 4.11. Genotypic correlations among yield, yield components and physiological traits in rice (*Oryza sativa* L.)

Character	DM	PH	NETP	PL	NFGP	NIFGP	1000GW	LAD 60-80 DAT	SCMR 80 DAT	SLA 80 DAT	SLW 80 DAT	HI	RDW	SDW	RSR	GYP
DFF	0.9922**	-0.1588	-0.0386	-0.6001**	0.0520	0.3881**	-0.1755	-0.2847*	-0.4433**	-0.3758**	0.2649*	-0.2784*	0.2434	-0.0937	0.3117*	**-0.0491**
DM	**1.0000**	-0.1593	-0.0067	-0.5341**	0.0769	0.3924**	-0.1603	-0.2879*	-0.4300**	-0.4760**	0.3422**	-0.2405	0.2048	-0.0527	0.2374	**-0.0015**
PH		**1.0000**	0.0354	0.8740**	0.1670	0.2152	0.2844*	0.3800**	-0.1501	0.5742**	-0.6020**	0.5749**	0.1410	0.5843**	-0.2458	**0.5218****
NETP			**1.0000**	0.1885	-0.2112	-0.1948	-0.3162*	-0.2096	0.1722	0.0059	0.1100	0.4549**	0.1222	0.2692*	-0.0892	**0.4314****
PL				**1.0000**	0.2010	0.3248**	0.2640*	0.7675**	0.4989**	0.0737	-0.1654	0.5897**	0.1197	0.7015**	-0.3631**	**0.7120****
NFGP					**1.0000**	0.4658**	-0.5353**	0.4431**	0.4503**	-0.4686**	0.9230**	0.0215	-0.1218	0.2402	-0.3048*	**0.1678**
NIFGP						**1.0000**	-0.2171	0.3458**	-0.2029	-0.5751**	0.6326**	-0.1605	0.2912*	-0.0035	0.3368**	**-0.0772**
1000GW							**1.0000**	-0.1606	-0.1667	0.5990**	-0.3518	0.2418	0.0329	0.2802*	-0.1760	**0.3087***
LAD 60-80 DAT								**1.0000**	0.3761**	0.2262	-0.2649*	0.0945	0.2003	0.0933	0.1950	**-0.0019**
SCMR 80 DAT									**1.0000**	0.0967	-0.1808	0.2167	-0.2159	0.2707*	-0.4525**	**0.3147***
SLA 80 DAT										**1.0000**	-0.9290**	0.1191	-0.0192	-0.4603**	0.5762**	**-0.7135****
SLW 80 DAT											**1.0000**	-0.0177	0.0557	0.2962**	-0.3387**	**0.5764****
HI												**1.0000**	0.0235	0.5225**	-0.2967*	**0.6353****
RDW													**1.0000**	0.3641**	0.6920**	**0.2131**
SDW														**1.0000**	-0.3973**	**0.9279****
RSR															**1.0000**	**-0.4894****

** Significant at 1% level * Significant at 5% level

Table 4.12. Direct and indirect effects (genotypic) of different traits on grain yield per plant in rice (*Oryza sativa* L.)

Characters	DFF	DM	PH	NETP	PL	NFGP	NIFGP	1000 GW	LAD	SCMR	SLA	SLW	HI	RDW	SDW	RSR
DFF	**1.2285**	1.2189	-0.1951	-0.0475	-0.7372	0.0639	0.4768	-0.2157	-0.3497	-0.5446	-0.4617	0.3254	-0.3421	0.2990	-0.1152	0.3829
DM	-1.1090	**-1.1177**	0.1781	0.0075	0.5969	-0.0860	-0.4386	0.1792	0.3218	0.4806	0.5320	-0.3824	0.2688	-0.2289	0.0589	-0.2654
PH	-0.0320	-0.0321	**0.2017**	0.0071	0.1763	0.0337	0.0434	0.0574	0.0767	-0.0303	0.1158	-0.1214	0.1160	0.0284	0.1178	-0.0496
NETP	-0.0279	-0.0048	0.0256	**0.7231**	0.1363	-0.1527	-0.1408	-0.2287	-0.1515	0.1245	0.0043	0.0795	0.3289	0.0884	0.1947	-0.0645
PL	0.1271	0.1131	-0.1851	-0.0399	**-0.2118**	-0.0426	-0.0688	-0.0559	-0.1626	-0.1057	-0.0156	0.0350	-0.1249	-0.0254	-0.1486	0.0769
NFGP	0.0256	0.0379	0.0823	-0.1041	0.0991	**0.4927**	0.2295	-0.2638	0.2183	0.2219	-0.7237	0.4548	0.0106	-0.0600	0.1184	-0.1502
NIFGP	0.0370	0.0374	0.0205	-0.0185	0.0309	0.0444	**0.0952**	-0.0207	0.0329	-0.0193	-0.1007	0.0602	-0.0153	0.0277	-0.0003	0.0321
1000 GW	-0.1234	-0.1127	0.1999	-0.2223	0.1856	-0.3763	-0.1526	**0.7030**	-0.1129	-0.1172	0.4211	-0.2473	0.1700	0.0231	0.1970	-0.1237
LAD	-0.0499	-0.0504	0.0666	-0.0367	0.1345	0.0776	0.0606	-0.0281	**0.1752**	0.0659	0.0396	-0.0464	0.0166	0.0351	0.0163	0.0342
SCMR	-0.0402	-0.0390	-0.0136	0.0156	0.0453	0.0409	-0.0184	-0.0151	0.0341	**0.0907**	0.0088	-0.0164	0.0197	-0.0196	0.0246	-0.0411
SLA	-0.1636	-0.2072	0.2500	0.0026	0.0321	-0.6394	-0.4604	0.2608	0.0985	0.0421	**0.4354**	-0.4045	0.0519	-0.0084	-0.2004	0.2509
SLW	0.1516	0.1958	-0.3444	0.0629	-0.0946	0.5281	0.3619	-0.2013	-0.1515	-0.1034	-0.5315	**0.5722**	-0.0101	0.0319	0.1695	-0.1938
HI	0.0437	0.0378	-0.0903	-0.0714	-0.0926	-0.0034	0.0252	-0.0380	-0.0148	-0.0340	-0.0187	0.0028	**-0.1570**	-0.0037	-0.0820	0.0466
RDW	0.0619	0.0521	0.0359	0.0311	0.0305	-0.0310	0.0741	0.0084	0.0510	-0.0549	-0.0049	0.0142	0.0060	**0.2545**	0.0926	0.1761
SDW	-0.0274	-0.0154	0.1707	0.0786	0.2049	0.0702	-0.0010	0.0818	0.0273	0.0791	-0.1344	0.0865	0.1526	0.1063	**0.2921**	-0.1160
RSR	-0.1511	-0.1151	0.1191	0.0432	0.1760	0.1478	-0.1633	0.0853	-0.0945	0.2194	-0.2793	0.1642	0.1438	-0.3354	0.1926	**-0.4848**
Correlate d with GYP	**-0.0491**	**-0.0015**	**0.5218****	**0.4314****	**0.7120****	**0.1678**	**-0.0772**	**0.3087***	**-0.0019**	**0.3147***	**-0.7135****	**0.5764****	**0.6353****	**0.2131**	**0.9279****	**-0.4894****

** Significant at 1% level

* Significant at 5% level