

**GENETIC DIVERGENCE IN ELITE LINES
FOR YIELD AND QUALITY ATTRIBUTES
IN RICE**

(*Oryza sativa* L.)

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B.Sc. (Ag)

**MASTER OF SCIENCE IN AGRICULTURE
(GENETICS AND PLANT BREEDING)**



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(Oryza satvia L.)

BY

ASHOK KUMAR MEENA

B.Sc. (Ag.)

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DECLARATION

I, **Mr. ASHOK KUMAR MEENA**, hereby declare that the thesis entitled **“GENETIC DIVERGENCE IN ELITE LINES FOR YIELD AND QUALITY ATTRIBUTES IN RICE (*Oryza sativa* L.)”** submitted to the **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of the original research work done by me. I also declare that no material contained in this thesis has been published earlier in any manner.

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CERTIFICATE

Mr. ASHOK KUMAR MEENA has satisfactorily prosecuted the course of research and that the thesis entitled “**GENETIC DIVERGENCE IN ELITE LINES FOR YIELD AND QUALITY 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 his for a degree of any University.

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CERTIFICATE

This is to certify that the thesis entitled “**GENETIC DIVERGENCE IN ELITE LINES FOR YIELD AND QUALITY ATTRIBUTES IN RICE (*Oryza sativa* L.)**” submitted in partial fulfilment of requirements for the degree of ‘Master of Science in Agriculture’ of the Acharya N. G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Mr. ASHOK KUMAR MEENA** 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 investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	per cent
σ^2_p	Phenotypic variance
σ^2_g	Genotypic variance
ANOVA	Analysis of variance
cm	Centimeter
CD	Critical difference
D ²	Genetic distance
<i>et al.</i>	and others
Fig.	Figure
g	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
h ²	heritability in broad sense
ha	hectare
i.e.,	that is
KLAC	kernel length after cooking
L/B ratio	Length/Breadth ratio
m.ha	million hectare
mm	millimeter
m.t	million tonnes
No.	Number
PCV	Phenotypic coefficient of variation
SE	Standard error
<i>viz.</i>	namely

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ABSTRACT

In the present investigation, thirty eight genotypes of rice were evaluated to study the genetic diversity present in the experimental material for selection of the diverse parents, to estimate the genetic parameters among the genotypes for yield and quality traits, and the extent of association between the yield and its component characters including the direct and indirect effects. The experiment was laid out in a randomized block design with two replications at rice section farm, Agricultural Research Institute, Rajendranagar, Hyderabad during *kharif* 2013.

Analysis of variance indicated high significant differences among the genotypes for all the traits under study. A perusal of genetic parameters revealed that phenotypic and genotypic coefficients of variation were high for thousand grain weight, followed by grain yield per plant, number of productive tillers per plant number of filled grains per panicle, head rice recovery and plant height.

The genetic divergence was high and the thirty eight genotypes of rice were grouped into 10 divergent clusters. Cluster I was the largest comprising of twenty nine genotypes and all other clusters II, III, IV, V, VI, VII, VIII, IX and X were represented by single genotype indicating high degree of heterogeneity among the genotypes. The pattern of group constellations indicated significant variability among the genotypes.

The thousand grain weight, kernel length, grain yield per plant, plant height, L/B ratio contributed 85.34 per cent towards total divergence. Therefore, these characters should be given importance during hybridization and selection of segregating populations.

The cluster VIII is having highest mean value for grain yield per plant and thousand grain weight, cluster VII for number of filled grains per panicle and cluster X is having highest number of productive tillers per plant, head rice recovery, kernel breadth and cluster VI for hulling percentage, high milling percentage and cluster III having highest plant height, panicle length, II having highest kernel length and cluster IV having high L/B ratio. The genotypes RNR 19371, RNR 19420, MTU 1010, MTU 1001 and RNR 19368 from these clusters having high mean values may be directly used for adaptation or may be used as parents in future hybridization programme.

Character association studies revealed that the grain yield per plant showed significant positive association with days to 50 per cent flowering, number of productive tillers per plant, number of filled grains per panicle, kernel length, kernel breadth and positive association with thousand grain weight. This indicated that simultaneous selection of all these characters was important for yield improvement.

Path analysis revealed that numbers of productive tillers per plant, number of filled grains per panicle, kernel breadth, kernel L/B ratio and thousand grain weight are the most important characters which could be used as selection criteria for effective improvement on grain yield.

Therefore, it is suggested that preference should be given to these characters in the selection programme to isolate superior lines with genetic potentiality for higher yield in rice genotypes

Chapter I

INTRODUCTION

Rice (*Oryza sativa*) is the premier food crop in India occupying nearly 44.41 million hectares area with annual production of 104.32 million tonnes and productivity of 2239 kg ha⁻¹. While, in Andhra Pradesh it is grown in an area of 40 lakh hectares with production of 128.8 lakh tonnes and productivity of 3050 kg ha⁻¹ (Indiastat 2011-12).

To meet the demands of growing population and to achieve food security in the country the present production levels need to be increased by two million tonnes every year. It is estimated that 120 million tonnes of rice required to feed the increasing population by 2020.

There are two distinct types of domesticated rice, *Oryza sativa*, or Asian rice and *Oryza glaberrima*, African rice. The genus *Oryza* contains 21 wild relatives of the domesticated rices. The genus is divided into four species complexes: the *O. sativa*, *O. officinalis*, *O. ridleyi* and *O. granulata* species complexes. All members of the *Oryza* genus have $n = 12$ chromosome and while inter-specific crossing is possible within each complex, it is difficult to recover fertile offspring from crosses across complexes. *Oryza sativa* is distributed globally with a high concentration in Asia (Vaughan *et al.*, 2003).

Yield is the most noticeable characteristic to farmers while the crop is in the ground, but when the product of the crop, the milled rice, reaches the market, quality becomes the key determinant of its sale-ability. Thus breeders are mandated to develop germplasm of high quality that suits the particular needs of the market being targeted. There are several defined classes of rice, based on the physical appearance of the milled rice, the cooking properties and the aroma of the rice. The traits of grain quality are common to every market, but the metric of the trait is not. For example, the trait of texture is common to all markets, but the metric, softness to hardness, depends on the market. Thus quality evaluation programs should go hand-in-hand with breeding programs, and all quality evaluation programs should have the capacity to measure at least the basic traits.

Grain quality of rice is getting prominence in breeding programmes in the countries, which are self-sufficient in their production. Preferences for milling characteristics, grain size and shape, appearance and cooking quality characters like kernel elongation. In India, consumers usually prefer long slender grain. At present the plant breeder should focus their attention towards the quality rice, added with high yield potential.

Before starting any pragmatic breeding programme, the knowledge of variability and genetic diversity is a basic pre-requisite for improving the character. Similarly, the additional information regarding the genetic parameter genotypic coefficient of variation, phenotypic coefficient of variation, heritability in broad sense (h^2), expected genetic advance as per cent mean helps in selecting a proper breeding methodology improvement.

Study of genetic diversity helps in not only knowing the variability available in the population, but also knowing the genetic distance genotypes and among the group of genotypes, which helps in selecting parents for hybridization in developing potential rice varieties.

Genetic diversity in a crop species is essential to sustain high level of productivity. The importance of information about the extent and magnitude of genetic divergence in rice and its utilization for the selection of desirable parents/donors either for exploitation of hybrid vigor or to get desirable recombinants has been stressed by many workers (Anand and Murthy, 1968). Arunachalam (1981) reported that the greater chance of getting heterotic hybrids and enhanced variation in the segregating population of varietal improvement programmes mainly depended on genetic divergence. Germplasm is the core of any breeding work. The variability and novel characters existing in the germplasm can be exploited during crossing programme to develop need based varieties and hybrids. Before using the germplasm it has to be characterized and also the genetic diversity has to be studied to use effectively in the crossing programme.

A thorough knowledge of nature and magnitude of genetic variability and association of characters in a crop species is a pre-requisite for a successful breeding programme. Information on direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process.

In addition to the above information, quantification of degree of divergence in a given experimental material is of immense value in identification of divergent genotypes for further use in hybridization to create new variability. Mahalanobis D^2 statistic has proved to be a powerful tool for quantifying genetic divergence in a given population. Divergent genotypes could be obtained by collection from different eco-geographical regions or it could be induced by combination breeding.

As such in the present rice growing situation, keeping in view of the importance of human nutritional requirement, equal emphasis need to be given for grain quality and nutritional value in developing the potential rice varieties beside higher yield.

So the direction of present investigation is focus at developing high yielding rice varieties with good quality with underlying motto of adding quality to the noble slogan i.e., "food for all" quality food for all. In the light of above, the present investigation is carried out with following objectives.

- 1) To estimate the extent of genetic diversity for yield and grain quality characters.
- 2) To study the variability of yield and grain quality characters.
- 3) To study the character association among yield and quality components.
- 4) To study the direct and indirect effects of yield components on yield.

Chapter II

REVIEW OF LITERATURE

The pertinent literature is cited here in the following sections as per the objectives of the experiment.

2.1 To estimate the extent of genetic diversity for yield and grain quality characters

2.2 To study the variability of yield and grain quality characters

2.3 To study the character association among yield and quality components

2.4 To study the direct and indirect effects of yield components on yield

2.1 To estimate the extent of genetic diversity for yield and grain quality characters

Genetic improvement in any crop mainly depends upon the amount of genetic variability present in the population. The expression “divergence in character” was used by Darwin (1859) for the variation in genera and species. Another term “morphism” was used by Huxley (1955) for genetic diversity implying “genetic polymorphism” which means the coexistence of distant genetic forms in population.

Murthy and Arunachalam (1966) emphasized the importance of genetic diversity in selection of parents for hybridization in different crops and reported that the greatest contributing characters to genetic diversity in grain crops were flowering time, plant height and tiller number per plant.

Sharma and Roy (1993) raised seventeen diverse genotypes of upland rice grouped into 5 clusters on the basis of D^2 analysis of data on eleven characters. Inter and Intra cluster distances are given and their use in the selection of parents for breeding programmes is mentioned.

Shanthi *et al.* (2001) evaluated genetic divergence for yield and its components in 17 induced mutants including one non-mutant mother variety of Mahsuri rice, for six quantitative characters (plant height, number of tillers per plant, panicle length, number of grains per panicle, thousand seed weight, and grain yield per plant). The genotypes differed significantly for six characters considered collectively and were grouped into four clusters.

Nayak *et al.* (2004) studied nature and magnitude of genetic divergence among two hundred genotypes of scented rice including one non-scented check using Mahalanobis D^2 statistics for 10 quantitative characters. On the basis of D^2 values, the genotypes were grouped into 10 clusters. Grain length and days to 50 per cent flowering played important role in the formation of clusters.

Bose and Pradhan (2005) assessed the nature and magnitude of genetic divergence among thirty five deep water rice genotypes and grouped them into 10 clusters showing fair degree of relationship between geographic distribution and genetic divergence. Traits such as plant yield, days to 50 per cent flowering, and plant height were the major contributors to genetic divergence.

Chand *et al.* (2005) studied nineteen genotypes of Aman rice for their genetic divergence by using Mahalanobis D^2 statistics and grouped them into six clusters. Cluster I was the largest with eight genotypes followed by cluster II with four genotypes. The maximum inter-cluster distance was found between these groups.

Suman *et al.* (2005) evaluated one hundred fourteen rice genotypes for 16 quantitative characters to quantify the genetic diversity existing among them using Mahalanobis D^2 statistics. The genotypes fell into 10 clusters. Cluster X had the maximum number of spikelets per panicle, panicle length, filled grains per panicle, plant yield and biological yield. Cluster III exhibited the lowest means for plant height, days to 50 percent flowering, panicle length, The genotypes from clusters III and X, which had high and low cluster means for majority of the characters, were recommended as parents for hybridization.

Vaithiyalingan (2005) twenty nine strains of rice collected from different geographical regions of world were studied to analyze the extent of genetic divergence. The genotypes were grouped into four clusters. The clustering pattern was independent of the geographical distribution, cluster II included twenty three genotypes and those can be useful in hybridization to create a wide spectrum of variability. Maximum distance (97.34) was observed between clusters III and IV. Plant height, single plant yield and thousand-seed weight were found to be important contributors to genetic divergence.

Devi *et al.* (2006) evaluated genetic diversity in fifty four rice cultivars for yield and yield components. The genotypes were grouped into 9 clusters. Cluster VI recorded high mean values for plant height (140.33 cm), flag leaf length (48.11 cm) and

flag leaf width (2.10 cm). Plant height contributed the most to genetic divergence (40.16%), followed by flag leaf width (20.12%) and yield per plant (15.79%).

Naik *et al.* (2006) a genetic divergence study was conducted to estimate the nature and magnitude of diversity in fifty aromatic rice accessions including five scented improved varieties. The D^2 analysis indicated the presence of appreciable amount of genetic diversity in the material. The genotypes were grouped into 7 clusters. The cluster VI had the highest mean grain yield per plant and for biological yield per plant. Inter cluster distance was recorded highest between cluster III and cluster IV. The least distance was recorded in between cluster I and cluster V.

Sankar *et al.* (2006) assessed the genetic divergence among forty six rice genotypes and grouped them into seven clusters. cluster IV showed highest inter-cluster distance from cluster VI which was immediately followed by cluster III and cluster VII. Highest intra-cluster distance was observed in cluster V and lowest in cluster I. The desirable yield and its contributing traits were distributed mainly in cluster III followed by cluster VII and Cluster I. The genotypes within cluster III, VII and I may be used as parents in hybridization programme to develop high yielding line.

Chandra *et al.* (2007) assessed genetic divergence among forty nine genotypes of non-scented rice including three checks, for seven quantitative characters. The significant varietal difference was observed for all the characters studied on the basis of D^2 values. The genotypes were grouped into eight clusters. Characters like kernel length, kernel breadth, days to 50 percent flowering and plant height had more contribution to total divergence.

Sandhya kishore *et al.* (2007) studied genetic divergence for different yield attributing traits in 70 rice genotypes. The analysis of variance revealed significant differences among the genotypes for each character. The genotypes were grouped into nine different clusters. The mode of distribution of genotypes from different eco-regions into various clusters was at random indicating that geographical diversity and genetic diversity were not related.

Sarawgi and Bisne (2007) studied genetic divergence among eighty one scented rice. Based on D^2 statistics genotypes were grouped into nine clusters The genotypes from cluster II having desired mean for characters like hulling percent, milling percent and head rice recovery and panicle length; cluster VII having high value for kernel length and Kernel L/B ratio and cluster V low value for days to 50 per cent flowering but highest value for grain yield kilogram per hectare.

Kumar and Ramesh (2008) estimated genetic divergence in thirty genetically diverse genotypes of rice by using Mahalanobis D^2 statistic and grouped them into eight clusters. The inter-cluster distance was highest between clusters V and VI. This indicates that the genotypes could be used in hybridization programme and are likely to exhibit high heterosis and possibility of throwing transgressive segregants in subsequent generations.

Ramya and Senthil Kumar (2008) carried out an investigation with fifty genotypes for studying genetic diversity and these genotypes formed into eleven clusters. Number of grains per panicle, number of productive tillers per plant and grain yield per plant showed high per cent contribution towards genetic divergence.

Raut *et al.* (2009) grouped forty rice genotypes into 3 clusters by using Mahalanobis D^2 statistic. Investigation revealed the independence of the genetic diversity from the eco geographic distribution of the genotypes. Length to breadth ratio of grain followed by number of grains per panicle, length of grain and seed yield per plant exhibited the greater contribution to the genetic divergence among genotypes.

Rouf *et al.* (2009) used D^2 analysis to measure the genetic distance in seventy five genotypes and grouped them into 11 clusters. Cluster VI, IX and X among themselves showed greater genetic separation. Though Cluster II and Cluster I had more strength which would help in achieving high genetic gain.

Sabesan *et al.* (2009) studied the genetic diversity in rice genotypes by using Mahalanobis D^2 statistic and grouped them into 13 clusters. The maximum inter cluster distance ($D^2 = 8235.56$) was recorded between clusters II and III. Cluster XII recorded highest mean value for grain yield per plant and lowest mean value for days to first flower. Number of grains per panicle (42.71%) followed by days to first flower (25.62%) contributed maximum to total divergence.

Shahidullah *et al.* (2009) assessed the genetic divergence in forty aromatic rices for grain quality and nutrition aspects. In multivariate analysis, genotypes were grouped into six clusters. The inter-cluster D^2 value was maximum (26.53) between I and VI followed by 21.28 (between I and V). Majority of the local aromatic rice varieties with smaller kernels were included in the cluster I. The cluster III contains Elai, sarwati and sugandha-1 with long-slender kernel and 'very good' appearance. Thus, these varieties can be used in breeding programme for improvement of germplasm.

Banumathy *et al.* (2010) were evaluated 53 rice genotypes for yield and yield attributing characters using D^2 analysis, based on the analysis the genotype were grouped into 11 clusters. Among the eight traits studied, grain yield, days to 50 per cent flowering, total grains per panicle and plant height together contribute 86.62 percent towards total divergence. Therefore, these characters may be given importance during hybridization programme.

Baradhan and Thangavel (2010) Mahalanobis D^2 statistics was used to study the nature and magnitude of genetic diversity among forty five genotypes of rice. The genotypes were grouped into six clusters. It is suggested that varietal improvement through hybridization, should be done among the genotypes more of divergent clusters.

Dushyantha Kumar *et al.* (2010) evaluated thirty nine rice genotypes using Mahalanobis D^2 statistic. On the basis of genetic distance, these genotypes were grouped into eight clusters. Based on high mean performance of the traits studied, may be used as parents in future breeding programme to achieve desirable segregants for tall plant stature, number of panicles per plant, panicle length and high grain yield

Hosan *et al.* (2010) were evaluated twenty rice landraces to assess the nature and magnitude of genetic divergence among them. Based on twelve characters, the genotypes were grouped into five clusters. Number of filled grains per panicle, number of panicles per plant and grain yield contributed considerably towards total divergence.

Nibedita Mohanty *et al.* (2010) were evaluated forty rice genotypes using Mahalanobis's D^2 analysis. The forty rice genotypes were grouped into five clusters. The pattern of distribution of genotypes from different eco-geographical regions into various clusters was at random indicating that geographical diversity and genetic diversity were not related. The characters viz. leaf area at 90 DAS, number of grains per panicle and days to 50 per cent flowering contributed maximum towards genetic divergence among the genotypes.

Reddy *et al.* (2010) estimated the genetic divergence in fifty rice genotypes and grouped into 11 clusters. Cluster IV was emerged as largest cluster with 12 genotypes. The highest inter-cluster distance was observed between clusters VIII and XI. The genotypes UPR-1840, PAU-3042-3-3-4, UPR-2554-9-1 and NDR-2062 were identified as genetically diverse parents. These genotypes may be used further as parents in hybridization programme.

Ubarhande *et al.* (2010) evaluated Forty four indica rice cultivars for sixteen quantitative traits to examine the nature and magnitude of variability and genetic divergence. On the basis of D^2 analysis Forty four rice genotypes were grouped into nine clusters and three ungrouped clusters.

Chaturvedi *et al.* (2011) assessed the nature and magnitude of genetic divergence in thirty five rice genotypes by using Mahalanobis D^2 and grouped them into eight clusters. The panicle weight followed by effective tillers per plant and yield per plant contributed maximum towards divergence. The genotypes belonging to cluster VII could be utilized as diverse parent in hybridization program with the genotypes of clusters II and VIII respectively, to achieve greater variability in the segregating generations.

Mall *et al.* (2011) studied the grain quality characteristics of twenty four drought promising genotypes were evaluated under irrigated and drought conditions for studying variability and genetic divergence. Genotypes were grouped into seven clusters, where cluster I was the largest and contained 18 genotypes while, rest of the clusters contained single genotypes. Based on clustering pattern and per se performance five genotypes were identified, which may be used in breeding programme to obtain improved genotypes with desirable attributes for stress environments.

Narendra Pratap *et al.* (2011) were assessed the genetic divergence in hundred four genotypes of rice comprising aromatic as well as non-aromatic germplasm lines by using Non-hierarchical Euclidean cluster analysis. The hundred four genotypes were grouped into 11 distinct clusters. Clustering pattern of genotypes showed lack of any relationship between geographic origin and genetic diversity. The crossing between superior genotypes of above diverse cluster pairs may provide desirable transgressive segregants for developing high yielding varieties of aromatic and non-aromatic rice is recommended.

Parikh *et al.* (2011) evaluated the Seventy-one rice accessions to study the diversity pattern among the genotypes. The genotypes were grouped into eight clusters. The mode of distribution of genotypes from different geographic regions into various clusters was at random, indicating no association between geographical distribution of genotypes and genetic divergence. The inter cluster distance in most of the cases was higher than the intra-cluster distance, indicating wider genetic diversity among the accessions of different groups.

Sharma *et al.* (2011) studied the genetic divergence using D^2 statistic in sixty three rice genotypes and grouped them into 8 different clusters, in which, cluster VII was the largest having 16 genotypes. Based on mean performance, genetic distances and clustering pattern, the genotypes; Pusa Basmati-1 and Taraori Basmati of cluster II, Sarju-52, Narendra Usar-3 and Narendra-80 of cluster IV, Badshah Bhog, MTU-7029 and BPT-5204 of cluster VI and Malviya-36, Kanakjeer and Super Basmati of cluster VIII proved to be promising for use in hybridization programme.

Vennila *et al.* (2011) evaluated forty one rice genotypes to identify diverse genotype for nine yield and yield attributing characters using Mahalanobis D^2 statistics. Forty one genotypes were grouped under thirteen different clusters. The characters like number of grains per panicle, plant height, grain length and grain breadth contributed maximum towards genetic diversity. Hence these characters could be given due importance for selection of genotypes for further crop improvement programme.

Yadav *et al.* (2011) were evaluated nine genotypes for genetic divergence among them based on nine characters grouped and arranged in to 3 non-overlapping clusters by Mahalanobis (1936) D^2 statistics. On the basis of analysis result of genetic divergence and mean performance of four diverse and superior genotypes viz., CSR-27, CSR-36, CSR-839-3 and USAR-3 being exceptionally better for one or more traits and reasonable for other, as compared to checks were selected.

Ovung *et al.* (2012) estimated the nature and magnitude of genetic divergence in seventy rice genotypes using Mahalanobis D^2 statistics by considering 13 quantitative characters. High estimates of GCV and PCV were observed for grain yield per hill followed by tillers per hill and harvest index. High heritability coupled with high genetic advance was recorded for spikelet's per panicle.

Chakravorty *et al.* (2013) analyzed the diversity of phenotypic traits of the landraces of rice. The analysis of variance found significant variability in eighteen quantitative traits used in distance analysis. All the traits except ligule length, culm length, number of grains panicle-1 and number of primary branches panicle-1 exhibited positive and significant correlation coefficients with kernel weight.

Rashid *et al.* (2013) studied twenty diverse cultivars of rice for variation and correlation. Highly significant differences were presented among the genotypes for all the traits. Among the traits days to heading, days to maturity, number of productive tillers, thousand grain weight showed highly significant positive correlation with grain yield per plant.

2.2 To study the variability of yield and grain quality characters

Variability refers to the presence of differences among the individuals of plant population. Variability results due to differences either in the genetic constitution of the individuals of a population or in the environment in which they have grown. The existence of variability is essential for resistance to biotic and abiotic factors as well as for wider adoptability. Variance is the amount of variation present among the member of a population.

Fisher (1918) partitioned the total phenotypic variance into genotypic variance and environmental variance. He further divided the genotypic variance in to additive, dominance and epistatic effects.

However, it is only the genetic variation which is heritable. Selection is also effective when there is significant amount of generic variability among the individuals in a population. Hence insight into the magnitude of generic variability present in a population is of paramount importance to plant breeder for starting a breeding programme in any crop including rice. The quantitative measurement of individual character provides the basis for an interpretation of analysis of variance.

The nature and extent of variability forms the basis for all crop improvement programme. According to Allard (1960), yield is polygenically controlled quantitative character and is highly influenced by environment. Partitioning of observed variability into heritable and non-heritable components is very much essential to get a true indication of the genetic coefficient of variability.

A brief review of studies on genotypic and phenotypic coefficients of variation in rice is presented hereunder in tabular form.

S.No.	Character	Range	Reference
1.	Days to 50 per cent flowering	High	Awasthi and Pandey (2000) Rita Bisne <i>et al.</i> (2009) Mulugeta Seyoum <i>et al.</i> (2012).
		Low	Patil <i>et al.</i> (2003) Sinha <i>et al.</i> (2004) Vijayalakshmi <i>et al.</i> (2008) Manoj Kumar Prajapati (2011).

S.No.	Character	Range	Reference
2.	Plant height (cm)	High	Sinha <i>et al.</i> (2004) Akhtar <i>et al.</i> (2011) Selvaraj <i>et al.</i> (2011) Mulugeta Seyoum <i>et al.</i> (2012)
		Moderate	Tara Satyavathi <i>et al.</i> (2001) Nayak <i>et al.</i> (2002) Krishna <i>et al.</i> (2008).
		Low	Chikkalingaiah <i>et al.</i> (1999) Patil <i>et al.</i> (2003) Kole and Hasib (2008)
3.	Number of productive tillers per plant	High	Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Selvaraj <i>et al.</i> (2011) Pratap <i>et al.</i> (2012)
		Moderate	Vange and Ojo (1997) Nagajyothi (2001) Krishna <i>et al.</i> (2008)
		Low	Niranjana Murthy <i>et al.</i> (1999) Tara Satyavathi <i>et al.</i> (2001) Surender Raju (2002) Pankaj Garg <i>et al.</i> (2010).
4.	Panicle length (cm)	High	Tripathi <i>et al.</i> (1999) Nayudu <i>et al.</i> (2007)
		Low	Tara Satyavathi <i>et al.</i> (2001) Patil <i>et al.</i> (2003) Kole and Hasib (2008) Manoj kumar prajapate (2011)
		High	Nayudu <i>et al.</i> (2007) Pankaj Garg <i>et al.</i> (2010) Mulugeta seyoun <i>et al.</i> (2012)

S.No.	Character	Range	Reference
5.	Number of filled grains per panicle.		Pratap <i>et al.</i> (2012)
		Moderate	Tara Satyavathi <i>et al.</i> (2001) Kole and Hasib (2008) Sanghera <i>et al.</i> (2013)
		Low	Nath and Talukdar (1997)
6.	Thousand grain weight (g)	High	Nayudu <i>et al.</i> (2007) Chandra <i>et al.</i> (2007) Mulugeta seyoum <i>et al.</i> (2012)
		Low	Chikkalingaiah <i>et al.</i> (1999) Vange <i>et al.</i> (1999) Tara Satyavathi <i>et al.</i> (2001)
7.	Grain yield per plant (g)	High	Pankaj Garg <i>et al.</i> (2010) Selvaraj <i>et al.</i> (2011) Mulugeta seyoum <i>et al.</i> (2012) Sanghera <i>et al.</i> (2013)
		Moderate	Chauhan <i>et al.</i> (1993) Pradyumna Rao <i>et al.</i> (1996) Nagajyothi (2001) Tara Satyavathi <i>et al.</i> (2001)
		Low	Supriyo Chakraborty and Hazarika (1994)
8.	Hulling percentage	Moderate	Nayak <i>et al.</i> (2003)
		Low	Nagajyothi (2001) Madhavi Latha (2002) Surender Raju (2002)
9.	Milling percentage	High	Chikkalingaiah <i>et al.</i> (1999)
		Low	Nagajyothi (2001) Chaudhary and Motiramani (2003)

S.No.	Character	Range	Reference
10.	Head rice recovery	High	Asish <i>et al.</i> (2010)
		Moderate	Nayak <i>et al.</i> (2003)
		Low	Chaudhary and Motiramani (2003) Patil <i>et al.</i> (2003)
11.	Kernel length (mm)	High	Sarawgi <i>et al.</i> (2000) Roy <i>et al.</i> (1995)
		Moderate	Chaudhary and Motiramani (2003) Nayak <i>et al.</i> (2003) Asish <i>et al.</i> (2010)
		Low	De and Suriya Rao (1988) Reddy and De (1996) Umadevi <i>et al.</i> (2009)
12.	Kernel breadth (mm)	High	Pathak and Sharma (1996)
		Moderate	Vivekanandan and Giridharan (1998)
		Low	Chauhan <i>et al.</i> (1991) Reddy and De (1996) Chikkalingaiah <i>et al.</i> (1999)
13.	Kernel L/B ratio	High	Sarawgi <i>et al.</i> (2000) Madhavi Latha (2002) Saxena <i>et al.</i> (2005)
		Moderate	Nayak <i>et al.</i> (2002) Vanaja <i>et al.</i> (2003) Asish <i>et al.</i> (2010) Sanghera <i>et al.</i> (2013)
		Low	Ramesh Kumar (1989) Chikkalingaiah <i>et al.</i> (1999) Tara Satyavathi <i>et al.</i> (2001)

2.1.2 Heritability

Heritability in broad sense refers to the genetic variation present in the population in relation to the total observed variance. Consistency in the performance of selection in succeeding generations depends on the magnitude of heritable variation present in relation to observed variation. Basic information on heritability is a prerequisite for planning any breeding programme. High heritability indicates that it should be easy to conduct effective selection for the traits

A brief review of studies on heritability in rice is presented hereunder in tabular form.

S.No.	Character	Range	Reference
1.	Days to 50 per cent flowering	High	Nayak <i>et al.</i> (2002) Sankar <i>et al.</i> (2006) Bharadwaj <i>et al.</i> (2007) Kishore <i>et al.</i> (2008) Idris <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013)
		Medium	Chauhan <i>et al.</i> (1993) Sahdev Singh <i>et al.</i> (1996) Singh and Choudhary (1985)
2.	Plant height (cm)	High	Akhtar <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011) Selvaraj <i>et al.</i> (2011) Mulugeta seyoum <i>et al.</i> (2012) Sanghera <i>et al.</i> (2013)
		Moderate	Akinwale <i>et al.</i> (2011)
		Low	Vijayalakshmi <i>et al.</i> (2008) Idris <i>et al.</i> (2013)
3.	Number of productive tillers per plant	High	Anbanandan <i>et al.</i> (2009) Nandan <i>et al.</i> (2010) Selvaraj <i>et al.</i> (2011) Pratap <i>et al.</i> (2012)

S.No.	Character	Range	Reference
			Idris <i>et al.</i> (2013)
		Moderate	Venkata Suresh (2001)
		Low	Ramesh Kumar (1989) Niranjana Murthy <i>et al.</i> (1999)
4.	Panicle length (cm)	High	Nayak <i>et al.</i> (2002) Nayudu <i>et al.</i> (2007) Mohan and Devendra (2011) Idris <i>et al.</i> (2013)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Venkata Suresh (2001)
		Low	Singh and Chaudhary (1996)
5.	Number of filled grains per panicle.	High	Sankar <i>et al.</i> (2006) Nayudu <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Pankaj Garg <i>et al.</i> (2010) Pratap <i>et al.</i> (2012) Idris <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Mulugeta <i>et al.</i> (2012)
6.	Thousand grain weight (g)	High	Bharadwaj <i>et al.</i> (2007) Nandan and Sweta Singh (2010) Abdul Fiyaz <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012) Idris <i>et al.</i> (2013)
		Moderate	Ramesh kumar (1989)

S.No.	Character	Range	Reference
7.	Grain yield per plant (g)	High	Nayudu <i>et al.</i> (2007) Anbanandan <i>et al.</i> (2009) Pankaj Garg <i>et al.</i> (2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1999)
		Low	Bharadwaj <i>et al.</i> (2007) Idris <i>et al.</i> (2013)
8.	Hulling percentage	High	Nayak <i>et al.</i> (2003) Madhavi latha <i>et al.</i> (2005)
		Moderate	Chikkalingaiah <i>et al.</i> (1999)
		Low	Nagajyothi (2001)
9.	Milling percentage	High	Chikkalingaiah <i>et al.</i> (1999) Nayak <i>et al.</i> (2003)
		Moderate	Nagajyothi. (2001)
10.	Head rice recovery	High	Nayak <i>et al.</i> (2003) Patil. <i>et al.</i> (2003)
11.	Kernel length (mm)	High	Madhavi Latha (2002) Surender Raju (2002)
12.	Kernel breadth (mm)	High	Venkata Suresh (2001) Madhavi Latha (2002) Surender Raju (2002) Chaudhary and Sarawgi (2004)
13.	Kernel L/B ratio	High	Nayak <i>et al.</i> (2003) Bharadwaj <i>et al.</i> (2007) Nandan and Sweta Singh (2010) Mohan and Devendra (2011)
		Moderate	Sahdev Singh <i>et al.</i> (1996) Chikkalingaiah <i>et al.</i> (1999)

2.1.3 Genetic advance as per cent of mean

Genetic advance refers to the improvement in the mean genotypic value of the selected plants over the base population. Johnson *et al.* (1955) reported that though the heritable estimates give useful indication of relative values of selection based on phenotypic expression, the genetic gain should also be considered to arrive at a more reliable conclusion

A brief review of studies on genetic advance as per cent of mean in rice is presented here under in tabular form.

S.No.	Character	Range	Reference
1.	Days to 50 per cent flowering	High	Sankar <i>et al.</i> (2006) Bharadwaj <i>et al.</i> (2007) Kishore <i>et al.</i> (2008)
		Medium	Marimuthu <i>et al.</i> (1990) Rao and Shrivastav (1994) Mulugeta seyoun <i>et al.</i> (2012)
		Low	Suman (2003) Madhavi Latha <i>et al.</i> (2005) Krishna <i>et al.</i> (2008) Vijayalakshmi <i>et al.</i> (2008)
2.	Plant height	High	Kishore <i>et al.</i> (2008) Kumar and Ramesh (2008) Mohan and Devendra (2011) Selvaraj <i>et al.</i> (2011)
		Moderate	Marimuthu <i>et al.</i> (1990) Patil <i>et al.</i> (2003) Sinha <i>et al.</i> (2004)
		Low	Vijayalakshmi <i>et al.</i> (2008)
3.	Number of productive tillers per plant	High	Suman (2003) Sankar <i>et al.</i> (2006) Nayudu <i>et al.</i> (2007) Anbanandan <i>et al.</i> (2009) Nandan and Sweta Singh. (2010)

S.No.	Character	Range	Reference
			Selvaraj <i>et al</i> (2011) Pratap <i>et al.</i> (2012)
		Moderate	Venkata Suresh (2001) Patra <i>et al.</i> (2006)
		Low	Sahdev Singh <i>et al.</i> (1996) Niranjana Murthy <i>et al.</i> (1999)
4.	Panicle length (cm)	High	Chikkalingaiah <i>et al.</i> (1999) Nayak <i>et al.</i> (2002) Nayudu <i>et al.</i> (2007) Mohan lal and Devendra (2011)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Venkata Suresh (2001) Patra <i>et al.</i> (2006)
		Low	Borbora and Hazarika (1998) Mokate <i>et al.</i> (1998) Nagajyothi (2001) Suman (2003)
5.	Number of filled grains per panicle.	High	Patil <i>et al.</i> (2003) Suman (2003) Sankar <i>et al.</i> (2006) Nayudu <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Pankaj Garg <i>et al.</i> (2010) Pratap <i>et al.</i> (2012)
		Moderate	Satya Priya Lalitha and Sreedhar (1996)
6.	Thousand grain weight (g)	High	Bharadwaj <i>et al.</i> (2007) Karad and Pol (2008) Anbanandan <i>et al.</i> (2009)

S.No.	Character	Range	Reference
			Nandan and Sweta Singh (2010) Abdul Fiyaz <i>et al.</i> (2011)
		Moderate	Reddy and De (1996) Reddy <i>et al.</i> (1997) Sinha <i>et al.</i> (2004) Mulugeta seyoun <i>et al.</i> (2012)
		Low	Chikkalingaiah <i>et al.</i> (1999) Nagajyothi (2001) Suman (2003) Vijayalakshmi <i>et al.</i> (2008)
7.	Grain yield per plant (g)	High	Madhavi Latha (2002) Sankar <i>et al.</i> (2006) Nayudu <i>et al.</i> (2007) Kumar and Ramesh (2008) Anbanandan <i>et al.</i> (2009) Pankaj Garg <i>et al.</i> (2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1999) Patra <i>et al.</i> (2006)
		Low	Ramesh Kumar (1989) Suman (2003) Sinha <i>et al.</i> (2004)
8.	Hulling percentage	High	Singh <i>et al.</i> (1998)
		Moderate	Chikkalingaiah <i>et al.</i> (1999) Nayak <i>et al.</i> (2003)
		Low	Nagajyothi (2001) Surender Raju (2002) Madhavi Latha <i>et al.</i> (2005)
9.	Milling percentage	High	Chikkalingaiah <i>et al.</i> (1999)
		Moderate	Nayak <i>et al.</i> (2003)

S.No.	Character	Range	Reference
		Low	Nagajyothi (2001)
10.	Head rice recovery	High	Nayak <i>et al.</i> (2003)
		Low	Patil <i>et al.</i> (2003)
11.	Kernel length (mm)	Moderate	Sarawgi <i>et al.</i> (2000) Bharadwaj <i>et al.</i> (2007) Krishna <i>et al.</i> (2008)
		Low	Venkata Suresh (2001) Surender Raju (2002) Nayak <i>et al.</i> (2003)
12.	Kernel breadth (mm)	High	Nayak <i>et al.</i> (2002)
		Moderate	Vivekanandan and Giridharan (1998) Sarawgi <i>et al.</i> (2000)
		Low	Venkata Suresh (2001) Madhavi Latha (2002) Chaudhary and Sarawgi (2004)
13.	Kernel L/B ratio	High	Nayak <i>et al.</i> (2003) Bharadwaj <i>et al.</i> (2007) Nandan and Sweta Singh (2010) Mohan and Devendra (2011)
		Moderate	Satya Priya Lalitha and Sreedhar (1999) Nayak <i>et al.</i> (2003) Patil <i>et al.</i> (2003) Krishna <i>et al.</i> (2008).
		Low	Venkata Suresh (2001) Madhavi Latha (2002) Madhavi Latha <i>et al.</i> (2005) Vijayalakshmi <i>et al.</i> (2008)

2.3 To study the character association among yield and quality components

Yield of paddy is a complex quantitative character controlled by many genes interacting with the environment and is the product of many factors called yield components. Selection of parents based on yield alone often misleading. Hence, the knowledge about relationship between yield and its contributing characters is needed for an efficient selection strategy for the plant breeders to evolve an economic variety. The information about phenotypic and genotypic interactions of various economic traits is the immense importance to a plant breeder for the selection and breeding of different genotypes with increasing yield potential.

A brief review of studies on the association of characters in rice is presented here under:

2.3.1 Association of yield component characters with grain yield per plant in rice

Character	Nature of association	Reference
Days to 50 per cent flowering	Positive significant	Suman (2003) Kuldeep <i>et al.</i> (2004) Sankar <i>et al.</i> (2006) Krishna <i>et al.</i> (2008) Abdul Fiyaz <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
	Positive non-significant	Rao and Shrivastav (1999) Madhavi Latha <i>et al.</i> (2005) Satish Chandra <i>et al.</i> (2009) Nandan and Sweta Singh (2010)
	Negative significant	Eradasappa <i>et al.</i> (2007) Pankaj Garge <i>et al.</i> (2010) Ravindra Babu <i>et al.</i> (2011) Augustina <i>et al.</i> (2013)
		Yolanda and Vijendra Das (1995) Meenakshi <i>et al.</i> (1999)

Character	Nature of association	Reference
	Negative non-significant	Muluget <i>et al.</i> (2012)
Plant height (cm)	Positive significant	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Abdul Fiyaz <i>et al.</i> (2011)
	Positive non-significant	Suman (2003) Madhavi Latha <i>et al.</i> (2005) Karad and Pol (2008) Nandan and Sweta Singh (2010)
	Negative significant	Rao and Shrivastava (1999) Tara Satyavathi <i>et al.</i> (2001) Mahto <i>et al.</i> (2003) Rashid <i>et al.</i> (2013)
	Negative non-significant	Gupta <i>et al.</i> (1998) Meenakshi <i>et al.</i> (1999) Satish Chandra <i>et al.</i> (2009) Muluget seyoum <i>et al.</i> (2012)
No. of productive tillers per plant	Positive significant	Suman (2003) Sankar <i>et al.</i> (2006) Abdul Fiyaz <i>et al.</i> (2011) Kiani and Nematzadeh (2012) Ravindra Babu <i>et al.</i> (2011) Nagaraju <i>et al.</i> (2013) Rashid <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013)
	Positive non-significant	Reddy <i>et al.</i> (1997) Madhavi Latha <i>et al.</i> (2005) Muluget seyoum <i>et al.</i> (2012)
	Negative non-significant	Haque <i>et al.</i> (1991)

Character	Nature of association	Reference
Panicle length (cm)	Positive significant	Madhavi Latha (2002) Sankar <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011) Nagaraju <i>et al.</i> (2013)
	Positive non-significant	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha <i>et al.</i> (2005) Krishna <i>et al.</i> (2008) Muluget seyoum <i>et al.</i> (2012)
	Negative non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999)
Number of filled grains per panicle	Positive significant	Sankar <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Satish Chandra <i>et al.</i> (2009) Pankaj Garg <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Kiani and Nematzadeh (2012) Zulqarnain <i>et al.</i> (2012) Nagaraju <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013)
	Positive non-significant	Madhavi Latha <i>et al.</i> (2005) Nandan and Sweta Singh (2010) Akinwale <i>et al.</i> (2011) Rashid <i>et al.</i> (2013)
Hulling percentage	Positive non-significant	Roy <i>et al.</i> (1995) Madhavi Latha (2002)
Milling percentage	Positive significant	Nagaraju <i>et al.</i> (2013)
	Positive significant	Mareker and Siddiqui (1996) Nagaraju <i>et al.</i> (2013)

Character	Nature of association	Reference
Kernel length (mm)	Positive non-significant	Ganesan <i>et al.</i> (1997) Reddy <i>et al.</i> (1997) Madhavi Latha (2002)
	Negative significant	Krishna <i>et al.</i> (2008)
	Negative non-significant	Geeta <i>et al.</i> (1994) Asha Christopher <i>et al.</i> (1999)
Kernel L/B ratio	Positive significant	Marekar and Siddiqui (1996) Tara Satyavathi <i>et al.</i> (2001) Pankaj Garge <i>et al.</i> (2010)
	Positive non-significant	Ramesh Babu (1999) Madhavi Latha (2002)
	Negative significant	Sakthivel (2001) Krishna <i>et al.</i> (2008)
	Negative non-significant	Asha Christopher <i>et al.</i> (1999) Satya Priya Lalitha and Sreedhar (1999)
Thousand grain weight (g)	Positive significant	Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Zulqarnain <i>et al.</i> (2012) Rashid <i>et al.</i> (2013)
	Positive non-significant	Gupta <i>et al.</i> (1998) Vange <i>et al.</i> (1999) Madhavi Latha <i>et al.</i> (2005)
	Negative non-significant	Suman (2003)
	Negative non-significant	Wilfred Manuel and Rangaswamy (1993) Geeta <i>et al.</i> (1994) Muluget seyounm <i>et al.</i> (2012)

2.3.2 Association among the yield component traits in rice, association of days to 50 per cent flowering with

Character	Nature of association	Reference
Plant height (cm)	Positive significant	Kavitha and Sree Rama Reddi (2001) Sakthivel (2001) Madhavi Latha (2002) Ravindra Babu <i>et al</i> (2011)
	Positive non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999)
	Negative significant	Satish Chandra <i>et al.</i> (2009)
	Negative non-significant	Debchoudhury and Das (1998) Rao and Shrivastav (1999) Nandan <i>et al</i> (2010)
Number of Productive tillers per plant	Positive significant	Sawant <i>et al.</i> (1995) Sakthivel (2001)
	Positive non-significant	Kavitha and Sree Rama Reddy (2001) Surender Raju (2002) Satish Chandra <i>et al.</i> (2009)
	Negative non-significant	Yolanda and Vijendra Das (1995)
	Negative and significant	Meenakshi <i>et al.</i> (1999) Ravindra Babu <i>et al.</i> (2011)
Panicle length (cm)	Positive significant	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
	Positive non-significant	Sarma and Roy (1993) Sawant <i>et al.</i> (1995) Kavitha and Sree Rama Reddi (2001)
	Negative non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999) Nandan <i>et al.</i> (2010)
Number of filled Grains per panicle	Positive significant.	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Mulugeta seyoun <i>et al.</i> (2012)

Character	Nature of association	Reference
	Positive non-significant	Vange <i>et al.</i> (1999) Satish Chandra <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)
	Negative non-significant	Sawant <i>et al.</i> (1995) Meenakshi <i>et al.</i> (1999)
Hulling percentage	Positive significant	Roy <i>et al.</i> (1995)
Kernel length (mm)	Negative significant	Ramesh Babu (1999) Nayak <i>et al.</i> (2001)
	Negative non-significant	Nandan <i>et al.</i> (2010)
Kernel breadth (mm)	Negative non-significant	Nandan <i>et al.</i> (2010)
Kernel L/B ratio	Positive significant	Deosarkar <i>et al.</i> (1989) Madhavi Latha (2002)
	Negative non-significant	Kavitha and Sree Rama Reddy(2001)
Thousand grain weight (g)	Positive significant	Ravindranath <i>et al.</i> (1982) Yadav <i>et al.</i> (2011)
	Positive non-significant	Roy <i>et al.</i> (1995)
	Negative significant	Ramesh Babu (1999) Kavitha and Sree Rama Reddy (2001) Nayak <i>et al.</i> (2001) Sakthivel (2001)
	Negative non-significant	Vange <i>et al.</i> (1999) Satish Chandra <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)

2.3.3 Association among the yield component traits in rice, association of plant height with

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Janardhanam <i>et al.</i> (2001) Kavitha and Sree Rama Reddy (2001) Surender Raju (2002) Satish Chandra <i>et al.</i> (2009)
	Positive Non-significant	Roy <i>et al.</i> (1995) Yolanda and Vijendra Das (1995) Pradyumna Rao <i>et al.</i> (1996)
	Negative significant	Meenakshi <i>et al.</i> (1999) Nayak <i>et al.</i> (2001)
Panicle length (cm)	Positive significant	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002) Sinha <i>et al.</i> (2004) Satish Chandra <i>et al.</i> (2009)
	Positive non-significant	Chaubey and Singh (1994) Yolanda and Vijendra Das (1995) Reddy <i>et al.</i> (1997) Rao and Shrivastav (1999)
Number of Grains per panicle	Positive significant	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009)
	Positive non-significant	Geeta <i>et al.</i> (1994) Meenakshi <i>et al.</i> (1999) Kavitha and Sree Rama Reddy (2001) Abdus salman khan <i>et al.</i> (2009)
	Negative significant	Debchoudhury and Das (1998) Surender Raju (2002)
	Negative non-significant	Chauhan <i>et al.</i> (1993) Sawant <i>et al.</i> (1995) Reddy <i>et al.</i> (1997)
Hulling percentage	Negative non-significant	Roy <i>et al.</i> (1995) Nandan <i>et al.</i> (2010)

Character	Nature of association	Reference
Kernel length	Positive non-significant	Ramesh Babu (1999)
	Negative significant	Nayak <i>et al.</i> (2001)
	Negative non-significant	De and Suriya Rao (1988) Geeta <i>et al.</i> (1994) Reddy <i>et al.</i> (1997) Nandan <i>et al.</i> (2010)
Thousand grain Weight (g)	Positive significant	Reddy <i>et al.</i> (1997) Suman (2003) Yogameenakshi <i>et al.</i> (2004)
	Positive non-significant	Ramesh Babu (1999) Satish Chandra <i>et al.</i> (2009)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative non-significant	Roy <i>et al.</i> (1995) Meenakshi <i>et al.</i> (1999) Nayak <i>et al.</i> (2001)

2.3.4 Association among the yield component traits in rice association of number of productive tillers per plant with

Character	Nature of association	Reference
Panicle length (cm)	Positive significant	Janardhanam <i>et al.</i> (2001) Sakthivel (2001) Padmaja <i>et al.</i> (2011)
	Positive non-significant	Yolanda and Vijendra Das (1996) Kavitha and Sree Rama Reddy (2001) Satish Chandra <i>et al.</i> (2009)
	Negative significant	Chaubey and Richharia (1993) Tara Satyavathi <i>et al.</i> (2001) Suman (2003)
	Negative non-significant	Reddy <i>et al.</i> (1997) Abdus salman kahan <i>et al.</i> (2009)
Plant height (cm)	Positive significant	Meenakshi <i>et al.</i> (1999) Janardhanam <i>et al.</i> (2001)

Character	Nature of association	Reference
		Sakthivel (2001)
Number of filled grains per panicle	Positive non-significant	Yolanda and Vijendra Dos (1995) Satya Priya Lalitha and Sreedhar (1996) Abdus salman kahan <i>et al.</i> (2009)
	Negative significant	Chaubey and Richharia (1993)
	Negative non-significant	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Tara Satyavathi <i>etal.</i> (2001) Satish Chandra <i>et al.</i> (2009)
Hulling percentage	Positive non-significant	Roy <i>et al.</i> (1995)
Kernel length (mm)	Positive significant	Hussain <i>et al.</i> (1989) Chauhan <i>et al.</i> (1994)
	Positive non-significant	Geeta <i>et al.</i> (1994)
	Negative significant	Ramesh Babu (1999)
	Negative non-significant	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001)
Kernel L/B ratio	Positive non-significant	Kavitha and Sree Rama Reddy (2001) Nayak <i>et al.</i> (2001)
	Negative significant	Tara Satyavathi <i>et al.</i> (2001)
	Negative non-significant	Ramesh Babu (1999)
Thousand grain Weight (g)	Positive and significant	Suryanarayana (2000) Sakthivel (2001)
	Positive non-significant	Meenakshi <i>et al.</i> (1999) Kavitha and Sree Rama Reddy (2001) Tara Satyavathi <i>et al.</i> (2001)
	Negative significant	Gopinath <i>et al.</i> (1984) Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011)
	Negative non-significant	Reddy <i>et al.</i> (1997) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)

2.3.5 Association among the yield component traits in rice association of panicle length with

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Bala (2001)
	Negative and significant	Ravindra Babu <i>et al.</i> (2011)
Number of grains per panicle	Positive significant	Satish Chandra <i>et al.</i> (2009) Abdus salman khan <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)
	Positive non-significant	Reddy <i>et al.</i> (1997) Debchoudhury and Das (1998) Tara Satyavathi <i>et al.</i> (2001)
	Negative significant	Gopinath <i>et al.</i> (1984)
	Negative non-significant	Sawant <i>et al.</i> (1995) Nandan <i>et al.</i> (2010)
Hulling percent	Positive non-significant	Roy <i>et al.</i> (1995)
Kernel length	Positive significant	Reddy <i>et al.</i> (1997) Ramesh Babu (1999)
	Negative non-significant	Nayak <i>et al.</i> (2001)
Kernel L/B ratio	Positive non-significant	Ramesh Babu (1999) Kavitha and Sree Rama Reddi (2001) Nandan <i>et al.</i> (2010)
	Negative significant	Nayak <i>et al.</i> (2001)
Thousand grain weight (g)	Positive significant	Gopinath <i>et al.</i> (1984) Yogameenakshi <i>et al.</i> (2004) Ravindra Babu <i>et al.</i> (2011)
	Positive non-significant	Kavitha and Sree Rama Reddy (2001) Satish Chandra <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative non-significant	Roy <i>et al.</i> (1995) Vange <i>et al.</i> (1999) Nayak <i>et al.</i> (2001)

2.3.6 Association among the yield component traits in rice association of number of grains per panicle with

Character	Nature of association	Reference
Hulling percentage	Positive non-significant	Roy <i>et al.</i> (1995) Nandan <i>et al.</i> (2010)
Kernel length (mm)	Negative significant	Geeta <i>et al.</i> (1994) Ramesh Babu (1999) Nayak <i>et al.</i> (2001)
	Negative non-significant	Reddy <i>et al.</i> (1997)
Kernel L/B ratio	Positive non-significant	Tara Satyavathi <i>et al.</i> (2001) Ramesh Babu (1999) Nayak <i>et al.</i> (2001)
	Negative significant	Kavitha and Sree Rama Reddy (2001)
Thousand grain weight	Positive significant	Ravindranath <i>et al.</i> (1982)
	Positive non-significant	Meenakshi <i>et al.</i> (1999) Satish Chandra <i>et al.</i> (2009)
	Negative significant	Geetha <i>et al.</i> (1994) Nayak <i>et al.</i> (2001)
	Negative non-significant	Kavitha and Sree Rama Reddy (2001) Reddy <i>et al.</i> (1997) Nandan <i>et al.</i> (2010)

2.3.7 Association among the yield component traits in rice association of hulling percentage with

Character	Nature of association	Reference
Thousand grain weight (g)	Positive and non-significant	Roy <i>et al.</i> (1995)

2.3.8 Association among the yield component traits in rice association of kernel length with

Character	Nature of association	Reference
Kernel L/B ratio	Positive significant	Asha Christopher <i>et al.</i> (1999) Madhavi Latha (2002) Nayak <i>et al.</i> (2003) Krishna <i>et al.</i> (2008)
	Positive and non-significant	Sarwar <i>et al.</i> (1999)
Thousand grain weight (g)	Positive significant	Singh <i>et al.</i> (1998) Nayak <i>et al.</i> (2001) Madhavi Latha (2002)
	Positive and non-significant	De and Suriya Rao (1988)
	Negative and non-significant	Madhavi Latha (2002)

2.3.9 Association among the yield component traits in rice association of kernel L/B ratio with

Character	Nature of association	Reference
Thousand grain weight (g)	Positive significant	Nayak <i>et al.</i> (2001) Tara Satyavathi <i>et al.</i> (2001)
	Positive non-significant	Ramesh Babu (1999) Kavitha and Sree Rama Reddi (2001)
	Negative significant	Sarwar <i>et al.</i> (1999)

2.4 To study the direct and indirect effects of yield components on yield

Path coefficient analysis, a statistical device developed by Wright (1921) helps in partitioning of the correlation coefficients into direct and indirect effects of independent variable on dependent variable. As grain yield is a complex character influenced by several factors, selection based on simple correlation without taking into consideration between the component characters is not effective. Hence, path analysis is of much importance in any plant breeding programme. Correlation in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters. Dewey and Lu (1959) demonstrated the utility of path coefficient analysis in plant selection and since then its application has been extended to almost to every crop.

The findings of earlier workers on the relative contribution of different characters to grain yield in rice are furnished here under in a tabular form:

2.4.1 Direct effects

Character	Positive direct effect on grain yield	Negative direct effect on grain yield
Days to 50 per cent flowering	Khedikar <i>et al.</i> (2004) Sankar <i>et al.</i> (2006) Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012) Sanghera <i>et al.</i> (2013)	Deb choudhury <i>et al.</i> (1998) Gupta <i>et al.</i> (1998) Nayak <i>et al.</i> (2001) Pankaj <i>et al.</i> (2010) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Plant height (cm)	Madhavi Latha (2002) Sankar <i>et al.</i> (2006) Basavaraja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012) Sanghera <i>et al.</i> (2013)	Saravanan <i>et al.</i> (1996) Tara Satyavathi <i>et al.</i> (2001) Suman (2003) Karad and Pol (2008) Satish Chandra <i>etal.</i> (2009) Akhtar <i>et al.</i> (2011)

Character	Positive direct effect on grain yield	Negative direct effect on grain yield
Number of productive tillers per plant	Sankar <i>et al.</i> (2006) Karad and Pod (2008) Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011) Kiani and Nematzadeh (2012) Azarpour (2013) Nagaraju <i>et al.</i> (2013)	Valarmathi and Leenakumari (1998) Kavitha and Sree Rama Reddy (2001) Mulugeta seyoun <i>et al.</i> (2012)
Panicle length (cm)	Khedikar <i>et al.</i> (2004) Karad and Pol (2008) Basavaraja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012)	Ganesan <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Pankaj <i>et al.</i> (2010)
Number of Grains per panicle	Sankar <i>et al.</i> (2006) Satish Chandra <i>et al.</i> (2009) Nandan and Sweta Singh (2010) Kiani and Nematzadeh (2012) Mulugeta <i>et al.</i> (2012) Azarpour (2013) Nagaraju <i>et al.</i> (2013)	Amirthadevarathinam (1990) Gupta <i>et al.</i> (1998) Akhtar <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Hulling percentage	Madhavi Latha (2002) Nandan and Sweta Singh (2010)	Nagajyothi (2001)
Kernel length (mm)	Sinha <i>et al.</i> (1999) Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)	Vivekanandan and Giridharan (1998) Madhavi Latha (2002)
Kernel L/B ratio	Nagajyothi (2001) Madhavi Latha (2002) Chaudhary and Mothiramani (2003) Saravananand Sabesan (2009)	Pankaj Garg <i>et al.</i> (2010)

Character	Positive direct effect on grain yield	Negative direct effect on grain yield
Thousand grain weight (g)	Suman (2003) Khedikar <i>et al.</i> (2004) Satish Chandra <i>et al.</i> (2009) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011)	Karad and Pol (2008) Pankaj Garge <i>et al.</i> (2010) Basavaraja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011) Mulugeta seyoum <i>et al.</i> (2012)

2.4.2 Indirect effects

2.4.2.1 Indirect effects of days to 50 per cent flowering on grain yield through

Character	Positive indirect effect	Negative indirect effect
Plant height (cm)	Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Debchoudhury and Das (1998) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
Number of productive tillers per plant	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Meenakshi <i>et al.</i> (1999) Kavitha and Sree Rama Reddy (2001) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011)
Panicle length (cm)	Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
Number of filled grains per panicle	Debchoudhury and Das (1998) Nayak <i>et al.</i> (2001) Madhavi Latha (2002)	Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Hulling percent	Roy <i>et al.</i> (1995)	Madhavi Latha (2002)
Kernel length (mm)	Sinha <i>et al.</i> (1999)	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011)
Kernel L/B ratio	Madhavi Latha (2002)	Kavitha and Sree Rama Reddy (2001) Nayak <i>et al.</i> (2001)
Thousand grain weight	Kavitha and Sree Rama Reddy (2001) Madhavi Latha (2002) Basavaraja <i>et al.</i> (2011)	Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)

2.4.2.2 Indirect effects of plant height on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Gupta <i>et al.</i> (1998) Madhavi Latha (2002) Madhavi Latha <i>et al.</i> (2005) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Sinha <i>et al.</i> (1999) Kavitha and Sree Rama Reddy (2001) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)
Number of productive tillers per plant	Nagajyothi (2001) Madhavi Latha <i>et al.</i> (2005) Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Tara Satyavathi <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Panicle length (cm)	Satish Chandra <i>et al.</i> (2009) Basavaraja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Padmaja <i>et al.</i> (2011)
Number of grains per panicle	Madhavi Latha <i>et al.</i> (2005) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Valarmathi and Leena Kumari (1998) Suryanarayana (2000)
Hulling percentage		Nagajyothi (2001) Madhavi Latha (2002)
Kernel length (mm)	Ramesh Babu (1999) Sinha <i>et al.</i> (1999) Madhavi Latha (2002)	Ganesan <i>et al.</i> (1997) Reddy <i>et al.</i> (1997) Rajamadhan <i>et al.</i> (2011)
Kernel L/B ratio	Ramesh Babu (1999) Nagajyothi (2001)	Nayak <i>et al.</i> (2001) Madhavi Latha (2002)
Thousand grain weight (g)	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)

2.4.2.3 Indirect effects of number of productive tillers per plant on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Amirthadevarathinam (1990) Kavitha and Sree Rama Reddy (2001) Basavaraja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Plant height (cm)	Madhavi Latha (2002) Basavaraja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Reddy <i>et al.</i> (1997) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
Panicle length (cm)	Madhavi Latha (2002) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Kavitha and Sree Rama Reddy (2001) Nayak <i>et al.</i> (2001) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
Number of filled grains per panicle	Tara Satyavathi <i>et al.</i> (2001) Satish Chandra <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012)	Valarmathi and Leena Kumari (1998) Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Ravindra Babu <i>et al.</i> (2011)
Hulling percentage	Madhavi Latha (2002)	Nagajyothi (2001)
Kernel length (mm)	Ramesh Babu (1999)	Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011)
Kernel L/B ratio	Nayak <i>et al.</i> (2001) Madhavi Latha (2002)	Ramesh Babu (1999)
Thousand grain weight (g)	Reddy <i>et al.</i> (1997) Nagajyothi (2001) Tara Satyavathi <i>et al.</i> (2001)	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)

2.4.2.4 Indirect effects of panicle length on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Satish Chandra <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Debchoudhury and Das (1998) Padmaja <i>et al.</i> (2011)
Plant height (cm)	Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Janardhanam <i>et al.</i> (2001) Tara Satyavathi <i>et al.</i> (2001)
Number of productive tillers per plant	Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Kiani and Nematzadeh (2012)	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002) Ravindra Babu <i>et al.</i> (2011)
Number of grains per panicle	Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Mulugeta <i>et al.</i> (2012)	Amirthadevarathinam (1990) Satish Chandra <i>et al.</i> (2009)
Hulling percentage	Roy <i>et al.</i> (1995)	Nagajyothi (2001) Madhavi Latha (2002)
Thousand grain weight (g)	Nagajyothi (2001) Madhavi Latha (2002) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Satish Chandra <i>et al.</i> (2009)

2.4.2.5 Indirect effects of number of grains per panicle on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Gupta <i>et al.</i> (1998) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)

Character	Positive indirect effect	Negative indirect effect
Plant height (cm)	Madhavi Latha (2002) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Reddy <i>et al.</i> (1997) Debchoudhury and Das (1998) Satish Chandra <i>et al.</i> (2009)
Number of productive tillers per plant	Amirthadevarathinam (1990) Valarmathi and Leena Kumari 1998) Akhtar <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Ganesan <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)
Panicle length (cm)	Reddy <i>et al.</i> (1997) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Madhavi Latha (2002)
Hulling percent	Roy <i>et al.</i> (1995)	Madhavi Latha (2002)
Kernel length	Ganesan <i>et al.</i> (1997) Madhavi Latha (2002)	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)
Kernel L/B ratio	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002)	
Thousand grain weight (g)	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Tara Satyavathi <i>et al.</i> (2001)

2.4.2.6 Indirect effects of hulling percentage on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Roy <i>et al.</i> (1995)	Madhavi Latha (2002)
Plant height (cm)	Roy <i>et al.</i> (1995) Nagajyothi (2001)	Madhavi Latha (2002)

Character	Positive indirect effect	Negative indirect effect
Number of productive tillers per plant	Roy <i>et al.</i> (1995) Nagajyothi (2001) Madhavi Latha (2002)	
Panicle length (cm)	Roy <i>et al.</i> (1995) Nagajyothi (2001) Madhavi Latha (2002)	
Thousand grain weight (g)	Madhavi Latha (2002)	Roy <i>et al.</i> (1995) Nagajyothi (2001)

2.4.2.7 Indirect effects of kernel length on grain yield per plant through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011)	Sinha <i>et al.</i> (1999)
Plant height (cm)	Ganesan <i>et al.</i> (1997)	Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011)
Number of productive tillers per plant	Madhavi Latha (2002)	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)
Panicle length (cm)	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001)	Ganesan <i>et al.</i> (1997) Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011)
Number of filled grains per panicle	Ramesh Babu (1999) Rajamadhan <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Madhavi Latha (2002)
L/B ratio	Vivekanandan <i>et al.</i> (1998) Asha Christopher <i>et al.</i> (1999)	Ramesh Babu (1999)
Thousand grain weight (g)	Sinha <i>et al.</i> (1999) Nayak <i>et al.</i> (2001) Madhavi Latha (2002)	Reddy <i>et al.</i> (1997) Rajamadhan <i>et al.</i> (2011)

2.4.2.8 Indirect effects of thousand grain weight on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Nayak <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009)	Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Plant height (cm)	Nagajyothi (2001) Madhavi Latha (2002) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)	Ganesan <i>et al.</i> (1997) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)
Number of productive tillers per plant	Nagajyothi (2001) Tara Satyavathi <i>et al.</i> (2001)	Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Ravindra Babu <i>et al.</i> (2011)
Panicle length (cm)	Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011)	Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Ravindra Babu <i>et al.</i> (2011)
Number of filled grain per panicle	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002) Satish Chandra <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)	Reddy <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)
Hulling percentage	Nagajyothi (2001) Madhavi Latha (2002)	Roy <i>et al.</i> (1993)
Kernel length (mm)	Reddy <i>et al.</i> (1997) Rajamadhan <i>et al.</i> (2011)	Ganesan <i>et al.</i> (1997) Madhavi Latha (2002)
Kernel L/B ratio	Nagajyothi (2001) Tara Satyavathi <i>et al.</i> (2001)	Madhavi Latha (2002)

2.4.2.9 Indirect effects of kernel L/B ratio on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Nayak <i>et al.</i> (2001) Madhavi Latha (2002)	Ramesh Babu (1999)
Plant height (cm)	Nagajyothi (2001) Tara Satyavathi <i>et al.</i> (2001)	Nayak <i>et al.</i> (2001) Madhavi Latha (2002)
Number of productive tillers per plant	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002)	Nagajyothi (2001) Nayak <i>et al.</i> (2001)
Panicle length (cm)	Nagajyothi (2001) Nayak <i>et al.</i> (2001)	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002)
Number of grain per panicle	Madhavi Latha (2002)	Nayak <i>et al.</i> (2001) Tara Satyavathi <i>et al.</i> (2001)
Kernel length (mm)	Ramesh Babu (1999) Nayak <i>et al.</i> (2001)	Asha Christopher <i>et al.</i> (1999) Modhavi Latha (2002)
Thousand grain weight (g)	Nagajyothi (2001) Nayak <i>et al.</i> (2001)	Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002)

Chapter III

MATERIAL AND METHODS

The present experiment was carried out during *kharif* -2013 at Rice section farm, Agriculture Research Institute, Acharya N. G. Ranga Agricultural University Rajendranagar, Hyderabad. The material used and methods followed are presented below.

3.1 MATERIAL

The experimental material consisted of thirty eight rice genotypes (including three checks) obtained from different sources. The information on source/origin of the genotypes is given in Table 3.1.

3.2 METHODS

All the genotypes were sown on 2nd July, 2013 separately in the nursery on raised beds. Thirty days old seedling of each genotype were transplanted in a plot of eight rows with 23 plants per row by adopting a spacing of 15 cm between plants and 15 cm between rows in a Randomized Block Design replicated twice. Recommended agronomic and plant protection measures for raising a healthy nursery and main crop were taken up during the experiment.

3.3 RECORDING OF OBSERVATIONS

Five plants of each genotype in each replication selected randomly from central rows, were used to record data on thirteen characters. The mean values were considered for statistical analysis.

3.3.1 Yield Characters

3.3.1.1 Days to 50 per cent flowering

The total number of days taken from the date of sowing to complete exersion of the panicle in fifty per cent of the total plants in the net plot.

3.3.1.2 Plant height (cm)

Plant height was measured in centimeters from ground level to the tip of the mother panicle in each plant at the time of harvest.

Table 3.1. Details of thirty eight rice genotypes used in the study

S.No.	Name of the genotype	Cross combination
1	RNR- 19358	MTU -1075 × WGL-32100
2	RNR- 19359	MTU -1075 × WGL-32100
3	RNR- 19360	MTU -1075 × WGL-32100
4	RNR- 19361	MTU -1075 × WGL-32100
5	RNR- 19362	MTU -1075 × WGL-32100
6	RNR- 19363	MTU -1075 × WGL-32100
7	RNR- 19366	MTU -1075 × WGL-32100
8	RNR- 19367	MTU -1075 × WGL-32100
9	RNR- 19368	MTU -1075 × WGL-32100
10	RNR- 19369	MTU -1075 × WGL-32100
11	RNR- 19370	MTU -1075 × WGL-32100
12	RNR- 19371	MTU -1075 × WGL-32100
13	RNR- 19372	MTU -1075 × WGL-32100
14	RNR- 19374	BM-71 × WGL-32100
15	RNR- 19379	BM-71 × WGL-32100
16	RNR- 19380	MTU -1075 × JLG - 1798
17	RNR- 19381	MTU -1075 × JLG - 1798
18	RNR- 19382	MTU -1075 × JLG - 1798
19	RNR- 19383	MTU -1075 × JLG - 1798
20	RNR- 19393	BPT- 4358 × RNR- M7
21	RNR- 19396	IR- 64 × Erramallelu
22	RNR- 19397	IR- 64 × Erramallelu
23	RNR- 19398	IR- 64 × Erramallelu
24	RNR- 19399	IR- 64 × Erramallelu
25	RNR- 19400	MTU - 1001 × JLG- 3844
26	RNR- 19401	MTU - 1001 × JLG- 3844
27	RNR- 19402	MTU - 1001 × JLG- 3844
28	RNR- 19403	MTU - 1001 × JLG- 3844
29	RNR- 19404	MTU - 1001 × JLG- 3844
30	RNR- 19405	MTU - 1001 × JLG- 3844
31	RNR- 19406	MTU - 1001 × JLG- 3844
32	RNR- 19407	MTU - 1001 × JLG- 3844
33	RNR- 19408	MTU - 1001 × JLG- 3844
34	RNR- 19420	MTU - 1010 × JLG- 3844
35	RNR- 19470	RNR- 15368 × Erramallelu
36	MTU - 1001	JLG - 418 × Gedongibetom
37	MTU- 1010	Krishnaveni × IR-64
38	BPT-1 010	Vajram × MTU- 7014

3.3.1.3 Productive tillers per plant

Number of ear bearing tillers per plant was counted at the time of harvest.

3.3.1.4 Panicle length (cm)

It was measured in centimeters at the time of plant maturity from the base of panicle (neck node) to the tip of last spikelet prior to harvesting.

3.3.1.5 Number of filled grains per panicle

Number of filled grains was counted from five panicles in each selected plant and the mean was taken.

3.3.1.6 Thousand grain weight (g)

One thousand well filled grains were counted at random from each plant and weighed after thorough drying to 15 per cent moisture content and was recorded in grams.

3.3.1.7 Grain yield per plant (g)

The weight of filled grains harvested from each plant was recorded in grams after bringing the grains to required moisture content.

3.3.2 GRAIN QUALITY CHARACTERS

3.3.2.1 Hulling percentage

Hundred grams of rough rice after thorough drying to a moisture level of 12-14 percent were passed through paddy sheller and the weight of the hulled rice taken and hulling percentage was calculated by using the following formula and presented in per cent:

$$\text{Hulling percentage} = \frac{\text{Total weight of hulled rice (g)}}{\text{Total weight of rough rice (g)}} \times 100$$

3.3.2.2 Milling percentage

Dehusked rice sample of 100 g paddy was collected from each plant and milled in kett type T₂ polisher for 60 seconds and milling recovery was estimated by the formula given below:

$$\text{Milling percentage} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

3.3.2.3 Head rice recovery percentage

From each milled rice sample brokens were separated and head rice recovery was calculated by the formula:

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of whole rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

3.3.2.4 Kernel length (mm)

Ten grains of milled rice were selected by hand randomly and the length in millimeter was recorded using Dial micrometer.

3.3.2.5 Kernel breadth (mm)

Ten grains of milled rice were selected by hand randomly and the length in millimeter was recorded using Dial micrometer.

3.3.2.6 Kernel L/B ratio

The kernel L/B ratio was calculated by using the following formula of Murthy and Govindaswamy (1967):

$$\text{Kernel L/B ratio} = \frac{\text{Mean length of grain (mm)}}{\text{Mean breadth of grain (mm)}}$$

Based on kernel length and kernel L/B ratio classification, the grain type was assigned to the experimental material as per Jennings *et al.* (1979).

Grain type	Length (mm)	Shape	Kernel L/B ratio
Extra long	More than 7.50	Slender	More than 3.0
Long	6.61-7.50	Medium	2.1-3.0
Medium	5.51-6.60	Bold	1.1-2.0
Short	Less than 5.50	Round	Less than 1.1

3.4 STATISTICAL ANALYSIS

The mean values with respect to the above characters were subjected to the following analysis with the help of standard statistical procedures:

1. Analysis of variance
2. Genotypic and phenotypic coefficients of variation
3. Heritability and genetic advance
4. Estimation of genetic divergence using Mahalanobis's generalized distance (D^2)
5. Estimation of correlation coefficients.
6. Direct and indirect effects of characters using path coefficient analysis

3.4.1 Analysis of Variance

Analysis of variance was computed based on randomized block design for each of the character separately as per standard statistical procedure (Panse and Sukhatme, 1978). The significance was tested by referring to the values of 'F' table (Fisher and Yates, 1967).

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

Where ,

Y_{ij} = phenotypic observation of i^{th} genotype and j^{th} replication

μ = general mean

g_i = effect of i^{th} genotype

r_j = effect of j^{th} replication

e_{ij} = random error associated with i^{th} genotype and j^{th} replication

Analysis of variance:

Source	Degrees of freedom	Mean sum of squares	F-ratio
Replication	(r-1)	M's	M's/M'e
Treatment	(t-1)	M't	M't/M'e
Error	(r-1)(t-1)	M'e	
Total	(tr-1)	TMSS	

Where,

r and t = Number of replications and treatments, respectively.

M's, M't and M'e = Mean sum of squares due to replications, treatments and error respectively.

The genotypic and phenotypic variance was calculated as per the formulae (Burton 1952).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{(\text{Mean sum of squares due to treatments} - \text{Mean sum of squares due to error})}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma^2_p) = (\sigma^2_g) + (\sigma^2_e)$$

$$(\sigma^2_e) = \text{error variance}$$

3.4.2 Genotypic and phenotypic coefficient of variance

The genotypic and phenotypic coefficient of variation were calculated according to the formula given by Falconer (1981).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

Categorization of the range of variation was done as proposed by Siva subramanian and Madhavamenon (1973).

<10% : Low

10-20% : Moderate

>20% : High

3.4.3 Heritability and genotypic advance

Heritability

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability (h^2) in the broad sense was calculated according to the formula given by Allard (1960).

$$h^2_{(bs)} = \frac{\sigma^2_g}{\sigma^2_p}$$

Where

$h^2_{(bs)}$ = heritability in broad sense

σ^2_g = genotypic variance

σ^2_p = phenotypic variance (σ^2_g) + (σ^2_e)

σ^2_e = environmental variance

As suggested by Johnson *et al.* (1955) (h^2) estimates were categorized as:

Low : 0-30%

Medium : 30-60%

High : above 60%

Genetic advance

Genetic advance refers to the expected gain or improvement in the next generation by selecting superior individuals under certain amount of selection pressure. From the heritability estimates the genetic advance was estimated by the following formula given by Burton (1952).

$$GA = K \cdot h^2(b) \cdot \sigma_p$$

Where,

GA = expected genetic advance

K = Selection differential, the value of which is 2.06 at 5% selection intensity

σ_p = phenotypic standard deviation

$h^2(b)$ = heritability in broad sense

In order to visualize the relative utility of genetic advance among the characters, genetic advance as percent for mean was computed.

$$\text{Genetic advance as percent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

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

Low	:	Less than 10 %
Moderate	:	10-20 %
High	:	More than 20 %

3.4.4 Estimation of genetic divergence using Mahalanobis's generalized distance (D^2)

Genetic diversity between genotypes can be better estimated using D^2 statistics given by Mahalanobis (1936).

3.4.4.1 Test of significance

Variances were calculated for all the thirteen characters studied and test of significance was done. Analysis of covariance for the character pairs was estimated on the basis of mean values (Panse and Sukhatme, 1978). After testing the difference between genotypes for each of the character, a simultaneous test of significance for differences in the mean values for a number of correlated variables with regard to pooled effect of 13 characters was carried out using 'V' statistic, which in turn utilizes Wilk's Criterion. The sum of squares and sum of products of error and error + variety variance – covariance matrix were used for this purpose. The estimation of 'V' (Wilk's criterion) was done by using the following relationship.

$$'V' = W/S$$

Where,

'V'	=	Wilk's criterion
W	=	Determinant of error matrix and
S	=	Determinant of error + variety matrix

The significance of 'V' was tested by V (stat):

$$\chi^2_{pq} = V(\text{stat}) = -m \log_e 'V' = \left[n - \frac{P+Q+1}{2} \right] \log_e 'V'$$

Where,

$$m = n - (P + Q + 1)/2$$

$$p = \text{number of characters (or) variable observations}$$

$$q = \text{number of genotypes-1 (or) degrees of freedom for population}$$

$$n = \text{degrees of freedom for error + genotypes at base of}$$

$$\text{natural log} = 2.7183$$

V (stat) can be approximately considered to be distributed as χ^2_{pq} and if the calculated 'V' value from the formulae exceeds $\chi^2_{pq} 'K'$, the hypothesis is rejected at 'K' level of significance; otherwise not.

3.4.4.2 Transformation of correlated variables

Transformation was done by using pivotal condensation method. Transformation of correlated variables into standardized uncorrelated ones was done before working out the D^2 values because of computation of D^2 values was reduced to simple enumeration of differences in mean values of various characters of the two genotypes i.e., $\sum d_i^2$.

3.4.4.3 Computation of D^2 values

The D^2 value between i^{th} and j^{th} genotypes for 'p' character was calculated as:

$$D^2_{ij} = \sum_{t=1}^P (\bar{Y}_{it} - \bar{Y}_{jt})^2$$

Where,

$$\bar{Y}_{it} = \text{uncorrelated mean value of the } i^{\text{th}} \text{ genotype for } t \text{ character}$$

$$\bar{Y}_{jt} = \text{uncorrelated mean value of the } j^{\text{th}} \text{ genotype for } t \text{ character}$$

$$D^2_{ij} = D^2 \text{ between } i^{\text{th}} \text{ and } j^{\text{th}} \text{ genotype}$$

3.4.4.4 Testing the significance of D^2 values

The D^2 value obtained for a pair of genotypes was taken as the calculated value of χ^2 and tested against tabulated χ^2 at p degrees of freedom where, 'p' is the number of characters considered.

3.4.4.5 Grouping of genotypes into various clusters

Grouping of genotypes into different clusters was done by using Tocher's method. The criterion used in clustering by this method was that any two genotypes belonging to the same cluster should have a smaller D^2 value among themselves than those belonging to different clusters.

The first step in grouping the genotypes into different clusters was to arrange the genotypes in the order of their relative distance from each other. For this purpose, D^2 values of all the combinations for each genotype were arranged in the increasing order of their magnitude (Singh and Chaudhary, 1985). To start with two genotypes having the smallest distance from each other was considered first to which third population having the smallest average D^2 value from the first two genotypes was considered and so on. At certain stage when it was felt that after adding a particular variety, there was a disrupt increase in the average D^2 value, then that genotype was not considered for inclusion in that cluster. Similarly, a second cluster was formed. The process was continued till all the genotypes were included in one or the other clusters.

3.4.4.6 Intra and inter cluster distance

Average intra cluster distance

For the measurement of intra cluster distance, the formula used was $\Sigma D_i^2/n$. where ΣD_i^2 was the sum of distance between all possible combinations and 'n' is the number of genotypes included in a cluster.

Average inter cluster distance

Clusters were taken one by one and their distances from other clusters were calculated. The distance between the two clusters as the sum of D^2 value between the number one cluster to each of the members of other cluster divided by the product of number of genotypes in both the clusters under consideration. The square root of the average D^2 value gave the genetic distance 'D' between the clusters. Based on D^2 values

(inter cluster distance), the scale given by Rao (1952) for rating of the distance was adopted and the cluster diagram was prepared.

$$\text{Average inter cluster distance} = \frac{D^2}{n_1 \times n_2}$$

n_1 and n_2 are number of genotypes of two clusters

Category	'D' values
Closely related	< Below 22
Moderately divergent	Between 22 and 30
Highly divergent	>Above 30

3.4.4.7 Cluster Diagram

The clusters and their mutual relationship were presented diagrammatically by using D^2 values.

3.4.4.8 Contribution of individual characters towards divergence

In all the combinations each character was ranked on the basis of their contribution towards divergence between two entries ($d_i = y_{it} - y_{jt}$). Rank I was given to the highest mean difference and rank 'p' to the lowest difference; p is the total number of characters considered. Percentage contribution of each character (X) towards genetic divergence was calculated using the following formula:

$$\text{Percent contribution of character (X)} = \frac{N \times 100}{M}$$

Where,

X = Percent contribution of character

N = Number of genotype combinations where the characters ranked first.

M = All possible combinations of genotypes considered.

3.4.5 Estimation of correlation coefficients

Correlation coefficients were calculated at genotypic and phenotypic level using the formulae suggested by Falconer (1964).

$$\text{Genotypic coefficient of correlation } (r_g) = r(x_i . x_j)_g = \frac{\text{Cov.}(x_i . x_j)_g}{\sqrt{v(x_i)_g \cdot v(x_j)_g}}$$

Where,

$r(x_i . x_j)_g$ is genotypic correlation between i^{th} and j^{th} characters

$\text{Cov.}(x_i . x_j)_g$ is genotypic covariance between i^{th} and j^{th} characters

$v(x_i)_g$ is genotypic variance of i^{th} character

$v(x_j)_g$ is genotypic variance of j^{th} character

$$\text{Phenotypic coefficient of correlation } (r_p) = r(x_i . x_j)_p = \frac{\text{Cov.}(x_i . x_j)_p}{\sqrt{v(x_i)_p \cdot v(x_j)_p}}$$

Where,

$r(x_i . x_j)_p$ is phenotypic correlation between i^{th} and j^{th} characters

$\text{Cov.}(x_i . x_j)_p$ is phenotypic covariance between i^{th} and j^{th} characters

$v(x_i)_p$ is phenotypic variance of i^{th} character

$v(x_j)_p$ is phenotypic variance of j^{th} character

3.4.6 Path coefficient analysis

The direct and indirect effects both at genotypic and phenotypic levels were estimated by taking seed yield as dependant variable, using path coefficient analysis as suggested by Wright (1921) and Dewey and Lu (1959). The following equations were formed and solved simultaneously for estimating the various direct and indirect effects.

$$r_{1y} = P_{1y} r_{11} + P_{2y} r_{12} + P_{3y} r_{13} \dots\dots\dots + P_{ny} r_{1n}$$

$$r_{2y} = P_{1y} r_{21} + P_{2y} r_{22} + P_{3y} r_{23} \dots\dots\dots + P_{ny} r_{2n} \dots\dots\dots$$

$$\vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots$$

$$r_{ny} = P_{1y} r_{n1} + P_{2y} r_{n2} + P_{3y} r_{n3} \dots\dots\dots + P_{ny} r_{nn}$$

Where;

1, 2 n = Independent variables

y = Dependant variable

$r_{1y}, r_{1y}, r_{2y} \dots r_{ny}$ = Coefficient of correlation between casual factors '1' to 'n' on dependent character 1

$P_{1y}, P_{2y} \dots P_{ny}$ = Direct effect of character 1 to n on character Y

The above equations can be written in matrix form as:

$$\begin{matrix} \text{A} & & \text{C} & & \text{B} \\ \left(\begin{array}{c} r_{1y} \\ r_{2y} \\ \cdot \\ \cdot \\ \cdot \\ r_{ny} \end{array} \right) & & \left(\begin{array}{cccc} 1 & r_{12} & r_{13} & \dots r_{1n} \\ r_{21} & 1 & r_{23} & \dots r_{2n} \\ \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \\ r_{n1} & r_{n2} & r_{n3} & \dots 1 \end{array} \right) & & \left(\begin{array}{c} P_{1y} \\ P_{2y} \\ \cdot \\ \cdot \\ \cdot \\ P_{ny} \end{array} \right) \end{matrix}$$

Then

$$B = (C)^{-1} A \text{ where } C^{-1} = \left(\begin{array}{cccc} c_{11} & c_{12} & c_{13} \dots & c_{1n} \\ c_{21} & c_{22} & c_{23} \dots & c_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ c_{n1} & c_{n2} & c_{n3} \dots & c_n \end{array} \right)$$

Direct effects were as follows:

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

$$P_{2y} = \sum_{i=1}^k c_{2i} r_{iy}$$

$$P_{ny} = \sum_{i=1}^k c_{ni} r_{iy}$$

Residual effect, which measures the contribution of characters not considered, was obtained as:

$$p_{ry} = \sqrt{1 - (p_{1y} r_{iy} + p_{2y} r_{iy} + \dots + p_{ny} r_{ny})}$$

Where,

p_{ny} = Direct effect of x_n on Y

r_{iy} = Correlation coefficient of x_n on y .

Chapter IV

RESULTS AND DISCUSSION

The results obtained from the present experimental study on evaluation of thirty eight rice (*Oryza sativa* L.) genotypes including three checks for seven quantitative and six grain quality characters are furnished under the following heads:

- 4.1 Mean performance
- 4.2 Genetic variability, heritability and genetic advance
- 4.3 Genetic divergence
- 4.4 Character association
- 4.5 Path coefficient analysis

4.1 MEAN PERFORMANCE

Analysis of variance showed significant differences for all the characters studied in the present investigation. The results of analysis of variance are presented in table 4.1. The mean values for thirteen characters for thirty eight rice genotypes are given in table 4.2.

4.1.1 QUANTITATIVE CHARACTERS

4.1.1.1 Days to 50 per cent flowering

The number of days to 50 per cent flowering ranged from 95.00 days to 110.00 days with a general mean of 103.01. Among all the genotype, (RNR19371) was earliest (95.00 days) while (BPT 1010) was found to be late (110.00 days).

4.1.1.2 Plant height (cm)

Plant height ranged from 79.95 cm to 161.00 cm with a general mean of 125.11 cm. The shortest genotype was (BPT 1010) (79.95 cm) while the tallest genotype was (RNR 19379) (129.90 cm), which was 2.01 times taller than BPT-1010.

4.1.1.3 Number of productive tillers per plant

The mean productive tillers per plant ranged from 5.00 tillers (RNR 19369) to 10.50 tillers (RNR 19360) with a general mean of 6.50 tillers per plant.

4.1.1.4 Panicle length (cm)

The panicle length ranged from 18.20 to 32.50 cm with a general mean of 25.81 cm. The genotype BPT-1010 has shorter panicle value 18.20 cm and the genotype RNR 19379 exhibited highest value of 32.50 cm. Which was almost 14.30 cm longer than BPT 1010 .

4.1.1.5 Number of filled grains per panicle

The mean values for number of filled grains per panicle ranged from 108.00 (RNR 19368) to 214.00 (RNR 19374) with general mean of 152.66.

4.1.1.6 Thousand grain weight (g)

The mean value of thousand-grain weight was 17.31 g and the values ranged from 12.47 (RNR 19380) to 24.71 g (MTU 1010).

4.1.1.7 Grain yield per plant (g)

The mean for grain yield per plant was 11.38 g and the mean value ranged from 6.31 (RNR-19368) to 15.54 (MTU 1010).

4.1.2 GRAIN QUALITY CHARACTERS

4.1.2.1 Hulling percentage

The hulling percentage ranged from 72.58 per cent (RNR 19407) to 88.12 per cent (RNR 19371) with general mean of 79.58 per cent.

4.1.2.2 Milling percentage

The milling percentage ranged from 44.75 per cent (RNR 19407) to 73.84 per cent (RNR 19371) with general mean of 66.39 per cent.

4.1.2.3 Head rice recovery percentage

The head rice recovery percentage ranged from 33.36 per cent (RNR 19407) to 67.14 per cent (RNR 19360) with a general mean of 56.18 per cent.

4.1.2.4 Kernel length (mm)

The range of variation observed for this character was from 4.65 mm to 6.02 mm with a mean value of 5.38 mm. The genotype RNR 19380 (4.65 mm) had minimum kernel length whereas the genotypes RNR 19396 (6.02 mm) had maximum kernel length.

4.1.2.5 Kernel breadth (mm)

This trait varied from 1.35 mm to 2.19 mm with a general mean value of 1.64 mm. The genotype RNR-19371 (1.35 mm) had minimum kernel breadth while the genotype MTU- 1001 (2.19 mm) had maximum kernel breadth.

4.1.2.6 Kernel L/B ratio

The range of variation observed for this character was from 2.59 to 3.92 with a mean value of 3.29. The genotype MTU 1001 (2.59) had minimum length/ breadth ratio while the genotype RNR 19363 (3.92) had maximum length/ breadth ratio.

The analysis of variance revealed highly significant differences among the 38 genotypes for all the characters indicating considerable genetic variation in the material (Table 4.1). The characters number of productive tillers per plant, panicle length, number of filled grains per panicle and thousand grain weight were important characters for grain yield per plant. Any improvement in above characters will ensure an increased yield.

4.2 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The genotypic and phenotypic coefficients of variation, heritability and genetic advance as per cent of mean were estimated for thirty eight genotypes. Results are furnished in table 4.3 for genotypic and phenotypic coefficients of variation, heritability and genetic advance as per cent of mean respectively. The characters studied in the present investigation exhibited low, moderate and high PCV and GCV values.

4.2.1 QUANTITATIVE CHARACTERS

4.2.1.1 Days to 50 per cent flowering

The genotypic and phenotypic coefficient of variation were low i.e., 3.66 and 4.23, respectively. The observed heritability estimate for this trait was high (75.00) while genetic advance as per cent of mean (6.54) were moderate. The result was in conformity with Manoj Kumar prajapati (2011) for low GCV and PCV; Chikkalingaiah *et al.* (1999) for high heritability and Mulugeta Seyoum, *et al.* (2012) for genetic advance as percent of mean. Akinwale *et al.* (2011) recorded broad sense heritability estimates of 98.9 per cent for days to 50 per cent flowering.

4.2.1.2 Plant height (cm)

The genotypic and phenotypic coefficient of variation estimates observed for this trait were moderate i.e., 14.19 and 14.88, respectively. The observed heritability estimates for this character was high (91.00) with high genetic advance as per cent of mean (27.88). The similar results were reported by Nayak *et al.* (2002) for moderate GCV and PCV, Umadevi *et al.* (2009) and Mohan lal and Devendra (2011) for high heritability coupled with high genetic advance as percent of mean for plant height.

4.2.1.3 Number of productive tillers per plant

The genotypic and phenotypic coefficient of variation for this trait were high i.e., 17.57 and 19.70 respectively. The observed heritability estimate was high (79.50 %) and with high genetic advance as per cent of mean (32.26). The similar result was reported by Vange and Ojo (1997), Nagajyothi (2001) and Krishna *et al.* (2008) for high GCV and PCV and Selvaraj *et al.* (2011) reported high heritability coupled with high genetic advance as per cent of mean for number of productive tillers per plant in rice.

4.2.1.4 Panicle length (cm)

The GCV and PCV for this trait were low i.e., 8.08 and 9.32, respectively. The heritability observed for this trait was high (75.20). This character recorded moderate genetic advance as per cent of mean (14.44). Mohan and Devendra (2011) and Idris *et al.* (2013) reported high broad sense heritability for panicle length.

4.2.1.5 Number of filled grains per panicle

Moderate GCV (17.60) and PCV (19.0) were observed for this trait. The heritability estimate for this trait was very high (85.00 %) with high genetic advance as per cent of mean (33.55). The similar results were observed by Tara Satyavathi *et al.* (2001), Kole and Hasib (2008) and Sanghera *et al.* (2013) for high GCV and PCV, Pankaj Garg *et al.* (2010) for high heritability and Umadevi *et al.* (2009) for high genetic advance as percent of mean.

4.2.1.6 Thousand grain weight (g)

A high genotypic (20.23) and phenotypic (20.84) coefficients of variation were recorded with high heritability of 94.20 per cent. The genetic advance as per cent of mean was high (40.44). The similar results was found by Chandra *et al.* (2009) and Mulugeta seyoum *et al.* (2012) for moderate GCV and PCV, Mohan Lal and Devendra (2011) and Pankaj Garg *et al.* (2010) for high heritability coupled with high genetic advance as percent of mean.

4.2.1.7 Grain yield per plant (g)

A high genotypic coefficient of variation (19.96) and phenotypic coefficient of variation (20.59) were observed for this trait. A high heritability estimate (93.90) coupled with high genetic advance as per cent of mean (39.85). The results are in conformity with Mulugeta seyoum *et al.* (2012) and Sanghera *et al.* (2013) for high GCV and PCV and Pankaj Garg *et al.* (2010) and Mohan Lal and Devendra (2011) for heritability coupled with high high genetic advance percent of mean.

4.2.2 GRAIN QUALITY CHARACTERS

4.2.2.1 Hulling Percentage

A low genotypic (3.53) and phenotypic (4.80) coefficients of variation were observed for this trait. The heritability estimate for this trait was medium (54.20) with low genetic advance as per cent of mean (5.35). The similar result were observed by Surender Raju (2002) for low GCV and PCV, Chikkalingaiah *et al.* (1999) for medium heritability and whereas for low genetic advance percent of mean were reported by Mall *et al.* (2011).

4.2.2.2 Milling Percentage

The genotypic and phenotypic coefficients of variation were low i.e., 7.60 and 10.19, respectively. The heritability estimate observed was high (55.60) with Moderate genetic advance as per cent of mean (11.68). The similar result were reported by Chaudhary and Motiramani (2003) for low GCV and PCV, Nagajyothi (2001) for low heritability and Nayak *et al.*(2003)for moderate genetic advance percent of mean.

4.2.2.3 Head Rice Recovery Percentage

The genotypic and phenotypic coefficients of variation were high i.e., 11.31 and 15.31, respectively. The heritability estimate for this trait was very high (54.60) with high genetic advance as per cent of mean (17.21). The similar result were reported by Nagajyothi (2001) for moderate heritability and for moderate genetic advance percent of mean were reported by Nayak *et al.* (2003).

4.2.2.4 Kernel length(mm)

A low genotypic (6.53) and moderate phenotypic (7.05) coefficients of variation were observed for this trait. The heritability estimate was very high (85.70) with a moderate genetic advance as per cent of mean (12.45).The similar result were observed by Umadevi *et al.*(2009) for low GCV and PCV, Krishna *et al.*(2008) for high heritability and moderate genetic advance percent of mean.

4.2.2.5 Kernel breadth(mm)

A low genotypic (10.71) and phenotypic (11.31) coefficients of variation were observed for this trait. The heritability estimate was very high (89.50) with a moderate genetic advance as per cent of mean (20.87). The similar results were reported by

Vivekanandan and Giridharan (1998) for moderate GCV and PCV, Vivekanandan and Giridharan (1998) and Sarawgi *et al.* (2000) reported high heritability and Nayak *et al.* (2002) for high genetic advance for this trait.

4.2.2.6 kernel L/B ratio

A moderate genotypic (7.50) and phenotypic (8.46) coefficients of variation were observed for this trait. The heritability estimate was very high (78.60) with a moderate genetic advance as per cent of mean (13.69). The similar results were found by Ramesh Kumar (1989), Chikkalingaiah *et al.* (1999) and Tara Satyavathi *et al.* (2001) for low GCV and PCV, and Nayak *et al.* (2003) for high heritability coupled with moderate genetic advance percent of mean.

The knowledge of genetic variability present in a given crop species for the character under improvement is of paramount importance for the success of any plant breeding programme. Information on coefficient of variation is useful in measuring the range of variability present in the characters. Heritability and genetic advance are important selection parameters. Genotypic coefficient of variation (GCV) along with heritable estimates would provide a better picture of the amount of genetic advance to be expected by phenotypic selection (Burton, 1952). It is suggested that genetic gain should be considered in conjunction with heritability estimates (Johnson *et al.*, 1955). Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone.

Coefficients of variation studies indicated that the estimates of PCV were slightly higher than the corresponding GCV estimates for days to 50% flowering, plant height, No. of productive tillers per plant, panicle length, number of grains per panicle, thousand grain weight, grain yield per plant, hulling percentage, milling percentage, head rice recovery percentage, kernel length, kernel breadth, kernel L/B ratio indicating that the characters were less influenced by the environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits.

The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic value. Therefore, high heritability helps in effective selection for a particular character.

High heritability for quantitative characters indicates the scope of genetic improvement of these characters through selection. All quality characters also exhibited high degree of broad-sense heritability, which revealed that these characters are less influenced by environment and there could be greater correspondence between phenotypic and breeding values.

The genetic advance as percent of mean is a useful indicator of the progress that can be expected as a result of exercising selection on the pertinent population. The traits showing high heritability coupled with high genetic advance indicate the control of additive gene and selection may be effective for these characters.

4.3 GENETIC DIVERGENCE

The quantitative assessment of genetic divergence was made by adopting Mahalanobis D^2 statistic for yield and its contributing characters. Genetic divergence was estimated for thirty eight rice genotypes and the results obtained from the study are presented below.

4.3.1 Wilk's 'V' criterion test

Wilk's 'V' (statistic) criterion was used to test the significant differences between the groups based on the pooled effects of all the characters. The significance of 'V' (statistic) value was tested by % at 702 degrees of freedom. The 'V' statistic value was highly significant indicating that the genotypes differed significantly when all the characters were considered simultaneously.

The significance of 38 genotypes in the analysis of variance of dispersion clearly indicated the significant pooled effect of all the characters studied between different genotypes. Hence, further analysis was made to estimate D^2 analysis.

4.3.2 Mahalanobis's generalized distance D^2 values

In order to assess the genetic diversity among thirty eight genotypes of rice, D^2 statistic was used following the procedure given by Rao (1952). Since the entire 13 yield component characters were correlated, they were transformed into uncorrelated linear combination through pivotal condensation method.

4.3.3 Grouping of genotypes into various clusters

Thirty eight genotypes were grouped into ten clusters based on D^2 values using Tocher's method (Rao, 1952) such that the genotypes belonging to same cluster had an average smaller D^2 values than those belonging to different clusters. The distribution of genotypes into various clusters is shown in table 4.4 and fig 4.2. Out of ten clusters, cluster I was the largest comprising of twenty nine genotypes and all other clusters II, III, IV, V, VI, VII, VIII, IX and X were represented by single genotype indicating high degree of heterogeneity among the genotypes.

4.3.3 Average inter and intra cluster distances

The average intra and inter cluster D^2 values are presented in table 4.5 and Statistical distance among thirty eight genotypes fig. 4.1 (3D plot). Intra cluster D^2 values ranged from zero (cluster II, III, IV, V, VI, VII, VIII, IX, X) to 8.78 (cluster I). Maximum intra cluster distance was observed in cluster I (8.78). indicating that some genetic divergence still existed among the genotypes. This could be made use of in the yield improvement through recombination breeding.

From the inter cluster D^2 values of the ten clusters, it can be seen that the highest divergence occurred between cluster V and X (23.65) followed by cluster V and VIII (22.07) cluster VI and X (20.49), cluster, cluster IV and VIII (20.08) and cluster VI and VIII (19.78), cluster III and VIII (19.67) suggesting that the crosses involving varieties from these clusters would give wider and desirable recombination. While the lowest was noticed between cluster III and V (6.70), followed by cluster V and VI (7.23), cluster IV and V (7.31), cluster II and VII (8.22), cluster II and IX (9.44).

It is assumed that maximum amount of heterosis will be manifested in cross combinations involving the parents belonging to most divergent clusters. But for a plant breeder, the objective is not only high heterosis but other quality characters also. The greater the distance between two clusters, the wider the genetic diversity between the genotypes. Keeping this in view, it is indicated that hybridization between the genotypes (RNR 19368) of cluster V and cluster X (MTU 1001), cluster VI (RNR 19371) and cluster X (MTU 1001), cluster V (RNR 19368) with cluster VIII (MTU 1010), cluster IV (RNR 19367) and VIII ((MTU 1010), cluster VI (RNR 19371) and VIII (MTU 1010) would produce encouraging results. The genotypes of these clusters may be used as parents in the crossing program to generate breeding material with high diversity.

4.3.4 Cluster means of the characters

The cluster means for each of thirteen characters are presented in Table 4.6. From the data it can be seen that considerable differences existed for all the characters under study. The data indicated that the cluster mean for days to 50 per cent flowering was highest in cluster IX (110.00) and the lowest in cluster VI (95.00). Plant height was highest in cluster III (154.45 cm) and lowest in cluster IX (79.95 cm). Number of productive tillers per plant is highest recorded in cluster X (10.00) and the lowest number of productive tillers per plant was in cluster III (5.00). Cluster V recorded the highest panicle length (28.00 cm) and the lowest was recorded in cluster IX (18.20 cm). The number of grains per panicle was highest in cluster VII (194.00) and the lowest in cluster V (108.00). Highest thousand grain weight was recorded in cluster VIII (24.71 g) and the lowest in cluster III (13.00 g). Cluster VIII recorded the highest grain yield per plant (15.54 g) while in cluster V it was low (6.31 g). Cluster VI recorded high hulling percentage (88.12) whereas it was low in cluster IV (76.06 %). High milling percentage was recorded in cluster VI (73.84%) while it was low in cluster IX (56.10%). Cluster X recorded the highest head rice recovery percentage (64.63%) and the lowest in cluster II (35.88%). High kernel length was recorded in cluster II (6.02 mm) whereas it was low in cluster III (4.73 mm). High kernel breadth was recorded in cluster X (2.19 mm) where as low in cluster VI (1.35 mm). High kernel L/B ratio was recorded in cluster IV (3.72) and low in cluster X (2.59). The result indicates that selection of genotypes having high values for particular trait could be made and used in the hybridization programme for improvement of that character.

Cluster VIII involving MTU 1010 and cluster X involving MTU 1001 are characterized by higher productive tillers, thousand grain weight, plant yield and head rice recovery hence these varieties are the ideal candidates for use as parents in hybridization programme.

Therefore, hybridization between the selected genotypes from divergent clusters is essential to judiciously combine all the targeted traits.

The cluster VIII is having highest mean value for grain yield per plant and thousand grain weight, cluster VII for number of filled grains per panicle and cluster X is having highest number of productive tillers per plant, head rice recovery, kernel breadth and cluster VI for hulling percentage, high milling percentage and cluster III having

highest plant height, panicle length, II having highest kernel length and cluster IV having high kernel L/B ratio, cluster. The genotypes RNR 19371, RNR 19420, MTU 1010, MTU 1001 and RNR 1936 from these clusters having high mean values may be directly used for adaptation or may be used as parents in future hybridization programme.

4.3.5 Relative contribution of characters towards genetic divergence

The number of times that each of the thirteen characters appeared in first rank and its respective per cent contribution towards genetic divergence is presented in Table 4.7. The results showed that the contribution of thousand grain weight was highest towards genetic divergence (24.75) by taking 174 times ranking first, followed by kernel breadth (23.61%) by 166 times, grain yield per plant (17.35%) by 122 times, plant height (11.10%) by 78 times, kernel L/B Ratio (8.53%) by 60 times, kernel length (4.84%) by 34 times, Number of filled grains per panicle (3.84%) by 27 times, number of productive tillers per plant (1.85 %) by 13 times, panicle length (1.56%) by 11 times, milling percentage (0.85%) by 6 times, days to 50% flowering (0.71%) by 5 times, head rice recovery (0.57%) by 4 times and hulling percentage (0.43%) by 3 times is respectively to the genetic divergence in decreasing order. similar result were conformity with Chandra *et al.* (2007) for thousand-grain weight, grain length, number of grains per panicle and plant height, and Surender Raju (2002) for kernel length, Vennila *et al* (2011) number of grains per panicle, plant height, kernel length and kernel L/B ratio, Raut *et al.* (2009) for length to breadth ratio of grain, number of grains per panicle.

The thousand grain weight, kernel breath, grain yield per plant, plant height, kernel L/B Ratio contributed 85.34% towards total divergence. Therefore, these characters should be given importance during hybridization and selection of segregating populations.

The conclusion drawn by the cluster analysis is that in the studied population high variability observed between the genotypes in different clusters for different traits. Recombination breeding among genotypes belonging to cluster I having maximum intra-cluster distance can improve the yield potential. As maximum inter-cluster distance was noticed between cluster V and X, cluster V and VIII, cluster VI and X and genotypes like MTU 1001, RNR 19371, RNR 19368, MTU 1010, RNR 19367 from these clusters would give wider and desirable recombination's.

4.4 CHARACTER ASSOCIATION

Crop yield is the end product of the interaction of a number of other, often interrelated attributes. A thorough understanding of the interaction of characters among themselves had been of great use in plant breeding. The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its component characters and also among themselves. Character association provides information on the nature and extent of association between pairs of metric traits and helps in selection for the improvement of the character. Phenotypic and genotypic correlations were worked out on yield and yield contributing characters in thirty eight genotypes. In general, genotypic correlations were found to be higher than phenotypic correlations, which indicate that though there is strong inherent association between characters studies, its expression is lessened due to influence of environment and considering the importance of phenotypic correlation it was discussed in the results as presented in table 4.8.

4.4.1.1 Days to 50 per cent flowering

The days to 50 per cent flowering recorded a significant positive phenotypic correlation with grain yield per plant (0.3316) and number of filled grains per panicle (0.3001). Where it has positive and non-significant correlation with panicle length (0.0484), number of productive tillers per plant (0.1967), kernel length (0.0682), kernel breadth (0.0438) and kernel L/B ratio (0.0306) The characters plant height (-0.1330), thousand grain weight (-0.0933) showed negative and non-significant association.

The similar result were reported by Ravindra Babu *et al* (2011) for grain yield per plant, Ramesh Babu (1999) for plant height, Satish Chandra *et al.* (2009) for number of filled grains per panicle, Satish Chandra *et al.* (2009), Kavitha and Sree Rama Reddi (2001) for panicle length, Satish Chandra *et al.* (2009) number of productive tillers per plant, Nandan *et al.* (2010) for thousand grain weight, Pankaj *et al.* (2010) for plant height, grain yield per plant, plant height, Abdul Fiyaz *et al.* (2011) for plant height and thousand grain weight.

4.4.1.2 Plant height (cm)

The plant height registered a significant positive phenotypic correlation with panicle length and L/B ratio. Where as it negative and non-significant correlation for number of productive tillers per plant (-0.1241) and number of grains per panicle (-0.1374). While negative and significant for the remaining characters.

The similar result were reported by Rashid *et al.* (2013) for grain yield per plant, Satish Chandra *et al.* (2009) for panicle length, Nandan *et al.* (2010)) for kernel length , Sukanya Subramanian and Rathinam (1984) for thousand grain weight, Reddy *et al.* (1997) Pankaj Garge *et al.* (2010) for panicle length, thousand grain weight, kernel length, kernel L/B ratio, Nandan *et al.* (2010) for number of grains per panicle, , Reddy *et al.* (1997) for number of grains per panicle.

4.4.1.3 Number of productive tillers per plant

Number of productive tillers per plant exhibited significant positive phenotypic correlation with grain yield per plant (0.7076) and number of grains per panicle (0.4166). It exhibited positive correlation with kernel breadth (0.1106) . The characters thousand grain weight(-0.0834), kernel length (-0.0072), kernel L/B ratio (-0.1370) showed negative non-significant correlation.

The similar result was reported by Panwar and Mashita Ali (2007) for grain yield per plant and number of grains per panicle. Nayak *et al.* (2001) for kernel length, Ravindra Babu *et al.* (2011), for thousand grain weight, Ramesh Babu (1999) for kernel L/B ratio, Promin *et al.* (2010) number of grains per panicle and grain yield per plant, Padmaja *et al.* (2011) and Ravindra babu *et al.*(2012) for grain yield per plant.

4.4.1.4 Panicle length (cm)

Panicle length registered significant negative phenotypic correlation with kernel L/B ratio (0.4842). Whereas number of productive tillers per plant(0.0650), number of filled grains per panicle 0.1033) showed non- significant positive correlation. While negative and significant with thousand grain weight (-0.2652), kernel breadth (-0.5151) and showing negative correlation with kernel length (-0.2206) and grain yield per plant (-0.0596).

The similar result were reported by Tara Satyavathi *et al.* (2001) for number of filled grains per panicle Ravindra Babu *et al.* (2011) for number of productive tillers per plant, Nandan *et al.*(2010) for thousand grain weight, kernel length, Padmaja *et al.*(2011) for thousand grain weight .

4.4.1.5 Number of filled grains per panicle

Number of filled grains per panicle exhibited a significant positive phenotypic correlation with grain yield per plant (0.6314) whereas negative and non significant correlation with thousand grain weight (-0.2245), kernel length (-0.0147), kernel breadth (-0.1170) and kernel L/B ratio (-0.1972).

The similar result were reported by Padmaja *et al.* (2011) for grain yield per plant Nandan *et al.* (2010) for thousand grain weight, Reddy *et al.* (1997) for kernel length, Pankaj Garge *et al.* (2010) for grain yield per plant, thousand grain weight, kernel length and kernel breadth.

4.4.1.6 Thousand grain weight (g)

Thousand grain weight showed a significant positive phenotypic correlation with kernel length (0.7021), kernel breadth (0.3613) and kernel L/B ratio (0.7830) whereas positively correlated with grain yield per plant (0.1732). The similar result reported by Pankaj Garge *et al.* (2010) for kernel length, kernel breadth, Nandan *et al.* (2010) for kernel length, kernel breadth and kernel L/B ratio.

4.4.1.7 Kernel length (mm)

Kernel length showed significant positively phenotypic correlation with grain yield per plant (0.3181), kernel breadth (0.6276) and it was and positively non-significant association with kernel L/B ratio (0.0291). The similar result were reported by Sarwar *et al.* (1999) for kernel L/B ratio, Mareker and Siddiqui (1996), Nagaraju *et al.* (2013) for grain yield per plant

4.4.1.8 Kernel breadth (mm)

Kernel breadth showed positively and significant association with grain yield per plant (0.2788) and significant negative phenotypic correlation with kernel L/B ratio (-0.7524). The similar result were reported by Pankaj Garge *et al.*(2010) and Rajeswari *et al.*(2010) for kernel L/B ratio).

4.4.1.9 Kernel L/B ratio

Kernel L/B ratio showed non-significant negative phenotypic correlations with grain yield per plant (-0.0838). The similar result was reported by Asha Christopher *et al.* (1999) Satya Priya Lalitha and Sreedhar (1999) for grain yield per plant.

4.4.10 Grain yield per plant

Phenotypic correlations revealed that grain yield per plant had significant positive association with days to 50 per cent flowering (0.3316), number of productive tillers per plant (0.7076), number of filled grains per panicle (0.6314), kernel length (0.3181) and kernel breadth (0.2788). This indicated that all these characters were important for yield improvement. The trait recorded a significant negative association with plant height (-0.3368). Whereas characters thousand grain weight (0.1732) is non-significant positive associated with it. While it was showing negative and non-significant association with panicle length (-0.0596) and kernel L/B ratio (-0.0838).

Similar kind of association was revealed by Ravindra Babu *et al.* (2011) for 50 per cent flowering, number of productive tillers per plant, Nagaraju *et al.* (2013) for number of productive tillers per plant, number of filled grains per panicle, kernel length, Sanghera *et al.* (2013) for number of productive tillers per plant, number of filled grains per panicle. Mahto *et al.* (2003) and Rashid *et al.* (2013) for plant height, Madhavi Latha *et al.* (2005) for thousand grain weight, Ramesh Babu (1999) for panicle length and Asha Christopher *et al.* (1999) for kernel L/B ratio

Hence, these characters could be considered as criteria for selection for higher yield as these were mutually and directly associated with grain yield. The characters like days to 50 per cent flowering, number of productive tillers per plant, number of filled grains per panicle positively associated with grain yield per plant it indicates that these characters also consider for selection for higher yield.

4.5 PATH COEFFICIENT ANALYSIS

Correlation gives only the relation between two variables whereas path coefficient analysis allows separation of the direct effect and their indirect effects through other attributes by partitioning the correlations (wright, 1921). Hence, this objective was undertaken in the present investigation. Based on the data recorded on the genotypes in the present investigation, the genotypic and phenotypic correlations were estimated to determine direct and indirect effects of yield and yield contributing characters.

As discussed in character association based on the importance of phenotypic effects the present results of phenotypic path coefficient of yield and yield contributing characters presented in table 4.9 and fig. 4.3 and 4.4 are discussed here under.

4.5.1 Days to 50 per cent flowering

The days to 50 per cent flowering had direct phenotypic positive effect (0.0964) on grain yield and the correlation between days to 50 per cent flowering and grain yield per plant was positive and significant. The correlation was positive and significant mainly due to positive indirect effect through panicle length (0.0047), number of productive tillers per plant (0.0190), number of filled grains per panicle (0.0289), thousand grain weight, kernel length (0.0066), kernel breadth (0.0042), kernel L/B ratio (0.0029).

Similar result of direct negative effect of days to 50 per cent flowering on grain yield per plant was reported by Mulugeta *et al.* (2012) and Sanghera *et al.* (2013).

4.5.2 Plant height (cm)

Plant height had phenotypic positive direct effect on grain yield per plant (0.1211). Where the correlation of plant height with grain yield was negative and significant. The correlation between plant height and grain yield was negative and significant mainly due to negative indirect effect contribution through days to 50 per cent flowering (-0.0161), number of productive tillers per plant (-0.0150), number of filled grains per panicle (-0.0166), thousand grain weight (-0.0587), kernel length (-0.0693), kernel breadth (-0.0728). The similar result reported by Mulugeta *et al.* (2012), Ravindra Babu *et al.* (2011), Sanghera *et al.* (2013) positive direct effect of plant height on grain yield per plant.

4.5.3 Number of productive tillers per plant

Productive tillers per plant which exhibited a phenotypic positive direct effect on grain yield per plant (0.5207) while the correlation with grain yield per plant was also positive and significant. The correlation was positive and significant mainly due to positive indirect effect contribution through days to 50 per cent flowering (0.1024), panicle length (0.0338), number of filled grain per panicle (0.2169), kernel breadth (0.0576). The similar result were reported by Pankaj Garge *et al.*(2010), Basavaraja *et al.*(2011) Abdul Fiyaz *et al.*(2011), Padmaja *et al.*(2011), Ravindra Babu *et al.*(2011), Kiani and Nematzaden (2012), Nagaraju *et al.* (2013), and Azarpour (2013) positive direct effect of number of productive tillers per plant on grain yield per plant.

4.5.4 Panicle length (cm)

Panicle length had direct negative phenotypic effect (-0.1160) on grain yield per plant. The correlation also was negative and non- significant. The correlation was negative mainly due to negative indirect contribution through due to 50 per cent flowering (-0.0056) plant height (-0.0809), number of productive tillers per plant (-0.0075), number of grains per panicle (-0.0120) and kernel L/B ratio (-0.0596).The similar result reported by Kole *et al.* (2008), Satish Chandra *et al.* (2009), Nandan *et al.*(2010), Abdul Fiyaz *et al.*(2011), Padmaja *et al.*(2011) negative direct effect of Panicle length on grain yield per plant.

4.5.5 Number of filled grains per panicle

Number of filled grains per panicle had direct phenotypic positive effect (0.4709) on grain yield per plant. It's correlation with grain yield per plant was also positive and significant. The correlation between number of filled grains per panicle and grain yield per plant was positive and significant mainly due to positive indirect effect contribution through due to 50 per cent flowering (0.1413), panicle length (0.0486), number of productive tillers per plant (0.1962), kernel L/B ratio (0.0929). The similar result reported by Nandan *et al.*(2010), Mulugeta *et al.* (2012), Kiani and Nematzadeh (2012), Nagaraju *et al.* (2013), Azarpour (2013) positive direct effect of Number of filled grains per panicle on grain yield per plant.

4.5.6 Thousand grain weight (g)

Thousand grain weight had direct positive phenotypic effect on grain yield per plant (0.1676) and its correlation with grain yield was also positive. The correlation between thousand grain weight and grain yield per plant was positive was mainly due to positive indirect effect influence through 50 per cent flowering (0.1156), kernel length (0.1176) kernel breadth (0.1244). The similar result reported by Satish Chandra *et al.* (2009), Yadav *et al.* (2011), Akhtar *et al.* (2011), Padmaja *et al.* (2011) positive direct effect of thousand grain weight on grain yield per plant.

4.5.7 Kernel length (mm)

Kernel length had direct negative phenotypic effect on grain yield per plant (-0.1146) while its correlation with grain yield was positive and significant. The correlation between kernel length and grain yield per plant was positive and significant was mainly due to positive indirect effect contribution through plant height (0.0656), panicle length (0.0253), number of productive tillers per plant (0.0008), number of filled grains per panicle (0.0017), kernel length (0.0719) on grain yield per plant. The similar result reported by Vivekanandan and Giridharan (1998) and Madhavi Latha (2002) negative direct effect of kernel length on grain yield per plant.

4.5.8 Kernel breadth (mm)

Positive direct phenotypic effect on grain yield per plant (0.5599) was exhibited by kernel breadth while its correlation with grain yield was also positive. The positive correlation between kernel breadth and grain yield per plant mainly due to positive indirect contribution through day to 50 per cent flowering (0.0245), number of productive tillers per plant (0.0619), thousand grain weight (0.4157) and kernel length (0.3513). The similar result reported by Ganesan *et al.* (1997), Pankaj Garge *et al.* (2010) and Nandan *et al.* (2010) negative direct effect of kernel breadth on grain yield per plant.

4.5.9 Kernel L/B ratio

Kernel L/B ratio had direct positive phenotypic effect on grain yield per plant (0.3973) and its correlation with grain yield per plant was negative and non-significant. The correlation between kernel L/B ratio and grain yield per plant was negative and non-significant was mainly due to negative indirect contribution number of productive tillers per plant (-0.0544), thousand grain weight (-0.1436) and kernel length (-0.2989) on grain

yield per plant. The similar result reported by Nagajyothi (2001), Madhavi Latha (2002), Chaudhary and Mothiramani (2003), Sabesan *et al.* (2009) were reported positive direct effect of kernel L/B on grain yield per plant.

The association of different component characters among themselves and with yield is quite important for devising an efficient selection criterion for yield. The total correlation between yield and component characters may be some times misleading, as it might be an over-estimate or under-estimate because of its association with other characters. Hence, indirect selection by correlated response may not be some times fruitful. When many characters are affecting a given character, splitting the total correlation into direct and indirect effects of cause as devised by Wright (1921) would give more meaningful interpretation to the cause of association between the dependent variable like yield and independent variables like yield components. This kind of information will be helpful in formulating the selection criteria. Indicating the selection for these characters is likely to bring about an overall improvement in single plant yield directly.

Path coefficient analysis revealed that number of productive tillers per plant exerted the highest positive direct effect on grain yield followed by number of filled grains per panicle, kernel breadth, kernel L/B ratio, days to 50 per cent flowering, plant height, thousand grain weight. The negative direct effect on grain yield by panicle length and kernel length. The similar result were conformity with Padmaja *et al.* (2011), Mulugeta *et al.* (2011), Sanghera *et al.* (2013) for days to 50 per cent flowering, Ravindra Babu *et al.* (2012) for plant height, number of productive tillers per plant and panicle length, Mulugeta Seyoum *et al.* (2012), Nagaraju *et al.* (2013), Azarpour (2013) for number of grains per panicle, Akhtar *et al.* (2011), Padmaja *et al.* (2011) for thousand grain weight, Madhavi Latha (2002) for kernel length and Saravananand Sabesan (2009) for kernel L/B ratio.

Path analysis revealed that numbers of productive tillers per plant, number of filled grains per panicle, kernel breadth, kernel L/B ratio and thousand grain weight are the most important characters which could be used as selection criteria for effective improvement on grain yield. Therefore, it is suggested that preference should be given to these characters in the selection programme to isolate superior lines with genetic potentiality for higher yield in rice genotypes.

Table 4.1: Analysis of variance for thirteen characters in rice (*Oryza sativa* L.)

S.No.	Character	Mean sum of squares		
		Replications (d.f.=1)	Treatments (d.f.=63)	Error (d.f.=63)
1.	Days to 50% flowering	0.01	33.23 **	4.743
2.	Plant height (cm)	1.62	661.55 **	31.29
3.	Panicle length (cm)	0.19	10.14 **	1.44
4.	Number of productive tillers per plan	0.01	3.91 **	0.45
5.	Number of filled grains per panicle	11.84	1566.73 **	121.79
6.	1000-grain weight (g)	0.04	25.29 **	0.76
7.	Grain yield per plant (g)	0.84	10.65 **	0.33
8.	Hulling %	4.59	22.48 **	6.68
9.	Milling %	9.61	71.21 **	20.30
10.	Head rice recovery	21.78	114.34 **	33.59
11.	Kernel length (mm)	0.00	0.27 **	0.02
12.	Kernel breadth (mm)	0.01*	0.07 **	0.00
13.	L/B ratio	0.04	0.14 **	0.01

Table 4.2: Mean performance of thirty eight genotypes of rice (*Oryza sativa* L.) for yield and yield contributing characters.

S.No.	Genotype	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers/ Plant	No. of filled grains/ panicle	1000 grain weight (g)	Grain yield/ plant (g)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
1	RNR- 19358	98.00	111.25	24.40	7.50	155.00	17.86	12.45	77.61	63.53	54.12	5.62	1.72	3.27
2	RNR-19359	108.00	109.35	26.35	9.50	149.50	14.77	12.06	79.99	64.46	61.33	5.08	1.54	3.30
3	RNR-19360	108.00	110.85	26.75	10.50	200.00	14.87	14.88	85.93	71.81	67.14	5.23	1.58	3.31
4	RNR-19361	107.50	107.95	27.10	8.50	189.50	13.79	13.32	80.77	73.06	61.12	5.36	1.52	3.53
5	RNR-19362	108.00	117.25	26.45	7.00	199.50	15.55	13.86	82.52	71.53	64.04	5.32	1.53	3.48
6	RNR-19363	105.50	121.50	26.95	8.00	163.50	16.41	12.04	78.24	58.15	55.89	5.86	1.50	3.92
7	RNR-19366	105.00	141.60	29.20	7.50	134.50	15.59	9.04	81.30	71.71	66.14	5.25	1.51	3.48
8	RNR-19367	108.50	143.80	27.25	5.50	135.50	15.09	8.92	76.06	60.86	55.23	5.11	1.38	3.70
9	RNR-19368	102.00	144.50	28.00	6.00	108.00	14.72	6.31	84.39	62.70	55.27	4.77	1.47	3.24
10	RNR-19369	101.50	154.45	27.65	5.00	109.00	13.00	8.45	76.38	65.08	61.26	4.73	1.44	3.28
11	RNR-19370	103.00	145.35	28.40	5.50	123.00	17.15	9.65	83.36	72.66	59.73	5.88	1.52	3.87
12	RNR-19371	95.00	132.45	26.35	6.50	138.50	15.24	8.29	88.12	73.84	58.25	4.97	1.35	3.68
13	RNR-19372	100.50	138.75	27.15	6.50	161.00	15.28	10.87	81.53	62.90	49.93	5.15	1.44	3.58
14	RNR-19374	98.00	129.25	24.70	9.50	214.00	14.45	14.89	72.83	56.46	55.86	5.19	1.50	3.46
15	RNR-19379	109.50	161.00	32.50	9.50	197.50	15.94	14.82	81.27	72.15	62.99	5.42	1.52	3.57
16	RNR-19380	103.50	152.20	26.00	8.00	175.50	12.47	10.60	73.44	60.71	50.90	4.65	1.51	3.08
17	RNR-19381	103.00	146.45	27.75	7.50	159.50	13.22	10.15	80.74	69.38	59.94	4.85	1.53	3.17

S.No.	Genotype	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers/ Plant	No. of filled grains/ panicle	1000 grain weight (g)	Grain yield/ plant (g)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
18	RNR-19382	103.00	145.05	25.10	7.50	126.50	12.66	10.57	76.83	65.33	59.31	4.90	1.56	3.14
19	RNR-19383	96.00	138.90	24.85	7.50	149.50	13.56	8.67	80.49	67.02	58.99	4.81	1.58	3.04
20	RNR-19393	100.50	144.75	25.90	9.00	145.00	14.25	12.29	77.50	70.74	64.18	5.07	1.54	3.29
21	RNR-19396	102.00	116.15	24.60	6.00	123.50	22.82	8.94	82.36	71.29	35.88	6.02	1.95	3.09
22	RNR-19397	103.50	120.45	24.95	8.00	144.00	20.96	11.79	80.13	69.31	53.49	5.41	1.70	3.18
23	RNR-19398	105.50	117.75	25.60	8.50	156.50	21.11	12.81	76.38	69.91	60.35	5.37	1.69	3.18
24	RNR-19399	104.00	111.85	25.15	7.50	132.50	21.12	12.38	82.63	70.96	48.95	5.77	1.91	3.02
25	RNR-19400	106.00	123.80	26.35	7.50	155.50	21.57	12.84	78.61	68.73	54.67	5.67	1.75	3.24
26	RNR-19401	97.50	146.90	28.60	8.50	134.50	18.29	12.04	78.11	66.97	51.15	5.51	1.82	3.03
27	RNR-19402	107.50	125.15	25.55	7.00	165.50	16.55	10.14	80.07	66.98	53.73	5.47	1.72	3.18
28	RNR-19403	105.50	123.60	23.95	6.00	175.00	17.05	12.15	81.11	69.72	65.60	5.43	1.68	3.23
29	RNR-19404	100.50	114.60	23.40	6.50	152.50	18.58	11.78	80.92	68.51	61.43	5.25	1.77	2.97
30	RNR-19405	101.50	119.30	24.00	6.50	152.50	20.03	11.36	79.15	67.75	61.88	5.55	1.73	3.21
31	RNR-19406	96.50	116.05	25.00	6.00	108.00	19.93	7.02	80.83	64.83	49.26	5.55	1.68	3.30
32	RNR-19407	97.50	115.80	24.25	8.00	123.50	19.52	9.73	72.58	44.75	33.36	5.63	1.64	3.43
33	RNR-19408	99.00	113.85	25.05	6.50	153.00	23.28	10.09	75.95	61.12	47.18	5.77	1.79	3.22
34	RNR-19420	103.50	102.70	25.85	5.50	194.00	23.69	11.80	78.71	68.68	51.85	5.66	1.83	3.09
35	RNR-15470	103.00	105.65	24.70	9.50	196.50	13.63	14.85	81.72	62.44	59.27	5.72	1.67	3.43
36	MTU-1001	108.00	104.05	22.85	10.00	126.00	23.71	14.72	77.41	73.20	64.63	5.66	2.19	2.59
37	MTU-1010	99.50	99.90	23.75	8.50	125.50	24.71	15.54	81.39	67.72	54.67	5.99	1.94	3.09
38	BPT-1010	110.00	79.95	18.20	6.50	148.50	15.55	10.39	76.88	56.10	46.08	5.65	1.91	2.96

S.No.	Genotype		Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers/ Plant	No. of filled grains/ panicle	1000 grain weight (g)	Grain yield/ plant (g)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
	General Mean		103.01	125.11	25.81	7.49	152.66	17.31	11.38	79.58	66.39	56.18	5.38	1.64	3.29
	Range	Lowest	95.00	79.95	18.20	5.00	108.00	12.47	6.31	72.58	44.75	33.36	4.65	1.35	2.59
		Highest	110.00	161.00	32.50	10.50	214.00	24.71	15.54	88.12	73.84	67.14	6.02	2.19	3.92
	S.E.		1.54	3.96	0.85	0.47	7.80	0.62	0.41	1.83	3.19	4.10	0.10	0.04	0.09
	C.D at 5%		4.41	11.33	2.43	1.35	22.36	1.76	1.17	5.24	9.13	11.74	0.29	0.12	0.26
	C.V (%)		2.11	4.47	4.64	8.92	7.23	5.02	5.08	3.25	6.79	10.32	2.66	3.66	3.91

Table 4.3: Magnitude of variability, heritability and genetic advance for thirteen characters in thirty eight genotypes of rice (*Oryza sativa* L.)

S.No.	Character	General Mean	Range		Phenotypic coefficient variation to percent	Genotypic coefficient variation to percent	Heritability in broad sense (h^2_{bs}) (%)	GA as per cent of mean (at 5%)
			Minimum	Maximum				
1.	Days to 50% flowering	103.01	95.00	110.00	4.23	3.66	75.00	6.54
2.	Plant height (cm)	125.11	79.95	161.00	14.88	14.19	91.00	27.88
3.	Number of productive tillers/plant	7.49	5.00	10.50	19.70	17.57	79.50	32.26
4.	Panicle length (cm)	25.81	18.20	32.50	9.32	8.08	75.20	14.44
5.	Number of filled grains / panicle	152.66	108.00	214.00	19.03	17.60	85.60	33.55
6.	1000-grain weight (g)	17.31	12.47	24.71	20.84	20.23	94.20	40.44
7.	Grain yield per plant (g)	11.38	6.31	15.54	20.59	19.96	93.90	39.85
8.	Hulling %	79.58	72.58	88.12	4.80	3.53	54.20	5.35
9.	Milling %	66.39	44.75	73.84	10.19	7.60	55.60	11.68
10.	Head rice recovery	56.18	33.36	67.14	15.31	11.31	54.60	17.21
11.	Kernel length (mm)	5.38	4.65	6.02	7.05	6.53	85.70	12.45
12.	Kernel breadth (mm)	1.64	1.35	2.19	11.31	10.71	89.50	20.87
13.	L/B Ratio	3.29	2.59	3.92	8.46	7.50	78.60	13.69

Table 4.5 : Average Intra (diagonal) and inter-cluster D² values for thirteen characters in thirty eight genotypes of rice (*Oryza sativa* L.)

[illegible]

Table 4.6. Cluster means for yield components and quality traits (D² analysis) for thirteen characters in thirty eight genotypes of rice (*Oryza sativa* L.)

Cluster No.	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers / Plant	Number of filled Grains / Panicle	Grain yield / plant (g)	1000-grain weight (g)	Hulling %	Millin g %	Head rice recovery	Kernel length (mm)	Kernel breadth (mm)	L/B ratio
I	102.92	126.77	26.07	7.76	158.36	11.69	16.87	79.40	66.33	55.96	5.37	1.62	3.32
II	102.00	116.15	24.60	6.00	123.50	8.94	22.82	82.36	71.29	35.88	6.02	1.95	3.10
III	101.50	154.45	27.65	5.00	109.00	8.45	13.00	76.38	65.08	61.26	4.73	1.44	3.29
IV	108.50	143.80	27.25	5.50	135.50	8.92	15.09	76.06	60.86	55.23	5.11	1.38	3.72
V	102.00	144.50	28.00	6.00	108.00	6.31	14.72	84.39	62.70	55.27	4.77	1.47	3.26
VI	95.00	132.45	26.35	6.50	138.50	8.29	15.24	88.12	73.84	58.25	4.98	1.35	3.69
V II	103.50	102.70	25.85	5.50	194.00	11.80	23.69	78.71	68.68	51.85	5.66	1.83	3.12
VIII	99.50	99.90	23.75	8.50	125.50	15.54	24.71	81.39	67.72	54.67	5.99	1.94	3.09
IX	110.00	79.95	18.20	6.50	148.50	10.39	15.55	76.88	56.10	46.08	5.65	1.91	2.97
X	108.00	104.05	22.85	10.00	126.00	14.72	23.71	77.41	73.20	64.63	5.66	2.19	2.59

Table.4.8. Estimation of genotypic (G) and phenotypic (P) correlation coefficient between yield and its component characters in rice (*Oryza sativa* L.)

Character		Days to 50% flowering	Plant height(cm)	Panicle length(cm)	Number of productive tillers per plan	Number of filled grains per panicle	1000-grain weight (g)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Grain yield per plant(g)
Days to 50% flowering	G	1.000	0.2045	0.1337	0.1947	0.3635**	- 0.1059	0.0964	0.0834	0.0083	0.3487**
	P	1.000	- 0.1330	0.0484	0.1967	0.3001**	- 0.0933	0.0682	0.0438	0.0306	0.3316**
Plant height(cm)	G		1.000	0.7772**	-0.1552	-0.1507	- 0.5323**	- 0.6393**	- 0.6733**	0.7000**	-0.3656**
	P		1.000	0.6971**	-0.1241	-0.1374	- 0.4847**	- 0.5720**	- 0.6014**	0.2957**	-0.3368**
Panicle length(cm)	G			1.000	0.0569	0.0880	- 0.3371	- 0.3588**	- 0.6671	0.6083	-0.0826
	P			1.000	0.0650	0.1033	-0.2652 *	-0.2206	-0.5151 **	-0.4842 **	-0.0596
Number of productive tillers per plant	G				1.000	0.4053**	- 0.0920	- 0.0605	- 0.12.67	-0.1137	0.7436**
	P				1.000	0.4166 **	-0.0834	-0.0072	0.1106	-0.1370	0.7076**
Number of filled grains per panicle	G					1.000	- 0.2519	- 0.0105	- 0.15.81	0.1892	0.6392**
	P					1.000	-0.2245	-0.0147	-0.1770	-0.1972	0.6314**
1000-grain weight(g)	G						1.000	0.7666	0.7997	-0.4183**	0.1766
	P						1.000	0.7021 **	0.3613 **	0.7830 **	0.1732
Kernel length(mm)	G							1.000	0.6914**	-0.0681	0.3616**
	P							1.000	0.6276 **	0.0291 **	0.3181**
Kernel breadth(mm)	G								1.000	-0.7604	0.3369**
	P								1.000	-0.7524 **	0.2788**
L/B ratio	G									1.000	-0.1379
	P									1.000	-0.0838

* Significant at 5 per cent level; ** Significant at 1 per cent level

Table.4.9. Estimation of genotypic (G) and phenotypic (P) direct and indirect effects between yield and yield attributing characters in thirty eight genotype of rice (*Oryza sativa* L.)

Character		Days to 50% flowering	Plant height (cm)	Panicle length(cm)	Number of productive tillers per plant	Number of filled grains per panicle	1000-grain weight(g)	Kernel length(mm)	Kernel breadth(mm)	L/B ratio	Correlation with grain yield per plant (r)
Days to 50% flowering	G	0.4472	-0.0914	0.0598	0.0871	0.1626	-0.0474	0.0431	0.0373	0.0037	0.3487
	P	0.0964	-0.0128	0.0047	0.0190	0.0289	-0.0090	0.0066	0.0042	0.0029	0.3316
Plant height(cm)	G	-0.1696	0.8294	0.6446	-0.1288	-0.1250	-0.4415	-0.5303	-0.5585	0.3016	-0.3656
	P	-0.0161	0.1211	0.0844	-0.0150	-0.0166	-0.0587	-0.0693	-0.0728	0.0358	-0.3368
Panicle length(cm)	G	0.1253	-0.7284	-0.9372	-0.0534	-0.0825	0.3160	0.3363	0.6252	-0.5701	-0.0826
	P	-0.0056	-0.0809	-0.1160	-0.0075	-0.0120	0.0308	0.0256	0.0598	-0.0562	-0.0596
No. of productive tillers per plant	G	0.1558	-0.1242	0.0456	0.8002	0.3243	-0.0736	0.0484	0.1014	-0.0910	0.7436
	P	0.1024	-0.0646	0.0338	0.5207	0.2169	-0.0434	-0.0038	0.0576	-0.0714	0.7076
Number of filled grains per panicle	G	0.1734	-0.0719	0.0420	0.1933	0.4770	-0.1202	-0.0050	-0.0754	0.0903	0.6392
	P	0.1413	-0.0647	0.0486	0.1962	0.4709	-0.1057	-0.0069	-0.0834	0.0929	0.6314
1000-grain weight(g)	G	-0.0949	-0.4771	-0.3022	-0.0824	-0.2258	0.8963	0.6871	0.7168	-0.3750	0.1766
	P	0.0156	-0.0812	-0.0444	-0.0140	-0.0376	0.1676	0.1176	0.1244	-0.0605	0.1732
Kernel length(mm)	G	0.0368	-0.2439	-0.1369	0.0231	-0.0040	0.2924	0.3815	0.2637	-0.0260	0.3616
	P	-0.0078	0.0656	0.0253	0.0008	0.0017	-0.0805	-0.1146	0.0719	-0.0033	0.3181
Kernel breadth(mm)	G	-0.0735	0.5933	0.5877	-0.1116	0.1393	-0.7046	-0.6092	-0.8811	0.6699	0.3369
	P	0.0245	-0.3367	-0.2884	0.0619	-0.0991	0.4157	0.3513	0.5599	-0.4213	0.2788
L/B ratio	G	-0.0012	-0.0514	-0.0860	0.0161	-0.0267	0.0591	0.0096	0.1075	-0.1413	-0.1379
	P	0.0121	0.1175	0.1924	-0.0544	0.0784	-0.1436	0.0116	-0.2989	0.3973	-0.0838
Genotypic Residual effect = 0.389 Phenotypic Residual effect = 0.470 Bold values are direct effects											

Table 4.4. Clustering pattern among in thirty eight genotypes of rice (*Oryza stiva* L.) by tocher's method.

Cluster No	No. of genotype	Genotype
I	29	RNR- 19397, RNR- 19398, RNR- 19400, RNR- 19405 , RNR- 19404, RNR- 19408, RNR- 19401, RNR- 19403, RNR- 19402, RNR- 19363, RNR- 19362, RNR- 19360, RNR- 19361, RNR- 19359, RNR- 19372, RNR- 19393, RNR- 19399, RNR- 19358, ,RNR- 19470, RNR- 19366, RNR- 19370, RNR- 19374, RNR- 19379, RNR- 19380, RNR- 19381, RNR- 19382, RNR- 19383, RNR- 19406,RNR- 19407
II	1	RNR- 19396
III	1	RNR- 19369
IV	1	RNR- 19367
V	1	RNR- 19368
VI	1	RNR- 19371
VII	1	RNR- 19420
VIII	1	MTU- 1010
IX	1	BPT- 1010
X	1	MTU- 1001

Table 4.7: Relative contribution of different characters to genetic diversity in thirty eight genotypes of rice (*Oryza stiva* L.).

S. No.	Character	No. of times ranked first	Contribution (%)
1	Days to 50% flowering	5	0.71
2	Plant height (cm)	78	11.10
3.	Number of productive tillers per hill	11	1.56
4	Panicle length (cm)	13	1.85
5	Number of filled grains per panicle	27	3.84
6	1000-grain weight (g)	174	24.75
7	Grain yield per plant (g)	122	17.35
8	Hulling per cent	3	0.43
9	Milling per cent	6	0.85
10	Head rice recovery	4	0.57
11	Kernel length (mm)	34	4.84
12	Kernel breadth (mm)	166	23.61
13	L/B ratio	60	8.53

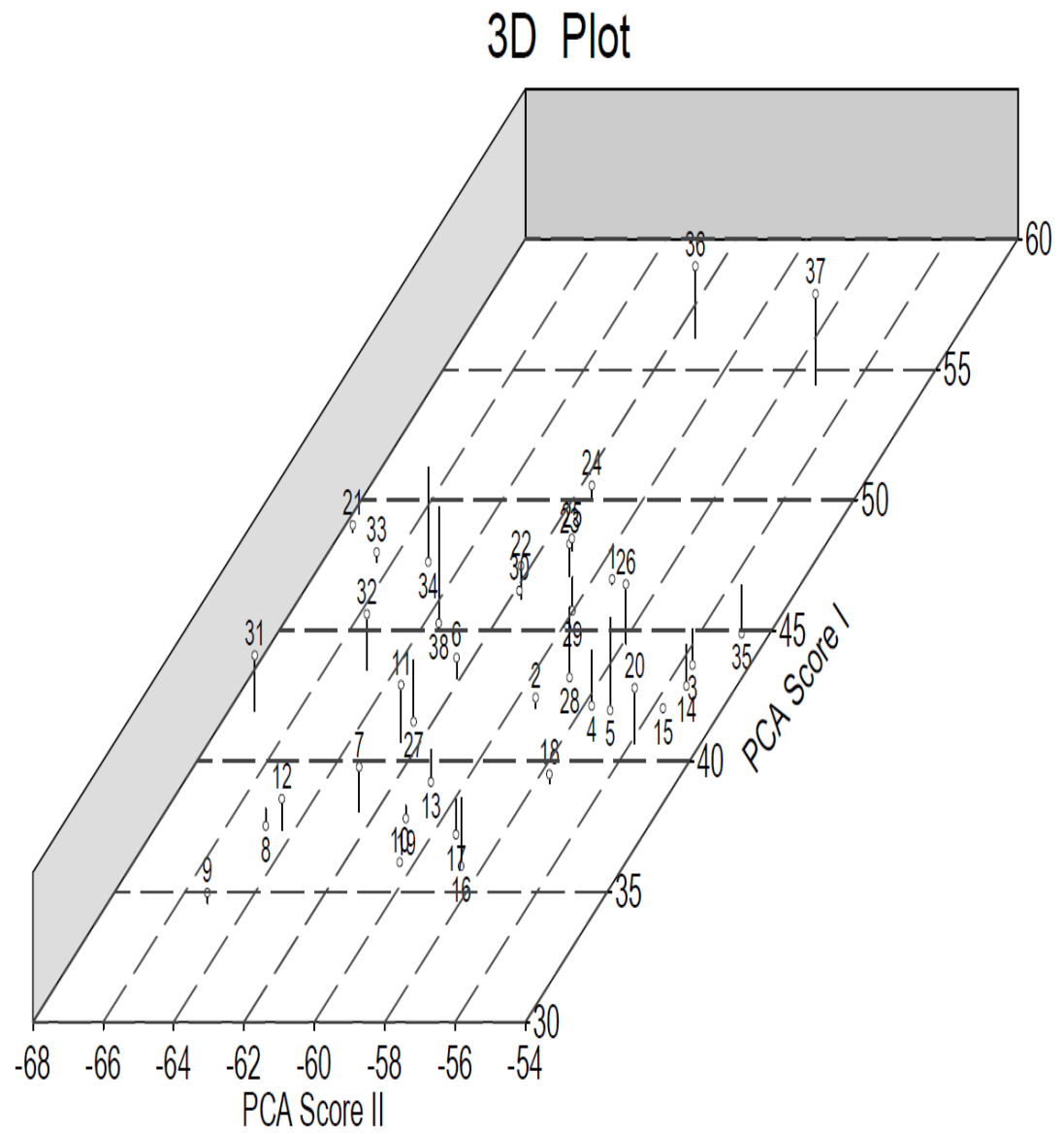


Fig.4.1: Statistical distance among thirty eight genotypes of rice (*Oryza stiva* L.).

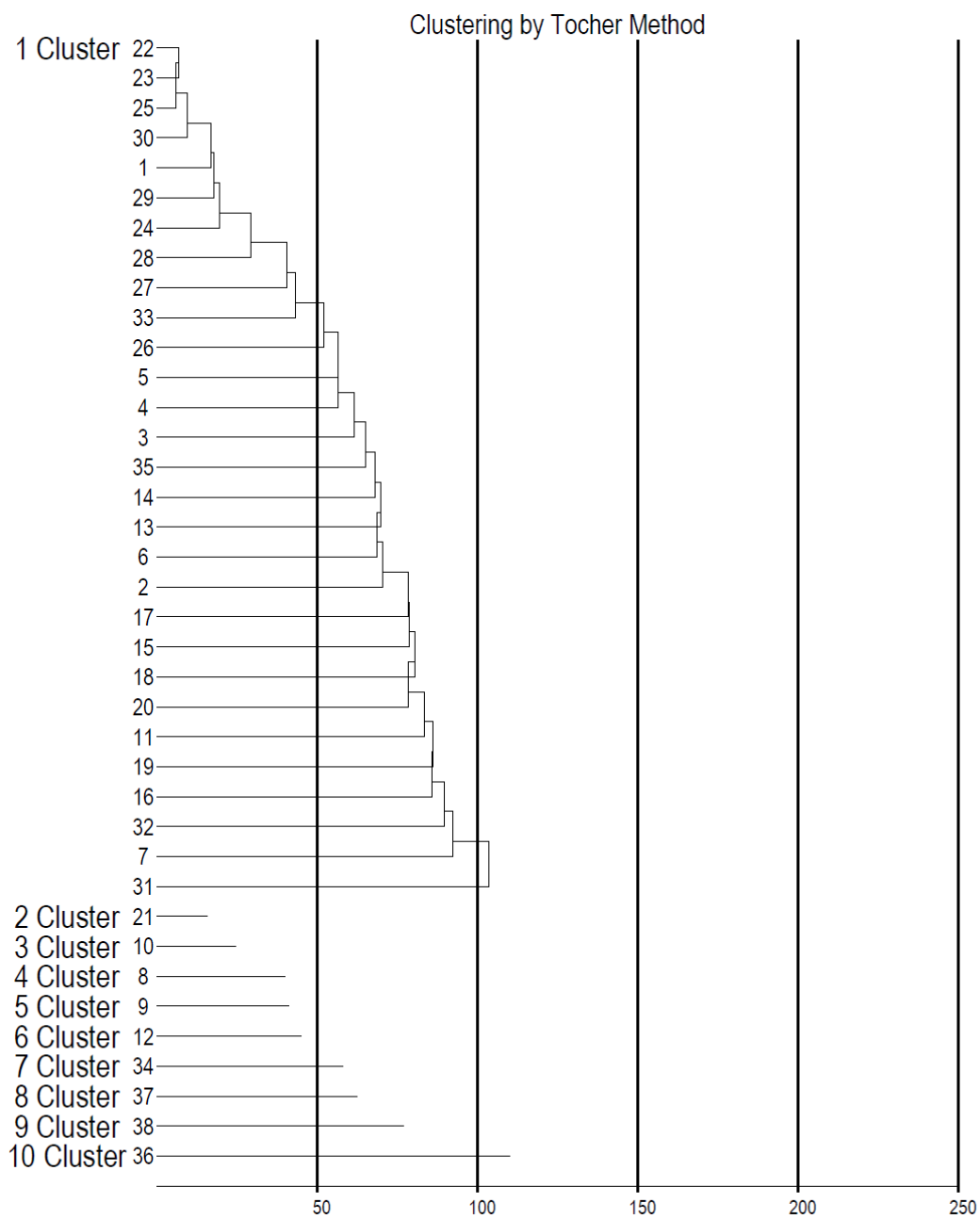


Figure 4.2 : Dendrogram for thirty eight genotypes of rice (*Oryza stiva* L.) by Tocher's Method.

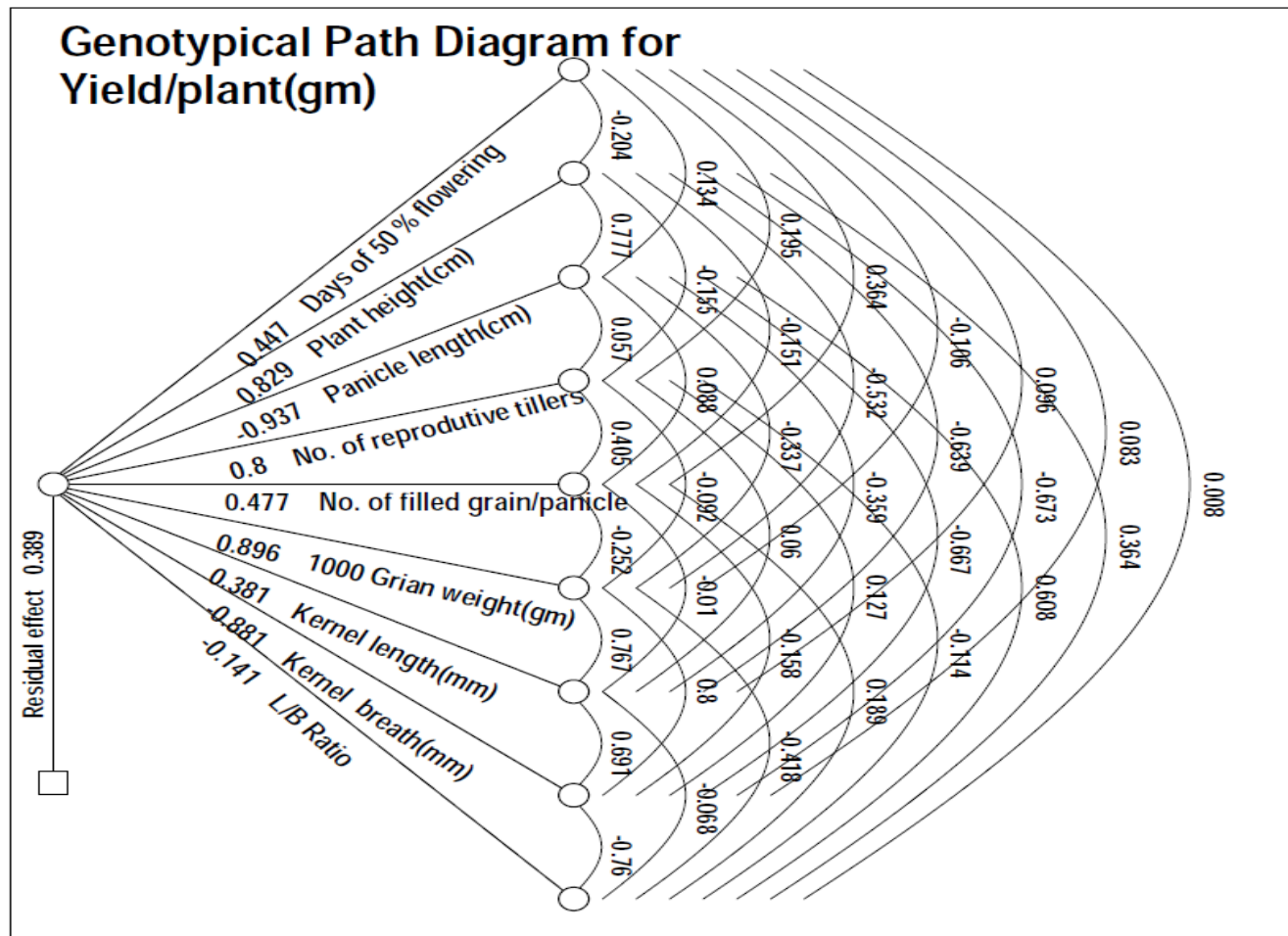


Fig. 4.3 : Genotypical path diagram for grain yield per plant (g).

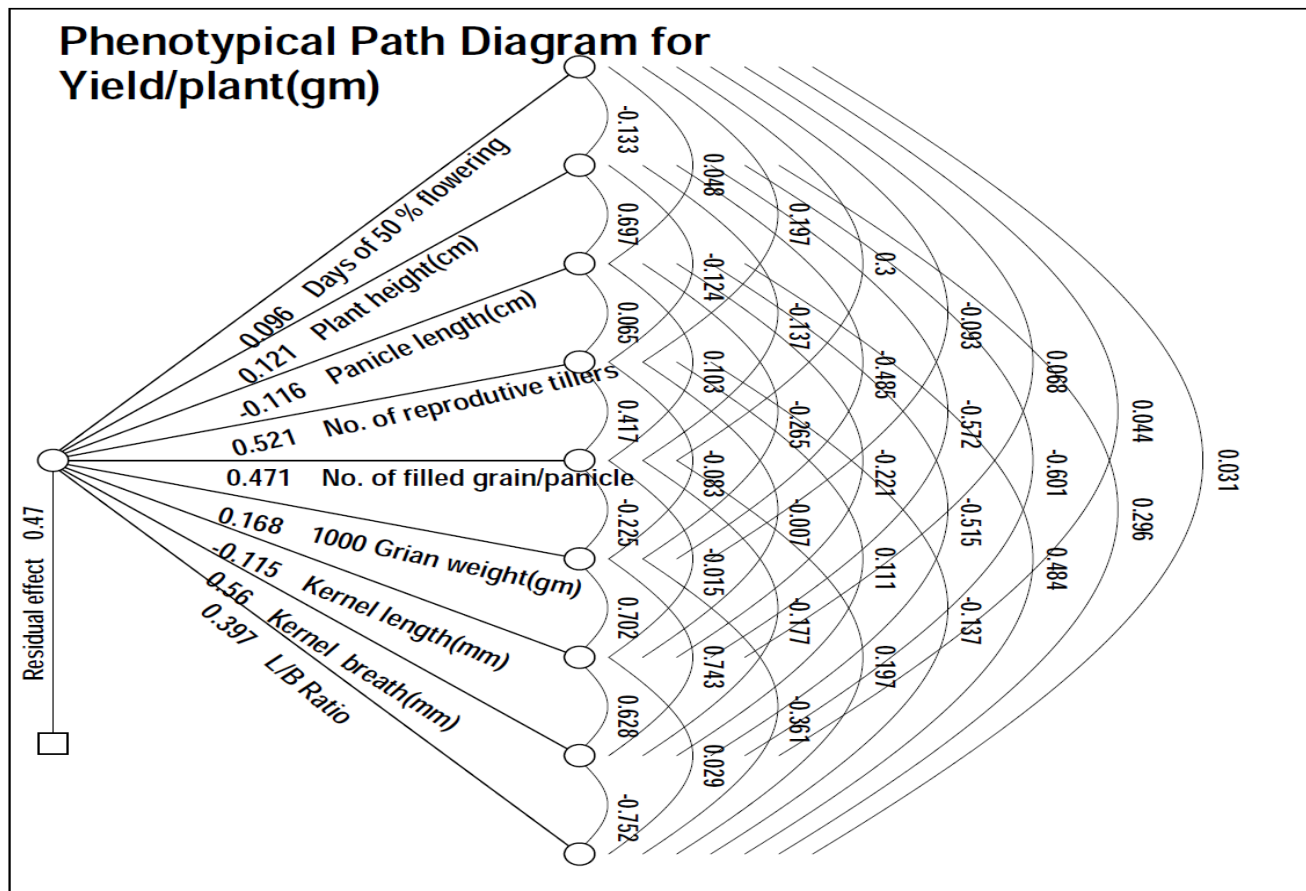


Fig. 4.4 : Phenotypal path diagram for grain yield per plant (g).

Chapter V

SUMMARY AND CONCLUSIONS

The research work entitled “Genetic divergence in elite lines for yield and quality attributes in rice (*Oryza sativa* L.)” was conducted with thirty eight rice genotypes in a randomized block design with two replications at Rice section farm, Agricultural Research Institute, Rajendranagar, Hyderabad during *kharif* 2013. The objectives of the investigation were to study the genetic diversity present in the experimental material for selection of the diverse parents, for yield and quality traits and the extent of association between the yield and its component characters including the direct and indirect effects.

The observations were recorded on five randomly selected plants per genotype in each replication for thirteen characters viz., days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle, thousand grain weight, grain yield per plant, hulling percentage, milling percentage, head rice recovery, kernel length, kernel breadth, kernel L/B ratio.

Analysis of variance indicated high significant differences among the genotypes for all the traits under study. A perusal of genetic parameters revealed that phenotypic and genotypic coefficients of variation were high for thousand grain weight, followed by grain yield per plant, number of productive tillers per plant, number of filled grains per panicle, head rice recovery and plant height. The values of genotypic and phenotypic coefficients of variation were low for days to 50 per cent flowering, panicle length, hulling percentage, milling percentage kernel length, kernel L/B ratio.

High heritability coupled with high genetic advance as percent of mean was observed for thousand grain weight, grain yield per plant, plant height, number of filled grains per panicle, number of productive tillers per plant and kernel breadth. Which indicated that these traits were controlled by additive type of gene action in the inheritance of these characters. These characters can be further improved by following simple selection procedure. The high estimates of heritability coupled with moderate genetic advance as percent of mean for kernel length , kernel L/B ratio, panicle length, days to 50 per cent flowering indicated the presence of non-additive gene effects, in addition to influence of environment to some extent.

Divergence studies through D^2 statistic indicated the presence of substantial diversity by forming large number of clusters with wide range of inter-cluster distances. The diversity was more for thousand grain weight, kernel breadth, grain yield per plant, plant height, kernel L/B ratio indicating their importance in contribution towards genetic diversity .

The genetic divergence was high and the thirty eight genotypes of rice were grouped into 10 divergent clusters. I was the largest comprising of twenty nine genotypes and all other clusters II ,III IV, V, VI ,VII, VIII, IX and X were represented by single genotype indicating high degree of heterogeneity among the genotypes. The pattern of group constellations indicated significant variability among the genotypes.

The higher amount of divergence was observed between cluster from the inter cluster D^2 values of the ten clusters, it can be seen that the highest divergence occurred between cluster V and X (23.65) followed by cluster V and VIII (22.07), cluster III and X (21.99), cluster VI and X (20.49), cluster), cluster IV and VIII (20.08) and cluster VI and VIII (19.78), cluster III and VIII (19.67) suggesting that the crosses involving varieties from these clusters would give wider and desirable recombination. Maximum intra cluster distance was observed in cluster I (8.78) is suggested to generate promising segregants for grain yield and quality traits would produce encouraging results.

The cluster VIII is having highest mean value for grain yield and thousand grain weight, cluster VII for number of filled grains per panicle and cluster X is having highest number of productive tillers per plant, head rice recovery, kernel breadth and cluster VI for hulling percentage, high milling percentage and cluster III having highest plant height, panicle length, II having highest kernel length and cluster IV having high L/B ratio, cluster. The genotypes RNR 19371, RNR 19420, MTU 1010 ,MTU 1001 and RNR 19367 from these clusters having high mean values may be directly used for adaptation or may be used as parents in future hybridization programme.

The results showed that the contribution of thousand grain weight was highest towards genetic divergence (24.75 %) followed by kernel breath (23.61%), grain yield per plant (17.35%), plant height (11.10%), L/B Ratio (8.53%), kernel length (4.84%), Number of filled grains per panicle (3.84%), number of productive tillers per plant (1.85 %),

panicle length (1.56%), milling percentage (0.85), days to 50% flowering (0.71%), head rice recovery (0.57%) and hulling percentage (0.43%) is respectively to the genetic divergence in decreasing order. The five characters like thousand grain weight, kernel breadth, grain yield per plant, plant height, L/B ratio contributed 85.34% towards total divergence. Therefore, these characters should be given importance during hybridization and selection of segregating populations.

Character association studies revealed that the characters grain yield per plant showed significant positive association with days to 50 per cent flowering, number of productive tillers per plant, number of filled grains per panicle, kernel length, kernel breadth and positive association with thousand grain weight. This indicated that simultaneous selection of all these characters was important for yield improvement.

A critical analysis of the results by path analysis revealed that the traits numbers of productive tillers per plant followed by kernel breadth, number of filled grains per panicle and kernel L/B ratio were directly influencing the grain yield per plant.

A critical analysis of correlation and direct and indirect effects indicated that emphasis should be directed towards selection of parents having higher number of productive tillers per plant coupled with higher number of filled grains per panicle, kernel length and kernel L/B ratio. As the yield component filled grains per panicle is inter dependent on days to 50 per cent flowering, panicle length and number of productive tillers per plant, attention should be paid towards increasing the panicle length, maintaining optimum days to 50 per cent flowering and number of productive tillers per plant.

Thus a plant with medium height, higher number of productive tillers per plant, higher number of filled grains per panicle and kernel L/B ratio would be more desirable for selection to realize higher yield with good quality traits.

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