STUDIES ON GENETIC DIVERGENCE AND CHARACTERIZATION OF BORO RICE (*Oryza sativa* L.) GENOTYPES

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B.Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE
(GENETICS AND PLANT BREEDING)

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BY

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B.Sc. (Ag.)

THESIS SUBMITTED TO THE ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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2014

DECLARATION

I, **K. RAJENDRA PRASAD** hereby declare that the thesis entitled **"STUDIES ON GENETIC DIVERGENCE AND CHARACTERIZATION OF BORO RICE (*Oryza sativa* L.) GENOTYPES"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Hyderabad **(K. RAJENDRA PRASAD)**

Date: I.D. No. RAM/2012-41

CERTIFICATE

Mr. K. RAJENDRA PRASAD has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON GENETIC DIVERGENCE AND CHARACTERIZATION OF BORO RICE (*Oryza sativa* L.) GENOTYPES"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any University.

(**Dr. K.V. RADHA KRISHNA**)

Date: **Chairman**

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON GENETIC DIVERGENCE AND CHARACTERIZATION OF BORO RICE (*Oryza sativa* L.) GENOTYPES"** submitted in partial fulfilment of the 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. K. RAJENDRA PRASAD** under our guidance and supervision.

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

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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
DUS	Distinctiveness, Uniformity and Stability
et al.	And others
Fig.	Figure
g	Gram
GA	Genetic advance
GAM	Genetic advance as per cent of mean
GCV	Genotypic coefficient of variation
h^2	Heritability in broad sense
ha	Hectare
i.e.,	That is
M ha	Million hectare
mm	Millimeter
m.t	Million tones
No.	Number
PCV	Phenotypic coefficient of variation
PPV & FRA	Protection of Plant Varieties and Farmers' Rights Authority
RBD	Randomized Block Design
SES	Standard Evaluation System
viz.,	Namely

ACKNOWLEDGEMENTS

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ABSTRACT

In the present investigation, fifty 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 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 three replications at Directorate of Rice Research Farm, ICRISAT Campus, Patancheru, Hyderabad, during *Rabi* 2013-14.

Analysis of variance indicated the existence of significant genotypic differences among the genotypes for the yield, its components for all the characters. High GCV and PCV values were observed for number of filled grains per panicle, number of unfilled grains per panicle, grain yield per plant. High heritability coupled with high genetic advance as per cent of mean was observed for plant height, number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, number of unfilled grains per panicle, 1000-grain weight and grain yield per plant. which indicated that these traits were controlled by additive type of gene action. The remaining traits were mostly under the influence of non-additive gene effects as they recorded low to moderate estimates of genetic advance.

Based on the relative magnitude of D^2 values, the genotypes were grouped into ten clusters. Cluster I was the largest comprising of eighteen genotypes followed by cluster II with fifteen genotypes, cluster IV with ten genotypes and cluster III, V, VI, VII, VIII, IX, X with one genotype each. The highest divergence occurred between cluster VI and cluster VIII (387.67) followed by cluster VIII and cluster X (387.16), cluster III and cluster VIII (321.26), while it was low between cluster V and cluster VII (21.35).

Based on the inter cluster distances, a hybridization between the genotypes (IC-70855) of cluster VI and cluster VIII (IC-145639), cluster VIII (IC-145639) and cluster X (IC-86143), cluster III (IC-67935) with cluster V (IC-145633), is suggested to generate promising segregants for grain yield and would produce encouraging results. The data on character means for ten clusters indicated that, cluster VIII is having highest mean value for days to fifty percent flowering, plant height, panicle length, days to maturity. cluster IX number of unfilled grains per panicle and cluster X for number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant.

The maximum genetic divergence was contributed by days to fifty percent flowering was highest towards genetic divergence (41.22%) followed by Number of filled grains per panicle (30.61%), number of unfilled grains/panicle (9.80%), days to maturity (6.04%), 1000 grain weight (4.65%), plant height (3.27%), grain yield per plant (2.29%), number of productive tillers per plant (1.22%), number of tillers per plant (0.82%) panicle length (0.08%).Three characters viz. days to fifty percent flowering, number of filled grains per panicle accounts for more than 70% towards genetic divergence. Hence, these two characters are very important for selection indices.

Character association studies revealed that the characters grain yield per plant showed significant positive association with number of productive tillers per plant, number of tillers per plant, plant height, number of filled grains per panicle,1000 grain weight, panicle length, This indicated that simultaneous selection of all these characters was important for yield improvement. Path analysis revealed that the traits viz., number of filled grains per panicle, 1000 grain weight, numbers of productive tillers per plant, number of filled grains per panicle, days to maturity and number of productive tillers per plant and number of tillers per plant, plant height 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,1000 grain weight, plant height, longer panicle length. As the yield component filled grains per panicle is intern dependent on panicle length and plant height, attention should be paid towards increasing the panicle length, maintaining optimum plant height. Thus, a plant with medium height, sturdy culm with increased panicle length, higher number of filled grains per panicle and productive tillers per plant would be more desirable for selection to realize higher yield.

Morphological characterization through DUS descriptors revealed that Out of total sixty two characters studied, 11 were found to monomorphic and 16 characters were dimorphic and remaining characters are polymorphic. The total of thirty three morphological characters (polymorphic) were most useful for varietal identification in selected rice genotypes.

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is a popular cereal crop commonly used as human food. It is actually a type of grass and belongs to a family of Poaceae that includes other cereals such as wheat and corn. Rice is rich in nutrients and contains a number of vitamins and minerals. It is an excellent source of complex carbohydrates the best source of energy. It is the most important staple food crop for more than 60 per cent of the global population and forms the cheapest source of food energy and protein. It provides 43 per cent of calorie of an average human diet in India and rice contributes 20-25 per cent of agricultural income due to its intensive cultivation. In Asia as a whole, much of the population consumes rice in every meal. In many countries, rice accounts for more than 70 per cent of human caloric intake.

In India, rice is grown in an area of 42.86 million hectares with the production and productivity levels of 100.00 m.t and 2023 kg/ha, respectively (INDIASTAT, 2012), while in Andhra Pradesh, rice is grown in an area of 40.75 lakh hectares with the production and productivity levels of 14.41 lakh tonnes and 3003 kg/ha (INDIASTAT, 2012), respectively.

To meet the food demands of the growing population and to achieve food security in the country, the present production levels need to be increased by 2 m.t every year. It is estimated that 120 m.t of rice is required to feed the increased population by 2020. This is possible, when the yield potentiality of the presently grown varieties is further increased by 20-25 per cent by changing the genetic architecture. Success of any breeding programme depends upon the amount of genetic variability available in the crop species, besides the efficiency of selection technique adapted by plant breeder.

The boro rice is commonly known as winter rice. The term boro is Bengali originated from the Sanskrit word "Boro" which refers to a cultivation from Nov.-May under irrigated condition. Boro rice cultivation is relatively a new phenomenon in Bihar agriculture, where rice is being grown since time immemorial, during both kharif and rabi seasons. The cultivation of rice during rabi crop season (Nov.-May) was unknown probably till the new rice strains through Bangladesh refugees were introduced in these parts of India. Boro rice has traditionally been cultivated in the river basins, deltas, chaurs or saucer shaped depressions, where water accumulates during the monsoons but cannot be drained, thus providing ideal settings for boro rice cultivation during winter season. Although, boro rice cultivation has been an old practice in deep water areas, it is only recently that it has emerged as a major break through in enhancing rice productivity, not only in traditional, but also in non-traditional boro rice areas with assured irrigation and modern inputs. The credit primarily goes to the farmers' own initiatives in adopting its cultivation in a big way. But proper research inputs have not been fully exploited by the farmers. It is therefore worthwhile to examine the current scenario and analyse the future concerns. With the increased availability of irrigation facilities, boro rice technology has also moved to non-traditional flood-free irrigated areas. Northeastern region of Bihar also known, as 'Kosi' region comprises of Saharsa, Madhepura, Supaul, Purnea, Katihar, Darbhanga, Madhubani, and Khagaria districts. This region is characterized by high water level and during good monsoon years, large tracts of land become unsuitable for traditional rabi crop due to water logging and flooding from Kosi and its many tributaries. Wheat cultivation in this region is a remote possibility due to water stagnation, thus rice is the only option left with the farmers. Boro rice has come as a boon to the farmers of this region, but it has become popular only recently with the introduction of cold tolerant rice varieties.

Boro rice produces more yields than the kharif rice in the same ecology. In fact, the yields recorded from experiments, both at research station and at farmers fields show that yields from boro rice are manifolds compared to kharif rice. 'Gautam' one of the recently released varieties, from Rajendra Agricultural University, Pusa (Samastipur) have recorded yields between 8-10 t/ha. Even on farmer's fields. (Thakur *et al.* 1994). Despite the higher cost of cultivating boro rice the returns per ha. are significantly higher than kharif rice (Singh *et al.* 1998). Boro rice cultivation despite being a new phenomenon in Bihar plains has been able to make a significant impact in the economy of North Bihar areas, which could be achieved through their own innovative approach, in the form of some new varieties of boro rice. Agronomic practices followed by the farmers varied from farm to farm but it was observed that in general the farmers followed most of the recommended practices. The high water requirement of the crop was met with a local innovation called “bamboo boring” which served as the chief source of irrigation during the months of April-May when there was a scarcity of surface water in the region and farmers had to use ground water sources , this led to the higher cost to be spend on fuel etc. by the farmers. The study strengthened the belief that farmers are better innovators and a little support to them in terms of research and infrastructure could lead to even better results. Shallow water level and water logged low land can be utilized by using boro rice cultivation, which remains fallow in winter due to excessive moisture and late maturing rice. Immense potential for improving boro rice yield over winter crops in low land areas. Boro rice matures before on-set of monsoon and get sufficient time for harvesting as compared to chaite rice (spring). Good market price of boro rice due to offseason production. Reduces risk of natural calamities like flood for main season under flood prone areas using boro rice cultivation.

Yield is a complex character which is influenced by several quantitative traits, these are governed by polygenes. Application of biometrical techniques in plant breeding has led to the greater understanding of genetics of quantitative characters and proved to be extremely useful to the plant breeder for systematic genetic analysis.

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.

There are a number of boro rice germplasm collections currently under production whose identity and distinctiveness need to be established by various approaches. Obviously there is a need of consolidated system in the country to protect such a vast variability present in the species and proper sharing of benefits derived out of them. In this context, Government of India under the obligation of the TRIPS agreement has enacted the protection of plant varieties against unauthorized multiplication of seeds or propagating materials for a specified period (Anonymous2001). The PPV&FR Act recognizes the farmers as breeders who bred new varieties as well as conserved the traditional varieties. The plant varieties must fulfill the distinctiveness, uniformity and stability (DUS) criteria for protection under the Act and hence, there is a need to characterize rice varieties according to DUS test guidelines for rice prescribed by PPV and FR Authority (Anonymous 2007). The variety identification serves the important goals, such as mitigating legal claims and confirming intellectual property rights and maintenance of genetic purity. Plant morphological characters have been recognized as the universally undisputed descriptors in sequential fashion is useful and convenient to discriminate the different varieties. Keeping this in view, the study was taken up with the objective to determine the relative extent of distinctiveness, uniformity and stability of different morphological DUS descriptors in 50 boro rice genotypes for their protection under the PPV & FR ACT.

Keeping in view the importance explained above the present investigation is being proposed to study genetic divergence among the promising rice cultures developed by different AICRIP centers of India which are tested at several locations for releasing them as national varieties by central variety release committee (CVRC/SVRC). Such varieties need to have genetic divergence to suit for different situation and to meet local requirement. Hence, to assessment of variability for quality and yield, this will be useful to initiate crossing programme by different centers. With this available background information, the present studies have been initiated with the following objectives.

1. To study the genetic divergence through D^2 analysis.
2. To study the correlation and estimate the direct and indirect effects of various yield component characters on grain yield.
3. Morphological characterization of boro rice genotypes using DUS descriptors.

Chapter II

REVIEW OF LITERATURE

A brief review of available literature in consonance with the objectives of the present investigation in respect of rice crop are reviewed and presented under the following heads.

2.1 Genetic parameters

2.2 Genetic divergence

2.3 Character association

2.4 Path Coefficient Analysis

2.5 DUS characterization

2.1 Genetic Parameters

2.1.1 Variability

The nature and extent of variability forms the basis for all crop improvement programmes. 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 as a useful measure of the magnitude of genetic variance present in the population.

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 *et al.* (2009) Mulugeta Seyoum *et al.* (2012).
		Low	Patil *et al.* (2005) Sinha *et al.* (2004) Vijayalakshmi *et al.*(2008) Manoj Kumar Prajapate (2011).
2.	Plant height	High	Sinha *et al.* (2004)

S.No.	Character	Range	Reference
			Akhtar *et al.* (2011) Mulugeta Seyoum*et al.* (2012).
		Moderate	Tara Satyavathi *et al.* (2001) Nayak *et al.* (2002) Krishna *et al.* (2008).
		Low	Chikkalingaiah *et al.* (1999) Patil *et al.* (2005) Kole *et al.* (2008)
3.	Number of productive tillers per plant	High	Nayudu *et al.* (2007) Akhtar *et al.* (2011) Padmaja *et al.* (2011)
		Moderate	Vange and Ojo (1997) Nagajyothi (2001) Krishna *et al.* (2008)
		Low	Niranjana Murthy *et al.* (1999) Tara Satyavathi *et al.* (2001), Surender Raju (2002) Pankaj Garg *et al.* (2010).
4.	Panicle length (cm)	High	Tripathi *et al.* (1999) Nayudu *et al.* (2007)
		Low	Tara Satyavathi *et al.* (2001) Patil *et al.* (2003) Kole *et al.* (2008) Manoj kumar prajapate (2011)
5.	Number of filled grains per panicle.	High	Nayak *et al.* (2002) Patil and Sarawgi (2005) Nayudu *et al.* (2007) Pankaj Garg *et al.* (2010) Mulugeta seyoum *et al.* (2012)
		Moderaet	Sarma and Roy (1993)

S.No.	Character	Range	Reference
			Tara Satyavathi *et al.* (2001) Kole *et al.* (2008)
		Low	Nath and Talukdar (1997)
6.	1000 grain weight (g)	High	Patil and Sarawgi (2005) Nayudu *et al.* (2007) Mulugeta seyoum *et al.*(2012)
		Low	Chikkalingaiah *et al.* (1999) Vange *et al.* (1999) Tara Satyavathi *et al.* (2001)
7.	Grain yield per plant (g)	High	Sinha *et al.* (2004) Nayudu *et al.* (2007) Anbanandan *et al.* (2009) Pankaj Garg *et al.* (2010) Mulugeta seyoum *et al.* (2012)
		Moderate	Chauhan *et al.* (1993) Pradyumna Rao *et al.*(1996) Nagajyothi (2001) Tara Satyavathi *et al.* (2001)
		Low	Supriyo Chakraborthy and Hazarika (1994)
8.	Days to maturity	Low	Chanbeni *et al.* (2012)
9	Number of tillers per plant	High	Shantha Kumar *et al.* (1998)
10	Number of unfilled grains per panicle.	High	Patil *et al.* (2005)

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 trait

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 *et al.* (2002) Sankar *et al.* (2006) Bharadwaj *et al.* (2007) Kishore *et al.* (2008)
		Medium	Chauhan *et al.* (1993) Sahdev Singh *et al.* (1996) Singh and Choudhary (1996)
2.	Plant height	High	Akhtar *et al* (2011) Mulugeta seyoum *et al* (2012)
		Moderate	Akinwale *et al.* (2011)
		Low	Vijayalakshmi *et al.(*2008)
3.	Number of productive tillers per plant	High	Sankar *et al.* (2006) Nayudu *et al.* (2007) Anbanandan *et al.* (2009) Nandan and Sweta Singh (2010) Immanuel selvarje *et al.* (2011)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Venkata Suresh (2001)
		Low	Ramesh Kumar (1989) Niranjana Murthy *et al.* (1999)
4.	Panicle length (cm)	High	Chikkalingaiah *et al.* (1999) Nayak *et al.* (2002) Nayudu *et al.* (2007) Mohan and Devendra (2011)

S.No.	Character	Range	Reference
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Venkata Suresh (2001)
		Low	Singh and Chaudhary (1996)
5.	Number of filled grains per panicle.	High	Nagajyothi (2001) Patil *et al.* (2005) Sankar *et al.* (2006) Nayudu *et al.* (2007) Krishna *et al.* (2008) Pankaj Garg *et al.* (2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Mulugeta *et al.(*2012)
6.	1000 grain weight (g)	High	Bharadwaj *et al.* (2007) Nandan and Sweta Singh (2010) Abdul Fiyaz *et al.* (2011) Mulugeta seyoum *et al*.(2012)
		Moderate	Ramesh kumar (1989)
7.	Grain yield per plant (g)	High	Nayudu *et al*. (2007) Anbanandan *et al.* (2009) Pankaj Garg *et al.* (2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1999)
		Low	Bharadwaj *et al.* (2007)
8.	Days to maturity	High	Chanbeni *et al.*(2012)
9.	Number of unfilled grains/panicle	High	Patil *et al.*(2005)
10.	Number of tillers per plant	High	Shanta kumar *et al.*(1998)

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 hereunder in tabular form.

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

S.No.	Character	Range	Reference
			Immanuel selvaraj *et al* (2011)
		Moderate	Satya Priya Lalitha and Sreedhar (1999) Venkata Suresh (2001) Patra *et al.* (2006)
		Low	Sahdev Singh *et al.* (1996) Niranjana Murthy *et al.* (1999)
4.	Panicle length (cm)	High	Chikkalingaiah *et al.* (1999) Nayak *et al.* (2002) Nayudu *et al.* (2007) Mohan lal and Devendra (2011)
		Moderate	Satya Priya Lalitha and Sreedhar (1996) Venkata Suresh (2001) Patra *et al.* (2006)
		Low	Borbora and Hazarika (1998) Mokate *et al.* (1998) Nagajyothi (2001) Suman (2003)
5.	Number of filled grains per panicle.	High	Patil *et al.* (2005) Suman (2003) Sankar *et al.* (2006) Nayudu *et al.* (2007) Krishna *et al.* (2008) Pankaj Garg *et al.*(2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1996)
6.	1000 grain weight (g)	High	Bharadwaj *et al.* (2007) Karad and Pol (2008) Anbanandan *et al.* (2009) Nandan and Sweta Singh (2010)

S.No.	Character	Range	Reference
			Abdul Fiyaz *et al.* (2011)
		Moderate	Reddy and De (1996) Reddy *et al.* (1997) Sinha *et al.* (2004) Mulugeta seyoum *et al.*(2012)
		Low	Mishra *et al.* (1996) Chikkalingaiah *et al.* (1999) Nagajyothi (2001) Suman (2003) Vijayalakshmi *et al.* (2008)
7.	Grain yield per plant (g)	High	Madhavi Latha (2002) Sankar *et al.* (2006) Nayudu *et al.* (2007) Kumar and Ramesh (2008) Anbanandan et al. (2009) Pankaj Garg *et al.* (2010)
		Moderate	Satya Priya Lalitha and Sreedhar (1999) Patra *et al.* (2006)
		Low	Ramesh Kumar (1989) Suman (2003) Sinha *et al.* (2004)
8.	Number of tillers per plant	High	Shanta kumar *et al.* (1998)
9.	Days to maturity	Moderate	Chambeni *et al.* (2012)
10.	Number of unfilled grains per panicle	High	Patil *et al.* (2005)

2.2 GENETIC DIVERGENCE

Genetic improvement in any crop mainly depends upon the amount of genetic variability present in the population. The importance of genetic diversity in crop plants was first realized by Darwin (1859) and the term "morphism" employing genetic morphs was given by Huxley (1955) which means the existence of distinct genetic forms in balance in a population.

2.2.1 Mahalanobis's D^2 analysis

Mahalanobis's D^2 analysis is a powerful tool in quantifying the degree of divergence between biological populations at genetic level and provides a quantitative measure of association between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936).

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.

Vivekanandan and Sukanya Subramanian (1993) carried out genetic divergence using D^2 analysis in 28 genotypes of rainfed rice and grouped them into five clusters. Plant height and grain yield contributed considerably (85 %) to the total divergence. The geographical diversity was not found to be related to genetic diversity.

Ushakumari and Rangaswamy (1997) carried out genetic divergence among 74 rice genotypes and grouped them into six clusters by multivariate analysis using D^2 statistic. The characters grain yield/plant and plant height contributed maximum towards divergence. Relation between geographic diversity and genetic diversity was not observed.

Pandey *et al*. (1999) Studies on fifty rice genotypes by using Mahalanobis's D^2-statistic assigned the genotypes into six clusters and revealed no correlation between genetic diversity and geographical diversity. The characters days to 50 per cent flowering, plant height, 100-seed weight contributed maximum to the genetic diversity.

Madhavi Latha (2002) studies 54 rice genotypes for their genetic divergence which were grouped into nine clusters. The mode 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, plant height and days to 50 per cent flowering were contributed maximum towards genetic divergence

Surender Raju (2002) assessed the genetic divergence among 42 genotypes by Mahalanobis's D^2 statistic and grouped them into 12 clusters. The characters 100-grain weight, volume expansion ratio, kernel length and days to 50per cent flowering have contributed maximum to the genetic divergence.

Vanaja *et al.* (2003) carried out genetic divergence among 56 high yielding rice genotypes representing different eco-geographical regions and grouped them into nine clusters. It was concluded that there was no association between geographical distribution and genetic diversity. At the same time the relationship between genetic divergence and geographical origin also exists to some extent.

Madhavilatha and Suneetha (2005) evaluated 54 elite rice germplasm lines for their genetic diversity with regard to yield, yield components and quality traits. The genotype were grouped into nine clusters, a perusal of the results on cluster means revealed plant height and days to 50 per cent flowering, together accounted for 82.04 per cent of the total genetic divergence, indicating their importance in the choice of parents for hybridization programmes..

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.

Subudhi *et al.* (2009) studied the divergence analysis for quality characters in 41 rice genotypes. The genotype grouped into 10 clusters. The cluster I is having highest cluster mean for head rice recovery and cluster IX is highest L/B ratio and lowest KB. The genotypes of these clusters may be used as parents. Selected for future breeding programme.

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 tighter contribute 86.62% towards total divergence. Therefore, these characters may be given importance during hybridization programme.

Baradhan *et al.* (2010) Mahalanobis D^2 statistics was used to study the nature and magnitude of genetic diversity among 45 genotypes of rice. The genotypes were grouped into six clusters. In the present study, parental lines selected from cluster VI for grain yield, number of productive tillers per hill, panicle length and plant height and cluster I for number of grains per panicle exhibited high mean values. It is suggested that varietal improvement through hybridization, should be done among the genotypes more of divergent clusters.

Dushyantha Kumar *et al.* (2010) evaluated 39 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 number /panicle, number of panicles/plant and grain yield contributed considerably towards total divergence.

Nibedita Mohanty *et al*. (2010) were 40 rice genotypes using Mahalanobis's D^2 analysis. The 40 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 panicle-1 and days to 50% flowering contributed maximum towards genetic divergence among the genotypes.

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 44 rice genotypes were grouped into nine clusters and three ungrouped clusters. The traits viz.days to maturity, effective tillers/plant, grain yield/plant and chlorophyll content. Contribution (%) towards the total divergence.

Anandan *et al*. (2011) evaluated forty four salt tolerant rice genotypes from different geographic regions were assessed using Mahalanobis D^2 and principal component analysis (PCA). The D^2 statistics grouped the genotypes into 12 distinct clusters. The number of grains per panicle (42.71%), followed by the grain yield per plot (29.81%), was the major contributor to the total divergence. Hybridization among the genotypes which had the maximum inter-cluster distances could produce heterotic combinations and wide variability in segregating generations for many beneficial traits.

Mall *et al*. (2011) studied the grain quality characteristics of 24 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 104 genotypes of rice comprising aromatic as well as non-aromatic germplasm lines by using Non-hierarchical Euclidean cluster analysis. The 104 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 intercluster distance in most of the cases was higher than the intra-cluster distance, indicating wider genetic diversity among the accessions of different groups.

Vennila *et al*. (2011) evaluated 41 rice genotypes to identify diverse genotype for nine yield and yield attributing characters using Mahalanobis D^2 statistics. Based on the genetic distance all the 41 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 Tocher’s method and Mahalanobis (1936) D^2 statistics. Clustering pattern of genotypes showed no definite relationship between genetic divergence and geographical distribution of genotypes. 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.

2.3 CHARACTER ASSOCIATION

Study of character association helps the breeder in fixing a selection criteria for grain yield in parental lines, such that selections will be effective in isolating the plants with desired combination of characters. Phenotypic correlation is the correlation of phenotypic values and is subjected to changes in the environment. It measures the environment deviation together with non-additive gene action. Genotypic correlation is the correlation of breeding value. Hence, knowledge of association between different characters is highly essential for planning a sound breeding programme.

Several workers have studied the correlation coefficients in rice and contradictory association have been reported for almost all the character pairs which may be due to the different experimental material handled by them.

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/plant in rice

Character	Nature of association	Reference
Days to 50per cent flowering	Positive significant	Suman (2003) Kuldeep *et al.* (2004) Sankar *et al.* (2006) Krishna *et al.* (2008) Abdul Fiyaz *et al.* (2011)
	Positive non-significant	Rao and Shrivastav (1999) Madhavi Latha *et al.* (2005) Satish Chandra *et al.* (2009) Nandan and Sweta Singh (2010)
	Negative significant	Eradasappa *et al.* (2007) Pankaj Garge *et al.*(2010) Ravindra Babu *et al.*(2012)
	Negative non-significant	Sarma and Roy (1993) Yolanda and Vijendra Das (1995) Meenakshi *et al.* (1999)

Character	Nature of association	Reference
Plant height	Positive significant	Nayak *et al.* (2001) Madhavi Latha (2002) Eradasappa *et al.* (2007) Krishna *et al.* (2008) Abdul Fiyaz *et al.* (2011)
	Positive non-significant	Suman (2003) Madhavi Latha *et al.* (2005) Karad and Pol (2008) Nandan and Sweta Singh (2010)
	Negative significant	Yolanda and Vijendra Das (1995) Reddy *et al.* (1997) Rao and Shrivastava (1999) Tara Satyavathi *et al.* (2001) Mahto *et al.* (2003)
	Negative non-significant	Gupta *et al.* (1998) Meenakshi *et al.* (1999) Satish Chandra *et al.* (2009) Mulugeta seyoum *et al.*(2012)
No. of productive tillers/plant	Positive significant	Suman (2003) Sankar *et al.* (2006) Eradasappa *et al.* (2007) Krishna *et al.* (2008) Satish Chandra *et al.* (2009) Abdul Fiyaz *et al.* (2011) Ravindra Babu *et al.* (2012)
	Positive non-significant	Chaubey and Singh (1994) Yolanda and Vijendra Das (1995) Reddy *et al.* (1997) Madhavi Latha *et al.* (2005) Muluget seyoum *et al.*(2012)

Character	Nature of association	Reference
Panicle length	Positive significant	Madhavi Latha (2002) Kuldeep *et al.* (2004) Sankar *et al.* (2006) Eradasappa *et al.* (2007) Satish Chandra *et al.* (2009) Basavaraja *et al* (2011)
	Positive non-significant	Vange *et al.* (1999) Tara Satyavathi *et al.* (2001) Madhavi Latha *et al.* (2005) Krishna *et al.* (2008) Muluget seyoum *et al.*(2012)
	Negative non-significant	Chauhan *et al.* (1993) Ramesh Babu (1999)
Number of filled grains/panicle	Positive significant	Sankar *et al.* (2006) Eradasappa *et al.* (2007) Krishna *et al.* (2008) Satish Chandra *et al.* (2009) Pankaj Garg *et al.* (2010) Padmaja *et al.* (2011) Zulqarnain *et al.(*2012)
	Positive non-significant	Sarma and Roy (1993) Chaubey and Singh (1994) Paul and Sarmah (1997) Madhavi Latha *et al.* (2005) Nandan and Sweta Singh (2010) Akinwale *et al.* (2011)
Number of un filled grains/panicle	Negative significant	Krishnaveni *et al.* (2006)
Days to maturity	Positive significant	Mareker and Siddiqui (1996)

Character	Nature of association	Reference
	Positive non-significant	Ganesan *et al.* (1997) Reddy *et al.* (1997) Madhavi Latha (2002)
	Negative significant	Krishna *et al.* (2008)
	Negative non-significant	Geeta *et al.* (1994) Asha Christopher *et al.* (1999)
Number of tillers per plant	Positive significant	Idris *et al.* (2013)
1000-grain weight	Positive significant	Satish Chandra *et al.* (2009) Yadav *et al.* (2011) Basavaraja *et al.* (2011) Zulqarnain *et al.* (2012)
	Positive non-significant	Supriyo Chakraborthy and Hazarika (1994) Gupta *et al.* (1998) Vange *et al.* (1999) Madhavi Latha *et al.* (2005)
	Negative non-significant	Suman (2003)
	Negative non-significant	Wilfred Manuel and Rangaswamy (1993) Geeta *et al.* (1994) Muluget seyoum *et al.*(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
	Positive significant	Kavitha and Sree Rama Reddi (2001) Sakthivel (2001) Madhavi Latha (2002) Ravindra Babu *et al* (2012)

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

Character	Nature of association	Reference
Number of unfilled grains/panicle	Positive significant	Roy *et al.* (1995)
Days to maturity	Negative significant	Ramesh Babu (1999) Nayak *et al.* (2001)
	Negative non-significant	Nandan *et al.* (2010)
Number of tillers per plant	Negative non-significant	Nandan *et al.*(2010)
1000-grain weight	Positive significant	Ravindranath *et al.* (1982) Yadav *et al.* (2011)
	Positive non-significant	Roy *et al.* (1995)
	Negative significant	Ramesh Babu (1999) Kavitha and Sree Rama Reddi (2001) Nayak *et al.* (2001) Sakthivel (2001)
	Negative non-significant	Vange *et al.* (1999) Satish Chandra *et al.* (2009) Nandan *et al.* (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/plant	Positive significant	Janardhanam *et al.* (2001) Kavitha and Sree Rama Reddy (2001) Surender Raju (2002) Satish Chandra *et al.* (2009)
	Positive Non-significant	Roy *et al.* (1995) Yolanda and Vijendra Das (1995) Pradyumna Rao *et al.* (1996)
	Negative significant	Satya Priya Lalitha and Sreedhar (1997) Meenakshi *et al.* (1999) Nayak *et al.* (2001) Nayak (2003)
Panicle length	Positive significant	Tara Satyavathi *et al.* (2001) Madhavi Latha (2002) Sinha *et al.* (2004) Satish Chandra *et al.* (2009)
	Positive non-significant	Chaubey and Singh (1994) Yolanda and Vijendra Das (1995) Reddy *et al.* (1997) Rao and Shrivastav (1999)
	Negative significant	Bala (2001)
Number of filled grains/panicle	Positive significant	Nayak *et al.* (2001) Madhavi Latha (2002) Satish Chandra *et al.* (2009)
	Positive non-significant	Geeta *et al.* (1994) Meenakshi *et al.* (1999) Kavitha and Sree Rama Reddy (2001) Abdus salman khan *et al.* (2009)
	Negative significant	Debchoudhury and Das (1998) Surender Raju (2002)

Character	Nature of association	Reference
	Negative non-significant	Chauhan *et al.* (1993) Sawant *et al.* (1995) Reddy *et al.* (1997)
Number of Unfilled grains/panicle	Negative non-significant	Roy *et al.* (1995) Nandan *et al* (2010)
Days to maturity	Positive non-significant	Ramesh Babu (1999)
	Negative significant	Nayak *et al.* (2001)
	Negative non-significant	De and Suriya Rao (1988) Geeta *et al.* (1994) Reddy *et al.* (1997) Nandan *et al*. (2010)
Number of tillers per plant	Positive non-significant	Ramesh Babu (1999) Kavitha and Sree Rama Reddy (2001)
	Negative non-significant	Nayak *et al.* (2001) Tara Satyavathi *et al.* (2001) Nandan *et al.* (2010)
1000-grain weight	Positive significant	Reddy *et al.* (1997) Suman (2003) Yogameenakshi *et al.* (2004)
	Positive non-significant	Ramesh Babu (1999) Satish Chandra *et al.* (2009)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative non-significant	Roy *et al.* (1995) Meenakshi *et al.* (1999) Nayak *et al.* (2001)

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

Character	Nature of association	Reference
Panicle length	Positive significant	Janardhanam *et al.* (2001) Sakthivel (2001) Padmaja *et al.*(2011)
	Positive non-significant	Yolanda and Vijendra Das (1995) Kavitha and Sree Rama Reddy (2001) Satish Chandra *et al.* (2009)
	Negative significant	Chaubey and Richharia (1993) Tara Satyavathi *et al.* (2001) Suman (2003)
	Negative non-significant	Reddy *et al.* (1997) Satya Priya Lalitha and Sreedhar (1996) Abdus salman kahan *et al.* (2009)
Plant height	Positive significant	Meenakshi *et al.* (1999) Janardhanam *et al.* (2001) Sakthivel (2001)
Number of filled grains per panicle	Positive non-significant	Yolanda and Vijendra Das (1995) Satya Priya Lalitha and Sreedhar (1996) Abdus salman kahan *et al.* (2009)
	Negative significant	Chaubey and Richharia (1993)
	Negative non-significant	Reddy *et al.* (1997) Tara Satyavathi *etal.* (2001) Nayak *et al.* (2001) Satish Chandra *et al.* (2009)
Number of tillers per plant	Positive non-significant	Roy *et al.* (1995)
Days to maturity	Positive significant	Hussain *et al.* (1989) Chauhan *et al.* (1994)
	Positive non-significant	Geeta *et al.* (1994)
	Negative significant	Ramesh Babu (1999)

Character	Nature of association	Reference
	Negative non-significant	Reddy *et al.* (1997) Nayak *et al.* (2001)
Number of unfilled grains per panicle	Positive non-significant	Kavitha and Sree Rama Reddy (2001) Nayak *et al.* (2001)
	Negative significant	Tara Satyavathi *et al.* (2001)
	Negative non-significant	Ramesh Babu (1999)
1000-grain weight	Positive and significant	Suryanarayana (2000) Sakthivel (2001)
	Positive non-significant	Meenakshi *et al.* (1999) Kavitha and Sree Rama Reddy (2001) Tara Satyavathi *et al.* (2001)
	Negative significant	Gopinath *et al.* (1984) Nayak *et al.* (2001) Padmaja *et al.*(2011)
	Negative non-significant	Reddy *et al.* (1997) Satish Chandra *et al.* (2009) Ravindra Babu *et al.* (2012)

2.3.5 Association among the yield component traits in rice association of number of productive tillers/plant with

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Sakthivel (2001) Padmaja *et al.*(2011) Janardhanam *et al.* (2001)
Grain yield per plant	Positive significant	Suman (2003) Sakthivel (2001)

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

Character	Nature of association	Reference
Number of productive tillers/plant	Positive significant	Bala (2001)
	Negative and significant	Ravindra Babu et al (2012)
Number of filled grains/panicle	Positive significant	Satish Chandra *et al.* (2009) Abdus salman khan *et al.* (2009) Padmaja *et al*.(2011)
	Positive non-significant	Reddy *et al.* (1997) Debchoudhury and Das (1998) Tara Satyavathi *el al.* (2001)
	Negative significant	Gopinath *et al.* (1984)
	Negative non-significant	Sawant *et al.* (1995) Nandan *et al*. (2010)
1000-grain weight	Positive significant	Gopinath *et al.* (1984) Yogameenakshi *et al.* (2004) Ravindra Babu *et al.* (2012)
	Positive non-significant	Kavitha and Sree Rama Reddy (2001) Satish Chandra *et al.* (2009) Nandan *et al*. (2010)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative non-significant	Roy *et al.* (1995) Vange *et al.* (1999) Nayak *et al.* (2001)

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

Character	Nature of association	Reference
Number of unfilled grains per panicle	Positive non-significant	Roy *et al.* (1995) Nandan *et al*. (2010)
Days to maturity	Negative significant	Geeta *et al.* (1994) Ramesh Babu (1999) Nayak *et al.* (2001)
	Negative non-significant	Reddy *et al.* (1997)
Number of tillers per plant	Positive non-significant	Tara Satyavathi *et a1.* (2001) Ramesh Babu (1999) Nayak *et al.* (2001)
	Negative significant	Kavitha and Sree Rama Reddy (2001)
1000-grain weight	Positive significant	Ravindranath *et al.* (1982)
	Positive non-significant	Meenakshi *et al.* (1999) Satish Chandra *et al.* (2009)
	Negative significant	Geetha *et al.* (1994) Nayak *et al.* (2001)
	Negative non-significant	Kavitha and Sree Rama Reddy (2001) Reddy *et al.* (1997) Nandan *et al*. (2010)

2.4 PATH COEFFICIENT ANALYSIS

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 *et al.* (2004) Sankar *et al.* (2006) Satish Chandra *et al.* (2009) Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Mulugeta *et al.* (2012)	Debchoudhury and Das (1998) Gupta *et al.* (1998) Nayak *et al.* (2001) Pankaj *et al.* (2010) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)
Plant height	Madhavi Latha (2002) Sankar *et al.* (2006) Basavaraja *et al.* (2011) Yadav *et al.* (2011) Mulugeta *et al.* (2012) Ravindra Babu *et al* (2012)	Saravanan *et al.* (1996) Tara Satyavathi *et al.* (2001) Suman (2003) Karad and Pol (2008) Satish Chandra *etal.* (2009) Akhtar *et al.*(2011)
Number of productive tillers/plant	Sankar *et al.* (2006) Karad and Pol (2008) Satish Chandra *et al.* (2009) Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Ravindra Babu *et al.* (2012)	Valarmathi and Leenakumari (1998) Kavitha and Sree Rama Reddy (2001) Mulugeta seyoum *et al.* (2012)
Panicle length (cm)	Khedikar *et al.* (2004) Karad and Pol (2008) Basavaraja *et al.* (2011) Mulugeta *et al.* (2012) Ravindra Babu *et al.* (2012)	Ganesan *et al.* (1997) Nayak *et al.* (2001) Madhavi Latha (2002) Satish Chandra *et al.* (2009) Pankaj *et al.* (2010)

Character	Positive direct effect on grain yield	Negative direct effect on grain yield
Number of filled grains/panicle	Sankar *et al.* (2006) Satish Chandra *et al*. (2009) Nandan and Sweta Singh (2010) Mulugeta *et al.* (2012)	Amirthadevarathinam (1990) Gupta *et al.* (1998) Akhtar *et al.(*2011) Rajamadhan *et al*. (2011) Ravindra Babu *et al.* (2012)
Number of tillers/plant	Singh *et al.* (2002)	Nagajyothi (2001)
Number of unfilled grains/panicle	Singh *et al.* (2002)	Krishnaveni (2006)
Days to maturity	Nagajyothi (2001)	Pankaj Garg *et al*.(2010)
1000-grain weight	Suman (2003) Khedikar *et al.* (2004) Satish Chandra *et al*. (2009) Yadav *et al.* (2011) Akhtar *et al. (*2011) Padmaja *et al*. (2011)	Karad and Pol (2008) Pankaj Garge *et al*. (2010) Basavaraja *et al*. (2011) Mulugeta seyoum *et al*. (2012) Ravindra Babu *et al*. (2012)

2.4.2 Indirect effects

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

Character	**Positive indirect effect**	**Negative indirect effect**
Plant height	Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Rajamadhan *et al.*(2011)	Debchoudhury and Das (1998) Satish Chandra *et al.* (2009) Ravindra Babu *et al.* (2012)
Number of productive tillers/plant	Madhavi Latha (2002) Satish Chandra *et al.* (2009) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)	Meenakshi *et al.* (1999) Kavitha and Sree Rama Reddy (2001) Padmaja *et al.* (2011) Basavaraja *et al.* (2011)
Panicle length	Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Madhavi Latha (2002) Satish Chandra *et al.* (2009) Ravindra Babu *et al.* (2012)
Number of filled grains/ panicle	Debchoudhury and Das (1998) Nayak *et al.* (2001) Madhavi Latha (2002)	Satish Chandra *et al.* (2009) Padmaja *et al* (2011) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)
Number of tillers/plant	Roy *et al.* (1995)	Madhavi Latha (2002)
Number of unfilled grains/ panicle	Singh *et al.* (2002)	Nayak *et al.* (2001) Madhavi Latha (2002) Rajamadhan *et al.* (2011)
Days to maturity	Madhavi Latha (2002)	Kavitha and Sree Rama Reddy (2001) Nayak *et al.* (2001)
1000-grain weight	Kavitha and Sree Rama Reddy (2001) Madhavi Latha (2002) Basavaraja *et al.* (2011)	Satish Chandra *et al.* (2009) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)

Indirect effects of plant height on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Gupta *et al.* (1998) Madhavi Latha (2002) Madhavi Latha *et al.* (2005) Rajamadhan *et al.* (2011) Ravindra Babu *et al*. (2012)	Kavitha and Sree Rama Reddy (2001) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011)
Number of productive tillers/plant	Nagajyothi (2001) Madhavi Latha *et al.* (2005) Satish Chandra *et al.* (2009) Basavaraja *et al.* (2011)	Nayak *et al.* (2001) Tara Satyavathi *et al.* (2001) Padmaja *et al.* (2011) Ravindra Babu *et al.* (2012)
Panicle length	Satish Chandra *et al.* (2009) Rajamadhan *et al.* (2011) Basavaraja *et al.* (2011) Ravindra Babu *et al*. (2012)	Nayak *et al.* (2001) Madhavi Latha (2002) Padmaja *et al.* (2011)
Number of filled grains per panicle	Madhavi Latha *et al.* (2005) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011) Ravindra Babu *et al*. (2012)	Valarmathi and Leena Kumari (1998) Suryanarayana (2000)
Number of tillers/plant	_	Nagajyothi (2001) Madhavi Latha (2002)
Number of unfilled grains/panicle	Ramesh Babu (1999) Madhavi Latha (2002)	Ganesan *et al.* (1997) Reddy *et al.* (1997) Rajamadhan *et al.* (2011)
Days to maturity	Ramesh Babu (1999) Nagajyothi (2001)	Nayak *et al.* (2001) Madhavi Latha (2002)
1000-grain weight	Madhavi Latha (2002) Satish Chandra *et al.* (2009) Rajamadhan *et al.* (2011)	Nayak *et al.* (2001) Padmaja *et al.* (2011) Ravindra Babu *et al.* (2012)

Panicle length	Madhavi Latha (2002) Padmaja *et al*. (2011) Basavaraja *et al*. (2011) Rajamadhan *et al*. (2011)	Kavitha and Sree Rama Reddy (2001) Nayak *et al*. (2001) Satish Chandra *et al*. (2009) Ravindra Babu *et al*. (2012)
Number of filled grains/panicle	Tara Satyavathi *et al*. (2001) Satish Chandra *et al*. (2009) Rajamadhan *et al* (2011) Mulugeta *et al*. (2012)	Valarmathi and Leena Kumari (1998) Nayak *et al*. (2001) Madhavi Latha (2002) Ravindra Babu et al (2012)
Number of tillers/plant	Reddy *et al*. (1995) Madhavi Latha (2002)	Nagajyothi (2001)
Number of unfilled grains/panicle	Ramesh Babu (1999)	Madhavi Latha (2002) Rajamadhan *et al*. (2011)
Days to maturity	Nayak *et al*. (2001) Madhavi Latha (2002)	Ramesh Babu (1999)
1000-grain weight	Reddy *et al*. (1997) Nagajyothi (2001) Tara Satyavathi *et al*. (2001)	Madhavi Latha (2002) Satish Chandra *et al*. (2009) Akhtar *et al*.(2011) Padmaja *et al*. (2011) Ravindra Babu *et al*. (2012)

Indirect effects of number of tillers/plant on grain yield through

Character	Positive indirect effect	Negative indirect effect
Panicle length	Singh *et al*.(2002)	Ravindra Babu *et al*. (2012)
Number of filled grain per panicle	Singh *et al*.(2002)	Ravindra Babu *et al*. (2012)

Indirect effects of panicle length on grain yield through

Character	**Positive indirect effect**	**Negative indirect effect**
Days to 50 per cent flowering	Satish Chandra *et al.* (2009) Rajamadhan *et al.* (2011) Ravindra Babu *et al*.(2012)	Debchoudhury and Das (1998) Padmaja *et al.* (2011)
Plant height	Satish Chandra *et al.* (2009) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011) Ravindra Babu *et al*. (2012)	Janardhanam *et al.* (2001) Tara Satyavathi *et al.* (2001)
Number of productive tillers/plant	Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Tara Satyavathi *et al.* (2001) Madhavi Latha (2002) Ravindra Babu *et al.* (2012)
Number of grains/panicle	Nayak *et al.* (2001) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011) Mulugeta *et al.* (2012)	Amirthadevarathinam (1983) Satish Chandra *et al.* (2009)
Number of tillers/plant	Roy *et al.* (1995)	Nagajyothi (2001) Madhavi Latha (2002)
Number of unfilled grains/panicle	Tara Satyavathi *et al.* (2001) Madhavi Latha (2002)	
1000-grain weight	Nagajyothi (2001) Madhavi Latha (2002) Basavaraja *et al.* (2011) Padmaja *et al.* (2011) Ravindra Babu *et al*. (2012)	Nayak *et al.* (2001) Satish Chandra *et al.* (2009)

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 *et al.* (1998) Madhavi Latha (2002) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011)	Kavitha and Sree Rama Reddy(2001) Nayak *et al.* (2001) Rajamadhan *et al.* (2011)
Plant height	Madhavi Latha (2002) Akhtar *et al.*(2011) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Reddy *et al.* (1997) Debchoudhury and Das (1998) Satish Chandra *et al.* (2009)
Number of productive tillers/plant	Amirthadevarathinam (1983) Valarmathi and Leena Kumari 1998) Akhtar *et al.*(2011) Rajamadhan *et al* (2011)	Ganesan *et al.* (1997) Nayak *et al.* (2001) Madhavi Latha (2002) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011)
Panicle length	Reddy *et al.* (1997) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Madhavi Latha (2002)
1000-grain weight	Madhavi Latha (2002) Satish Chandra *et al.* (2009) Akhtar *et al.*(2011) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Tara Satyavathi *et al.* (2001)

Indirect effects of 1000-grain weight on grain yield through

Character	Positive indirect effect	Negative indirect effect
Days to 50 per cent flowering	Nayak *et al.* (2001) Madhavi Latha (2002) Satish Chandra *et al.* (2009)	Padmaja *et al.* (2011) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)

Plant height	Nagajyothi (2001) Madhavi Latha (2002) Rajamadhan *et al.* (2011) Ravindra Babu *et al.* (2012)	Ganesan *et al.* (1997) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011)
Number of productive tillers/plant	Nagajyothi (2001) Tara Satyavathi *et al.* (2001)	Satish Chandra *et al.* (2009) Rajamadhan *et al.* (2011) Padmaja *et al.* (2011) Ravindra Babu *et al.* (2012)
Panicle length	Nayak *et al.* (2001) Padmaja *et al.* (2011) Rajamadhan *et al.* (2011)	Madhavi Latha (2002) Satish Chandra *et al.* (2009) Ravindra Babu *et al.* (2012)
Number of filled grain/panicle	Tara Satyavathi *et al.* (2001) Madhavi Latha (2002) Satish Chandra *et al.* (2009) Padmaja *et al.* (2011)	Reddy *et al.* (1997) Nayak *et al.* (2001) Rajamadhan *et al.* (2011)

2.5 DUS characterization

Kaw *et al.* (1985) studied characteristics of some popularly grown promising varieties of rice in the low-temperature areas of india and nepal and significant results achieved in improving yield and other attributes are briefly discussed.

Standard Evaluation System of Rice. 4th edition. (1996) Philippines.

Diaz *et al.* (2000) studied 19 rice germplasm entries using system of standard evaluation for rice and varietal description form and there were varietal differences for most of the characters evaluated.

Subba Rao *et al.* (2001) studied 123 native cultivars and land races which were characterized using morpho agronomic discriptors to estimate variability. Based on frequency distribution for eleven morphological characters,a majority of cultivars were found to possess green basal leaf sheath ,green corolla and white stigma.

Joseph *et al.* (2007) studied Navara - a traditional medicinal rice cultivar of Kerala to characterize this rice cultivar based on morphological features. Detailed characterization of navara germplasm revealed that there are many different morphotypes with respect to qualitative traits. Different groups could be identified based on vegetative, panicle and grain characters.

Rita Binse' *et al*. (2008) studied characterize thirty two aromatic rice accessions of Badshah bhog group from IGKV, Raipur, Chhattisgarh germplasm. These germplasm accessions were evaluated for twenty-two morphological, six agronomical and eight quality characters.

Ahmed *et al.* (2010) conducted experiment with 36 accessions of traditional (local) Boro rice germplasm accessions of three different groups (20 accessions of Kaliboro,12 of Jagliboro and 4 of Tepiboro) during Boro season 2004 at BRRI farm to identify the duplicates with the help of morpho-agronomic characters.

Nandita Patra *et al.* (2010) studied eighteen basmati rice varieties were characterized using morphological descriptors adopted from the DUS guidelines of PPV & FR Authority and subsequently examined for their Distinctiveness, Uniformity and Stability. Among the 46 visually assessed characters 26 characters were monomorphic, 11 characters were dimorphic and seven characters were polymorphic indicating their potential for varietal characterization and distinctiveness.

Shilpa *et al.* (2010) studied were studied for 22 traditionally cultivated rice varieties from Goa, in comparison with high yielding rice varieties Jaya, Jyoti and IR8. The hulling percentage ranged from 63-81% and HR recovery from 45-74%. Among the varieties Length/Breath ratio ranged from 1.5-3.5 and the AC ranged from 14-25%. The lowest percentage of chalkiness was recorded in variety Barik Kudi. Highest GC was recorded in variety Salsi and lowest in Khochro. The kernel elongation ratio ranged from 4.78-1.83 mm and water uptake ratio ranged from 160-390.

Joshi *et al.* (2011*)* conducted experiment on twenty indigenous rice varieties and characterized than using morphological descriptors adopted from the DUS guidelines and subsequently examined for their distinctiveness, uniformity and stability.

Ashim Chakravorty *et al*. (2012) studied characterization of fifty one landraces of rice was done using 46 agro-morphological traits following Distinctiveness, Uniformity and Stability test (DUS) Out of fifty one varieties studied, twenty seven were found to be distinctive on the basis of twenty two essential and twenty four additional characters.

Sarawgi *et al.* (2012) studied characterization forty six aromatic rice accessions of Dubraj group from Chhattisgarh and Madhya Pradesh. These germplasm accessions were evaluated for twenty morphological, six agronomical and eight quality characters. 9 were identified for quality and agronomical characteristics.

Wellington Ferreira do Nascimento *et al.* (2012) studied characterization 146 accessions of upland rice (*Oryza sativa* L.)based on qualitative and quantitative agro-morphological descriptors. Polymorphism was observed among 12 of 14 qualitative characters evaluated, There is high variability among the rice accessions from the germplasm collection studied, which presents great importance for breeding programs or for genetic studies on this species.

Sinha *et al*. (2013) studied characterization of twenty landraces of rice using DUS testing protocol. this study he observed that out of the 20 investigated varieties 11 varieties are distinctive according to the five essential and the eighteen additional characters proposed by the DUS guideline.

Sinha *et al*. (2013) studied Characterization for 20 qualitative and 13 quantitative morphological characters with 82 agro-morphic descriptors was carried out. Most traits were polymorphic except coleoptiles colour, present of leaf collar, shape of ligule and present of secondary branching in panicle and indicated that morphological traits were useful for preliminary evaluation for crop improvement program and can be used for assessing genetic diversity among morphologically distinguishable rice landraces.

Ruth Elizabeth Ekka *et al*. (2013) conducted experiment on characterization of the germplasm indicated that out of the eighteen qualitative characters, the absolute frequency was very high for intermediate type of leaf pubescence, white ligule colour, cleft type of ligule shape, pale green auricle colour, green internode colour, absent type of awning and straw sterile lemma colour. The accessions exhibited substantial variation for all the characters.

Chapter III

MATERIAL AND METHODS

The present experiment was carried out during *Rabi*, 2013-14 at Directorate of Rice Research Farm, ICRISAT Campus, Patancheru, Hyderabad, The material used and methods followed are presented below.

3.1 MATERIAL

The experimental material consists of 50 genotypes obtained from different sources. The information of the genotypes is given in Table 3.1.

3.2 METHODS

All the 50 genotypes were sown separately in the nursery on raised beds. Twenty five days old seedlings of each genotype were transplanted in six rows of 6 m length by adopting a spacing of 30cm between plants and 20cm between rows in a Randomized Block Design replicated thrice. Recommended agronomic practices and plant protection measures for raising a healthy crop were taken up during experiment.

3.3 RECORDING OF OBSERVATIONS

Five plants of each genotype in each replication selected randomly from central rows, used to record data on 10 characters. The mean values were considered for statistical analysis.

3.3.1 QUANTITATIVE CHARACTERS

3.3.1.1 Days to 50 per cent flowering

The number of days from sowing to the days when primary panicles in 50 per cent plants were in heading was recorded.

3.3.1.2 Plant height (cm)

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

3.3.1.3 Number of tillers per plant

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

3.3.1.4 Number of productive tillers per plant

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

3.3.1.5 Panicle length (cm)

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

3.3.1.6 Number of filled grains per panicle

Numbers of filled grains were counted from five panicles in each selected plant.

3.3.1.7 Number of unfilled grains per panicle

Numbers of unfilled grains were counted from five panicles in each selected plant.

3.3.1.8 Days to maturity

The number of days from sowing to the time of harvest was recorded

3.3.1.9 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.

3.3.1.10 1000-grain weight (g)

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

3.4 STATISTICAL PROCEDURE

The data with respect to the above characters was 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 distances (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 (Fischer 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 = True effect of ‘ith’ genotype

r_j = True effect of ‘jth’ replication

e_{ij} = Random error association with ‘ith’ genotype and ‘jth’ replication.

The structure of analysis of variance:

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

Where,

r and t = number of replications and treatments, respectively

M’r, M’t and M’e = mean sum of squares due to replications, treatments and error respectively.

3.4.2 Variance

The genotypic and phenotypic variance was calculated as per the formulae (Burton and Devane, 1953).

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

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

(σ^2_e) = Error variance

3.4.3 Genotypic and phenotypic coefficients of variance

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

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

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

Categorization of the range of variation was effected as proposed by Sivasubramanian and Madhavamenon (1973).

$<10\%$: low

10-20% : moderate

$>20\%$: high

3.4.4 Heritability and genetic 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).

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

Where

h^2 = 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).

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

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.

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

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 %

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

A measure of group distance based on multiple characters was given by Mahalanobis (1936) using D^2 statistic. With the help of this, genetic divergence between genotypes was estimated.

D^2 values between i^{th} and j^{th} genotypes for `p` characters were calculated as.

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

Where

Y_{it} = Uncorrelated mean values of i_{th} genotype for 't' character,

Y_{jt} = Uncorrelated mean values of j_{th} genotype for 't' character,

D^2_{ij} = D^2 between i_{th} and j_{th} genotypes

3.4.5.1 Test of significance

After testing the differences between genotypes for each of the characters, a simultaneous test for significance for differences in the mean values of a number of correlated variations with regard to the pooled effect of characters was carried out by using `V` statistic which in turn utilizes Wilk`s 'Λ' criterion. The sum of squares and sum of product of *error + genotype* were used for this purpose. The estimation of 'Λ' (Wilk`s criterion) was done using the following relationship.

'Λ' = W/S

Where

‘Λ’ = Wilk`s criterion

W = determination of error matrix

S = determination of error variety matrix

The significance of ‘Λ’ was tested by:

$$X^2pq = V\ (stat) = -m \log_e \text{‘}\Lambda\text{’} = -[n- \frac{P+Q+1}{2}] \log_e \text{‘}\Lambda\text{’}$$

Where,

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

P = Number of variables or characters

Q = Number of variables-1(or d.f. for population)

n = Degrees of freedom for error + varieties

Log_e `A` = 2.3026 log_{10} ‘Λ’

V (stat) can be approximately considered to be distributed as X^2 pq and if the calculated ‘V’ value from the formula exceeds X^2 pq‘K’, the hypothesis is rejected at K level of significance; otherwise not.

3.4.5.2 Transformation of correlated variables

In the present model, computation of D^2 values were reduced to simple summation values of the differences in mean values of various characters of the two genotypes i.e., di^2. Therefore, transformation of correlated variables to uncorrelated ones was done before working out the D^2 values. Transformation was done by using pivotal consideration method.

3.4.5.3 Computation of D^2 values

For a given combination of `i` and `j` genotype, the mean deviation i.e., $\bar{Y}_{it} - \bar{Y}_{jt}$

for t = 1, 2 ………….P variables were computed and D^2 values were calculated as sum of square deviations:

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

Where,

Y_{it} = Uncorrelated mean values of i_{th} genotype for ‘t’ character,

Y_{jt} = Uncorrelated mean values of j_{th} genotype for ‘t’ character,

D^2_{ij} = D^2 between i_{th} and j_{th} genotype,

3.4.5.4 Testing of significance of D^2 values

The D^2 values obtained for a pair of population is taken as the calculated values of X^2 and is tested against the tabulated value of X^2 for P degrees of freedom, where P is the number of characters considered.

3.4.5.5 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 ($di = r_t^i - r_t^j$) Rank 1 is given to the highest mean difference and rank P to the lowest difference, where P is the total number of characters. Percentage contribution of each character towards genetic divergence was calculated using the formula:

$$\text{Percentage contribution of characters} = \frac{N \times 100}{M}$$

Where

N = Number of genotype contribution where the character was ranked first

M = All possible combinations of number of genotypes considered

3.4.5.6 Grouping of genotypes into various clusters

Grouping of populations into different clusters was done using Tocher`s method as described by Rao (1952). The criterion used in clustering by this method is that any two varieties belonging to same cluster should at least on an average show a similar D^2 value than those belonging to different clusters. For this purpose, D^2 values of all combinations of each genotype were arranged in an increasing order of magnitude in a tabular form as described by Singh and Chaudhary (1979). To start with two populations having the smallest distance from each other were considered to which a third population having the smallest D^2 value from the first two populations was added. Similarly, next nearest fourth population was considered and this procedure is continued. At certain stage where it was felt that after adding a particular population there was abrupt increase in the average D^2 value, that population was not considered for including in that cluster. The group of the first cluster was then omitted and the rest was treated in a similar way. This process was continued till all the genotypes were included into one or other cluster.

3.4.5.7 Average intra cluster distance

For the measurement of intra cluster distance, the formula used was $\Sigma D^2_i/n$

Where,

ΣD^2_i = Sum of distances between all possible combinations (n) of the populations included in a cluster

n = Number of clusters

3.4.5.8 Average inter-cluster distance

Clusters were taken one by one and their distances from other clusters were calculated. The distance between two clusters was the sum of D^2 values between the numbers of one cluster to each of the number 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 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.

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

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

3.4.6 Estimation of correlation coefficients

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

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

Where

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

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

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

Where:

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

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

3.4.7 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 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.

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

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

$$. \quad . \quad . \quad . \quad .$$

$$: \quad : \quad : \quad : \quad :$$

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

Where;

1, 2 ……………..n = Independent variables

y = Dependant variable

r_{1y}, r_{2y} ……….. r_{ny} = Coefficient of correlation between casual factors `1` to `n` on dependent character 1

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

The above question can be written in matrix form as:

$$\underset{A}{\begin{pmatrix} r_{1y} \\ r_{2y} \\ . \\ . \\ . \end{pmatrix}} \quad \underset{C}{\begin{pmatrix} 1 & r_{12} & r_{13} & \ldots\ldots\ldots\ r_{1n} \\ r_{21} & 1 & r_{23} & \ldots\ldots\ldots\ r_{2n} \\ . & . & . & \\ . & . & . & \\ . & . & . & \end{pmatrix}} \quad \underset{B}{\begin{pmatrix} P_{1y} \\ P_{2y} \\ . \\ . \\ . \end{pmatrix}}$$

r_{ny} r_{n1} r_{n2} r_{n3} ……….. 1 P_{ny}

Then

$$B = (C)^{-1} A \text{ where } C^{-1} = \begin{pmatrix} c_{11} & c_{12} & c_{13} \ldots\ldots\ldots & c_{1n} \\ c_{21} & c_{22} & c_{23} \ldots\ldots\ldots & c_{2n} \\ . & . & . & . \\ : & : & : & : \\ : & : & : & : \\ c_{n1} & c_{n2} & c_{n3} \ldots\ldots\ldots & c_{nn} \end{pmatrix}$$

Direct effects were as follows:

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

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

$$p_{ny} = \sum_{i=1}^{k} c_{3i} \; r_{iy}$$

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

$$P_{ry} = \sqrt{1\text{-}(p_{1y}\, r_{iy} + p_{2y}\, r_{iy} + \ldots\ldots + p_{ny}\, r_{ny}}$$

Where:

p_{ny} = direct effect of x_n on Y

r_{iy} = correlation coefficient of x_n on Y

3.5 DUS Charactrization:

Characteristics and symbols

1. To assess distinctness, uniformity and stability, the characteristics and their states as given in the Table of characteristics should be used.

2. Notes (1 to 9), for the purpose of electronic data processing are given opposite the states of each characteristic.

3. Legend:(*) Characteristics should be used on all varieties in every growing season over which examinations are made and always be included in the variety descriptions, except when the state of expression of a preceding characteristic or regional conditions render this impossible.

4. (+) Characteristic is illustrated by explanation.

5. The optimum stage of plant growth for assessment of each characteristic is indicated by a number in the sixth column. These are explained below.

6. Decimal Code for the growth stages:

Code		Growth stage
10	:	First leaf through coleoptile / second leaf visible (less than 1 cm)
40	:	Booting (early boot stage)
50	:	First spikelet of inflorescence just visible
55	:	½ of inflorescence emerged
60	:	Beginning of anthesis
65	:	Anthesis half-way
70	:	Milk development
80	:	Dough development
90	:	Ripening (terminal spikelets ripened)
92	:	Caryopsis hard (can no longer be dented by thumbnail and over 90% of spikelets ripened)

Methods and observations

1. The characteristics described in the Table of characteristics should be used for the testing of varieties and hybrids for DUS.

2. For the assessment of distinctness and stability all observations should be made on at least 30 plants or parts of 30 plants in 3 replications.

3. For the assessment of uniformity of characteristics on the plot as a whole (visual assessment by a single observation of a group of plants or parts of plants), a population standard of 0.1% with an acceptance probability of at least 95% should applied. In the case of a sample size of 1500 plants the number of off-types should not exceed 4.

4. Unless otherwise indicated, all observations on the leaf should be made on the penultimate leaf.

5. For the assessment of uniformity of characteristics on single panicle-rows, plants or parts of plants (visual assessment by observations of a number of individual panicle-rows, plants or parts of plants) the number of aberrant panicle-rows, plants or parts of plants should not exceed 2 in 50.

6. For the assessment of colour characteristics, it is recommended that Royal Horticultural Society (RHS) colour chart should be used.

7. Type of assessment of characteristics indicated in Table of characteristics is as follows.

Dus characters

S.No.	Characteristics	States	Note	Stage of obser vation	Type of assessment
1.	Coleoptile: colour	colourless green purple	1 2 3	10	VS
2. (*)	Basal leaf: sheath colour	green light purple purple lines purple	1 2 3 4	40	VS
3.	Leaf: intensity of green colour	light medium dark	3 5 7	40	VG
4.	Leaf: anthocyanin colouration	absent present	1 9	40	VG
5.	Leaf : distribution of anthocyanin colouration	on tips only on margins only in blotches only uniform	1 2 3 4	40	VG
6.	Leaf sheath: anthocyanin colouration	absent present	1 9	40	VG
7.	Leaf sheath : intensity of anthocyanin colouration	very weak weak medium strong very strong	1 3 5 7 9	40	VG
8. (*)	Leaf: pubescence of blade surface	absent weak medium strong very strong	1 3 5 7 9	40	VS
9. (*)	Leaf : auricles	absent present	1 9	40	VS
10. (*)	Leaf: anthocyanin colouration of auricles	colourless light purple purple	1 2 3	40	VS
11.	Leaf: collar	absent present	1 9	40	VS
12.	Leaf: anthocyanin colouration of collar	absent present	1 9	40	VS
13.	Leaf: ligule	absent present	1 9	40	VS

14. (*)	Leaf: shape of ligule	truncate acute split	1 2 3	40	VS
15 (*).	Leaf: colour of ligule	green light purple purple	1 2 3	40	VS
16.	Leaf: length of blade	short medium long	3 5 7	40	MS
17.	Leaf: width of blade	narrow medium broad	3 5 7	40	MS
18.	Culm: attitude (for floating rice only)	non procumbent procumbent	1 9	40	VS
19. (+)	Culm: attitude	erect semi-erect open spreading	1 3 5 7	40	VS
20. (*)	Time of heading (50% of plants with panicles)	very early (<71 days) early (71-90 days) medium (91-110 days) late (111-130 days) very late (>130 days)	1 3 5 7 9	55	VG
21. (*) (+)	Flag leaf: attitude of blade (early observation)	erect semi-erect horizontal deflexed	1 3 5 7	60	VG
22. (*)	Spikelet: density of pubescence of lemma	absent weak medium strong very strong	1 3 5 7 9	60-80	VS
23.	Male sterility	absent present	1 9	65	VG
24.	Lemma: anthocyanin colouration of keel	absent or very weak weak medium strong very strong	1 3 5 7 9	65	VS
25.	Lemma: anthocyanin colouration of area below apex	absent weak medium strong very strong	1 3 5 7 9	65	VS

26. (*)	Lemma: anthocyanin colouration of apex	absent weak medium strong very strong	1 3 5 7 9	65	VS
27. (*)	Spikelet: colour of stigma	white light green yellow light purple purple	1 2 3 4 5	65	VS
28. (+)	Stem: thickness	thin medium thick	3 5 7	70	VS
29. (*)	Stem: length (excluding panicle; excluding floating rice)	very short (<91 cm) short (91-110 cm) medium (111-130 cm) long (131-150 cm) very long (>150 cm)	1 3 5 7 9	70	VS
30. (*)	Stem: anthocyanin colouration of nodes	absent present	1 9	70	VS
31.	Stem : intensity of anthocyanin colouration of nodes	weak medium strong	3 5 7	70	VS
32.	Stem: anthocyanin colouration of internodes	absent present	1 9	70	VS
33. (*) (+)	Panicle: length of main axis	very short (<16 cm) short (16-20 cm) medium (21-25 cm) long (26-30 cm) very long (>30 cm)	1 3 5 7 9	70-90	MS
34. (*) (+)	Flag leaf: attitude of blade (late observation)	erect semi-erect horizontal deflexed	1 3 5 7	90	VG
35. (*) (+)	Panicle: curvature of main axis	straight semi-straight drooping deflexed	1 3 5 7	90	VG
36.	Panicle: number per plant	few (<11) medium (11-20) many (>20)	3 5 7	80-90	MS

37. (*)	Spikelet : colour of tip of lemma	white yellowish brown red purple black	1 2 3 4 5 6	80-90	VS
38.	Lemma and Palea: colour	straw gold and gold furrows on straw background brown spots on straw brown furrows on straw brown (tawny) reddish to light purple purple spots on straw purple furrows on straw purple black	1 2 3 4 5 6 7 8 9	80-90	VG
39. (*)	Panicle : awns	absent present	1 9	90	VG
40. (*)	Panicle: colour of awns (late observation)	yellowish white yellowish brown brown reddish brown light red red light purple purple black	1 2 3 4 5 6 7 8 9	90	VS
41.	Panicle: length of longest awn	very short short medium long very long	1 3 5 7 9	90	VG-MS
42. (*)	Panicle: distribution of awns	tip only upper half only whole length	1 3 5	90	VS
43. (+)	Panicle: presence of secondary branching	absent present	1 9	90	VG
44. (+)	Panicle: secondary branching	weak strong clustered	1 2 3	90	VG
45. (*) (+)	Panicle: attitude of branches	erect erect to semi-erect semi-erect semi-erect to spreading spreading	1 3 5 7 9	90	VG

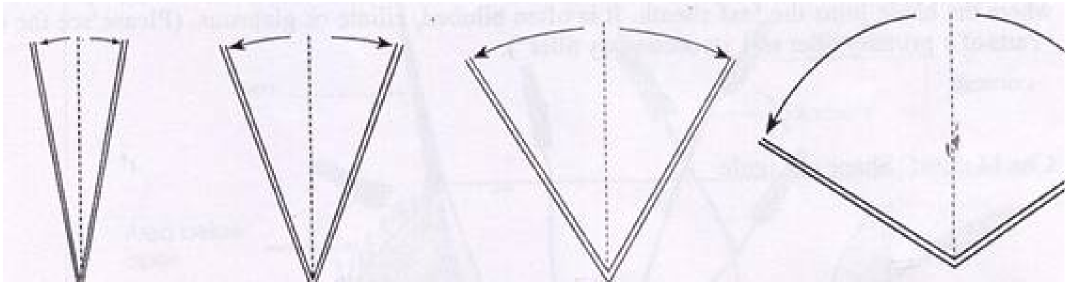
46. (*) (+)	Panicle: exsertion	partly exserted exserted well exserted	3 5 7	90	VG
47.	Time of maturity	very early early medium late very late	1 3 5 7 9	90	VG
48. (+)	Leaf: senscence	early medium late	3 5 7	92	VG
49. (*)	Sterile lemma: colour	straw gold red purple	1 2 3 4	92	VS
50.	Grain: weight of 1000 fully developed grains	very low low medium high very high	1 3 5 7 9	92	MG
51. (+)	Grain: length	very short short medium long very long	1 3 5 7 9	92	MS
52. (+)	Grain: width	very narrow narrow medium broad very broad	1 3 5 7 9	92	MS
53. (+)	Grain: phenol reaction of lemma	absent present	1 9	92	VG
54. (*)	Decorticated grain: length	very short short medium long very long	1 3 5 7 9	92	MS
55. (*)	Decorticated grain: width	narrow (<2.0 mm) medium (2.0-2.5 mm) broad (>2.5 mm)	3 5 7	92	MS
56. (*) (+)	Decorticated grain: shape (in lateral view)	short slender short bold medium slender long slender long bold extra long slender	1 2 3 4 5 6	92	MS

57. (*)	Decorticated grain: colour	white light brown variegated brown dark brown light red red variegated purple purple dark purple	1 2 3 4 5 6 7 8 9	92	VG
58. (+)	Endosperm: presence of amylose	absent present	1 9	92	MG
59. (*) (+)	Endosperm: content of amylose	very low (<10%) low(10-19%) medium(20-25%) high(26-30%) very high (>30%)	1 3 5 7 9	92	MG
60. (+)	Varieties with endosperm of amylose absent only Polished grain : expression of white core	absent or very small smal medium large	1 3 5 7	90	MG
61. (+)	Gelatinization temperature through alkali spreading value.	low medium high medium high	1 3 5 7	92	MG
62. (*) (+)	Decorticated grain: aroma	absent present	1 9	92	MG

Characteristic 14. Leaf : shape of ligule

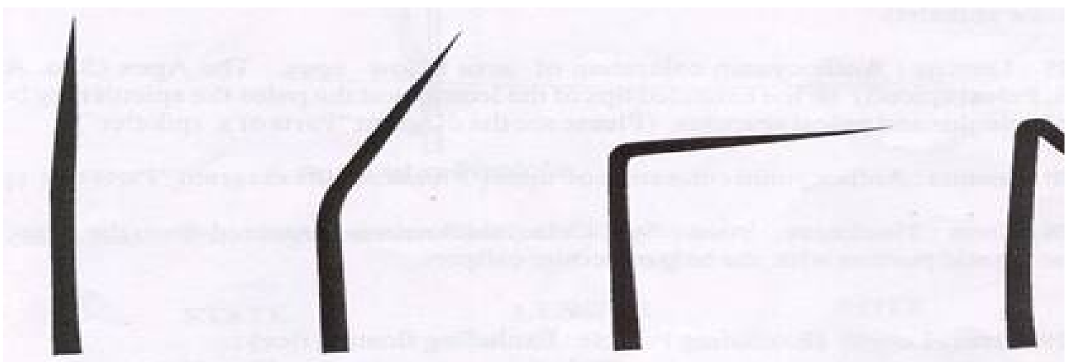
1	2	3
truncate	acute	split

Characteristic 19. Culm : attitude



1	3	5	7
erect	semi erect	open	spreading

Characteristic 21 and 34. Flag leaf : attitude of blade (early observations (21), (late observations (34

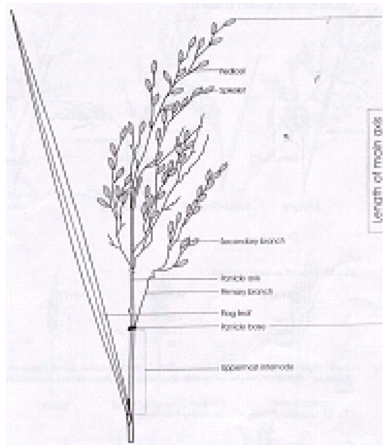


1	3	5	7
erect	semi-erect	horizontal	deflexed

Characteristic 28. Stem : thickness.

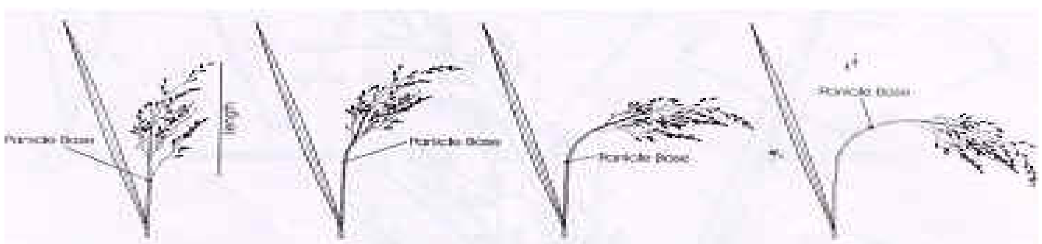
Stem (Syn. Culm) thickness is measured from the outer diameter of the culm at the mid portion with the help of vernier calipers

Characteristic 33. Panicle : length of main axis



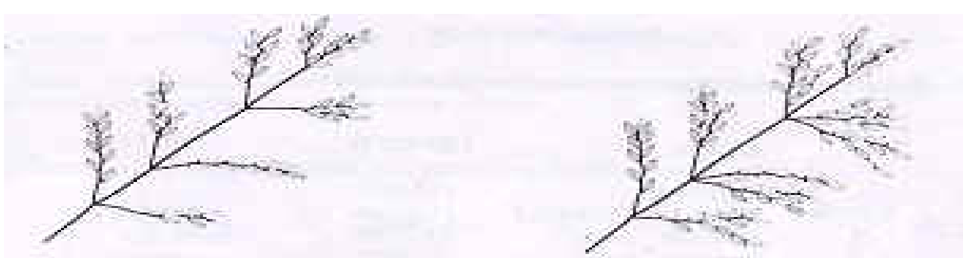
Parts of a panicle

Characteristic 35. Panicle : curvature of main axis



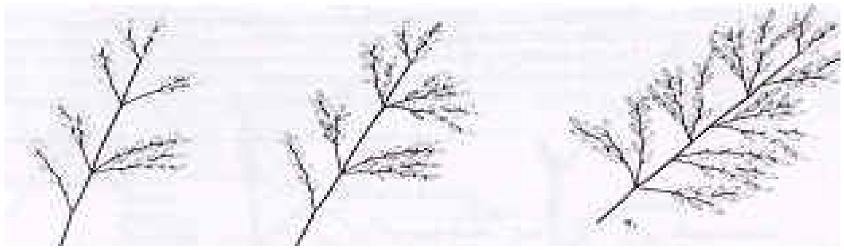
1	3	5	7
straight	semi straight	drooping	deflexed

Characteristic 43. Panicle : presence of secondary branching



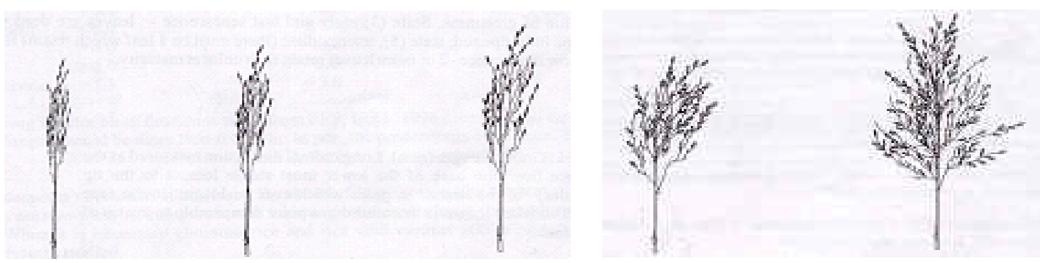
1	9
absent	present

Characteristic 44. Panicle : secondary branching



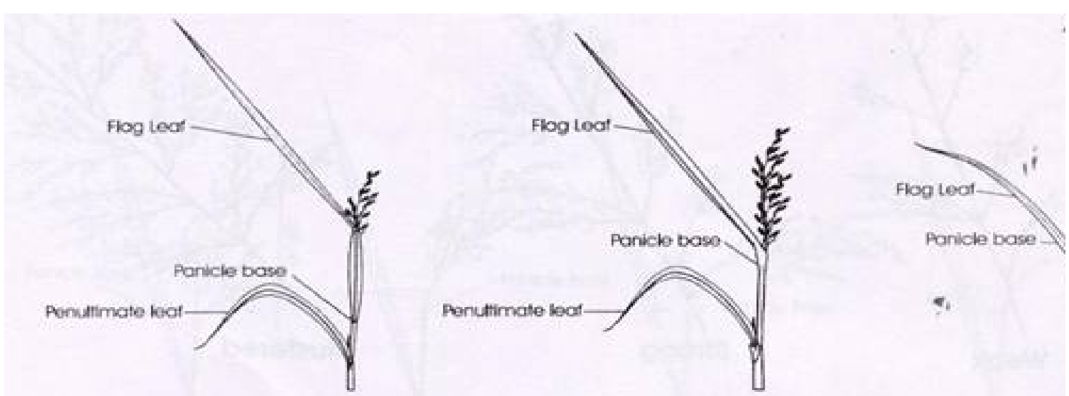
1	2	3
weak	strong	clustered

Characteristic 45. Panicle : attitude of branches



1	3	5	7	9
weak	erect to semi-erect	semi-erect	semi-erect to spreading	spreading

Characteristic 46. Panicle : exsertion



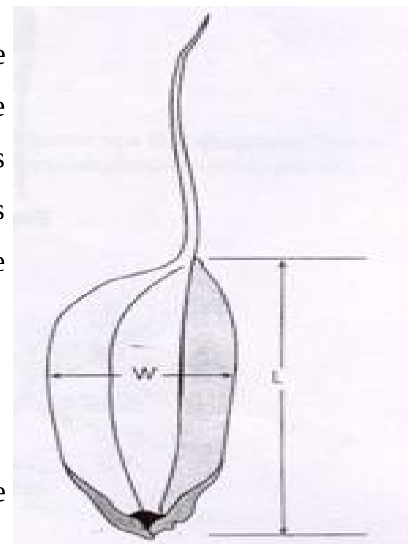
3	5	7
partly exserted	fully exserted	well exserted

Characteristic 48. Leaf : senescence

The leaves below the flag leaf are observed at the time of harvest for their retention of greenness. State (3), early senescence - leaves are dead when the grains have become fully ripened; state (5), medium senescence (there must be 1 leaf which retains its colour); state (7) late and slow senescence - 2 or more leaves retain their colour at maturity.

Characteristic 51. Grain : length

Longitudinal dimension measured as the distance from the base of the lower most sterile lemma to the tip (apiculus) of the lemma or palea which ever is longer. In the case of awned varieties, length is measured to a point comparable to the tip of the apiculus.



Characteristic 52. Grain : width

Dorsiventral diameter measured as the distance across the lemma and the palea at the widest point.

Characteristic 53. Grain : phenol reaction of lemma

Grains are soaked in 1.5 percent aqueous phenol solution for 24 hours, drained and air-dried. Hull colour is then recorded unstained and stained. (Chang TT and E.A. Bardenas 1965).

Characteristic 56. Decorticated grain : shape (in lateral view)

After dehusking (brown rice) or after milling (polished rice) the length and breadth of the grains are measured for computing the shape and size. Select minimum of 10 full grains per replication with both the ends intact and measure the length and breadth by using Grain Shape Tester or Dial Micrometer. Average of length and breadth measurements are taken in millimeters and length/breadth ratio is calculated. Based on length and breadth (L/B) ratio, Ramaiah (1969) classification is used to assign the grain shape.

As referred in Rice Research in India . ICAR Publication 1985.

State	Kernel length(mm)	Length/Breadth Ratio	Note
Short slender	<6.0	>3.0	1
Short Bold	<6.0	<2.5	2
Medium Slender	<6.0	2.5-3.0	3
Long Slender	>6.0	>3.0	4
Long Bold	>6.0	>3.0	5
Extra long Slender	>7.5	>3.0	6

Note : The classification of extra long slender of grain is done according to SES, IRRI 1996; for Basmati type long slender grain length should be more than 6.61 mm as per the proceedings of Annual Rice Workshop 1998.

Characteristic 58. Endosperm : presence of amylose

By observation glutinous rice has waxy grains and non-glutinous rice are non-waxy to transparent with various grades according to the amylose content of the endosperm. When it is necessary glutinous rice and rice with various grades of amylose content, chemical analysis is needed.

Characteristic 59. Endosperm : content of amylose

The simplified procedure of Juliano (1971) is used for the amylose content analysis. Twenty whole-grain milled rice is ground in a UDY cyclone mill (sieve mesh size 60). 100 mg of rice powder is put into a 100 ml volumetric flask and 1 ml of 95% ethanol and 9 ml of 1N Sodium hydroxide are added. The contents are heated on a boiling water bath to gelatinize the starch. After cooling for one hour, distilled water is added and contents are mixed well. For each set of samples run, low, intermediate and high amylose standard varieties are included to serve as checks. Five ml of the starch solution is put in a 100 ml volumetric flask with a pipette. One ml of 1N acetic acid, 2 ml of iodine solution (0.2 g iodine and 2.0 g potassium iodide in 100 ml of aqueous solution) are added and volume is made up with distilled water. Contents are shaken well and let stand for 20 minutes. Absorbance of the solution is measured at 620 mu with a spectrophotometer of standard make. Amylose content is determined by using a conversion factor and the results are expressed on a dry weight basis. The moisture content of the samples is essentially constant and need not be determined if the relative humidity and temperature of the laboratory is controlled.

State	Content of Amylose	Note
Very low	3-9%	1
Low	10-19%	3
Medium	20-25%	5
High	26-30%	7
Very High	>30%	9

Characteristic 60. Polished grain : expression of white core (Varieties with endosperm of amylose absent only)

Degree of chalkiness describing the milled sample rice with respect to (a) white core (b) white belly, (c) white back. Chalky white spots often appear in the starchy endosperm. A white chalky region extending to the edge of the ventral side and towards the centre of the endosperm is called a white core. Soft textured, white spots occurring in the middle part on the ventral side (side on which the embryo lies) are called (abdominal white) or white belly. A long white streak on the dorsal side is called the white back.

State	Kernel Area(mm)	Note
Absent/Very small	None	1
Small	<11%	3
Medium	11-20%	5
Very large	>20%	7

Characteristic 61. Gelatinization temperature through alkali spreading and clearing test (Little *el al*, 1958)

Duplicate sets of six whole milled grains are spaced evenly in transparent plastic boxes (50 mm x 42 mm x 22 mm) containing 10 ml of 1.7% Potassium Hydroxide. The dishes are kept at 27-30^{0}C for 23 hours undisturbed in an incubator. Standard varieties must be used as checks for high, medium and low gelatinization temperature. The spreading of kernels noted on a 7 point scale is expressed as average of six values. Scoring is done as follows.

Alkali Spreading Value/Scale

1. Kernel not affected
2. Kernel swollen
3. Kernel swollen, collar incomplete and narrow
4. Kernel swollen, collar complete and wide
5. Kernel split or segmented, collar complete
6. Kernel dispersed, merging with collar
7. All kernel dispersed and intermingled

Alkali spreading Value/Scale	Classification	GelatinizationTemperature	Note
6-7	High	Low	1
4-5	Medium	Medium	3
3	Low,Medium	High,Medium	5
1-2	Low	High	7

Characteristic 62. Decorticated grain : aroma

The method consists of adding about 15ml of water to 5 g of rice sample in a test tube (200 mm x 35 mm), soak for 10 minutes. Cook the sample in the water bath for 15 minutes. Transfer the cooked rice in to a petridish. After cooling keep it in the refrigerator for 20 minutes. Then the petri plates are opened and the contents are smelled. The samples possessing the scent, as one could easily feel, produce a sharp and readily recognizable aroma. (DRR un published).

Chapter IV

RESULTS AND DISCUSSION

The results obtained from the present experimental study on evaluation of 50 rice genotypes 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

4.6 DUS chracterization

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 10 characters of 50 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 88 days to 123.67 days with a general mean of 106.82. Among all the genotype, (IC-70855) was earliest (88.00 days) while (IC-145639) was found to be late (123.67 days).

4.1.1.2 Plant height (cm)

Plant height ranged from 68.80 cm to 126.60 cm with a general mean of 94.60 cm. The shortest genotype was (IC-89079) (68.80 cm) while the tallest genotype was found (IC-86011) (126.60 cm).

4.1.1.3 Number of tillers per plant

The mean tillers per plant ranged from 7.87 tillers (IC-89079) to 17.30 tillers (IC-99513) with a general mean of 13.19 tillers per plant.

4.1.1.4 Number of productive tillers per plant

The mean productive tillers per plant ranged from 5.74 tillers (IC-86154) to 13.13 tillers (IC-89143) with a general mean of 9.29 tillers per plant.

4.1.1.5 Panicle length (cm)

The panicle length ranged from 19.23 to 28.00 cm with a general mean of 23.56 cm. The genotype IC-89079 has shorter panicle value 19.23 cm and the genotype **(**IC-99288) exhibited highest value of 28.00 cm. Which was almost 8.77 cm longer than IC-89079.

4.1.1.6 Number of filled grains per panicle

The mean values for number of filled grains per panicle ranged from 112.00 (IC-145643) to 313.23 (IC-89115) with general mean 172.03.

4.1.1.7 Number of unfilled grains per panicle

The mean values for number of unfilled grains per panicle ranged from 5.59 (IC-99437) to 45.33 (IC-137335) with general mean 16.48.

4.1.1.8 Days to maturity

The number of days to maturity ranged from 119.33 days to 154.00 days with a general mean of 137.11. Among all the genotype, (IC-70855) was earliest (119.33 days) while (IC-145639) was found to be late (154.00 days).

4.1.1.9 1000-grain weight (g)

The mean of 1000-grain weight was 20.19g and the mean values ranged from 11.18g (IC-67586) to 27.78g (IC-86143). Among the genotypes tested IC-86143 recorded the highest grain weight and IC-67586 recorded the lowest IC-67586.

4.1.1.10 Grain yield per plant (g)

The mean for grain yield per plant was 11.28g and the mean value ranged from 5.96g (IC-145651) to 18.10g (IC-86143). The genotype IC-145651 recorded lowest grain yield were the genotype IC-86143 exhibited highest grain weight.

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 50 genotypes. Results are furnished in Table 4.3 and Fig 4.1 and 4.2 for pcv, gcv and heritability, 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 coefficients of variation were low i.e., 8.054 and 8.160, respectively. The observed heritability estimate for this trait was high (97.40) while genetic advance as per cent of mean (16.37) were medium. The result is conformity with Manoj Kumar prajapati (2011) for low gcv and pcv and Nayak *et al.*(2001) for high heritability and moderate genetic advance as percent of mean.

4.2.1.2 Plant height (cm)

The genotypic and phenotypic coefficients of variation estimates observed for this trait were moderate i.e., 13.044 and 14.20, respectively. The observed heritability estimates for this character was high (84.30) with high genetic advance as per cent of mean (24.67). The similar result 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 tillers per plant

The genotypic and phenotypic coefficients of variation for this trait were moderate i.e., 16.29 and 19.30 respectively. The observed heritability estimate was high (71.20) and with high genetic advance as per cent of mean (28.32). The similar results were reported by Sinha *et al.* (2004) for high gcv and pcv and Shanta kumar *et al.* (1998) reported high heritability coupled with high genetic advance as per cent of mean for number of tillers per plant in rice

4.2.1.4 Number of productive tillers per plant

The genotypic and phenotypic coefficients of variation for this trait were medium and high i.e., 16.46 and 20.09 respectively. The observed heritability estimate was high (67.20) and with high genetic advance as per cent of mean (27.80). The similar results were reported by Akhtar *et al.* (2011) for high pcv and Immanuel 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

4.2.1.5 Panicle length (cm)

The GCV and PCV for this trait were low i.e., 6.32 and 8.19, respectively. The heritability observed for this trait was medium (59.50). This character recorded moderate genetic advance as per cent of mean (10.04). The similar results were observed by Kole *et al.* (2008) and Manoj kumar prajapate *et al.* (2011) for low gcv and pcv. Venkata suresh *et al* (2001) for moderate heritability and Ubarhande *et al.* (2010) for moderate genetic advance percent of mean.

4.2.1.6 Number of filled grains per panicle

A high GCV (27.87) and PCV (28.37) were observed for this trait. The heritability estimate for this trait was very high (96.50) with high genetic advance as per cent of mean (56.41). The similar result were observed by Pankaj Garg *et al*. (2010) and Mulugeta seyoum *et al*.(2012) for high gcv and pcv, Pankaj Garg *et al.* (2010) for high heritability and where as Umadevi *et al*. (2009) for high genetic advance as percent of mean.

4.2.1.7 Number of unfilled grains per panicle

A high GCV (43.25) and PCV (45.58) were observed for this trait. The heritability estimate for this trait was very high (90.10) with high genetic advance as per cent of mean (84.56). The similar result were observed by Patil *et al*. (2005)

4.2.1.8 Days to maturity

A high GCV (6.34) and PCV (6.45) were observed for this trait. The heritability estimate for this trait was very high (96.70) with high genetic advance as per cent of mean (12.85). The similar result were observed by Chambeni *et al*. (2012).

4.2.1.9 1000-grain weight (g)

Moderate genotypic (19.34) and high phenotypic (20.69) coefficients of variation were recorded with high heritability estimate of 87.40 and the genetic advance as per cent of mean was high (37.24). The similar result were found by Mohan lal and Devendra (2011) for moderate gcv and pcv and Mohan lal and Devendra (2011) and Pankaj Garg *et al*. (2010) for high heritability coupled with high genetic advance as percent of mean.

4.2.1.10 Grain yield per plant (g)

A high genotypic coefficient of variation (26.31) and phenotypic coefficient of variation (28.40) were observed for this trait. A high heritability estimate (85.80) coupled with high genetic advance as per cent of mean (50.20). The results are conformity with Pankaj Garg *et al.* (2010) and Mulugeta seyoum *et al.* (2012) for high gcv and pcv and Pankaj Garg *et al.* (2010) and Mohan lal and Devendra (2010) for heritability coupled with high high genetic advance as 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, number of tillers per plant, number of productive tillers per plant, panicle length, number of filled grains per panicle, number of unfilled grains per panicle, days to maturity,1000 grain weight, grain yield per plant, 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. 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 which are recorded showed high heritability coupled with high genetic advance. It indicates 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 50 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 490 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 50 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 50 genotypes, D^2 statistic was used following the procedure given by Rao (1952). Since the entire 10 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

Fifty 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 4.3. Out of Ten clusters, cluster I was the largest comprising of 18 genotypes followed by clusters II with 15 genotypes, cluster IV with 10 genotypes, and cluster III,V, VI,VII,VIII, IX, X with one genotype each. The clusters III,V, VI,VII,VIII, IX, X were represented by single genotype indicating high degree of heterogeneity among the genotypes.

4.3.4 Average inter and intra cluster distances

The average intra and inter cluster D^2 values are presented in Table 4.5 and Fig.4.4. Statistical distance among 50 genotypes Fig.4.5 (3D plot). Intra cluster D^2 values ranged from zero (cluster III, V, VI, VII, VIII, IX, X) to 38.68 (cluster IV). Maximum intra cluster distance was observed in cluster IV (38.68), followed by cluster II (30.90), cluster I (26.30), 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 VI and VIII (387.67) followed by cluster VIII and X (387.16), cluster III and VIII (321.26), cluster V and X (275.89) and cluster VII and X (267.84), cluster VIII and IX (256.80) suggesting that the crosses involving varieties from these clusters would give wider and desirable recombination .While the lowest was noticed between cluster V and VII (21.35), followed by cluster III and VI (30.21), cluster II and III (39.62), cluster II and V (47.60), cluster II and VII (52.61) cluster V and IX (56.60).

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 Based on the inter cluster distances, a hybridization between the genotypes (IC-70855) of cluster VI and cluster VIII (IC-145639), cluster VIII (IC-145639) and cluster X (IC-86143), cluster III (IC-67935) with cluster V (IC-145633), is suggested to generate promising segregants for grain yield, and would produce encouraging results The genotypes of these clusters may be used as parents in the crossing programme to generate breeding material with high diversity.

4.3.5 Cluster means of the characters

The cluster means for each of fifteen 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 VIII (123.67) and the lowest in cluster VI (88.00). Plant height was highest in cluster VIII (111.57cm) and lowest in cluster VII (74.20cm). Cluster X recorded the highest number of tillers per plant (16.7) and the lowest number of productive tillers per plant was in cluster IX (9.63). Cluster X recorded the highest number of productive tillers per plant (13.74) and the lowest number of productive tillers per plant was in cluster IX (6.86). Cluster VIII recorded the highest panicle length (25.81cm) and the lowest was recorded in cluster V (21.01cm). The number of filled grains per panicle was highest in cluster X (272.90) and the lowest in cluster III (128.97). The number of unfilled grains per panicle was highest in cluster IX (45.33) and the lowest in cluster VIII (9.25). highest mean for days to maturity was highest in cluster VIII (154.00) and the lowest in cluster VI (119.33). Highest 1000 grain weight was recorded in cluster X (27.78 g) and the lowest in cluster VII (14.72 g). Cluster X recorded the highest grain yield per plant (18.10 g) while in cluster IX it was low (4.11g). 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.

It is observed that no cluster contained at least one genotype with all the desirable traits, which ruled out the possibility of selecting directly one genotype for immediate use. 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 days to fifty percent flowering, plant height, panicle length, days to maturity. cluster IX number of unfilled grains per panicle and cluster X for number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant. The genotypes IC-145639, IC-137335, and IC-86143, from these clusters having high mean values may be directly used for adaptation or may be used as parents in future hybridization programme.

4.3.6 Relative contribution of characters towards genetic divergence

The number of times that each of the ten characters appeared in first rank and its respective per cent contribution towards genetic divergence is presented in Table 4.7. and Fig 4.6. The results showed that the contribution of days to fifty percent flowering was highest towards genetic divergence (41.22%) by taking 505 times ranking first, followed by Number of filled grains per panicle (30.61%) by 375 times, No. of unfilled grains/panicle (9.80%) by 120 times, Days to maturity (6.04%) by 74 times, 1000 Grain weight (4.65%) by 57 times, Plant Height (3.27%) by 40 times, Grain yield per plant (2.29%) by 28 times, Number of productive tillers per plant (1.22%) by 15 times, Number of tillers per plant (0.82%) by 10 times, panicle length (0.08%) by 1 time, respectively to the genetic divergence in decreasing order. The results were in conformity with Ramya and Senthil Kumar (2008) for number of filled grains per panicle, number of productive tillers per plant and grain yield per plant, Vennila *et al* (2011) number of grains per panicle, plant height contributed maximum towards genetic diversity.

The days to fifty percent flowering and number of filled grains per panicle together contributed 71.83% 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 IV having maximum intra-cluster distance can improve the yield potential. As maximum inter-cluster distance was noticed between cluster VI and VIII, cluster VIII and X, crosses involving genotypes 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 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 50 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 which were 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 negative phenotypic correlation with grain yield per plant (-0.1963) and positive and non-significant correlation with plant height (0.0381),number of unfilled grains per panicle (0.1119) and positive and significant correlation with days to maturity(0.9788). The characters, number of tillers per plant(-0.2214), number of productive tillers per plant (-0.2352) showed negative and significant correlation association. panicle length (-0.0181), number of filled grains per panicle (-0.0860), 1000 grain weight (-0.0899) showed negative and non-significant association. The similar result were reported by Pankaj *et al.*(2010) for grain yield per plant, Vange *et al.*(1999) for 1000 grain weight, Chauhan *et al.* (1993) for plant height and panicle length, Ravindra Babu *et al.*(2012) for number of productive tillers per plant, Padmaja *et al.*(2011) for 1000 grain weight, Meenakshi *et al.* (1999) for number of filled grains per panicle and grain yield per plant.

4.4.1.2 Plant height (cm)

The plant height registered a significant positive phenotypic correlation with grain yield per plant (0.3867), number of tillers per plant (0.1882), panicle length (0.4776) and number of filled grains per panicle (0.2908) where as it is positive and non-significant correlation with number of productive tillers per plant (0.0770),days to maturity(0.0420) and 1000grain weight(0.0385). It had negative and significant correlation with number of unfilled grains per panicle (-0.2614). The present results in agreement to the results reported by Roy *et al.*(1995) for number of productive tillers per plant, Madhavi latha *et al.* (2002) for panicle length, number of filled grains per panicle, Rameshbabu *et al.* (1999) for 1000 grain weight, Nayak *et al.* (2001) for grain yield per plant.

4.4.1.3 Number of Tillers per Plant

Number of tillers per plant exhibited significant positive phenotypic correlation with grain yield per plant (0.4341) and number of productive tillers per plant (0.3851), 1000grain weight(0.1973). It exhibited positive non-significant correlation with panicle length (0.0984). It had significant negative correlation with number of unfilled grain per panicle(-0.2670) and days to maturity(-0.2250). The character number of filled grains per panicle showed negative non-significant correlation (-0.0014). Idris *et al.* (2013) reported similar results for grain yield per plant.

4.4.1.4 Number of Productive Tillers per Plant

Number of productive tillers per plant exhibited significant positive phenotypic correlation with grain yield per plant (0.5072) and number of filled grains per panicle (0.2635), 1000 grain weight(0.2084). It exhibited positive and non-significant correlation with panicle length (0.1097). It had significant negative correlation with number of unfilled grains per panicle (-0.1618) and days to maturity (-0.2099). The earlier results reported by Satish Chandra *et al.* (2009) for panicle length, Suryanarayana *et al.* (2000) for 1000 grain weight. Suman *et al.* (2003) for grain yield per plant were in agreement to the present results.

4.4.1.5 Panicle Length (cm)

Panicle length registered significant positive phenotypic correlation with grain yield per plant (0.2481) and 1000 grain weight(0.1680). And positive non-significant correlation with number of filled grains per panicle (0.0737). It had significant negative correlation with number of unfilled grains per panicle (-0.1620) and negative non-significant correlation with days to maturity (-0.0082). The similar results were reported by Reddy *et al*.(1997) for number of filled grains per panicle, Gopinath *et al*.(1984) for 1000 grain weight, Basavaraj *et al*.(2011) for grain yield per plant.

4.4.1.6 Number of filled Grains per Panicle

Number of filled grains per panicle exhibited a significant positive phenotypic correlation with grain yield per plant (0.3251) where as negative and significant correlation with 1000 grain weight (-0.4530),and negative and non-significant correlation with number of unfilled grains per panicle(-0.1237) and days to maturity(-0.0682). Geetha *et al.* (1994) for 1000 grain weight, Sankar *et al.* (2006) for grain yield per plant reported similar results.

4.4.1.7 Number of unfilled Grains per Panicle

Number of unfilled grains per panicle exhibited a significant negative phenotypic correlation with grain yield per plant (-0.5752) and 1000grain weight(-0.1698). whereas positive and non-significant correlation with days to maturity (0.1211). The similar result were reported by Krishnaveni *et al.* (2006) for grain yield per plant.

4.4.1.8 1000 Grain Weight (g)

1000 grain weight showed a significant positive phenotypic correlation with grain yield per plant (0.2892). Similar results was reported by Satish Chandra *et al.* (2009) for grain yield per plant.

4.4.1.9 days to maturity

Days to maturity showed significant negative phenotypic correlations with grain yield per plant(-0.1786) And whereas 1000 grain weight had negative and non-significantly correlated (-0.0903). The results were reported by Nandan *et al*. (2010) and Krishna *et al*. (2008) for grain yield per plant were in coincidence to the present results.

4.4.10 Grain Yield per Plant (g)

Phenotypic correlations revealed that grain yield per plant had significant positive association with Plant height (0.3867), number of tillers per plant (0.4341), number of productive tillers per plant (0.5072), panicle length (0.2481), number of filled grains per panicle (0.3251), 1000 grain weight (0.2892). The trait recorded a significant negative association with days to 50 per cent flowering (-0.1963), number of unfilled grains per panicle (-0.5752),and days to maturity(-0.1786).

Grain yield per plant showed positive significant association with plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of filled grains per panicle. This indicated that all these characters were important for yield improvement. Similar kind of association was revealed by Krishna *et al*.(2008) and Abdul Fiyaz *et al.*(2011) for plant height, Abdul Fiyaz *et al.*(2011) and Ravindra Babu *et al.*(2012) number of productive tillers per plant, Pankaj Garge *et al.*(2010), Padmaja *et al.*(2011) and Zulqarnain *et al*.(2012) for number of filled grains per panicle. 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 panicle length and 1000 grain weight also positively associated with grain yield per plant it indicates that these characters can be considered for selection for higher yield.

The study of phenotypic correlation studies showed that selection of plants with more number of filled grains per panicle, more number of productive tillers per plant, plant height and panicle length would result in improvement of 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 discussed here under which were presented in Table 4.9 and Fig 4.7 and 4.8.

4.5.1 Days to 50 percent flowering

The days to 50 per cent flowering had direct phenotypic negative effect (-0.2492) on grain yield and the correlation between days to 50 per cent flowering and grain yield per plant was negative and significant. The correlation was negative and significant mainly due to negative indirect effect through number of tillers per plant (-0.0362), number of productive tillers per plant (-0.0537), panicle length (-0.0002), number of filled grains per panicle (-0.0254), number of unfilled grains per panicle (-0.0419). Similar result of direct negative effect of days to 50 per cent flowering on grain yield per plant was reported by Pankaj Garge *et al*. (2010), Rajamadhan *et al*. (2011) and Ravindra Babu *et al*. (2012).

4.5.2 Plant height (cm)

Plant height had phenotypic positive direct effect on grain yield per plant (0.1391) while the correlation of plant height with grain yield was positive and significant. The correlation between plant height and grain yield was positive and significant mainly due to positive indirect effect contribution through number of tillers per plant (0.0308), number of productive tillers per plant(0.0176), panicle length(0.0048), number of filled grains per panicle (0.0858), number of unfilled grains per panicle (0.0979), days to maturity(0.0098) 1000 grain weight (0.0104) The similar result reported by Madhavi Latha *et al.*(2002), Sanker *et al.*(2006), Basavaraja *et al.*(2011) and Mulugeta Seyoum *et al.*(2012) also reported positive direct effect of plant height on grain yield per plant.

4.5.3 Number of tillers per plant

Tillers per plant which exhibited a phenotypic positive direct effect on grain yield per plant (0.1635) 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 (0.0552), plant height (0.0262),number of productive tillers per plant(0.0879), panicle length(0.0010), number of unfilled grain per panicle (0.1000), 1000 grain weight (0.0535). the similar result were reported by Singh *et al*.(2002).

4.5.4 Number of productive tillers per plant

Productive tillers per plant which exhibited a phenotypic positive direct effect on grain yield per plant (0.2281) 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 (0.0586), plant height (0.0107), number of tillers per plant (0.0630), panicle length(0.0011), number of filled grains per panicle(0.0777), number of unfilled grains per panicle(0.0606), 1000 grain weight (0.0565). Sanker *et al*.(2010), Basavaraja *et al.*(2011), Padmaja *et al.(*2011), Ravindra Babu *et al*.(2012) reported positive direct effect of number of productive tillers per plant on grain yield per plant which are in accordance to the present results.

4.5.5 Panicle length (cm)

Panicle length had direct positive phenotypic effect (0.0100) on grain yield per plant. Where the correlation was positive significant .The correlation was positive mainly due to positive indirect contribution through days to fifty percent flowering(0.0045), plant height (0.0664), number of tillers per plant (0.0161), number of productive tillers per plant (0.0250), number of filled grains per panicle (0.0218) and number of unfilled grains per panicle (0.0607),1000 grain weight(0.0455). Similar results reported by Sanker *et al*. (2006), Satish Chandra *et al*. (2009), Nandan *et al.*(2010), Mulugeta *et al.*(2012).

4.5.6 Number of filled grains per panicle

Number of filled grains per panicle had direct phenotypic positive effect (0.2950) on grain yield per plant. Its 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 days to fifty percent flowering(0.0214) plant height (0.0405), number of productive tillers per plant (0.0601), panicle length(0.0007), number of unfilled grains per panicle(0.0464). Sanker *et al*.(2006), Satish Chandra *et al*.(2009), Nandan and Sweta Singh (2010), reported similar results of positive direct effect of Number of filled grains per panicle on grain yield per plant.

4.5.7 Number of unfilled grains per panicle

Number of unfilled grains per panicle had direct phenotypic negative effect (-0.3747) on grain yield per plant. Its correlation with grain yield per plant was also negative and significant. The correlation between number of filled grains per panicle and grain yield per plant was negative and significant mainly due to negative indirect effect contribution through days to fifty percent flowering(-0.0279),plant height (-0.0364), number of tillers per plant (-0.0437) number of productive tillers per plant (-0.0369),panicle length(-0.0016),1000 grain weight (-0.0460). The similar result reported by Krishnaveni *et al*.(2006).

4.5.8 1000-grain weight (g)

1000 grain weight had direct positive phenotypic effect on grain yield per plant (0.2711) while its correlation with grain yield was positive significant. The correlation between 1000 grain weight and grain yield per plant was positive it's mainly due to positive indirect effect influence through days to fifty percent flowering(0.0224), plant height (0.0054), number of tillers per plant(0.0323), number of productive tillers per plant (0.0475), panicle length(0.0017), number of unfilled grains per panicle(0.0636). on grain yield per plant. Similar results were reported by Suman *et al*.(2003), Khedikar *et al* (2004), Yadav *et al.*(2011), Akhtar *et al.*(2011) and Padmaja *et al.*(2011) negative direct effect of 1000 grain weight on grain yield per plant.

4.5.9 Days to maturity

The days maturity had direct phenotypic positive effect(0.2342) on grain yield and the correlation between days to maturity and grain yield per plant was negative and significant. The correlation was negative and significant mainly due to positive indirect effect through days to fifty percent flowering(-0.2439), number of tillers per plant (-0.0368), number of productive tillers per plant (-0.0479), panicle length (-0.0001), number of filled grains per panicle (-0.0201), number of unfilled grains per panicle (-0.0454),1000 grain weight(-0.0245). Similar result of direct negative effect of days to 50 per cent flowering on grain yield per plant was reported by Pankaj Garge *et al*. (2010).

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 on overall improvement in single plant yield directly.

Path coefficient analysis revealed that number of filled grains per panicle exerted the highest positive direct effect on grain yield followed by 1000 grain weight, days to maturity, number of productive tillers per plant and number of tillers per plant, plant height. The negative direct effect on grain yield by number of unfilled grains per panicle, days to 50 per cent flowering. These results were conformity with Pankaj Garge *et al*. (2010), Rajamadhan *et al*. (2011) and Ravindra Babu *et al*. (2012) for days to 50 per cent flowering, Ravindra Babu et al (2012) plant height, number of productive tillers per plant and panicle length, Mulugeta Seyoum *et al*. (2012) for number of filled grains per panicle, Padmaja *et al*. (2011) for 1000 grain weight

Path analysis revealed that number of filled grains per panicle, 1000 grain weight numbers of productive tillers per plant, number of filled grains per panicle, days to maturity and number of productive tillers per plant and number of tillers per plant, plant height 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.

4.6 DUS chracterization

Currently, the documentation and characterization of plant genetic resources has assumed grant significance especially for the germplasm collections and notified/extant cultivars that are in active commerce in different parts of India. Immense attention is being paid towards comprehensive characterization and identification of these resources, which would constitute the base material to establish sovereign rights of genetic wealth. Standard criteria for grant of protection, based on morphological DUS criteria (Distinctiveness, Uniformity and Stability) are indispensible in this endeavor. Keeping this in view, the study was undertaken to characterize fifty boro rice genotypes on the basis of DUS morphological descriptors.

In our present investigation an attempt was made to characterize fifty boro rice genotypes using plant morphological traits developed for DUS guidelines. The DUS guidelines for rice are available in the schedule released by Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA). Hence, the characteristics and their states were formed using PPV & FRA and National guidelines for DUS testing in Rice. The fifty boro rice genotypes were characterized with sixty two morphological characters including both qualitative and quantitative characters (Table.5.0).

Morphological characters have been widely used for descriptive purposes and are commonly used to distinguish plant varieties. Use of morphological descriptors in sequential fashion is useful and convenient to discriminate the different varieties.

Out of total sixty two morphological visually assessed DUS descriptors studied, 11 were found to monomorphic and 16 characters were dimorphic and remaining characters are polymorphic.

The characters coleoptile colour, leaf auricles, leaf collar, leaf ligule presence and shape, leaf width of blade, male sterility, panicle: length of longest awn, panicle-presence of secondary branching, endosperm-presence of amylose, decorticated grain aroma were monomorphic.

The characters viz., leaf-anthocyanin colouration, leaf sheath-anthocyanin colouration, leaf-anthocyanin colouration of auricles, leaf-anthocyanin colouration of collar, leaf-length of blade, stem length(excluding panicle,excluding floatin rice), stem-anthocyanin coloration of nodes, stem-anthocyanin coloration of internodes, flag leaf-attitude of main blade, panicle number per plant, panicle-awns, panicle-secondary branching, time maturity(days), leaf senescence, sterile lemma color, grain-phenol reaction of lemma were dimorphic.

The characters viz., basal leaf-sheath colour, leaf-intensity of green colour, leaf-distribution of anthocyanin colouration, leaf sheath-intensity of anthocyanin colouration, leaf-pubescence of blade surface, leaf-colour of ligule, culm-attitude, time of heading(50% of plants with panicle), flag leaf-attitude of blade(early observation), spikelet-density of pubescence of lemma, lemma-anthocyanin coloration of keel, lemma-anthocyanin coloration of area below apex, lemma-anthocyanin coloration of apex, spikelet-colour of stigma, stem-thickness, stem-intensity of anthocyanin coloration of nodes, panicle length of main axis, panicle-curvature of main axis, spikelet-color of tip of lemma, lemma and palea-color, panicle-attitude of branches, panicle-exertion, grain-weight of 1000fully developed grains, grain length, grain-width, decorticated grain length, decorticated grain width, decorticated grain-shape(in lateral view), decorticated grain color, endosperm-content of amylose, gelatinization temperature through alkali spreading value were polymorphic.

Out of total sixty two morphological visually assessed DUS descriptors studied, 11 were found to monomorphic and 16 characters were dimorphic and remaining characters are polymorphic. The total of thirty two morphological characters (polymorphic) were most useful for varietal identification in selected rice genotypes.

Table 4.3. Estimates of variability, heritability and genetic advance in rice genotypes

Characters	Phenotypic Variance	Genotypic Variance	PCV (%)	GCV (%)	Heritability in broad sense(h^2) (%)	Gen. Adv as per cent of Mean (at 5%)
Days to 50% Flowering	75.984	74.023	8.160	8.054	97.40	16.376
Plant Height (cm)	180.574	152.288	14.204	13.044	84.30	24.676
No. of tillers/ plant	6.482	4.618	19.301	16.290	71.20	28.323
No. of productive tillers/plant	3.491	2.345	20.091	16.468	67.20	27.808
Panicle length(cm)	3.730	2.218	8.195	6.320	59.50	10.041
No. of filled grains/panicle	2382.463	2299.696	28.373	27.876	96.50	56.418
No. of unfilled grains/panicle	56.495	50.879	45.584	43.259	90.10	84.568
Days to maturity	78.229	75.659	6.451	6.344	96.70	12.852
Grain yield/plant(g)	10.271	8.813	28.405	26.312	85.80	50.209
1000 grain weight(g)	17.469	15.264	20.694	19.344	87.40	37.248

Table 4.2. Mean performance of 50 genotypes of rice for yield and yield contributing characters

S. No	Genotype	Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
1	IC-65889	94.00	96.83	11.20	9.05	25.53	178.07	11.45	124.33	23.45	12.51
2	IC-67586	113.00	97.97	13.60	10.68	22.81	244.10	11.43	144.00	11.18	12.54
3	IC-67589	104.33	81.53	12.33	8.88	20.17	171.97	10.20	134.33	17.37	11.97
4	IC-67626	103.00	94.27	11.40	10.97	24.67	145.53	14.60	133.33	25.87	12.63
5	IC-67638	97.00	85.37	15.50	11.08	24.23	143.63	15.34	127.67	24.10	13.99
6	IC-67729	105.67	96.43	15.08	12.82	24.73	143.63	10.66	137.67	24.42	14.70
7	IC-67935	92.00	94.87	14.20	11.07	22.76	128.97	13.04	121.67	24.63	12.30
8	IC-70855	88.00	96.81	13.41	8.81	22.87	181.77	19.07	119.33	15.78	11.97
9	IC-85969	92.00	85.80	12.42	7.18	23.83	154.50	12.68	122.33	21.32	11.04
10	IC-86011	107.00	126.60	9.83	9.82	25.13	292.17	10.05	136.67	16.30	12.52
11	IC-86123	107.00	120.50	11.20	7.10	25.46	224.70	17.50	136.67	18.23	8.78
12	IC-86142	100.33	104.47	14.43	7.59	22.58	175.63	17.65	131.00	19.18	8.78
13	IC-86143	92.67	90.20	16.70	13.74	21.70	272.90	18.03	123.33	27.78	18.10
14	IC-86154	107.33	83.03	9.13	5.74	23.53	168.63	22.63	137.33	15.60	6.89
15	IC-89079	115.33	68.80	7.87	6.06	19.23	152.93	26.20	144.67	13.32	6.80
16	IC-89115	104.67	82.73	13.27	11.88	23.38	313.23	15.69	135.00	14.70	12.01
17	IC-89125	93.00	102.07	14.23	11.55	23.87	154.17	16.15	123.33	24.17	15.50

S. No	Genotype	Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
18	IC-89138	100.33	88.27	16.85	11.28	20.87	183.93	20.56	130.33	17.07	13.59
19	IC-89143	96.33	93.07	16.50	13.13	24.53	152.33	18.54	126.33	21.60	13.27
20	IC-98731	116.67	110.33	15.17	8.73	25.23	203.40	17.43	149.00	17.77	14.37
21	IC-98734	113.67	79.40	9.50	7.95	20.26	174.57	20.83	144.67	15.47	7.28
22	IC-98938	106.00	86.50	10.07	9.61	23.39	283.50	12.12	136.67	14.40	12.41
23	IC-98974	104.00	103.43	16.93	9.15	23.60	137.77	16.10	133.67	19.88	10.43
24	IC-98997	99.00	104.67	14.44	9.05	24.98	145.80	13.74	127.67	21.22	9.61
25	IC-99132	101.33	89.10	14.47	9.00	23.72	128.83	11.70	131.67	23.03	11.18
26	IC-99143	97.00	89.90	12.17	8.50	24.23	175.83	9.86	127.33	17.90	11.55
27	IC-99288	112.67	107.40	13.43	10.93	28.00	234.13	15.49	145.00	19.82	15.23
28	IC-99437	104.00	104.13	14.40	8.51	24.93	180.40	5.59	134.33	17.98	15.19
29	IC-99445	111.00	78.90	12.27	8.71	22.07	123.90	11.26	141.00	21.55	7.51
30	IC-99487	107.33	88.93	15.23	8.62	24.20	167.20	17.64	136.67	24.40	12.37
31	IC-99510	97.33	86.87	13.53	9.52	21.80	175.67	19.04	126.00	17.37	7.34
32	IC-99512	109.67	114.00	16.23	9.20	24.92	254.13	15.49	141.00	14.22	14.93
33	IC-99513	110.67	118.80	17.30	8.90	23.27	218.13	14.49	140.00	19.65	12.97
34	IC-99518	116.00	116.50	13.40	9.27	23.03	159.13	16.44	145.67	24.45	13.95
35	IC-99520	103.67	81.30	15.77	8.34	23.10	127.47	7.58	133.00	22.57	11.36
36	IC-99527	105.67	84.68	14.77	7.78	26.01	118.50	16.40	135.67	20.80	9.00

S. No	Genotype	Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
37	IC-137335	103.33	92.87	9.63	6.86	23.67	130.17	45.33	134.00	17.67	4.11
38	IC-145194	114.67	96.03	14.70	8.68	23.00	138.33	13.45	145.00	23.47	12.30
39	IC-145239	115.00	94.71	11.93	9.62	23.70	129.50	12.28	146.33	22.72	6.77
40	IC-145408	115.67	93.75	14.40	9.99	24.39	121.07	25.94	145.33	22.30	8.25
41	IC-145632	114.33	90.25	9.03	9.02	23.80	120.00	24.88	145.67	23.35	9.04
42	IC-145633	116.00	79.63	10.87	8.58	21.01	143.33	36.20	147.33	22.72	5.71
43	IC-145634	116.00	89.81	12.10	8.38	23.33	179.33	16.01	146.33	26.53	11.24
44	IC-145635	116.00	110.10	11.43	9.46	24.69	170.20	13.18	145.00	16.50	12.28
45	IC-145639	123.67	111.57	12.90	8.73	25.81	133.90	9.25	154.00	25.62	15.44
46	IC-145640	122.00	79.17	14.57	9.61	20.97	142.97	14.56	151.67	17.42	8.62
47	IC-145643	110.67	88.16	13.00	8.34	23.58	112.00	15.37	140.67	23.58	11.91
48	IC-145645	115.67	90.27	11.53	8.01	22.73	133.47	7.25	145.00	25.50	14.29
49	IC-145651	117.00	74.20	13.30	9.32	24.03	175.73	33.90	146.33	14.72	5.96
50	IC-203562	112.67	105.37	11.93	9.02	25.00	180.40	14.15	144.67	19.23	11.64
	Mean	106.82	94.60	13.19	9.29	23.56	172.03	16.48	137.11	20.19	11.28
	CV.	1.31	5.62	10.35	11.50	5.21	5.28	14.37	1.16	7.35	10.70
	S.E.	0.80	3.07	0.78	0.61	0.70	5.25	1.36	0.92	0.85	0.69
	C.D.5%	2.26	8.61	2.21	1.73	1.99	14.74	3.83	2.59	2.40	1.95

Table 4.1. ANOVA for yield and yield contributing characters in rice genotypes

S.No.	Character	Mean sum of squares		
		Replications (d.f.=2)	Treatments (d.f.=49)	Error (d.f.=98)
1	Days to 50% Flowering	1.94	224.03**	1.96
2	Plant Height (cm)	0.848	485.15**	28.28
3	No. of tillers/ plant	0.032	15.71**	1.86
4	No. of productive tillers/plant	1.425	8.18**	1.14
5	Panicle length(cm)	2.033	8.16**	1.51
6	No. of filled grains/panicle	1.334	6981.85**	82.76
7	No. of unfilled grains/panicle	5.316	158.25**	5.61
8	Days to maturity	0.727	229.54**	2.57
9	Grain yield/plant(g)	0.161	27.89**	1.45
10	1000 grain weight(g)	1.946	47.99**	2.20

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

Table 3.1. Details of 50 genotypes of boro rice

S.No	Name of the genotype	Place of collection	S.No	Name of the genotype	Place of collection
1	IC-65889	DRR, Hyderabad	26	IC-99143	DRR, Hyderabad
2	IC-67586	DRR, Hyderabad	27	IC-99288	DRR, Hyderabad
3	IC-67589	DRR, Hyderabad	28	IC-99437	DRR, Hyderabad
4	IC-67626	DRR, Hyderabad	29	IC-99445	DRR, Hyderabad
5	IC-67638	DRR, Hyderabad	30	IC-99487	DRR, Hyderabad
6	IC-67729	DRR, Hyderabad	31	IC-99510	DRR, Hyderabad
7	IC-67935	DRR, Hyderabad	32	IC-99512	DRR, Hyderabad
8	IC-70855	DRR, Hyderabad	33	IC-99513	DRR, Hyderabad
9	IC-85969	DRR, Hyderabad	34	IC-99518	DRR, Hyderabad
10	IC-86011	DRR, Hyderabad	35	IC-99520	DRR, Hyderabad
11	IC-86123	DRR, Hyderabad	36	IC-99527	DRR, Hyderabad
12	IC-86142	DRR, Hyderabad	37	IC-137335	DRR, Hyderabad
13	IC-86143	DRR, Hyderabad	38	IC-145194	DRR, Hyderabad
14	IC-86154	DRR, Hyderabad	39	IC-145239	DRR, Hyderabad
15	IC-89079	DRR, Hyderabad	40	IC-145408	DRR, Hyderabad
16	IC-89115	DRR, Hyderabad	41	IC-145632	DRR, Hyderabad
17	IC-89125	DRR, Hyderabad	42	IC-145633	DRR, Hyderabad
18	IC-89138	DRR, Hyderabad	43	IC-145634	DRR, Hyderabad
19	IC-89143	DRR, Hyderabad	44	IC-145635	DRR, Hyderabad
20	IC-98731	DRR, Hyderabad	45	IC-145639	DRR, Hyderabad
21	IC-98734	DRR, Hyderabad	46	IC-145640	DRR, Hyderabad
22	IC-98938	DRR, Hyderabad	47	IC-145643	DRR, Hyderabad
23	IC-98974	DRR, Hyderabad	48	IC-145645	DRR, Hyderabad
24	IC-98997	DRR, Hyderabad	49	IC-145651	DRR, Hyderabad
25	IC-99132	DRR, Hyderabad	50	IC-203562	DRR, Hyderabad

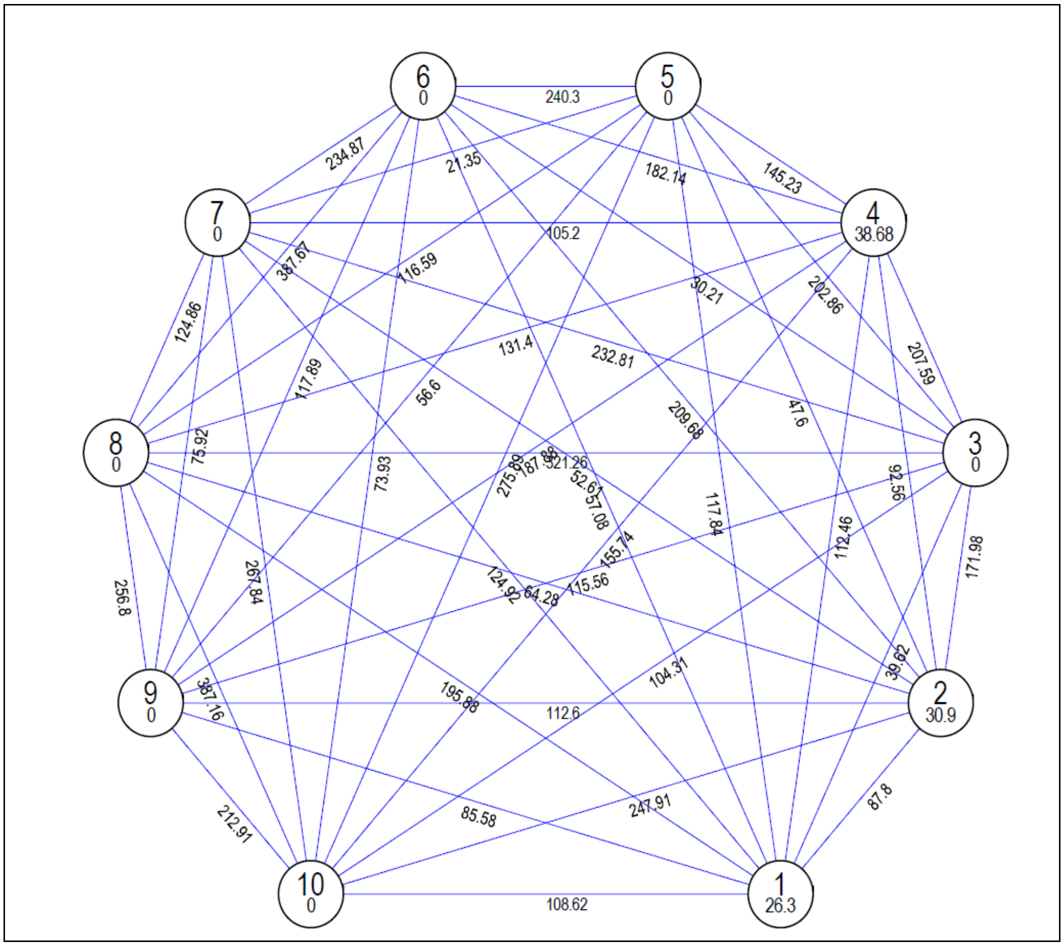


Fig.4.4. Mahalnobis Euclidean Disatnce among 50 genotypes of boro rice

Table 4.4. Clustering pattern among 50 rice genotypes (in cluster analysis)

Cluster No.	No. of genotypes	Names of the genotypes
I	**18**	IC-99132, IC-99520, IC-99527, IC-98974, IC-67626, IC-98997, IC-99487, IC-67729, IC-86142, IC-67589, IC-99143, IC-67638, IC-89143, IC-89138, IC-99510, IC-65889, IC-85969, IC-89125.
II	**15**	IC-145635,IC-203562,IC-99518,IC-145194, IC-145634, IC-145645, IC-145239, IC-145632, IC-145643, IC-145408, IC-99445, IC-98734, IC-145640, IC-86154, IC-89079,
III	**1**	IC-67935
IV	**10**	IC-89115, IC-98938, IC-99512, IC-67586, IC-86011, IC-99288, IC-86123, IC-99513, IC-98731, IC-99437
V	**1**	IC-145633
VI	**1**	IC-70855
VII	**1**	IC-145651
VIII	**1**	IC-145639
IX	**1**	IC-137335
X	**1**	IC-86143

Table 4.7. Relative contribution of different characters to genetic diversity in rice genotypes

S. No	Characters	Times ranked first	Contribution (%)
1.	Days to 50% Flowering	505	41.22
2.	Plant Height (cm)	40	3.27
3.	No. of tillers/ plant	10	0.82
4.	No. of productive tillers/plant	15	1.22
5.	Panicle length(cm)	1	0.08
6.	No. of filled grains/panicle	375	30.61
7.	No. of unfilled grains/panicle	120	9.80
8.	Days to maturity	74	6.04
9.	Grain yield/plant(g)	28	2.29
10.	1000 grain weight(g)	57	4.65

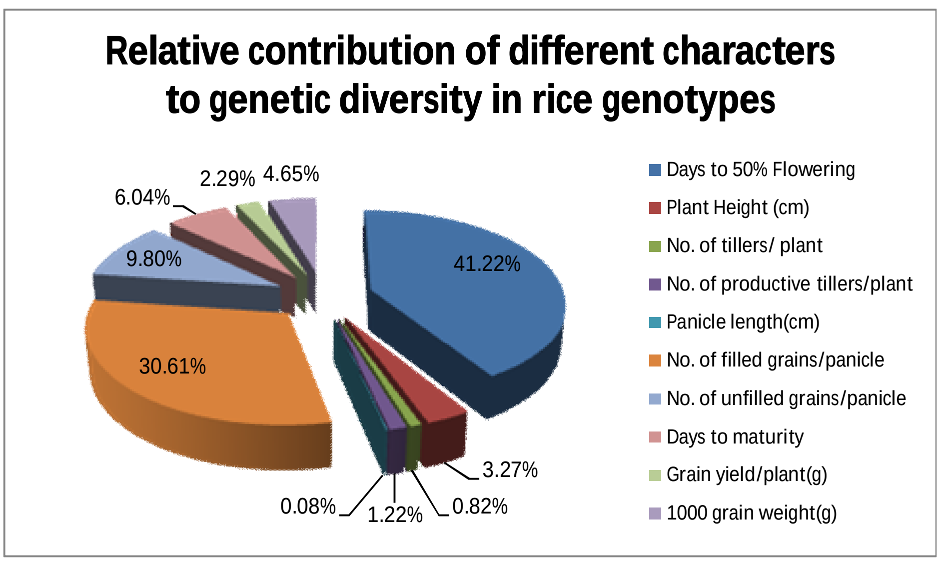


Figure 4.6. Relative contribution of different characters to genetic diversity in boro rice genotypes

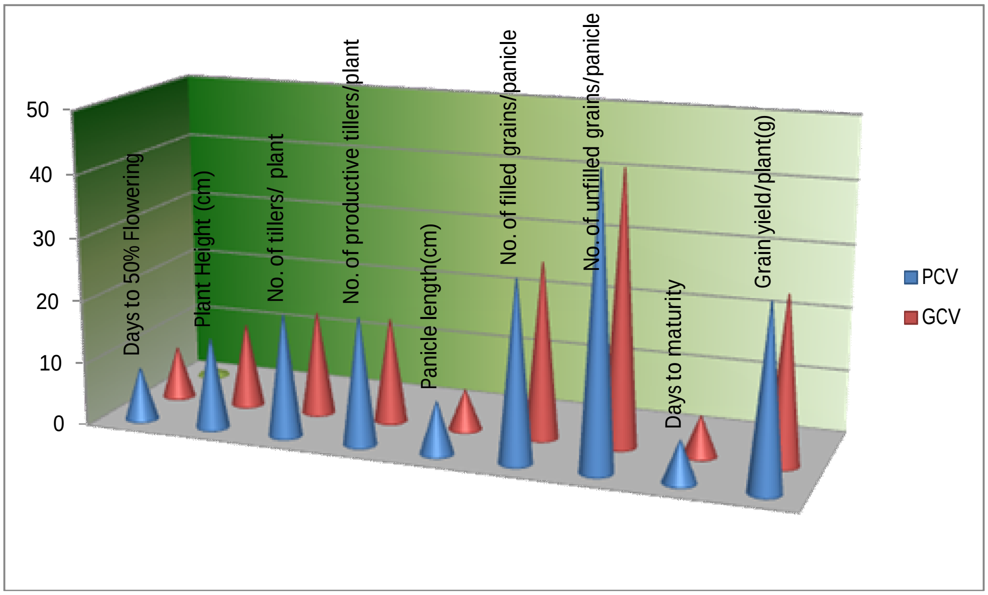


Figure 4.1. Graphical representation of PCV and GCV

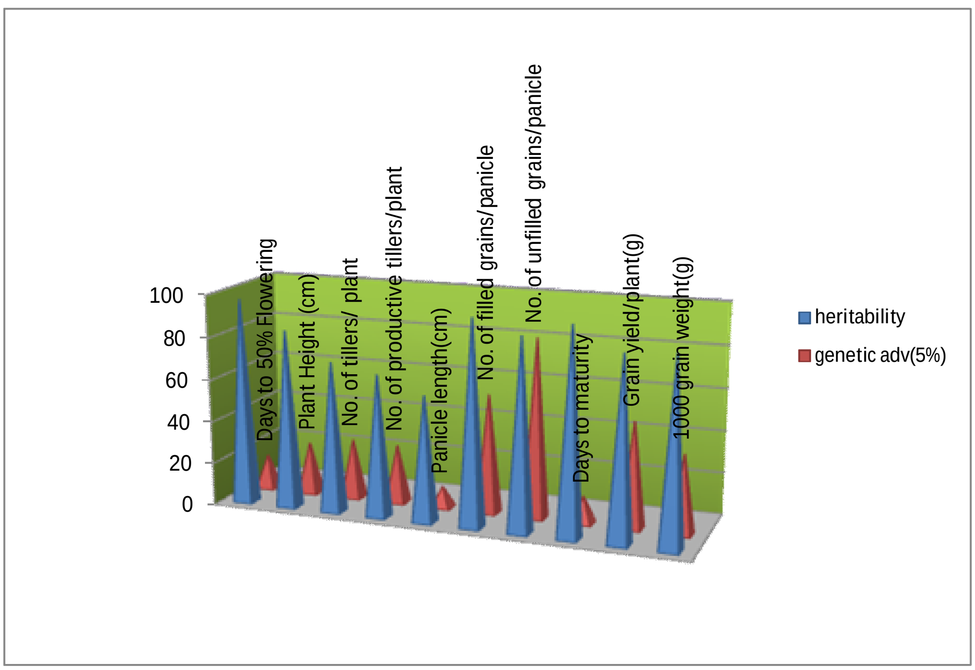


Figure 4.2. Graphical representation of h^2 and Genetic advance (5%)

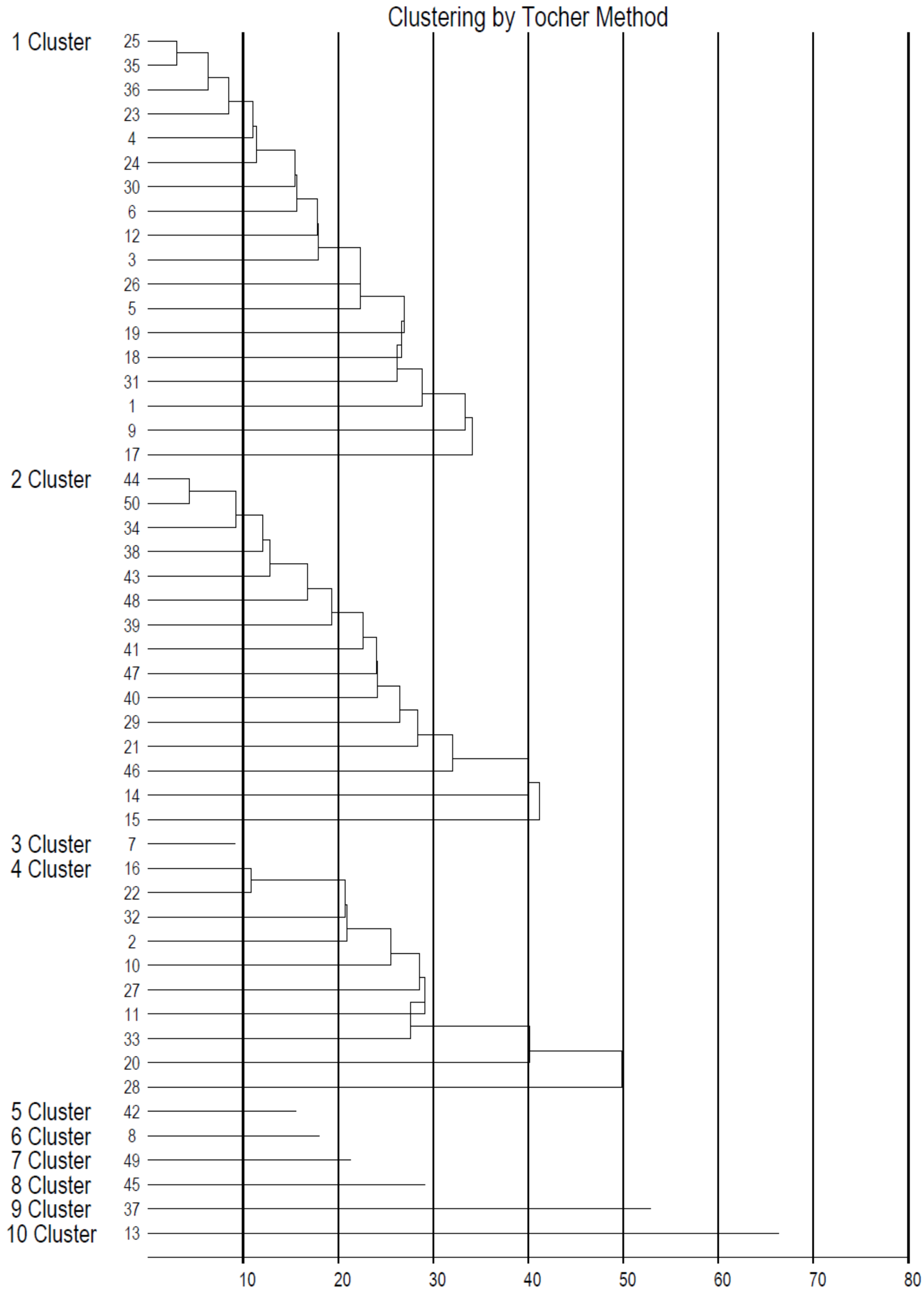


Figure 4.3. Clustering pattern of fifty genotypes in boro rice by Tocher Method.

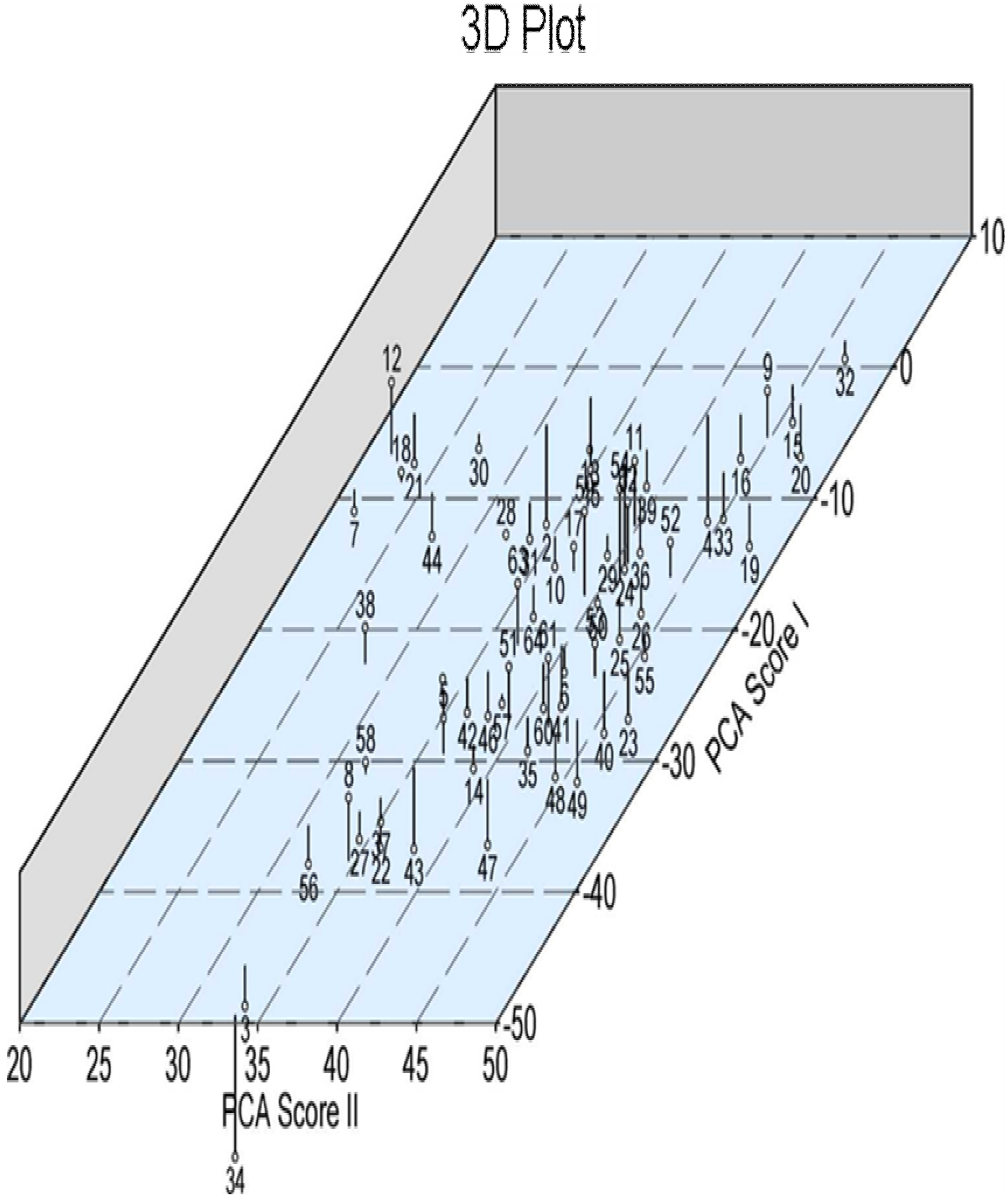


Fig.4.5. Statistical distance among 50 genotypes of boro rice (3D plot)

Table 4.6. Cluster means for 10 characters in 50 rice genotypes (cluster analysis)

Cluster No.	Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
I	100.07	92.06	14.29	9.64	23.70	154.47	14.44	130.13	21.43	11.71
II	114.40	90.95	11.79	8.54	22.89	147.10	16.96	144.60	20.73	9.92
III	92.00	94.87	14.20	11.07	22.76	128.97	13.04	121.67	24.63	12.30
IV	109.13	106.90	13.45	9.63	24.65	244.79	13.53	139.83	16.43	13.10
V	116.00	79.63	10.87	8.58	21.01	143.33	36.20	147.33	22.72	5.71
VI	88.00	96.81	13.41	8.81	22.87	181.77	19.07	119.33	15.78	11.97
VII	117.00	74.20	13.30	9.32	24.03	175.73	33.90	146.33	14.72	5.96
VIII	**123.67**	**111.57**	12.90	8.73	**25.81**	133.90	9.25	**154.00**	25.62	15.44
IX	103.33	92.87	9.63	6.86	23.67	130.17	**45.33**	134.00	17.67	4.11
X	92.67	90.20	**16.70**	**13.74**	21.70	**272.90**	18.03	123.33	**27.78**	**18.10**

Table 4.5. Intra (diagonal) and inter-cluster average of D^2 values of 50 rice genotypes

Clusters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Cluster I	5.12 **(26.30)**	9.37 (87.80)	6.29 (39.62)	10.60 (112.46)	10.86 (117.84)	7.56 (57.08)	11.18 (124.92)	14.00 (195.88)	9.25 (85.58)	10.42 (108.62)
Cluster II		5.56 **(30.90)**	13.11 (171.98)	9.62 (92.56)	6.90 (47.60)	14.48 (209.68)	7.25 (52.61)	8.02 (64.28)	10.61 (112.60)	15.75 (247.91)
Cluster III			**0.00**	14.41 (207.59)	14.24 (202.86)	5.50 (30.21)	15.26 (232.81)	17.92 (321.26)	10.75 (115.56)	10.21 (104.31)
Cluster IV				6.22 **(38.68)**	12.05 (145.23)	13.50 (182.14)	10.26 (105.20)	11.46 (131.40)	13.71 (187.88)	12.48 (155.74)
Cluster V					**0.00**	15.50 (240.30)	4.62 **(21.35)**	10.80 (116.59)	7.52 (56.60)	16.61 (275.89)
Cluster VI						**0.00**	15.33 (234.87)	19.69 (387.67)	10.86 (117.89)	8.60 (73.93)
Cluster VII							**0.00**	11.17 (124.86)	8.71 (75.92)	16.37 (267.84)
Cluster VIII								**0.00**	16.02 (256.80)	19.68 **(387.16)**
Cluster IX									**0.00**	14.59 (212.91)
Cluster X										**0.00**

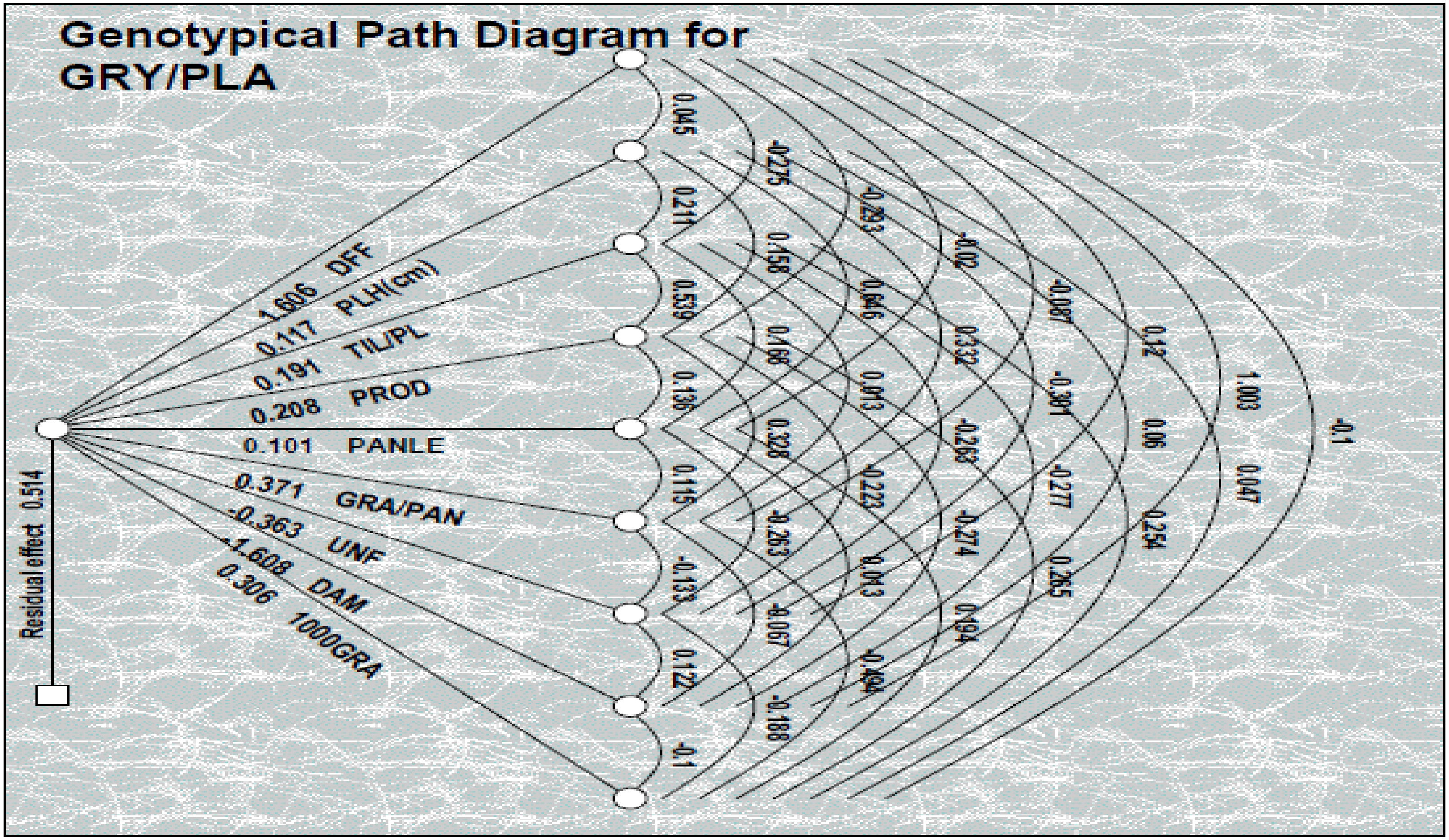


Fig. 4.7. Genotypical path diagram for grain yield per plant (g)

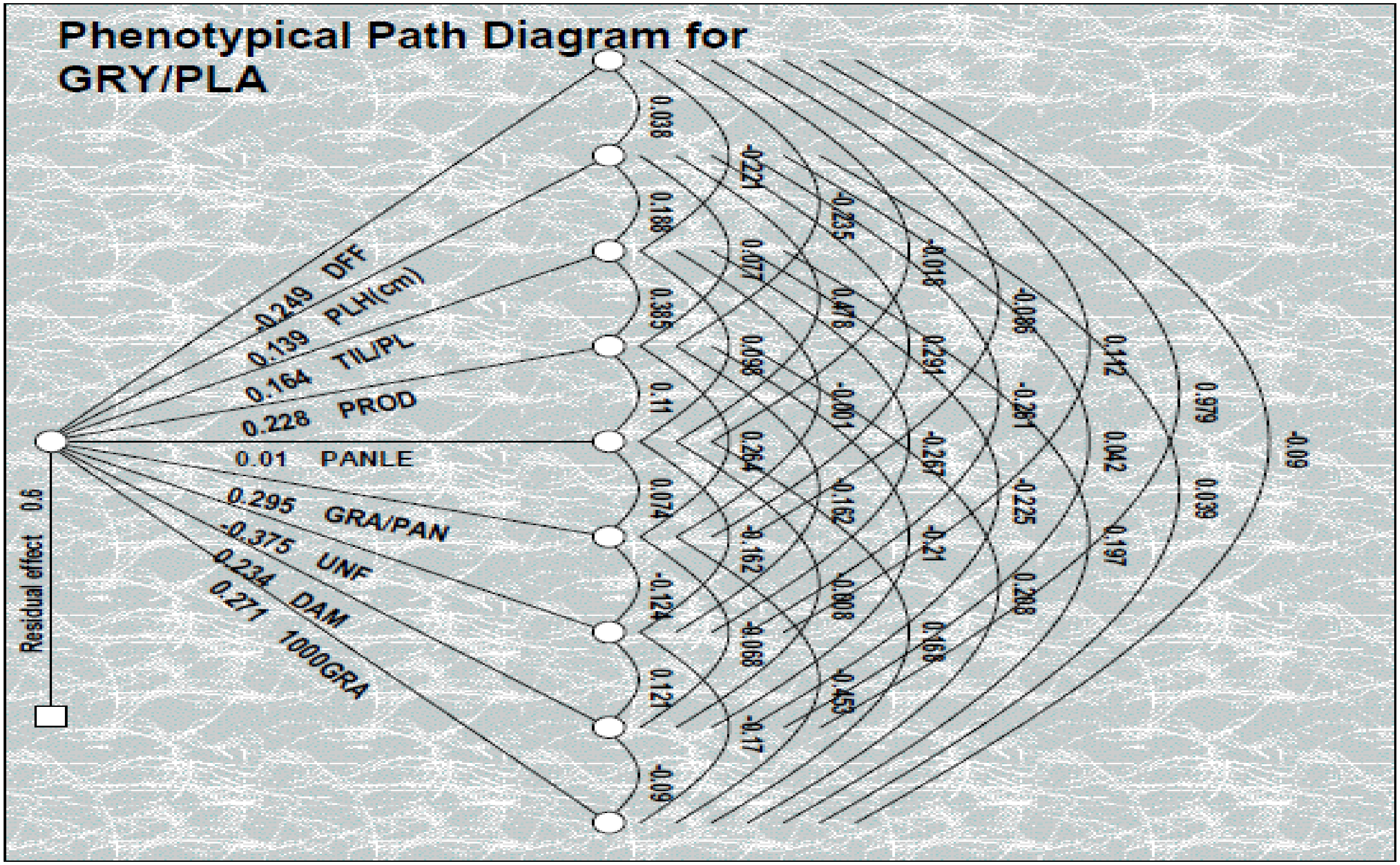


Fig. 4.8. Phenotypical path diagram for grain yield per plant (g)

Table 4.8. Phenotypic (P) and Genotypic (G) correlation coefficient analysis of yield and yield contributing characters in rice

Character		Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
Days to 50% flowering	**P**	**1.0000**	0.0381	-0.2214**	-0.2352**	-0.0181	-0.0860	0.1119	0.9788	-0.0899	**-0.1963***
	G	**1.0000**	0.0454	-0.2750**	-0.2928**	-0.0200	-0.0873	0.1203	1.0034	-0.1004	**-0.2242****
Plant Height (cm)	**P**		**1.0000**	0.1882*	0.0770	0.4776**	0.2908**	-0.2614**	0.0420	0.0385	**0.3867****
	G		**1.0000**	0.2106**	0.1582	0.6465**	0.3317**	-0.3005**	0.0601	0.0474	**0.4785****
Number of tillers / plant	**P**			**1.0000**	0.3851**	0.0984	-0.0014	-0.2670**	-0.2250**	0.1973*	**0.4341****
	G			**1.0000**	0.5395**	0.1663*	0.0132	-0.2634**	-0.2769**	0.2540**	**0.5261****
Number of prod. tillers / plant	**P**				**1.0000**	0.1097	0.2635**	-0.1618*	-0.2099**	0.2084**	**0.5072****
	G				**1.0000**	0.1363	0.3284**	-0.2230**	-0.2737**	0.2651**	**0.5968****
Panicle Length (cm)	**P**					**1.0000**	0.0737	-0.1620*	-0.0082	0.1680*	**0.2481****
	G					**1.0000**	0.1149	-0.2634**	0.0131	0.1944*	**0.3812****
Number of filled grains/panicle	**P**						**1.0000**	-0.1237	-0.0682	-0.4530**	**0.3251****
	G						**1.0000**	-0.1330	-0.0675	-0.4938**	**0.3580****
Number of un filledgrains/panicle	**P**							**1.0000**	0.1211	-0.1698*	**-0.5752****
	G							**1.0000**	0.1220	-0.1877*	**-0.6311****
Days to maturity	**P**								**1.0000**	-0.0903	**-0.1786***
	G								**1.0000**	-0.1000	**-0.1976***
1000 Grain Weight (g)	**P**									**1.0000**	**0.2892****
	G									**1.0000**	**0.3191****

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

Table 4.9. Phenotypic (P) and Genotypic (G) Path coefficient analysis of yield and yield contributing characters in rice

Character		Days to 50% Flowering	Plant Height (cm)	No. of tillers/ plant	No of prod. Tillers / Plant	Panicle Length (cm)	No.of filled grains/ Panicle	No.of unfilled grains/ Panicle	Days to maturity	1000 Grain Weight (g)	Grain Yield/ Plant (g)
Days to 50% flowering	P	**-0.2492**	0.0053	-0.0362	-0.0537	-0.0002	-0.0254	-0.0419	0.2293	-0.0244	-0.1963*
	G	**1.6064**	0.0053	-0.0525	-0.0608	-0.0020	-0.0324	-0.0436	-1.6138	-0.0307	-0.2242**
Plant Height (cm)	P	-0.0095	**0.1391**	0.0308	0.0176	0.0048	0.0858	0.0979	0.0098	0.0104	0.3867 **
	G	0.0730	**0.1172**	0.0402	0.0329	0.0652	0.1232	0.1091	-0.0967	0.0145	0.4785**
Number of tillers / plant	P	0.0552	0.0262	**0.1635**	0.0879	0.0010	-0.0004	0.1000	-0.0527	0.0535	0.4341**
	G	-0.4418	0.0247	**0.1908**	0.1120	0.0168	0.0049	0.0956	0.4454	0.0777	0.5261**
Number of prod. tillers / plant	P	0.0586	0.0107	0.0630	**0.2281**	0.0011	0.0777	0.0606	-0.0492	0.0565	0.5072**
	G	-0.4703	0.0185	0.1029	**0.2077**	0.0137	0.1220	0.0809	0.4401	0.0811	0.5968**
Panicle Length (cm)	P	0.0045	0.0664	0.0161	0.0250	**0.0100**	0.0218	0.0607	-0.0019	0.0455	0.2481**
	G	-0.0322	0.0758	0.0317	0.0283	**0.1008**	0.0427	0.0956	-0.0210	0.0595	0.3812**
Number of filled grains/panicle	P	0.0214	0.0405	-0.0002	0.0601	0.0007	**0.2950**	0.0464	-0.0160	-0.1228	0.3251**
	G	-0.1402	0.0389	0.0025	0.0682	0.0116	**0.3714**	0.0483	0.1085	-0.1512	0.3580**
Number of un filledgrains/panicle	P	-0.0279	-0.0364	-0.0437	-0.0369	-0.0016	-0.0365	**-0.3747**	0.0284	-0.0460	-0.5752**
	G	0.1932	-0.0352	-0.0502	-0.0463	-0.0266	-0.0494	**-0.3629**	-0.1962	-0.0575	-0.6311**
Days to maturity	P	-0.2439	0.0058	-0.0368	-0.0479	-0.0001	-0.0201	-0.0454	**0.2342**	-0.0245	-0.1786*
	G	1.6119	0.0070	-0.0528	-0.0568	0.0013	-0.0251	-0.0443	**-1.6083**	-0.0306	-0.1976*
1000 Grain Weight (g)	P	0.0224	0.0054	0.0323	0.0475	0.0017	-0.1337	0.0636	-0.0211	**0.2711**	0.2892**
	G	-0.1612	0.0056	0.0485	0.0550	0.0196	-0.1834	0.0681	0.1608	**0.3061**	0.3191**

Genotypic residual effect = 0.514   **Phenotypic residual effect = 0.6**   **BOLD values are direct effects**

Chapter V

SUMMARY AND CONCLUSIONS

The research work entitled "Studies on Genetic divergence and characterization of Boro rice (*Oryza sativa* L.) Genotypes" was conducted with fifty rice genotypes in a randomized block design with three replications at Directorate of Rice Research Farm, ICRISAT Campus, Patancheru, Hyderabad during *Rabi*, 2013-14. The objectives of the investigation were to study the genetic diversity present in the experimental material for selection of the diverse parents and the extent of association between the yield and its component characters including the direct and indirect effects and morphological characterization of boro rice genotypes using DUS descriptors

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 number of filled grains per panicle, followed by number of unfilled grains per panicle, grain yield per plant. The values of genotypic and phenotypic coefficients of variation were low for days to 50% flowering, panicle length, days to maturity.

High heritability coupled with high genetic advance as percent of mean was observed for plant height, number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, number of unfilled grains per panicle, 1000-grain weight, grain yield per plant. 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 low genetic advance as percent of mean for days to 50% flowering and days to maturity 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 days to fifty percent flowering, number of filled grains per panicle, number of unfilled grains per panicle, days to maturity indicating their importance in contribution towards genetic diversity. The multivariate analysis revealed that 50 genotypes were distributed into 10 clusters. The clusters VIII and X recorded high mean values for the yield components like number of days to fifty percent flowering, plant height, panicle length, days to maturity and number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and also they were divergent from each other. Hence, crosses between genotypes selected from these clusters may be used to generate rice genotypes with good grain yield.

The genetic divergence was high and the 50 genotypes of rice were grouped into 10 divergent clusters. Cluster I was the largest one comprising of eighteen genotypes followed by cluster II with fifteen genotypes, cluster IV with ten genotypes and cluster III, V,VI,VII,VIII,IX,X with one genotype each. The pattern of group constellations indicated significant variability among the genotypes.

The higher amount of divergence was observed between cluster VI and cluster VIII (387.67) followed by cluster VIII and cluster X (387.16), cluster III and cluster VIII (321.26) and cluster V and cluster X (275.89), while it was low between cluster V and cluster VII (21.35**).** Maximum intra cluster distance was observed in cluster IV (38.68), followed by cluster II (30.90), cluster I (26.30). Based on the inter cluster distances, a hybridization between the genotypes (IC-70855) of cluster VI and cluster VIII (IC-145639), cluster VIII (IC-145639) and cluster X (IC-86143), cluster III (IC-67935) with cluster V (IC-145633), is suggested to generate promising segregants for grain yield would produce encouraging results.

The cluster VIII is having highest mean value for days to fifty percent flowering, plant height, panicle length, days to maturity. cluster IX number of unfilled grains per panicle and cluster X for number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant. The genotypes IC-145639, IC-137335, IC-86143 from these clusters having high mean values may be directly used for adaptation or may be used as parents in future hybridization programme.

The maximum genetic divergence was contributed by days to fifty percent flowering was highest towards genetic divergence (41.22%) followed by Number of filled grains per panicle (30.61%), No. of unfilled grains/panicle (9.80%), Days to maturity (6.04%), Test weight (4.65%), Plant Height (3.27%), Seed yield per plant (2.29%), Number of productive tillers per plant (1.22%), Number of tillers per plant (0.82%) panicle length (0.08%).Three characters viz. days to fifty percent flowering, number of filled grains per panicle and accounts for more than 70% towards genetic divergence. Hence these two characters are very important for selection indices.

Character association studies revealed that the characters grain yield per plant showed significant positive association with number of productive tillers per plant, number of tillers per plant, plant height, number of filled grains per panicle, 1000 grain weight, panicle length, 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 viz., number of filled grains per panicle, 1000 grain weight, number of productive tillers per plant, number of filled grains per panicle, days to maturity and number of productive tillers per plant and number of tillers per plant, plant height 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,1000 grain weight, plant height, longer panicle length. As the yield component, filled grains per panicle is intern dependent on panicle length and plant height, attention should be paid towards increasing the panicle length, maintaining optimum plant height. Thus, a plant with medium height, sturdy culm with increased panicle length, higher number of filled grains per panicle and productive tillers per plant would be more desirable for selection to realize higher yield.

In our present investigation an attempt was made to characterize fifty boro rice genotypes using plant morphological traits developed for DUS guidelines. The DUS guidelines for rice are available in the schedule released by Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA). Hence, the characteristics and their states were formed using PPV & FRA and National guidelines for DUS testing in Rice. The fifty boro rice genotypes were characterized with sixty two morphological characters including both qualitative and quantitative characters.

Morphological characters have been widely used for descriptive purposes and are commonly used to distinguish plant varieties. Use of morphological descriptors in sequential fashion is useful and convenient to discriminate the different varieties.

Out of total sixty two morphological visually assessed DUS descriptors studied, 11 were found to monomorphic and 16 characters were dimorphic and remaining characters are polymorphic. The totals of thirty three morphological characters (polymorphic) were most useful for varietal identification in selected rice genotypes.

Chapter VI

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