

**EVALUATION OF LANDRACES OF
RICE (*Oryza sativa* L.) FOR
GENETIC DIVERSITY**

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B.Sc. (Ag.)

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



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EVALUATION OF LANDRACES OF RICE (*Oryza sativa* L.) FOR GENETIC DIVERSITY

BY

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B.Sc. (Ag.)

**THESIS SUBMITTED TO THE ACHARYA N.G. RANGA
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2014**

CERTIFICATE

Ms. UMARANI ERRABELLI has satisfactorily prosecuted the course of research and that the thesis entitled “**EVALUATION OF LANDRACES OF RICE (*Oryza sativa* L.) FOR GENETIC DIVERSITY**” 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 her for a degree of any University.

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This is to certify that the thesis entitled “**EVALUATION OF LANDRACES OF RICE (*Oryza sativa* L.) FOR GENETIC DIVERSITY**” submitted in partial fulfillment of the requirements for the degree of “**MASTER OF SCIENCE IN AGRICUTLURE**” of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide original research work carried out by **Ms. UMARANI ERRABELLI** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

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I, **UMARANI ERRABELLI**, hereby declare that the thesis entitled “**EVALUATION OF LANDRACES OF RICE (*Oryza sativa* L.) FOR GENETIC DIVERSITY**” submitted to **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is a result of original research work done by me. It is further declared that no material contained in the thesis has been published earlier in any manner.

Place : Hyderabad

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Date :

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
$^{\circ}\text{C}$	Degree Celsius
σ^2_{p}	Phenotypic variance
σ^2_{g}	Genotypic variance
ANOVA	Analysis of variance
cm	Centimeter
CD	Critical difference
D^2	Genetic distance
DRR	Directorate of Rice Research
DUS	Distinctness, Uniformity and Stability
<i>et al.</i>	And others
etc.	and so on
Fig.	Figure
g	Gram
GA	Genetic Advance
GATT	General Agreement on Trade and Tariffs
GCV	Genotypic Coefficient of Variation
$h^2(\text{bs})$	Heritability in broad sense
ha	Hectare
i.e.,	That is
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IRRI	International Rice Research Institute
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
L/B ratio	Length / Breadth ratio
m	Meter
mg	Milligram
mg kg^{-1}	Milligram per kilogram
mm	Millimeter

ml	Milliliter
No.	Number
nm	Nanometer
PCV	Phenotypic Coefficient of Variation
PPV & FRA	Protection of Plant Varieties and Farmers' Right Act
RBD	Randomized Block Design
<i>viz.,</i>	Namely

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ABSTRACT

In the present investigation, seventy landraces of rice were evaluated to study the extent of genetic variability among these genotypes for agro-morphological and grain quality parameters, to estimate the genetic diversity using Mahalanobis D^2 analysis for the selection of diverse parents and to study the extent of association among yield and its component traits and to determine the direct and indirect effects of these component characters on yield.

The experiment was conducted in a Randomized Block Design (RBD) with three replications during *kharif* 2013 and the data was recorded on 24 agro-morphological and grain quality traits. Characterization of the experimental material was carried out based on fourteen DUS characters. Among these characters, stem anthocyanin colouration of node was dimorphic, spikelet colour of stigma, stem length and panicle exertion were trimorphic, basal leaf sheath colour, time of heading (50 % plants with panicles), flag leaf attitude (late observation), panicle length, decorticated grain length and shape were tetramorphic and lemma anthocyanin colouration of apex and amylose content showed five states of expression and based on decorticated grain colour highest number of groups i.e., six were made.

Analysis of variance indicated the existence of significant differences among the landraces under study for all the sixteen metric characters studied. Total number of grains per panicle exhibited highest PCV and GCV values followed by single plant yield, whereas lowest PCV and GCV values were recorded for spikelet fertility. Among all the grain quality characters gel consistency expressed highest values of PCV and GCV. All the characters under study except spikelet fertility and panicle length exhibited high heritability coupled with high genetic advance as a per cent of mean, which indicated the preponderance of additive gene action in controlling these traits. Hence direct selection of

these characters would be effective in improving the seed yield. Panicle length expressed high heritability coupled with moderate genetic advance as a per cent of mean, suggesting that the expression of this trait was mostly influenced by additive type of gene action. Hence its response to selection would be effective in improving the seed yield. Spikelet fertility exhibited high heritability coupled with low genetic advance as a per cent of mean indicating that the expression of this trait was under the control of non-additive type of gene action and its response to selection would be poor.

Based on the relative magnitude of D^2 values, landraces of rice under study were distributed into nine clusters by using Tocher's method. Out of nine clusters, cluster I was the largest comprising of fifty landraces, followed by cluster III with eight, cluster VI with four and cluster VII with 3 landraces. Cluster II, IV, V, VIII and IX were monogenotypic clusters. The clustering pattern showed that the landraces originating from similar geographical regions were categorized into different clusters, indicating that geographical diversity and genetic diversity were not related. Total number of grains per panicle, decorticated grain length, 100-grain weight, amylose content, time of heading and stem length together contributed maximum (94.16 %) to the total genetic divergence.

Maximum inter cluster distance was exhibited between clusters VIII and IX followed by clusters V and IX, clusters VII and IX and clusters I and IX. The greater the distance between two clusters, the wider the genetic diversity among the genotypes of these clusters. Hence hybridization between the landraces from these clusters would produce high heterotic recombinants.

The cluster I was having highest mean value for productive tillers per plant, cluster II had highest mean values for single plant yield, 100 grain weight, decorticated grain width and amylose content, cluster V recorded maximum mean values for total number of grains per panicle, spikelet fertility and grain iron concentration, cluster VII showed maximum mean value for time of heading, cluster VIII had highest mean values for decorticated grain length, L/B ratio and gel consistency and cluster IX recorded highest mean values for stem length, panicle length, total number of grains per panicle and grain zinc concentration. The promising landraces from these clusters with high mean values for different traits may be directly used for adaptation or may be used as parents in future hybridization.

Character association studies revealed that single plant yield registered positive significant association with time of heading, stem length, panicle length, total number of grains per panicle and 100-grain weight indicating that these characters were important for yield improvement. Decorticated grain width and grain zinc concentration also exhibited positive significant association with single plant yield indicating that these characters could also be considered to achieve better results for improving yield as well as grain quality.

A critical analysis of the results by path analysis revealed that number of productive tillers per plant exerted highest positive direct effect on grain yield followed by decorticated grain length, total number of grains per panicle, stem length, panicle length, 100-grain weight, decorticated grain width, grain zinc concentration and spikelet fertility. Hence, these traits must be considered as important attributes in formulating selection criteria for achieving desired targets in future breeding programmes.

Chapter I

INTRODUCTION

“Rice is life” was the famous theme of International Year of Rice, 2004 denoting its overwhelming importance as an item of food, commerce and the close connection between rice-based systems and many cultures and people worldwide, in particular the poor in developing nations. Devoting an International Year to a single crop is unprecedented in the world history. Today rice is grown and harvested on every continent except Antarctica. Rice remains a staple food for more than half of the world population and forms the cheapest source of food, energy and protein. More than two thirds of the world relies on the nutritional benefit of rice (Pandey and Anurag, 2010).

In India, rice is cultivated in an area of nearly 42.75 million hectares with an annual production of 105.23 million tones and productivity of 2461 kg ha⁻¹, while in Andhra Pradesh, rice is grown in an area of 3628 hectares with an annual production and productivity of 11510 tones and 3173 kg ha⁻¹, respectively (Directorate of Economics and Statistics, Ministry of Agriculture, India, 2012-13).

Rice is grown under diverse eco-geographical conditions in various tropical and subtropical countries. Rice yield growth has fallen from 2.3% per year during 1970–1990 to 1.5% during 1990’s and to <1.0% during the first decade of present century. Global rice demand is estimated to rise from 676 million tons in 2010 to 763 million tons by 2020 and to further increase to 852 million tons by 2035. This clearly indicates that an overall increase of 26% or 176 million tons of rice is required in the next 25 years. However, area planted with rice in major production countries has been decreasing because of industrialization and urbanization. Hence, increasing rice yields on existing land remains the primary strategy for increasing production, to meet the future demand for food, anticipated from the projected world population increase. To produce 176 million tons additional rice by 2035, the yield potential of rice needs to be increased from 10 to 12.3 tons per hectare (Khush, 2013).

Green revolution has considerably improved the production of food grains in India and its role in achieving the status of self sufficiency in food grains is beyond any doubt. But high yielding varieties, which are the back bone of green revolution, reached their yield plateau. So, there is an urgent need to broaden the genetic base of the varieties by

introgressing genes from diverse sources. Thus, there is a need to collect, exploit and evaluate the untapped germplasm.

Rice has the largest germplasm collections in the world. This accessible collection of diverse cultivated varieties, landraces and related wild species has made great contributions to rice breeding. Landraces harbour a great deal of useful traits with genetic potential for rice improvement and they played a very important role in the local food security and sustainable development of agriculture, in addition to their significance as genetic resource for rice genetic improvement (Tang *et al.* , 2002).

Evaluation and characterization of existing landraces of rice is important due to increasing needs of varietal improvement. Characterization is the technique used to evaluate the phenotypic diversity through agro-morphological traits. It has been successfully used in recent years to help in identifying elite individual genotypes. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters. Characterization of accessions is used to evaluate the phenotypic diversity through agro-morphological traits that are essential for the gene bank management to protect the unique rice (Bajracharya *et al.*, 2006).

The landraces maintained by farmers are endowed with tremendous genetic variability, as they are not subjected to subtle selection over a long period of time. This aids in the adaptation of landraces to wide agro-ecological conditions. This rich variability of complex quantitative traits with respect to maturity, growing adaptation and with respect to their physicochemical and organoleptic properties still remains unexploited. Land-races are also important genetic resources for resistance to pests and diseases; they provide “adaptability genes” for specific environmental conditions. Incorporation of adaptability genes from landraces could ensure optimum grain yield for the region (Vijayakumar *et al.*, 2012).

The success of plant breeding depends on the extent of genetic variability present in a crop. Knowledge on the nature and magnitude of genetic variation governing the inheritance of quantitative characters like yield and its components is essential for genetic improvement. A critical analysis of genetic variability present in the germplasm of a crop and its estimation is a pre-requisite for initiating any crop improvement programme as well as adopting appropriate selection techniques.

It is very difficult to judge whether observed variability is heritable or not. Heritability indicates the extent of transmissibility of a character into future generations.

Moreover, knowledge of heritability is also essential for selection of component traits for yield improvement. Genetic advance measures the difference between the mean genotypic values of selected population and the original population from which these were selected. Heritability estimates along with genetic advance is normally more helpful in predicting the genetic gain under selection than heritability estimates alone.

Genetic diversity is a ubiquitous feature of all species in nature. Genetic diversity is an inherited variation among and between populations, created, activated and maintained by evolution. It is a fundamental characteristic without which breeders are very limited and powerless in plant breeding. Genetic divergence among the genotypes plays an important role in the selection of parents having wider variability for different characters and ultimately for a rational use of genetic resources.

Genetic diversity can be evaluated with morphological traits, seed proteins, isozymes and DNA markers. Morphological and agronomic traits have long been the means of studying variability among population and species. The breeders are interested to evaluate genetic diversity based on morphological traits because they are inexpensive, rapid and simple to score. The study of these traits needs neither sophisticated method nor complicated equipment. Agro-morphological properties of rice cultivars determine their yield potential, local agronomic suitability and ability to escape from or tolerate biotic and abiotic stresses.

In addition to the above information, quantification of the degree of divergence in a given experimental material is of immense value in the identification of divergent genotypes for further use in hybridization to create new variability. Mahalanobis D^2 statistic has been proven 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.

Yield is the end product of multiplicative interaction between various yield components and this necessitates a thorough understanding of character association and direct and indirect effects contributed by each character on grain yield before launching any breeding programme. Correlation is the measure of the mutual relationship between two variables. The study of correlation may help the plant breeder to know how the improvement of one character will bring simultaneous improvement in other characters. Knowledge of correlation between grain yield and other characters is helpful in the selection of suitable plant type.

As correlation does not provide the true contribution of the characters towards yield, the genotypic and phenotypic correlation coefficients should be partitioned into direct and indirect effects through path coefficient analysis. Path coefficient analysis is a standardized regression coefficient and measures the direct influence of one variable upon the other. It allows separating the direct effect and their indirect effects through other attributes by apportioning the correlations for better interpretation of cause and effect relationship.

Keeping in view the importance of aforesaid aspects, the present investigation was undertaken with the following objectives:

1. To study the genetic variability among the landraces of rice for agro-morphological and grain quality parameters
2. To estimate the genetic diversity among the landraces of rice using Mahalanobis D^2 analysis
3. To study the extent of association among yield and its components and determine the direct and indirect effects of these components on yield

Chapter II

REVIEW OF LITERATURE

The spread of modern high yielding varieties in intensive agriculture has posed a great threat to the security of the age old practice of growing traditional varieties and landraces which may have immense potential for different important traits. In order to prevent any further gene erosion, collection and conservation of such invaluable genetic resources of rice is essential.

The exploitation of genetic diversity for crop improvement should be the ultimate objective of exploration and conservation of genetic resources. It is important to ensure that plant genetic resources are adequately safeguarded for future generations. The vital stages of evaluation and incorporation of valuable characters into new varieties are the justifications of genetic resource activities.

For a successful plant breeding programme to improve genetic potential in any crop, variability is the basic requirement. The estimates of different genetic parameters are important for better understanding of the nature and magnitude of genetic variability available in the breeding material along with the association of different yield and quality attributing characters.

The available literature on morphological characterization, genetic variability, character association, path coefficient analysis and genetic divergence in rice are summarized below:

- 2.1 Morphological characterization
- 2.2 Genetic variability
- 2.3 Heritability and genetic Advance
- 2.4 Genetic divergence
- 2.5 Character association
- 2.6 Path coefficient analysis

2.1 MORPHOLOGICAL CHARACTERIZATION

Morphological characterization of germplasm is fundamental in order to provide information for plant breeding programmes. Characterization of variety is useful to identify and avoid duplication. Characterization should eventually lead to a system of recording and storing useful data that can be readily retrieved and made available to others and help in planning breeding programmes.

Singh and Kochhar (1994) suggested the following criteria for selecting lines for characterization.

- i) New collections through explorations
- ii) New exotic introductions
- iii) New accessions generated from parasexual methods/vegetative propagules/tissue culture raised propagules etc.
- iv) Samples redrawn from gene bank after long intervals to monitor the changes in expression of stable traits
- v) Samples procured from other gene banks as duplicate sets to monitor the changes due to the location effect in character expression.

Graham (1913) classified the Indian rice varieties based on leaf sheath colour and grain dimensions.

Beale (1927) classified rice genotypes of Burma primarily on the constitution of rice kernel, i.e., whether glutinous or starchy and secondarily on grain size, colour of stigma, apiculus and leaf sheath.

Ramaiah (1953) classified rice varieties on the basis of pigment distribution in different plant parts.

Ramaiah (1953) and Hadgal *et al.* (1980) reported that both linkage and pleiotrophy were responsible for simultaneous occurrence of anthocyanin in different plant parts.

Vachhani *et al.* (1962) classified rice genotypes into different groups based on colour, fragrance, texture and shape.

Rosta (1975) grouped the rice varieties based on leaf blade length and width and colour of leaf, ligule, auricle and flowers.

Das *et al.* (1981) while classifying *ahu* rice germplasm in Assam explained the relevance of broad categorization of characters and choice of a few rather than several characters in varietal characterization.

Chauhan and Nanda (1984) suggested that kernel colour and appearance of milled grains were major identification characters of rice varieties.

Naidu *et al.* (1986) classified 20 rice varieties as slender, medium and bold classes based on grain length to breadth ratio.

Vanangamudi *et al.* (1988) grouped 85 rice varieties based on colour of hulled grain, grain vitreous characters like length, width, shape and 100 grain weight.

Sharma *et al.* (1990) studied awning and pigmentation of 43 traditional scented varieties of rice and reported that 13 varieties possessed awns and 23 varieties showed pigmentation on different plant parts.

Chaudhary and Sahai (1993) found high variability for stigma colour, while evaluating 1270 Cambodian rice germplasm. Among the plant characters plant habit, stem length, stem thickness, internode colour, node anthocyanin colour, ligule colour, auricle colour, days to 50 per cent heading and time of maturity were found to be distinguishable characters.

Ahmed and Das (1994) made an attempt to characterize 85 indigenous glutinous rice varieties on the basis of pigment distribution in 11 plant parts and the entire rice germplasm was grouped into 47 groups.

Baruah *et al.* (1994) characterized 144 traditional *ahu* cultivars of Assam into 55 phenotypic groups on the basis of high, medium and low category levels of five key characters viz., day to 50% flowering, plant height, panicle number hill⁻¹, grain weight panicle⁻¹ and 250 grain weight.

Kumar *et al.* (1997) studied variability for different characters in 112 samples of wild rice. Grouping was done according to their habit. Among 112 samples, four were placed in erect, 26 in semi erect, 49 in semi spreading and 34 were kept in spreading type. Pigmentation range was observed for 1 to 12 different plant parts.

Patra (2000) reported purple basal leaf sheath colour in 22 accessions among the rice varieties of Orissa. Statistically significant difference was observed for leaf length. Among the panicle characters, colour of stigma, density of pubescence of lemma, colour of tip of lemma, panicle length, panicle curvature of main axis, panicle type and awning were considered to be some distinguishing characters.

Thimmanna *et al.* (2000) studied the morphological characteristics of the parents of Karnataka rice hybrids and opined that the leaf length, width, pubescence and colour, flag leaf angle, ligule length, colour and shape, auricle colour, inter node colour, panicle type, secondary branching and exertion percentage, awning, seed length, width, L/W ratio and 100 seed weight could be used to differentiate the parental lines.

Rao *et al.* (2001) studied 123 native cultivars and land races which were characterized using morpho-agronomic descriptors (IRRI, 1996) to estimate the variability. Based on the frequency distribution for 11 morphological characters, majority of cultivars were found to possess green basal leaf sheath, light green collar and white stigma.

Suman (2003) characterized the rice germplasm on the basis of anthocyanin pigmentation and awning characters. On the basis of pigment distribution in eight plant parts the entire rice germplasm was grouped into nine groups and by using awning character three groups were made.

Sarma *et al.* (2004) made an attempt to characterize the 142 *ahu* rice genotypes of Assam for 21 morpho-agronomic traits. Majority of them were having the traits viz., early maturing, intermediate plant height, low tillering, erect growing, intermediate panicle type and flag leaf angle, easy threshability and long bold grain.

Bajracharya *et al.* (2006) studied about 147 rice accessions comprising of landraces for agro-morphological variability and concluded that several traits like colour of lemma and palea, sterile lemma and seed coat (bran) were variable. Culm strength, culm angle, panicle type and secondary branching were perfectly correlated.

Subbarao *et al.* (2006) characterized one thousand and fifty six accessions, using morpho-agronomic descriptors (IRRI, 1996) to estimate variability for 21 agro-morphological characters. The results revealed that 54 per cent of them showed very good early plant vigour, 41 per cent exhibited intermediate plant vigour while 5 per cent accessions were found to exhibit poor plant vigour. The study revealed that 57 per cent accessions exhibited green basal leaf sheath colour, 18 per cent possessed purple colour and 12 per cent showed light purple colour, while another 13 per cent accessions exhibited purple lines.

Nineteen varieties of rice belonging to basmati and non-basmati group were characterized by Joshi *et al.* (2007) based on 52 morphological descriptors at different plant growth stages. Although the cultivars showed overlapping of descriptor expression in various combination traits, still the identity of all the cultivars could be established individually. So, it is useful for registration of these varieties.

Padmaja (2007) has characterized one hundred and fifty genotypes using eleven morphological characters as per standard evaluation system (IRRI, 1996). The experimental material showed great variability for all the eleven morphological traits viz., early plant vigour, basal leaf sheath colour, leaf blade colour, leaf pubescence, ligule shape, ligule colour, panicle exertion, panicle type, stigma colour, awning and threshability.

Bisne and Sarawgi (2008) evaluated 32 germplasm accessions for twenty-two morphological, six agronomical and eight quality characters. Out of 22 morphological characters, leaf blade colour, lemma and palea colour, apiculus colour and lemma and palea

pubescence exhibited highest variation in different accessions. Quality traits viz., hulling and milling percentage, head rice recovery, kernel length, breadth, L/B ratio, alkali spreading value and aroma were also contributed to the variability.

Eleven local and popular rice varieties of Assam were characterized on the basis of hulled and unhulled grain characters like grain colour, length, width, grain L/B ratio, dehusked grain length, width, colour, shape and 1000 grain weight (Bora, 2008).

Qadir *et al.* (2008) studied ten rice varieties for sixteen plant morphological characters. The rice genotypes were characterized into two different classes for each trait which include, plant habit, flag leaf angle, leaf sheath colour, auricle colour, panicle type, secondary branching, panicle exertion and apiculus colour. On the basis of leaf colour, leaf pubescence, ligule shape and stigma colour, three classes were made for each character.

Das and Ghosh (2010) studied four hundred and thirty one traditional rice cultivars; characterization was done based on thirty one traits. Among the qualitative traits, considerable variability was recorded for basal leaf sheath colour, awning and auricle colour. Characters like leaf blade colour, panicle exertion, stigma colour *etc.* showed moderate variability. Maximum variability was observed for grains per panicle.

Joshi and Chawla (2010) studied twenty indigenous aromatic rice varieties through morphological descriptors. Out of the 46 visually assessed DUS descriptors, 24 were found to be monomorphic, 17 were dimorphic and 5 were polymorphic, while out of 14 measurable descriptors, one was monomorphic, 6 were dimorphic and 7 characters were polymorphic. Among eight grouping characteristics of DUS test guidelines, basal leaf sheath colour and decorticated grain aroma were monomorphic in the varieties under study. Grouping of varieties was thus based on six characteristics viz., time of heading, stem length, decorticated grain length, decorticated grain shape, decorticated grain colour and amylose content.

Patra *et al.* (2010) characterized eighteen basmati rice varieties using morphological descriptors adopted from the DUS guidelines of PPV&FR Authority. Among the visually assessed characters, 26 characters were monomorphic, 11 characters were dimorphic and 7 characters were polymorphic indicating their potential for varietal characterization and distinctiveness. No intra-varietal variation was observed for any of the visual characteristics and expression of characters in different varieties remained same for two consecutive years confirming the uniformity and stability of the varieties.

Nascimento *et al.* (2011) characterized 146 accessions of upland rice based on qualitative and quantitative agro-morphological descriptors (IRRI, 1980). Polymorphism was observed among 12 of 14 qualitative characters evaluated, whereas significant differences were observed for 11 of the 14 analyzed quantitative traits. Genetic variance was higher than environmental variance, which ensures the predominance of the genetic components in the differences observed among accessions.

Sreejayan *et al.* (2011) characterized the genetic resources of Njavara rice varieties using 24 morphological traits. Different multivariate methods revealed four morphologically distinct types in the Njavara germplasm.

Bhartiya *et al.* (2012) tested 19 varieties as per the DUS test guidelines. Out of 60 morphological traits 17 traits did not show any variation while 23 traits were dimorphic and 20 traits were found to be polymorphic. Eight grouping characters have been described in DUS test guidelines namely decorticated grain aroma, basal leaf sheath colour, time of heading, stem length, amylose content, decorticated grain colour, decorticated grain length and shape. In six varieties distinct morpho-physiological features were observed.

Ninety one farmers' grown rice varieties were evaluated by Chakrabarty *et al.* (2012) for 52 plant morphological and grain characteristics. Of the 44 qualitative traits studied, maximum variability was recorded with respect to density of pubescence of lemma, curvature of main axis of panicle, attitude of branches of panicle, anthocyanin colour of keel in lemma, colour of tip of lemma and lemma and palea colour. The varieties showed distinct visual differences in the lemma and palea colour, grain length and width. Majority of the varieties had long bold and extra long slender grains.

Kumar *et al.* (2012) reported the distinguishing features to characterize and identify KRH-2 and DRRH-2 hybrids including their parental lines. 30 qualitative traits related to seed, seedling and plant characters were studied. Seed length, seed width, seed colour, dehusked seed colour, shoot length, root length and mesocotyl length, panicle attitude of branches, panicle exertion and number of days taken to maturity were the major traits found to be useful for varietal characterization of hybrids and parents.

Studies were carried out by Parikh *et al.* (2012) to characterize seventy one aromatic rice germplasm. They were characterized and grouped on the basis of anthocyanin pigmentation, plant habit and awning character. On the basis of pigmentation distribution in 10 plant parts, a total of twelve groups were formed. On the basis of plant habit and awning character, three groups of each were formed.

Patra and Marndi (2012) carried out the characterization and evaluation of a set of collected germplasm accessions of medicinal rice based on the morpho-agronomic characters for both vegetative and reproductive stages as per IRRI-IPGRI descriptor. The seedling height recorded at 21 days showed a great deal of variability.

Vijayakumar *et al.* (2012) examined the morphological, physicochemical properties of milled rice of 60 Farmers' varieties, which revealed the presence of significant differences among them. The length and breadth of milled raw rice varied from 3.99 to 7.65 mm and from 1.43 to 3.09 mm, respectively. Based on length to breadth ratio, varieties were grouped into seven classes. The amylose content ranged from 6.82% to 29.69%. The gelatinization temperature (GT) was medium to high in 13 varieties and high in 47 varieties.

Chakravorty and Ghosh (2013) characterized 51 landraces using 46 agro-morphological traits following Distinctiveness, Uniformity and Stability (DUS) testing guidelines. Out of 51 varieties studied, 27 were found to be distinctive.

Sarawgi *et al.* (2013) characterized seven hundred eighty two rice germplasm accessions were characterized using morpho-agronomic descriptors according to DUS guidelines (DRR, 2006). Frequency distribution was computed to categorize the accession into different classes. Most of the morphological characters showed variation in different accessions except for leaf collar, leaf ligule and leaf shape of ligule.

Sinha and Mishra (2013) made an attempt to characterize 20 landraces of rice cultivars in West Bengal based on 20 qualitative and 13 quantitative morphological characters as per the DUS test guide lines. Most traits were polymorphic except coleoptile colour, presence of leaf collar, shape of ligule and presence of secondary branching in panicle.

Semwal *et al.* (2014) assessed variability in seed morphology in 23 landraces of rice in West Bengal, using qualitative traits mainly for kernel colour and type, seed coat colour, presence or absence of awns and aroma.

2.2 GENETIC 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 to avoid redundancy in presentation.

Character	Coefficient of variation		References
	PCV	GCV	
Time of heading (50% plants with panicles)	High	High	Awasthi and Pandey (2000) Seyoum <i>et al.</i> (2012)
	Moderate	Moderate	Mohanty <i>et al.</i> (2012) Singh <i>et al.</i> (2012) Bekele <i>et al.</i> (2013)
	Low	Low	Padmaja <i>et al.</i> (2008) Singh <i>et al.</i> (2011) Sravan <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Singh <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
Plant height (cm)	High	High	Akhtar <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012)
	Moderate	Moderate	Padmaja <i>et al.</i> (2008) Singh <i>et al.</i> (2011) Kailashnath (2012) Lakshmi (2012) Sravan <i>et al.</i> (2012) Vanisree <i>et al.</i> (2013)

Character	Coefficient of variation		References
	PCV	GCV	
	Low	Low	
			Kole <i>et al.</i> (2008) Pandey <i>et al.</i> (2012) Prasad <i>et al.</i> (2013)
Total number of tillers per plant	High	High	Padmaja <i>et al.</i> (2008) Yadav <i>et al.</i> (2010) Yadav <i>et al.</i> (2011) Ovung <i>et al.</i> (2012) Singh <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013)
	Moderate	Moderate	Parray and Shikari (2008) Singh <i>et al.</i> (2011) Dhanwani <i>et al.</i> (2013)
	High	Low	Kumar <i>et al.</i> (1998)
Number of productive tillers per plant	High	High	Suman (2003) Padmaja <i>et al.</i> (2008) Chandra <i>et al.</i> (2009a) Kailashnath (2012) Lakshmi (2012) Singh <i>et al.</i> (2012) Basavaraja <i>et al.</i> (2013) Bekele <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
	Moderate	Moderate	Mohanty <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Dhanwani <i>et al.</i> (2013)
	Low	Low	Yadav <i>et al.</i> (2010)

Character	Coefficient of variation		References
	PCV	GCV	
Panicle length (cm)	High	High	Tripathi <i>et al.</i> (1999)
	Moderate	Moderate	Singh <i>et al.</i> (2002) Parray and Shikari (2008) Yadav <i>et al.</i> (2010) Dhanwani <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Singh <i>et al.</i> (2013)
	Low	Low	Kole <i>et al.</i> (2008) Padmaja <i>et al.</i> (2008) Singh <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Pandey <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Prasad <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
Total number of grains per panicle	High	High	Padmaja <i>et al.</i> (2008) Chandra <i>et al.</i> (2009a) Yadav <i>et al.</i> (2010) Singh <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Singh <i>et al.</i> (2012) Basavaraja <i>et al.</i> (2013) Singh <i>et al.</i> (2013)
	Moderate	Moderate	Kole <i>et al.</i> (2008) Parray and Shikari (2008) Pandey <i>et al.</i> (2012) Sravan <i>et al.</i> (2012)
	Low	Low	Nath and Talukdar (1997)

Character	Coefficient of variation		References
	PCV	GCV	
Spikelet fertility (%)	High	High	Saravan and Senthil (1997) Kumar <i>et al.</i> (1998)
	Low	Low	Kole <i>et al.</i> (2008) Saidaiah <i>et al.</i> (2010) Pandey <i>et al.</i> (2012)
Single plant yield (g)	High	High	Suman (2003) Padmaja <i>et al.</i> (2008) Chandra <i>et al.</i> (2009a) Yadav <i>et al.</i> (2010) Singh <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Singh <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Dhanwani <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Singh <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
	Moderate to high	Moderate to high	Saidaiah <i>et al.</i> (2010)
	Moderate	Moderate	Kole <i>et al.</i> (2008) Parray and Shikari (2008) Adilakshmi <i>et al.</i> (2012) Pandey <i>et al.</i> (2012)
	Low	Low	Babu <i>et al.</i> (2012)
100-grain weight (g)	High	High	Chaubey and Singh (1994) Sawant <i>et al.</i> (1994) Mani <i>et al.</i> (1997) Parikh <i>et al.</i> (2011)
	Low	Low	Ganesan and Subramanian (1990)

Character	Coefficient of variation		References
	PCV	GCV	
Decorticated grain: length (mm)	High	High	Singh <i>et al.</i> (2012)
	Moderate	Moderate	Roy <i>et al.</i> (2009) Bekele <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
	Low	Low	Veerabadhiran <i>et al.</i> (2009)
Decorticated grain: width (mm)	High	High	Singh <i>et al.</i> (2012)
	Moderate	Moderate	Veerabadhiran <i>et al.</i> (2009)
	Low	Low	Vanisree <i>et al.</i> (2013)
Decorticated grain: L/B ratio	High	High	Singh <i>et al.</i> (2012) Vanisree <i>et al.</i> (2013)
	Moderate	Moderate	Veerabadhiran <i>et al.</i> (2009) Dhanwani <i>et al.</i> (2013)
Amylose content (%)	High	High	Vanaja and Babu (2006) Basavaraja <i>et al.</i> (2013)
	Moderate	Moderate	Parray and Shikari (2008) Roy <i>et al.</i> (2009) Veerabadhiran <i>et al.</i> (2009) Adilakshmi <i>et al.</i> (2012) Shejul <i>et al.</i> (2013)
	Low	Low	Rajeswari <i>et al.</i> (2010) Subudhi <i>et al.</i> (2011)
Gel consistency (mm)	High	High	Veerabadhiran <i>et al.</i> (2009) Dhanwani <i>et al.</i> (2013) Shejul <i>et al.</i> (2013)
Grain iron concentration (mg/kg)	High	High	Babu <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)
Grain zinc concentration (mg/kg)	High	High	Bekele <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013)

2.3 HERITABILITY AND GENETIC ADVANCE

The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability. Heritability in broad sense refers to the genetic variation present in the population in relation to the total observed variance. Genetic advance measures the difference between the mean genotypic values of selected population and the original population from which these were selected.

Since broad sense heritability includes both additive and epistatic effects. It will be reliable only when accompanied by high genetic advance. Heritability estimates along with genetic advance is more useful than heritability alone in predicting the effectiveness of selection (Johnson *et al.*, 1955).

A brief review of studies on broad sense heritability and genetic advance as per cent of mean in rice is presented hereunder

Character	Range		References
	Heritability	Genetic Advance	
Time of heading (50% plants with panicles)	High	High	Madhavilatha (2002) Nayak <i>et al.</i> (2002) Sandhyakishore (2002) Sankar <i>et al.</i> (2006)
	High	Moderate	Singh <i>et al.</i> (2011) Singh <i>et al.</i> (2012)
	High	Low	Suman (2003) Yadav <i>et al.</i> (2010) Dhanwani <i>et al.</i> (2013)
	Moderate	Moderate	Singh <i>et al.</i> (2013)
Plant height (cm)	High	High	Sankar <i>et al.</i> (2006) Chandra <i>et al.</i> (2009a) Mohanty <i>et al.</i> (2012) Singh <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Kumar <i>et al.</i> (2013)

Character	Range		References
	Heritability	Genetic Advance	
	High	Moderate	Nayak <i>et al.</i> (2002) Suman (2003) Parikh <i>et al.</i> (2011)
Total number of tillers per plant	High	High	Suman (2003) Gangashetty <i>et al.</i> (2013)
	High	Moderate	Singh <i>et al.</i> (2011)
Number of productive tillers per plant	High	High	Nayak <i>et al.</i> (2002) Suman (2003) Sankar <i>et al.</i> (2006) Jaiswal <i>et al.</i> (2007) Sreeparvathy <i>et al.</i> (2010) Gangashetty <i>et al.</i> (2013) Kumar <i>et al.</i> (2013)
	Moderate	Moderate	Singh <i>et al.</i> (2011)
	Low	Low	Singh <i>et al.</i> (2013)
Panicle length (cm)	High	Moderate	Yadav <i>et al.</i> (2010) Parikh <i>et al.</i> (2011) Singh <i>et al.</i> (2011)
	High	Low	Suman (2003)
	Moderate	Moderate	Lalitha and Sreedhar (1996)
	Low	Low	Kole <i>et al.</i> (2008)
Total number of grains per panicle	High	High	Padmaja <i>et al.</i> (2008) Chandra <i>et al.</i> (2009a) Yadav <i>et al.</i> (2010) Singh <i>et al.</i> (2011) Pandey <i>et al.</i> (2012) Singh <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Kumar <i>et al.</i> (2013) Singh <i>et al.</i> (2013)

Character	Range		References
	Heritability	Genetic Advance	
	Moderate	Moderate	Lalitha and Sreedhar (1996) Singh <i>et al.</i> (2011)
Spikelet fertility (%)	High	High	Satyanarayana <i>et al.</i> (2005)
	High	Moderate	Saravan and Senthil (1997) Sankar <i>et al.</i> (2006)
	High	Low	Madhavalatha <i>et al.</i> (2005)
Single plant yield (g)	High	High	Nayak <i>et al.</i> (2002) Madhavalatha <i>et al.</i> (2005) Jaiswal <i>et al.</i> (2007) Yadav <i>et al.</i> (2010) Parikh <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Pandey <i>et al.</i> (2012) Dhanwani <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Kumar <i>et al.</i> (2013) Singh <i>et al.</i> (2013)
	High	Moderate	Singh <i>et al.</i> (2011) Singh <i>et al.</i> (2012)
	High	Low	Suman (2003)
	Moderate	Moderate	Lalitha and Sreedhar (1999)
	Low	Moderate	Sawant <i>et al.</i> (1994)
100-grain weight (g)	High	High	Sawant <i>et al.</i> (1994) Padmaja <i>et al.</i> (2008) Parikh <i>et al.</i> (2011)
	High	Moderate	Suman (2003)
Decorticated grain: length (mm)	High	High	Jaiswal <i>et al.</i> (2007) Patil <i>et al.</i> (2003)
	High	Moderate	Sreeparvathy <i>et al.</i> (2010)
	High	Low	Pandey and Anurag (2010)

Character	Range		References
	Heritability	Genetic Advance	
Decorticated grain: width (mm)	High	High	Jaiswal <i>et al.</i> (2007) Veerabadhiran <i>et al.</i> (2009)
	High	Moderate	Subudhi <i>et al.</i> (2007) Sreeparvathy <i>et al.</i> (2010)
	High	Low	Pandey and Anurag (2010)
Decorticated grain: L/B ratio	High	High	Patil <i>et al.</i> (2003) Jaiswal <i>et al.</i> (2007) Subudhi <i>et al.</i> (2007) Roy <i>et al.</i> (2009) Veerabadhiran <i>et al.</i> (2009) Gangashetty <i>et al.</i> (2013) Shejul <i>et al.</i> (2013)
	High	Low	Pandey and Anurag (2010)
	High	Moderate	Sreeparvathy <i>et al.</i> (2010)
Amylose content (%)	High	High	Vanaja and Babu (2006) Amudha and Thiyagarajan (2008) Roy <i>et al.</i> (2009) Veerabadhiran <i>et al.</i> (2009) Shejul <i>et al.</i> (2013)
	High	Moderate	Nayak and Reddy (2005) Chakraborty <i>et al.</i> (2009) Rajeswari <i>et al.</i> (2010) Sreeparvathy <i>et al.</i> (2010)
	High	Low	Hussain <i>et al.</i> (1987) Das <i>et al.</i> (2007)

Character	Range		References
	Heritability	Genetic Advance	
Gel consistency (mm)	High	High	Sarawgi <i>et al.</i> (2000) Amudha and Thiyagarajan (2008) Veerabadhiran <i>et al.</i> (2009) Dhanwani <i>et al.</i> (2013) Shejul <i>et al.</i> (2013)
	High	Moderate	Chakraborty <i>et al.</i> (2009)
Grain iron and zinc concentration (mg/kg)	High	High	Gangashetty <i>et al.</i> (2013)

2.4 GENETIC DIVERGENCE

Estimation of degree of divergence between populations and contribution of different characters to total divergence can be done by Mahalanobis's D^2 statistics, which is more reliable method in selection of parents for hybridization programme.

Genetic diversity determines the inherent potential of a cross for heterosis and frequency of desirable recombinants in advanced generations. For the same, genetic distance plays a vital role, as the parental diversity in optimum magnitude is required to obtain superior genotypes in segregating population. Some of the important reports regarding this have been cited below:

Vivekanandan and Subramanian (1993) carried out genetic divergence studies using D^2 analysis in 28 genotypes of rain fed 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.

Baruah *et al.* (1994) studied the genetic divergence in 144 traditional *ahu* rice of Assam, using seven characters and seven divergent clusters were obtained. Clustering pattern indicated sufficient genetic diversity in *ahu* rice germplasm and lack of correspondence between ecological situations and genetic divergence.

Genetic diversity among 44 breeding lines and two improved cultivars was studied by Chauhan and Chauhan (1994) using Mahalanobis D^2 statistics. The genotypes were grouped into 12 clusters. 1000 grain weight contributed maximum to the total divergence.

Other traits with appreciable contribution to the total divergence were days to 50% flowering, panicle weight and number of spikelets per panicle.

Rahaman *et al.* (1997) estimated the nature and magnitude of genetic divergence in 52 lowland rice collections. The cultivars were grouped into eight clusters, among which cluster VII and VIII were identified as genetically most divergent. Cluster V exhibited high mean for spikelets panicle⁻¹ and grain yield plant⁻¹, while cluster VI scored highest value for productive tillers plant⁻¹ and panicle length.

Sardana *et al.* (1997) evaluated the genetic divergence in eighty two local rice varieties of Tripura, using D² analysis based on 15 agro-morphological characters. The cultivars were grouped into 18 clusters, of which cluster I with 15 genotypes was the largest. Number of grains per panicle, leaf area, grain weight per panicle, effective tillers per panicle and grain yield per panicle were the major components contributing to the genetic diversity.

Studies on fifty rice genotypes by Pandey *et al.* (1999) using Mahalanobis's D² 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 and 100-seed weight contributed maximum to the genetic diversity.

Shanmugasundaram *et al.* (2000) estimated the genetic diversity among thirty eight cultivars, which were grouped into four different clusters revealing sufficient amount of variation among the varieties. Cluster I and III were most divergent. Plant height, panicle length, grain yield and tiller number were the major contributors to the total divergence among the varieties.

Chaudhary and Sarawgi (2002) studied the genetic diversity among 54 rice genotypes using 19 morphological and quality traits. The genotypes were grouped into five clusters and maximum intra-cluster distance was observed in cluster III comprising of six traditional cultivars. Cluster II and III were identified as genetically more divergent. Genotypes in cluster III had the highest mean for characters viz., yield per plant, alkali value, elongation index, kernel length after cooking, biological yield, effective tillers per plant and intermediate plant height, whereas, genotypes in cluster II were having highest mean values for the traits like harvest index and elongation ratio.

Madhavalatha (2002) studied 54 rice genotypes for their genetic divergence and grouped them 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, contributed maximum towards genetic divergence.

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 50 per cent flowering contributed maximum to the genetic divergence.

Chauhan and Singh (2003) analyzed the genetic the divergence among 45 genotypes them and grouped them into 11 clusters. Hybridization among genotypes included in the diverse clusters (I, IV, VIII, X and XI) and the clusters having high means for quality traits such as high elongation (cluster IV), intermediate alkali value (cluster VIII and IX) and high milling recovery (cluster IX and X) would give high heterotic combinations and produce large variability and better segregants in the segregating generations.

Manonmani and Khan (2003) studied the nature and magnitude of genetic divergence among fourteen *indica* rice genotypes and grouped them into five clusters. Days to 50% flowering and plant height showed maximum contribution towards genetic diversity.

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 the relationship between genetic divergence and geographical origin exists to some extent only.

Gahalain (2004) assessed the amount of genetic divergence in a collection of 55 rice genotypes grown in Kumaun Himalaya. On the basis of D^2 values, they were grouped into twelve clusters. The highest contribution towards total divergence was rendered by total grains panicle⁻¹, followed by fertile grains panicle⁻¹, panicle weight, days to 50% flowering and shoot height.

Nayak *et al.* (2004) analyzed the nature and magnitude of genetic divergence among two hundred scented rice genotypes for ten quantitative traits and grouped the genotypes into ten clusters. No relationship was found between the clustering pattern and geographic distribution. Days to 50% flowering played an important role in the formation of clusters.

Chand *et al.* (2005) studied 19 genotypes of Aman rice for their genetic divergence by using Mahalanobis D^2 statistics and grouped them into six clusters. Cluster I was the largest with eight genotypes followed by cluster II with four genotypes. Maximum inter-cluster distance was found between these groups.

Pradhan and Mani (2005) estimated the genetic divergence in 38 elite basmati rice genotypes for 12 characters and grouped them into ten clusters using D^2 statistics. Days to 50 % flowering contributed maximum to the genetic divergence. Cluster means indicated that none of the clusters was superior with respect to all the characters studied.

Sankar *et al.* (2005) assessed the nature and magnitude of genetic divergence among 34 genotypes for 8 characters using Mahalanobis D^2 statistics. The genotypes were grouped into 7 clusters. Days to 50 % flowering, single plant yield and grains per panicle were the major characters contributing towards divergence.

Fourty tall *indica* rice genotypes were studied by Senapati and Sarkar (2005) to assess the genetic divergence by pooling data of eight grain yield and its related traits. Based on D^2 values, the genotypes were clustered in 5 groups. Majority of the genotypes were included in the cluster I. Panicle number per hill, panicle length, sterility percentage, yield per plot and 1000 grain weight were the chief contributors towards genetic divergence.

Suman *et al.* (2005) grouped 114 rice genotypes into 10 clusters by using Mahalanobis D^2 statistic. The maximum inter-cluster distance was observed between clusters V and X. Harvest index gave the highest contribution towards divergence followed by seed density and total number of tillers per plant. Geographical diversity did not relate to genetic diversity

Babu *et al.* (2006) studied the genetic diversity for different quality traits in 70 rice genotypes and grouped them into nine different clusters. The characters like water uptake, gel consistency and head rice recovery contributed maximum towards genetic diversity. Maximum inter-cluster distance was recorded between cluster VI and VIII.

Devi *et al.* (2006) evaluated genetic diversity in 54 rice cultivars for yield and its component traits. The genotypes were grouped into 9 clusters. Cluster VI recorded high mean values for plant height, flag leaf length and flag leaf width. Plant height contributed the most to genetic divergence, followed by flag leaf width and yield per plant.

Sarkar *et al.* (2006) assessed the genetic divergence among 46 rice genotypes and grouped them into seven clusters. Cluster IV showed highest inter-cluster distance from Cluster VI which was immediately followed by Cluster III and Cluster VII. Highest intra-cluster distance was observed in Cluster V and lowest in Cluster I. The genotypes within Cluster III, VII and I may be used as parents in hybridization programme to develop high yielding lines.

Thirteen land races of paddy were evaluated by Bisht *et al.* (2007) to assess the pattern of genetic diversity present using Mahalanobis D^2 statistics. These landraces formed seven distinct clusters. Most of the genotypes exhibited the characters such as intermediate maturity, tall to medium stature, aroma, slender grain type and red or white grain type.

Sandhyakishore *et al.* (2007) studied genetic divergence for different yield attributing traits among 70 rice genotypes and grouped them into nine different clusters. The mode of distribution of genotypes from different eco-regions into various clusters was at random indicating that geographical diversity and genetic diversity were not related.

Sarawgi and Bisne (2007) studied genetic divergence in 81 scented rice genotypes. Based on D^2 statistics genotypes were grouped into nine clusters. The genotypes from cluster II having desired mean for characters like hulling %, milling % and head rice recovery and panicle length; cluster VII having high value for kernel length and L/B ratio and cluster V low value for days to 50% flowering but highest value for grain yield.

Ramya and Kumar (2008) studied the genetic divergence in 50 genotypes of rice and formed them into 11 clusters. Cluster I was the largest with 35 genotypes. The inter-cluster distances were greater than intra-cluster distances. The inter cluster distance between clusters IV and VIII was maximum. Number of grains per panicle, number of productive tillers per plant and grain yield per plant showed high per cent contribution towards genetic divergence.

Prasad *et al.* (2009) classified fifty two rice genotypes into eight diverse clusters based on D^2 analysis. The largest cluster included most of the indigenous aromatic fine-grained rice varieties of India. The maximum inter-cluster distance was observed between clusters VI and VII followed by clusters III and VIII. Grain maturity duration, plant height and panicle weight contributed maximum towards divergence.

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

Genetic diversity among twenty six genotypes of rice collected from four states of South Eastern Region of India was evaluated by Thayumanavan *et al.* (2009) using Mahalanobis D^2 statistic. Based on 12 morphological and quality characters these genotypes were grouped into 13 clusters. Cluster I with seven genotypes was the largest

cluster followed by Cluster V with four genotypes. Clusters IV, VII, VIII, X, XI, XII and XIII were mono genotypic clusters. Geographical origin was not found to be a good parameter of genetic divergence. Number of grains per panicle followed by days to first flower contributed maximum to total divergence.

Twenty landraces of rice were studied by Hosan *et al.* (2010) to assess the nature and magnitude of genetic divergence among them. The genotypes were grouped into five clusters. The genotypes under cluster IV showed highest divergence among them as it exhibited highest intra-cluster distance. High level of inter-cluster distance was found between clusters II and V and between clusters I and III. Number of filled grains panicle⁻¹, number of panicles plant⁻¹, biomass index and grain yield contributed considerably towards total divergence.

Mohanty *et al.* (2010) studied 40 rice genotypes using Mahalanobis D² analysis and grouped them into five clusters. The pattern of distribution of genotypes revealed 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.

Padmaja *et al.* (2010) analyzed the genetic divergence among 150 genotypes of rice by using Mahalanobis D² statistics. On the basis of D² values, the genotypes were categorized into 13 clusters. Cluster XI was the largest consisting of 28 genotypes, while cluster I contained only two genotypes. Cluster I showed maximum inter-cluster distance with cluster IX. Grains per panicle and spikelet fertility were the major characters contributing towards divergence among the genotypes.

One hundred and ten rice genotypes representing different origins were studied for genetic diversity on the basis of quantitative and quality traits using Mahalanobis D² statistics by Umadevi *et al.* (2010). Out of twenty nine clusters obtained, cluster III was the largest with twenty five genotypes. The highest contribution towards genetic divergence was recorded by water uptake followed by L/B ratio, volume expansion ratio, linear elongation ratio and gel consistency. Hence, these traits may be used as selection parameters in the segregating generations.

Parikh *et al.* (2011) evaluated 71 rice accessions to study the diversity pattern among the genotypes, which 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.

Chakrabarty *et al.* (2012) evaluated ninety one farmers' grown rice varieties based on the eight quantitative traits. The D^2 analysis of the quantitative characters grouped the genotypes into four clusters. Maximum variation was observed for stem length, length of the leaf blade and 1000 grain weight. The least variable trait was the width of the leaf blade followed by the grain width.

Chakravorty and Ghosh (2012) evaluated 51 landraces of rice based on 18 agro-morphological traits to know the extent of genetic divergence present among them. By using Mahalanobis D^2 analysis, they were grouped into 11 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 are not related. Maximum contribution towards genetic divergence came from the characters viz., culm length, culm diameter and grain length.

Sixty four rice germplasm lines were evaluated by Chamundeswari *et al.* (2012) to study the degree and magnitude of genetic diversity by using Mahalanobis D^2 technique. Based on genetic distance values all the genotypes were grouped into eight clusters. Cluster I was the largest with 23 genotypes. Days 50% flowering contributed maximum towards genetic divergence followed by iron content, grain yield per plant, gel consistency and test weight.

An investigation was carried out by Mahalingam *et al.* (2012) with 31 rice germplasm accessions with an objective of studying genetic diversity through Mahalanobis D^2 statistics. Observations recorded were related to Distinctiveness, Uniformity and stability (DUS) test and eleven yield attributing measures. The genotypes were grouped into 13 clusters. Single plant yield contributed to 45.16% and hundred grain weight contributed to 17.20% of the total genetic divergence.

Ovung *et al.* (2012) grouped seventy rice genotypes into nine clusters using Mahalanobis D^2 analysis. The inter-cluster distance was maximum between clusters VI and VII and minimum inter-cluster distance was observed between clusters III and cluster IV.

Kar *et al.* (2013) evaluated 65 indigenous aromatic rice genotypes through divergence analysis. The genotypes were grouped into thirteen clusters. Based on clustering pattern, maximum genetic distance among genotypes existed between clusters IV and V and clusters IV and XI.

Kumar *et al.* (2013) grouped 73 genotypes of rice into 9 clusters based on relative magnitude of D^2 statistics. Genotypes from the same center of origin were distributed in

different clusters which may be due to differential adaptation to varied agro ecosystems. The highest intra-cluster distance was recorded for cluster V and lowest for cluster III.

Twenty four genotypes of rice comprising landraces of Goa and improved cultivars were studied by Manohara and Singh (2013) for genetic diversity on the basis of yield and its attributing characters. Based on D² analysis, the 24 rice genotypes were grouped into 6 clusters. Grouping of most of the landraces of Goa and few improved cultivars of rice into one cluster III indicated the genetic relatedness among these genotypes. Among different traits, days to 50 per cent flowering, 1000 grain weight, grain breadth and plant height had maximum contribution towards the total divergence.

Tirkey *et al.* (2013) studied one hundred and ninety five rice accessions to know the diversity pattern among the genotypes, which were grouped into ten clusters. The inter-cluster distance was higher than intra-cluster distance indicating wide genetic diversity among the genotypes. The highest inter-cluster distances was observed between clusters VI and VII followed by clusters IV and VII which showed wider diversity among the groups. The highest intra-cluster distance was observed for cluster I followed by cluster IX.

2.5 CHARACTER ASSOCIATION

Most of the characters of interest to breeders are complex and are the result of the interaction of a number of component traits. Understanding the relationship between yield and its components is of paramount importance for making the best use of these relationships in selection. Character association derived by correlation coefficient, forms the basis for selecting the desirable plant, aiding in evaluation of relative influence of various component characters on grain yield.

A brief review of studies on correlation coefficients in rice are presented below;

2.5.1. Association of yield component characters and grain quality parameters with single plant yield (g) in rice with

Character	Nature of association	Reference
Time of heading (50% plants with panicles)	Positive significant	Suman (2003) Sankar <i>et al.</i> (2006) Petchiammal and Kumar (2007) Nandan <i>et al.</i> (2010) Ekka <i>et al.</i> (2011) Reddy <i>et al.</i> (2013)

Character	Nature of association	Reference
	Positive non- significant	Madhavilatha <i>et al.</i> (2005) Chandra <i>et al.</i> (2009b)
	Negative significant	Eradasappa <i>et al.</i> (2007) Garg <i>et al.</i> (2010) Babu <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Hasan <i>et al.</i> (2013)
	Negative non-significant	Sarma and Roy (1993) Yolanda and Das (1995) Meenakshi <i>et al.</i> (1999) Nagaraju <i>et al.</i> (2013)
Plant height (cm)	Positive significant	Suman (2003) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Nandan <i>et al.</i> (2010) Ekka <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)
	Positive non-significant	Madhavilatha <i>et al.</i> (2005)
	Negative significant	Yolanda and Das (1995) Rao and Shrivastav (1999) Satyavathi <i>et al.</i> (2001) Babu <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Nagaraju <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013)
	Negative non-significant	Meenakshi <i>et al.</i> (1999) Chandra <i>et al.</i> (2009b)

Character	Nature of association	Reference
Total number of tillers per plant	Positive significant	Garg <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)
	Negative non-significant	Reddy <i>et al.</i> (2008)
Number of productive Tillers per plant	Positive significant	Bhattacharyya <i>et al.</i> (2007) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Hasan <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Nagesh <i>et al.</i> (2013)
	Positive non-significant	Yolanda and Das (1995) Suman (2003)
	Negative non-significant	Nandan <i>et al.</i> (2010) Bekele <i>et al.</i> (2013)
Panicle length (cm)	Positive significant	Reddy <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Hasan <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)

Character	Nature of association	Reference
	Positive non-significant	Suman (2003) Madhavilatha <i>et al.</i> (2005) Krishna <i>et al.</i> (2008)
	Negative significant	Nandan <i>et al.</i> (2010) Sharma <i>et al.</i> (2012)
	Negative non-significant	Chauhan <i>et al.</i> (1993) Sandhyakishore (2005)
Total number of grains per panicle	Positive significant	Reddy <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Garg <i>et al.</i> (2010) Nandan <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2012) Mohanty <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Nagesh <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)
Spikelet fertility (%)	Positive significant	Padmaja <i>et al.</i> (2011) Nandan <i>et al.</i> (2010) Pandey <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Hasan <i>et al.</i> (2013)
	Positive non-significant	Yolanda and Das (1995)
	Negative non-significant	Chakraborty and Hazarika (1994)
100- grain weight (g)	Positive significant	Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011)
	Positive non-significant	Suman (2003)
Decorticated grain: length (mm)	Positive significant	Mohanty <i>et al.</i> (2012)

Character	Nature of association	Reference
	Negative significant	Krishna <i>et al.</i> (2008)
Decorticated grain: L/B ratio	Positive significant	Satyavathi <i>et al.</i> (2001) Garg <i>et al.</i> (2010) Nagaraju <i>et al.</i> (2013)
	Negative significant	Kailashnath (2012) Sharma <i>et al.</i> (2012)
Amylose content (%)	Positive significant	Bhattacharyya <i>et al.</i> (2007) Basavaraja <i>et al.</i> (2012)
	Negative significant	Garg <i>et al.</i> (2010)
	Negative non-significant	Petchiammal and Kumar (2007)
Grain iron concentration (mg/kg)	Positive non-significant	Patil (2008)
	Negative significant	Nagesh <i>et al.</i> (2013)
Grain zinc concentration (mg/kg)	Positive non-significant	Patil (2008)
	Negative non-significant	Nagesh <i>et al.</i> (2013)

2.5.2. Association of the yield component traits and grain quality parameters with time of heading (50% plants with panicles)

Character	Nature of association	Reference
Plant height (cm)	Positive significant	Madhaviatha (2002) Babu <i>et al.</i> (2012)
	Positive non-significant	Chauhan <i>et al.</i> (1993) Babu (1999)
	Negative significant	Nayak <i>et al.</i> (2004) Chandra <i>et al.</i> (2009b) Yadav <i>et al.</i> (2011)
	Negative non-significant	Rao and Shrivastav (1999) Nandan <i>et al.</i> (2010)

Character	Nature of association	Reference
Total number of tillers per plant	Positive non-significant	Chandra <i>et al.</i> (2009b)
	Negative non-significant	Yadav <i>et al.</i> (2011) Reddy <i>et al.</i> (2013)
Number of productive tillers per plant	Positive significant	Sawant <i>et al.</i> (1995) Sakthivel (2001)
	Positive non-significant	Raju (2002) Chandra <i>et al.</i> (2009b)
	Negative significant	Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Lakshmi (2012) Hasan <i>et al.</i> (2013)
	Negative non-significant	Yolanda and Das (1995) Meenakshi <i>et al.</i> (1999) Madhavalatha (2002)
Panicle length (cm)	Positive significant	Madhavalatha (2002) Suman (2003) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012)
	Positive non-significant	Sawant <i>et al.</i> (1995)
	Negative significant	Nandan <i>et al.</i> (2010)
Total number of grains per panicle	Positive significant	Padmaja <i>et al.</i> (2011) Nagesh <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)
	Positive non-significant	Yolanda and Das (1995)
	Negative non-significant	Meenakshi <i>et al.</i> (1999)
100-grain weight (g)	Positive significant	Yolanda and Das (1995)
Spikelet fertility (%)	Positive significant	Hasan <i>et al.</i> (2013)
	Positive non-significant	Rao and Shrivastav (1999)
	Negative significant	Yolanda and Das (1995)
	Negative non-significant	Madhavalatha (2002)

Character	Nature of association	Reference
Decorticated grain: length (mm)	Negative significant	Nayak <i>et al.</i> (2001) Krishna <i>et al.</i> (2008) Yadav <i>et al.</i> (2012)
Decorticated grain: width (mm)	Negative non-significant	Nandan <i>et al.</i> (2010)
Decorticated grain: L/B ratio	Positive significant	Madhavilatha (2002)
	Negative significant	Yadav <i>et al.</i> (2012)
Amylose content (%)	Positive significant	Basavaraja <i>et al.</i> (2011)

2.5.3. Association of the yield component traits and grain quality parameters with plant height

Character	Nature of association	Reference
Total number of tillers per plant	Negative significant	Suman (2003) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011)
Number of productive tillers per plant	Positive significant	Sakthivel (2001) Raju (2002) Chandra <i>et al.</i> (2009b)
	Positive non-significant	Yolanda and Das (1995)
	Negative significant	Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)
Panicle length (cm)	Positive significant	Suman (2003) Chandra <i>et al.</i> (2009b) Yadav <i>et al.</i> (2010) Yadav <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Hasan <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)

Character	Nature of association	Reference
	Positive non- significant	Raju (2002)
	Negative significant	Padmaja <i>et al.</i> (2011)
Total number of grains per panicle	Positive significant	Suman (2003) Chandra <i>et al.</i> (2009b) Sravan <i>et al.</i> (2012) Reddy <i>et al.</i> (2013)
	Positive non-significant	Meenakshi <i>et al.</i> (1999) Kavitha and Reddi (2001)
	Negative significant	Raju (2002) Akhtar <i>et al.</i> (2011)
	Negative non-significant	Chauhan <i>et al.</i> (1993) Sawant <i>et al.</i> (1995)
Spikelet fertility (%)	Negative significant	Padmaja <i>et al.</i> (2011)
100-seed weight (g)	Negative non-significant	Padmaja <i>et al.</i> (2011)
	Positive significant	Suman (2003)
Decorticated grain: length (mm)	Positive non-significant	Babu (1999)
	Negative significant	Nayak <i>et al.</i> (2001)
	Negative non-significant	Reddy <i>et al.</i> (1997) Nandan <i>et al.</i> (2010)
Decorticated grain: width (mm)	Positively significant	Krishna <i>et al.</i> (2008)
Decorticated grain: L/B ratio	Positive non-significant	Babu (1999) Kavitha and Reddi (2001)
	Negative non-significant	Nayak <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001) Nandan <i>et al.</i> (2010)
Grain iron and zinc concentrations (mg/kg)	Positive significant	Gangashetty <i>et al.</i> (2013)

2.5.4. Association of the yield component traits and grain iron concentration with total number of tillers per plant

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Suman (2003) Reddy <i>et al.</i> (2008) Padmaja <i>et al.</i> (2011) Bekele <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013)
Panicle length (cm)	Positive significant	Padmaja <i>et al.</i> (2011)
	Negative significant	Suman (2003) Yadav <i>et al.</i> (2011)
Total number of grains per panicle	Negative significant	Suman (2003)
Grain iron concentration (mg/kg)	Positive significant	Gangashetty <i>et al.</i> (2013)

2.4.5. Association of yield component traits and grain quality parameters with number of productive tillers per plant

Character	Nature of association	Reference
Panicle length (cm)	Positive significant	Janardhanam <i>et al.</i> (2001) Sakthivel (2001) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Nagaraju <i>et al.</i> (2013)
	Positive non-significant	Yolanda and Das (1996) Kavitha and Reddi (2001) Chandra <i>et al.</i> (2009b)
	Negative significant	Suman (2003) Babu <i>et al.</i> (2012)
	Negative non-significant	Sandhyakishore (2005)

Character	Nature of association	Reference
Plant height (cm)	Positive significant	Meenakshi <i>et al.</i> (1999) Janardhanam <i>et al.</i> (2001) Sakthivel (2001)
	Negative significant	Suman (2003)
Total number of grains per panicle	Positive significant	Meenakshi <i>et al.</i> (1999) Janardhanam <i>et al.</i> (2001) Nagaraju <i>et al.</i> (2013)
	Positive non-significant	Yolande and Das (2003) Sandhyakishore (2005)
	Negative significant	Satyavathi <i>et al.</i> (2001)
	Negative non-significant	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001)
Spikelet fertility (%)	Positive significant	Sravan <i>et al.</i> (2012) Hasan <i>et al.</i> (2013)
	Negative significant	Petchiammal and Kumar (2007)
	Positive non-significant	Madhavalatha (2002)
100-grain weight (g)	Negative significant	Padmaja <i>et al.</i> (2011)
Decorticated grain: length (mm)	Positive significant	Mohanty <i>et al.</i> (2012)
Amylose content (%)	Negative significant	Petchiammal and Kumar (2007)
Gel consistency (mm)	Positive significant	Sravan <i>et al.</i> (2012)
Grain iron concentration (mg/kg)	Positive significant	Gangashetty <i>et al.</i> (2013)

2.5.6. Association of yield component traits and grain quality parameters with panicle length

Character	Nature of association	Reference
Total number of grains per panicle	Positive significant	Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011)
	Positive non-significant	Satyavathi <i>et al.</i> (2001)
	Negative non-significant	Sawant <i>et al.</i> (1995) Nandan <i>et al.</i> (2010)
Spikelet fertility (%)	Positive significant	Hasan <i>et al.</i> (2013)
	Positive non-significant	Padmaja <i>et al.</i> (2011)
100-grain weight (g)	Positive significant	Meenakshi <i>et al.</i> (1999)
Decorticated grain: length (mm)	Positive significant	Krishna <i>et al.</i> (2008) Mohanty <i>et al.</i> (2012)
	Negative non-significant	Nayak <i>et al.</i> (2001)
Decorticated grain: width (mm)	Positive significant	Mohanty <i>et al.</i> (2012)
Decorticated grain: L/B ratio	Negative significant	Nayak <i>et al.</i> (2001)
Gel consistency (mm)	Positive significant	Sravan <i>et al.</i> (2012)

2.5.7. Association of yield component traits with total number of grains per panicle

Character	Nature of association	Reference
Spikelet fertility (%)	Positive significant	Nandan <i>et al.</i> (2010)
	Positive non-significant	Madhavalatha (2002)
	Negative significant	Padmaja <i>et al.</i> (2011)
100-grain weight (g)	Positive significant	Meenakshi <i>et al.</i> (1999)

2.5.8 Association of yield component traits with spikelet fertility (%)

Character	Nature of association	Reference
100- grain weight (g)	positive significant	Padmaja <i>et al.</i> (2011)

2.5.9. Association of grain quality parameters with decorticated grain: length

Character	Nature of association	Reference
Decorticated grain: width (mm)	Positive significant	Krishna <i>et al.</i> (2008)
	Positive non-significant	Anuradha <i>et al.</i> (2012)
Decorticated grain: L/B ratio	Positive significant	Nandan <i>et al.</i> (2001) Khatun <i>et al.</i> (2003) Subudhi <i>et al.</i> (2007) Kailashnath (2012) Mohanty <i>et al.</i> (2012)
Amylose content (%)	Positive significant	Chauhan and Nanda (1982) Subudhi <i>et al.</i> (2007)
	Negative significant	Khatun <i>et al.</i> (2003) Shivani <i>et al.</i> (2008)
Gel consistency (mm)	Positive significant	Khatun <i>et al.</i> (2003)
	Negative significant	Rajeswari <i>et al.</i> (2010)
Grain iron and zinc concentration (mg/kg)	Negative non-significant	Anuradha <i>et al.</i> (2012)

2.5.10. Association of grain quality parameters with decorticated grain: width

Character	Nature of association	Reference
Decorticated grain: L/B ratio	Negative significant	Khatun <i>et al.</i> (2003) Subudhi <i>et al.</i> (2007)
Grain iron and zinc concentration (mg/kg)	Negative non-significant	Anuradha <i>et al.</i> (2012)

2.5.11. Association among of grain quality parameters with decorticated grain: L/B ratio

Character	Nature of association	Reference
Amylose content (%)	Negative non-significant	Shivani <i>et al.</i> (2007)
Gel consistency (mm)	Positive significant	Khatun <i>et al.</i> (2003)

2.5.12. Association of grain quality parameters with amylose content (%)

Character	Nature of association	Reference
Gel consistency (mm)	Positive non-significant	Shivani <i>et al.</i> (2007)
	Negative significant	Khatun <i>et al.</i> (2003)

2.4.13. Association of yield component traits with grain zinc concentration

Character	Nature of association	Reference
100- grain weight (g)	Positive non-significant	Bekele <i>et al.</i> (2013)

2.5.14. Association of grain iron concentration with grain zinc concentration

Character	Nature of association	Reference
Grain zinc concentration (mg/kg)	Positive significant	Patil (2008) Nagesh <i>et al.</i> (2013)
	Positive non-significant	Gangashetty <i>et al.</i> (2013)

2.6 PATH COEFFICIENT ANALYSIS

Grain yield is a complex character and is associated with number of component characters which are interrelated, among themselves interdependence often affects their relationship with yield, thereby making correlation ineffective. Wright (1921) devised the analysis of path coefficient, to provide an effective means of finding out direct and indirect causes of association. Correlation in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters.

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:

2.6.1. Direct effects of yield contributing characters on single plant yield (g)

Character	Positive direct effect on single plant yield	Negative direct effect on single plant yield
Time of heading (50% plants with panicles)	Sankar <i>et al.</i> (2006) Chandra <i>et al.</i> (2009b) Nandan <i>et al.</i> (2010) Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2012) Mohanty <i>et al.</i> (2012) Seyoum <i>et al.</i> (2012)	Garg <i>et al.</i> (2010) Yadav <i>et al.</i> (2010) Yadav <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Kailashnath (2012) Lakshmi (2012) Pandey <i>et al.</i> (2012) Bekele <i>et al.</i> (2013)
Plant height (cm)	Sankar <i>et al.</i> (2006) Garg <i>et al.</i> (2010) Nandan <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Basavaraja <i>et al.</i> (2012) Kailashnath (2012) Lakshmi (2012) Mohanty <i>et al.</i> (2012) Seyoum <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013)	Satyavathi <i>et al.</i> (2001) Suman (2003) Karad and Pol (2008) Chandra <i>et al.</i> (2009b) Akhtar <i>et al.</i> (2011)
Total number of tillers per plant	Reddy <i>et al.</i> (2008) Yadav <i>et al.</i> (2011) Neha and Lal (2012) Sharma <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)	Madhavalatha (2005) Suman <i>et al.</i> (2005) Garg <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011)

Character	Positive direct effect on single plant yield	Negative direct effect on single plant yield
Number of productive tillers per plant	Sankar <i>et al.</i> (2006) Chandra <i>et al.</i> (2009b) Garg <i>et al.</i> (2010) Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Pandey <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Hasan <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Nagesh <i>et al.</i> (2013)	Kavitha and Reddi (2001) Yadav <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012)
Panicle length (cm)	Suman (2003) Karad and Pol (2008) Ekka <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Mohanty <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)	Nayak <i>et al.</i> (2001) Madhavalatha (2002) Kole <i>et al.</i> (2008) Krishna <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011)
Total number of grains per panicle	Sandhyskishore (2005) Reddy <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Garg <i>et al.</i> (2010) Nandan <i>et al.</i> (2010) Yadav <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Nagaraju <i>et al.</i> (2013)	Akhtar <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Neha and Lal (2012)

Character	Positive direct effect on single plant yield	Negative direct effect on single plant yield
Spikelet fertility (%)	Padmaja <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Hasan <i>et al.</i> (2013)	Yolanda and Das (1995)
100-grain weight (g)	Yolanda and Das (1995) Sankar <i>et al.</i> (2006) Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011)	---
Decorticated grain: length (mm)	Nayak <i>et al.</i> (2001) Bhattacharyya <i>et al.</i> (2007) Lakshmi (2011) Singh <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012)	Madhavalatha (2002)
Decorticated grain: width (mm)	Bhattacharyya <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Ekka <i>et al.</i> (2011) Yadav and Kumar (2012)	---
Decorticated grain: L/B ratio	Krishna <i>et al.</i> (2008) Nagaraju <i>et al.</i> (2013)	Garg <i>et al.</i> (2010)
Amylose content (%)	Petchiammal and Kumar (2007) Basavaraja <i>et al.</i> (2012)	Garg <i>et al.</i> (2010)
Gel consistency (mm)	---	Garg <i>et al.</i> (2010)
Grain iron concentration (mg/kg)	---	Nagesh <i>et al.</i> (2013)
Grain zinc concentration (mg/kg)	Nagesh <i>et al.</i> (2013)	Bekele <i>et al.</i> (2013)

2.6.2 Indirect Effects

2.6.2.1. Indirect effects of Time of heading (50% plants with panicles) on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Plant height (cm)	Meenakshi <i>et al.</i> (1999) Nayak <i>et al.</i> (2001) Madhavalatha (2002) Padmaja <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012) Yadav and Kumar (2012)	Kole <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012)
Number of productive tillers per plant	Madavilatha (2002) Sankar <i>et al.</i> (2006) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)	Meenakshi <i>et al.</i> (1999) Kavitha and Reddi (2001) Padmaja <i>et al.</i> (2011) Yadav and Kumar (2012)
Panicle length (cm)	Kavitha and Reddi (2001) Padmaja <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012)	Kole <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012)
Total number of grains per panicle	Nayak <i>et al.</i> (2001) Madhavalatha (2002) Sandhyakishore (2005) Sankar <i>et al.</i> (2006)	Meenakshi <i>et al.</i> (1999) Yadav and Kumar (2012)
Spikelet fertility (%)	---	Madhavalatha (2002)
Decorticated grain: length (mm)	Yadav and Kumar (2012)	Nayak <i>et al.</i> (2001) Madavilatha (2002) Bhadru <i>et al.</i> (2012)
Decorticated grain: width (mm)	Yadav and Kumar (2012)	---
Decorticated grain: L/B ratio	Madavilatha (2002)	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Yadav and Kumar (2012)

2.6.2.2. Indirect effects of plant height on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Madhavalatha (2002) Sandhyakishore (2005) Yadav <i>et al.</i> (2010) Babu <i>et al.</i> (2012)	Kavitha and Reddi (2001) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012) Yadav and Kumar (2012)
Number of productive tillers per plant	Janardhanam <i>et al.</i> (2001) Suman (2003) Madhavalatha <i>et al.</i> (2005) Chandra <i>et al.</i> (2009b) Yadav <i>et al.</i> (2010) Bhadru <i>et al.</i> (2012) Mohanty <i>et al.</i> (2012) Pandey <i>et al.</i> (2012) Reddy <i>et al.</i> (2013)	Nayak <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012)
Panicle length (cm)	Satyavathi <i>et al.</i> (2001) Suman (2003) Yadav <i>et al.</i> (2010) Babu <i>et al.</i> (2012) Mohanty <i>et al.</i> (2012) Pandey <i>et al.</i> (2012)	Nayak <i>et al.</i> (2001) Madhavalatha <i>et al.</i> (2005) Kole <i>et al.</i> (2008) Padmaja <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012)
Total number of grains per panicle	Madhavalatha <i>et al.</i> (2002) Sandhyakishore (2005) Akhtar <i>et al.</i> (2011) Yadav and Kumar (2012) Reddy <i>et al.</i> (2013)	Kole <i>et al.</i> (2008) Pandey <i>et al.</i> (2012) Yadav and Kumar (2012)
Spikelet fertility (%)	Madhavalatha (2002)	---
100-grain weight (g)	---	Suman (2003)
Decorticated grain: length (mm)	Mohanty <i>et al.</i> (2012) Yadav and Kumar (2012)	---

Character	Positive indirect effect	Negative indirect effect
Decorticated grain: width (mm)	Yadav and Kumar (2012)	---
Decorticated grain: L/B ratio	Babu (1999) Nagajyothi (2001) Mohanty <i>et al.</i> (2012)	Madhavalatha (2002) Yadav and Kumar (2012)

2.6.2.3. Indirect effects of total number of tiller per plant on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Plant height	Akhtar <i>et al.</i> (2011)	---
Panicle length (cm)	Gangashetty <i>et al.</i> (2013)	---
Total number of grains per panicle	Akhtar <i>et al.</i> (2011)	---

2.6.2.4. Indirect effects of number of productive tillers per plant on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Nayak <i>et al.</i> (2001) Madhavalatha (2002) Sandhyakishore (2005) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011)	Kavitha and Reddi (2001) Yadav <i>et al.</i> (2010) Babu <i>et al.</i> (2012)
Plant height (cm)	Janardhanam <i>et al.</i> (2001) Madhavalatha (2002) Yadav <i>et al.</i> (2010)	Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012)
Panicle length (cm)	Madhavalatha (2002) Padmaja <i>et al.</i> (2011) Gangashetty <i>et al.</i> (2013)	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Chandra <i>et al.</i> (2009b) Yadav <i>et al.</i> (2010) Babu <i>et al.</i> (2012)
Total number of grains per panicle	Janardhanam <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001) Sandhyakishore (2005)	Nayak <i>et al.</i> (2001) Madhavalatha (2002) Yadav <i>et al.</i> (2010)

Character	Positive indirect effect	Negative indirect effect
Spikelet fertility (%)	Madhavilatha (2002)	---
Decorticated grain: length (mm)	Babu (1999)	Madavilatha (2002)
Decorticated grain: L/B ratio	Nayak <i>et al.</i> (2001) Madavilatha (2002)	Babu (1999)

2.6.2.5. Indirect effects of panicle length on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Sandhyakishore (2005) Sankar <i>et al.</i> (2006) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)	Padmaja <i>et al.</i> (2011)
Plant height (cm)	Nayak <i>et al.</i> (2001) Madhavilatha (2002) Sandhyakishore (2005) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)	Janardhanam <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001) Yadav <i>et al.</i> (2010)
Number of productive tillers per plant	Nayak <i>et al.</i> (2001) Sankar <i>et al.</i> (2006) Padmaja <i>et al.</i> (2011) Kiani and Nematzadeh (2012) Mohanty <i>et al.</i> (2012) Reddy <i>et al.</i> (2013)	Madhavilatha (2002) Satyavathi <i>et al.</i> (2001) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)
Total number of grains per panicle	Sankar <i>et al.</i> (2006) Yadav <i>et al.</i> (2010)	Kole <i>et al.</i> (2008) Pandey <i>et al.</i> (2012) Reddy <i>et al.</i> (2013)
Spikelet fertility (%)	Madhavilatha (2002)	---

Character	Positive indirect effect	Negative indirect effect
Decorticated grain: length (mm)	Mohanty <i>et al.</i> (2012)	---
Decorticated grain: L/B ratio	Mohanty <i>et al.</i> (2012)	---

2.6.2.6. Indirect effects of total number of grains per panicle on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Madhavilatha (2002) Sandhyakishore (2005) Sankar <i>et al.</i> (2006) Kole <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011) Sharma <i>et al.</i> (2012)	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Bhadru <i>et al.</i> (2012)
Plant height (cm)	Nayak <i>et al.</i> (2001) Madhavilatha (2002) Sandhyakishore (2005) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012)	Kole <i>et al.</i> (2008) Chandra <i>et al.</i> (2009b)
Number of productive tillers per plant	Akhtar <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Madhavilatha (2002) Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011)
Panicle length (cm)	Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Madhavilatha (2002) Kole <i>et al.</i> (2008) Bhadru <i>et al.</i> (2012)
Spikelet fertility (%)	Madhavilatha (2002)	---
Decorticated grain: length (mm)	Madavilatha (2002)	Nayak <i>et al.</i> (2001)

Character	Positive indirect effect	Negative indirect effect
Decorticated grain: L/B ratio	Satyavathi <i>et al.</i> (2001) Madhavalatha (2002)	---

2.6.2.7. Indirect effects of spikelet fertility on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Plant height (cm)	Madhavalatha (2002)	---
Number of productive tillers per plant	Madhavalatha (2002)	---
Panicle length (cm)	---	Madhavalatha (2002)
Total number of grains per panicle	Madhavalatha (2002)	---

2.6.2.8. Indirect effects of 100-grain weight on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Panicle length (cm)	Padmaja <i>et al.</i> (2011)	---
Total number of grains per panicle	Padmaja <i>et al.</i> (2011)	---

2.6.2.9. Indirect effects of decorticated grain length on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Madhavalatha (2002) Krishna <i>et al.</i> (2008) Yadav and Kumar (2012)	---
Plant height (cm)	Ganesan <i>et al.</i> (1997)	Krishna <i>et al.</i> (2008)
Number of productive tillers per plant	Mohanty <i>et al.</i> (2012) Yadav and Kumar (2012)	Nayak <i>et al.</i> (2001) Krishna <i>et al.</i> (2008)
Panicle length (cm)	Nayak <i>et al.</i> (2001) Mohanty <i>et al.</i> (2012)	Ganesan <i>et al.</i> (1997) Krishna <i>et al.</i> (2008)
Total number of grains per panicle	---	Yadav <i>et al.</i> (2012)
Decorticated grain: width (mm)	Yadav and Kumar (2012)	Krishna <i>et al.</i> (2008)

Character	Positive indirect effect	Negative indirect effect
Decorticated grain: L/B ratio	Yadav and Kumar (2012)	Babu (1999) Krishna <i>et al.</i> (2008)

2.6.2.10. Indirect effects of decorticated grain: L/B ratio on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (50% plants with panicles)	Nayak <i>et al.</i> (2001) Madavilatha (2002) Yadav and Kumar (2012)	Babu (1999) Krishna <i>et al.</i> (2008)
Plant height (cm)	Satyavathi <i>et al.</i> (2001) Krishna <i>et al.</i> (2008)	Madavilatha (2002) Yadav and Kumar (2012)
Number of productive tillers per plant	Satyavathi <i>et al.</i> (2001) Madavilatha (2002) Yadav and Kumar (2012)	Nayak <i>et al.</i> (2001) Krishna <i>et al.</i> (2008)
Panicle length (cm)	Nayak <i>et al.</i> (2001) Krishna <i>et al.</i> (2008)	Satyavathi <i>et al.</i> (2001) Madavilatha (2002)
Total number of grain per panicle	Madavilatha (2002) Krishna <i>et al.</i> (2008) Yadav and Kumar (2012)	Nayak <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001)
Decorticated grain: length (mm)	Babu (1999) Nayak <i>et al.</i> (2001) Krishna <i>et al.</i> (2008)	Madavilatha (2002) Yadav and Kumar (2012)
Decorticated grain: width (mm)	---	Krishna <i>et al.</i> (2008) Yadav and Kumar (2012)

2.6.2.11. Indirect effects of grain iron concentration on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Grain zinc concentration	Negative significant	Nagesh <i>et al.</i> (2013)

Chapter III

MATERIAL AND METHODS

The present experiment to study the genetic diversity among the landraces of rice was carried out during *kharif*, 2013-2014 at Directorate of Rice Research Farm, ICRISAT campus, Patancheru, Hyderabad, India, situated at 17.53⁰ N latitude, 78.27⁰ E longitude and altitude of 545 m above mean sea level. The material used, experimental design adopted, the mode of data collection and the statistical procedures followed in present the study are outlined below.

3.1 EXPERIMENTAL MATERIAL

The experimental material used in the present investigation comprised of seventy landraces of rice obtained from the Plant Breeding Division, Crop Improvement Section, Directorate of Rice Research, Rajendranagar, Hyderabad. The details of landraces were furnished in Table 3.1.

3.2 METHODS

Seventy landraces of rice were sown separately in raised bed nursery. Thirty days old seedlings of each genotype were transplanted in 5 rows of 3 m length by adopting a spacing of 20 cm between rows and 15 cm between plants with in a row in a Randomized Block Design replicated thrice. All the necessary precautions were taken to maintain uniform plant population in each treatment per replication. All the recommend package of practices were adopted besides providing necessary prophylactic plant protection measures to raise a good crop.

3.3 RECORDING OF OBSERVATIONS

Twenty four characteristics which include six qualitative, nine quantitative and nine grain quality and nutritional traits were recorded. The details of the observations recorded and the techniques adopted to record each of them are furnished below.

3.3.1 Qualitative Characters

Visual observations were recorded on single plant basis on ten randomly selected plants in each genotype at appropriate growth stages according to Rao *et al.* (2013) on six qualitative characters viz., basal leaf sheath colour, flag leaf attitude (late obseravtion), lemma anthocyanin colouration of apex, stigma colour, stem anthocyanin colouration of node and panicle exsertion. A description of qualitative characters observed is given in Table 3.2.

3.3.2 Quantitative Traits

Data on eight metric parameters were recorded on five randomly selected plants in each plot, while the data on time of heading (50 % plants with panicles) were noted on plot basis. These characters were measured as per the standard techniques and the mean of five plants for all the characters except time of heading was utilized for carrying statistical analysis.

3.3.2.1 Time of Heading (50% Plants with Panicles)

The number of days taken from sowing to the days when primary panicles in fifty percent of plants in each plot and in each replication were in heading was recorded.

3.3.2.2 Stem Length (cm)

Stem length was measured in centimeters from ground level to the tip of the neck node in each plant at the time of harvest with a measuring scale.

3.3.2.3 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 with measuring scale

3.3.2.4 Total Number of Tillers per Plant

Number of both ear bearing and non-bearing tillers per hill were counted at the time of harvest.

3.3.2.5. Number of Productive Tillers per Plant

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

3.3.2.6. Total Number of Grains per Panicle

Total number of grains was counted from five panicles of each selected plant and their mean was computed.

3.3.2.7 Spikelet Fertility (%)

Number of filled and chaffy grains in each panicle of each selected plant was counted and spikelet fertility percentage was calculated as the ratio of number of filled grains to the total number of grains in the panicle and expressed as a percentage.

$$\text{Spikelet fertility (\%)} = \frac{\text{Number of filled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.3.2.8 100-Grain Weight (g)

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

3.3.2.9 Single Plant Yield (g)

Selected single plants in a plot of each genotype in each replication were harvested, hand threshed, cleaned, dried and weighed in grams and their mean was computed.

All the landraces of rice used in the present investigation were categorized into different groups based on these quantitative characters according to Rao *et al.* (2013) as described in Table 3.3.

Table 3.3. Description of quantitative characters according to Rao *et al.* (2013)

S. No	Character	States	Note	Stage of observation
1.	Time of heading (50% of plants with panicles)	Very early (<71 days)	1	Half of inflorescence emerged
		Early (71-90 days)	3	
		Medium (91-110 days)	5	
		Late (111-130 days)	7	
		Very late (>130 days)	9	
2.	Stem: length (excluding panicle; excluding floating rice)	Very short (<91 cm)	1	Milking stage
		Short (91-110 cm)	3	
		Medium (111-130 cm)	5	
		Long (131-150 cm)	7	
		Very long (>150 cm)	9	
3.	Panicle length	Very short (<16 cm)	1	Milking to ripening stage
		Short (16-20 cm)	3	
		Medium (21-25 cm)	5	
		Long (26-30 cm)	7	
		Very long (>30 cm)	9	

3.3.3 Grain Quality and Nutritional Characters

Data on various grain quality and nutritional parameters were collected as mentioned below.

3.3.3.1 Decorticated Grain: Length (mm)

Ten grains of hulled rice were randomly selected and their length was recorded in millimeter using dial micrometer.

3.3.3.2 Decorticated Grain: Width (mm)

Ten grains of hulled rice were randomly selected and their width was recorded in millimeter using dial micrometer.

3.3.3.3 Decorticated Grain: Colour

Ten grains of hulled rice were randomly selected and their colour was determined visually by using latest Royal Horticultural Society colour chart.

3.3.3.4 Decorticated Grain: L/B ratio

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

$$\text{L/B ratio} = \frac{\text{Mean length of the kernel in mm}}{\text{Mean breadth of the kernel in mm}}$$

3.3.3.5 Decorticated Grain: Shape

Based on kernel length and L/B ratio, the experimental material was classified into different grain types as per Rao *et al.* (2013) as mentioned below:

State	Length (mm)	L/B ratio	Note
Short Slender	Less than 6.0	More than 3.0	1
Short Bold	Less than 6.0	Less than 2.5	2
Medium Slender	Less than 6.0	2.5-3.0	3
Long Slender	More than 6.0	More than 3.0	4
Long Bold	More than 6.0	Less than 3.0	5
Extra Long Slender	More than 7.5	More than 3.0	6
Basmati type	More than 6.61	More than 3.0	7

3.3.3.6 Amylose Content (%)

Amylose is the linear fraction of starch in the non-glutinous genotypes. Amylose content has a major influence on the texture of cooked milled rice.

For standard curve, 40 mg of potato amylose was wetted with 1ml ethyl alcohol (absolute) and 9 ml of 1 N NaOH, heated for 5-10 minutes in a boiling water bath, cooled and made upto 100 ml with distilled water. 1, 2, 3, 4 and 5 ml solution was taken followed by addition of 0.2, 0.4, 0.6, 0.8 and 1.0 ml of 1 N acetic acid and 2 ml Iodine solution (0.2% I₂ in 2% KI) and factor was derived as per Juliano (1971).

For amylose estimation of the rice sample, about 20 lots of whole-grain milled rice was ground with mortar and pestle to obtain a fine powder. 100 mg rice flour passed through 100 mm sieve was taken in a test tube (19.5 cm × 2.0 cm), 1 ml ethyl alcohol (absolute) and 9 ml of 1 N NaOH was added to it and the mixture was shaken well. The tubes were heated over water bath for 15 minutes and the contents were transferred to 100 ml volumetric flask and the volume was made upto 100 ml with

distilled water. From this, 5 ml of solution was taken in 100 ml volumetric flask (in three replications) and 1ml acetic acid and 2 ml iodine solution were added and the final volume was made upto 100 ml. These flasks were covered with black cloth for color development and after 20 minutes, the transmission values at 620 nm were recorded. Then the amylose content of the sample was calculated by multiplying the mean of the transmission values of that sample with the factor calculated by using the standard curve and expressed as percentage.

Based on the above grain quality parameters, the seventy landraces of rice were classified into different groups as indicated in Table 3.4.

3.3.3.7 Gel Consistency (mm)

To determine the gel consistency of sample, about 10 milled rice grains were ground in mortar and pestle to obtain a fine powder. 100 mg rice flour passed through 100 mm sieve was taken in quadruplicates in culture tubes (15.0 cm x 1.4 cm). 0.2 ml of ethanol containing 0.25 % of thymol blue was added to the sample. Then 2 ml of 0.2 N KOH was added, after that the solution was mixed thoroughly on a cyclone mixer. The test tubes were kept on a water bath at 90-100⁰C for 8 minutes after putting one glass tube marble on each test tube. The test tubes were cooled for 5 minutes after removing from water bath. Once again the solution was mixed on a cyclone mixture, then the culture tubes were kept at low temperature of 0-2⁰C for 20 minutes. Then the culture tubes were removed from the ice bath and laid horizorantally for one hour over ruled or graph paper. Length of the blue coloured gel from the inside bottom of the test tube to the gel front was then measured as gel consistency of the sample.

Length of the coloured gel	Gel consistency of the sample
26-40 mm	Hard gel consistency
41-60 mm	Medium gel consistency
61-100 mm	Soft gel consistency

3.3.3.8 Grain Iron and Zinc Concentrations

Grain iron and zinc concentrations were determined by X-Ray Fluorescence Spectrometry (XRF) (EDXRF, model-X-supreme8000). In XRF the preselected wavelength of incident X-rays expel an electron from the inner most orbit followed by the transfer of one of the electrons from the outermost orbit to the innermost orbit leading to the release of specific wavelength of X-rays. The energy of the emitted radiation is specific for a particular atom. Therefore, it is simultaneously identified and quantified by the detector. This instrument is quite useful in non-destructive determination of relative iron and zinc concentrations in rice samples with more ease.

Ten dust free decorticated grain sample sachets were arranged in a row. Nearly 5 g of each sample was weighed and poured into pre-identified aluminium cup which was properly loaded with disposable inner XRF film and they were arranged in sample tray. The tray was carefully tapped along with aluminium cups by holding the ends of tray with both hands in order to spread the grain uniformly in all the aluminium cups and each cup was placed into a sample sleeve of XRF machine without disturbing the grain starting from 1 to 10. X-ray lamp key was inserted into machine and turned it on. Then the name of each sample was entered using keyboard, the entries were checked once again, the suitable method was selected and start button was selected to start analysis. At the end of analysis time, Iron and Zinc concentration values appeared in a new window on the screen and the values were noted down and then accept button was clicked.

3.4 MORPHOLOGICAL CHARACTERIZATION AND STATISTICAL ANALYSIS

Morphological characterization of seventy landraces of rice was carried out using fourteen DUS characters namely basal leaf sheath colour, flag leaf attitude (late observation), time of heading (50 % plants with panicles), lemma anthocyanin colouration of apex, stigma colour, stem length, stem anthocyanin colouration of node, panicle length, panicle exertion, decorticated grain length, width, colour, shape and amylose content, while statistical analysis was carried out for using sixteen traits viz., time of heading, stem length, total number of tillers per plant, number of productive tillers per plant, panicle length, total number of grains per panicle, spikelet fertility, 100-grain weight, single plant yield, decorticated grain length, width and L/B ratio, amylose content, gel consistency, grain iron and zinc concentrations.

The data with respect to the above characters were subjected to the following analyses with the help of standard statistical procedures:

1. Analysis of variance
2. Genotypic and phenotypic coefficients of variation
3. Heritability and genetic advance
4. Estimation of genetic divergence using Mahalanobis's generalized distance (D^2)
5. Estimation of extent of association
6. 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, 1985). The significance was tested by referring to the values of 'F' table (Fisher and Yates, 1963).

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

Where ,

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

μ = general mean

g_i = effect of i^{th} genotype

r_j = effect of j^{th} replication

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

Analysis of variance

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

Where,

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

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

Variance

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

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

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

Where, (σ^2_e) = error variance

3.4.2 Genotypic and Phenotypic Coefficients of Variance

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

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

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

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

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

3.4.3 Heritability and Genetic Advance

3.4.3.1 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).

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

Where,

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

$$\sigma^2_g = \text{genotypic variance}$$

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

$$\sigma^2_e = \text{environmental variance}$$

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

Low : 0-30 %

Medium : 30-60 %

High : above 60 %

3.4.3.2 Genetic Advance

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

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

Where,

GA = Expected genetic advance

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

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

σ_p = Phenotypic standard deviation

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 %

3.4.4 Estimation of Genetic Divergence using Mahalanobis's Generalized Distance (D^2)

A measure for group distance based on multiple characters was given by Mahalanobis (1936) using D^2 statistics. With the help of this, genetic divergence between the genotypes was estimated. The various steps involved in the estimation of D^2 values is given below:

3.4.4.1 Test of Significance

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

$$'V' = W/S$$

Where,

$$\begin{aligned} 'V' &= \text{Wilk's criterion} \\ W &= \text{Determinant of error matrix and} \\ S &= \text{Determinant of error + variety matrix} \end{aligned}$$

The significance of 'V' was tested by

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

Where,

$$\begin{aligned} m &= n-(p + q + 1)/2 \\ p &= \text{number of characters (or) variables} \\ q &= \text{number of genotypes-1 (or) degrees of freedom for population} \\ n &= \text{degrees of freedom for error + genotypes at base of} \\ &\quad \text{natural log} = 2.7183 \end{aligned}$$

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

3.4.4.2 Transformation of Correlated Variables

Transformation was done by using pivotal condensation method. Transformation of correlated variables into standardized uncorrelated ones was done before working out

the D^2 values because computation of D^2 values were reduced to simple enumeration of differences in mean values of various characters of the two genotypes i.e., $\sum di^2$.

3.6.4.3 Computation of D^2 Values

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

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

Where,

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

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

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

3.4.4.4 Testing the Significance of D^2 Values

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

3.4.4.5 Grouping of Genotypes into Various Clusters

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

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

3.4.4.6 Intra and Inter Cluster Distance

3.4.4.6.1 Average Intra Cluster Distance

For the measurement of intra cluster distance, the formula used was $\sum D_i^2/n$

Where,

$\sum D_i^2$ = sum of distance between all possible combinations

'n' = number of genotypes included in a cluster

3.4.4.6.2 Average Inter Cluster Distance

Clusters were taken one by one and their distances from other clusters were calculated. The distance between the two clusters is the sum of D^2 value between the number one cluster to each of the members of other cluster divided by the product of number of genotypes in both the clusters under consideration. The square root of the average D^2 value gave the genetic distance 'D' between the clusters. Based on D^2 values (inter cluster distance), the scale given by Rao (1952) for rating of the distance was adopted and the cluster diagram was prepared.

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

Where, n_1 and n_2 are number of genotypes of two clusters

3.4.4.7 Cluster Diagram

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

3.4.4.8 Contribution of Individual Characters towards Divergence

In all the combinations, each character was ranked on the basis of their contribution towards divergence between two entries ($d_i = y_{it} - y_{jt}$). Rank 1 was given to the highest mean difference and rank 'p' to the lowest difference; where, p is the total number of characters considered.

Percentage contribution of each character (X) towards genetic divergence was calculated using the following formula:

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

Where,

N = Number of genotype combinations where the characters ranked first

M = All possible combinations of genotypes considered

3.4.5 Estimation of Character Association

Correlation coefficients were calculated to determine the degree of association of yield components with seed yield and also among themselves.

Correlation coefficients were calculated at genotypic and phenotypic level using, the formulae suggested by Falconer (1981).

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

Where,

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

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

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

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

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

Where,

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

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

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

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

3.4.6 Path Coefficient Analysis

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

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

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

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$

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

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

Where;

1, 2 n = Independent variables

y = Dependant variable

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

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

The above equations can be written in matrix form as:

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

Then

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

Direct effects were as follows:

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

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

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

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

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

Where,

p_{ny} = Direct effect of x_n on Y

r_{ny} = Correlation coefficient of x_n on Y

Table 3.1. Details of landraces of rice used in the present study and their place of collection

S. No	Code. No	Name of the landrace	Place of collection
1.	FV 1	Nimisaal	Paschim Medinipur, West Bengal
2.	FV 2	Thuroodi	Wayanad, Kerala
3.	FV 3	Danaguri	Bankura, West Bengal
4.	FV 6	Kottathondi	Wayanad, Kerala
5.	FV 7	Kankri	Barrackpore, West Bengal
6.	FV 8	Chandrakanta	Barrackpore, West Bengal
7.	Fv9	Krishna Kamod	Kheda, Gujarat
8.	FV10	Banshpati	Barrackpore, West Bengal
9.	FV11	Chakhao Poiretion	Imphal, Manipur
10.	FV12	Batiasora	Kamrup, Assam
11.	FV15	Moirangphou Yenthik	Imphal, Manipur
12.	FV16	Srabanti Sal	Barrackpore, West Bengal
13.	FV17	Kuruka	Wayanad, Kerala
14.	FV18	Chetuveliyen	Wayanad, Kerala
15.	FV20	Kuttiveliyen	Wayanad, Kerala
16.	FV21	Taothabi	Imphal, Manipur
17.	FV22	Gandha Malati	Barrackpore, West Bengal
18.	FV23	Chenthadi	Wayanad, Kerala
19.	FV24	Kayama	Wayanad, Kerala
20.	FV25	Karad	Chamba, Himachal Pradesh
21.	FV26	Surjeet Basmati 01	Karnal, Haryana
22.	FV27	Jhuli	Barrackpore, West Bengal
23.	FV29	Urunikayama	Wayanad, Kerala
24.	FV30	Phourelamubi	Imphal, Manipur
25.	FV33	Baid Dulah	Barrackpore, West Bengal
26.	FV34	Mullankayama	Wayanad, Kerala
27.	FV36	Bagh Jhapta	Barrackpore, West Bengal
28.	FV37	Adukkann	Wayanad, Kerala

S. No	Code. No	Name of the landrace	Place of collection
29.	FV39	Valichoori	Wayanad, Kerala
30.	FV40	Onavattan	Wayanad, Kerala
31.	FV41	Marathondi	Wayanad, Kerala
32.	FV42	Mannuvelian	Wayanad, Kerala
33.	FV43	Kailash Rana	Ranipool, East Sikkim
34.	FV44	Titabora	Kamrup, Assam
35.	FV45	Nata	Barrackpore, West Bengal
36.	FV46	Phoudum	Imphal, Manipur
37.	FV47	Lal Dhepa	Barrackpore, West Bengal
38.	FV48	Kunjootti Matta	Wayanad, Kerala
39.	FV49	Gandeshwari	Barrackpore, West Bengal
40.	FV50	Thonnuran Thondi	Wayanad, Kerala
41.	FV51	Kurumottan	Wayanad, Kerala
42.	FV32-1	Nuapada-padampur-Assam chudi	Nuapada, Odisha
43.	FV33-1	Dubraj	Nuapada, Odisha
44.	FV34-1	Sapari	Nuapada, Odisha
45.	FV59	Kalamara	Koraput, Odisha
46.	FV66	Koraput-Kundra- Assam chudi	Koraput, Odisha
47.	FV67	Koraput-Kundra- Haldi chudi	Koraput, Odisha
48.	FV93	Kathi Dhan	Koraput, Odisha
49.	FV98	Bhulo	Bargarh, Odisha
50.	FV108	Yubaraj	Subarnapur, Odisha
51.	FV115	Akul-B	Bargarh, Odisha
52.	FV120	Lalkain	Bargarh, Odisha
53.	FV125	Ganthia Sikila	Subarnapur, Odisha
54.	FV126	Majhali Jhuli	Subarnapur, Odisha
55.	FV133	Jubaraj	Subarnapur, Odisha
56.	FV136	Ankul	Subarnapur, Odisha
57.	FV142	Akula	Subarnapur, Odisha
58.	FV151	Makadhana	Keonjhar, Odisha

S. No	Code. No	Name of the landrace	Place of collection
59.	FV154	Dhinkiasiali	Keonjhar, Odisha
60.	FV170	Ganjamgedi	Cuttack, Odisha
61.	FV171	Rajahansa	Cuttack, Odisha
62.	FV182	Champe Siali-C	Cuttack, Odisha
63.	FV201	Sagiri	Balasore, Odisha
64.	FV217	Mayurkantha-K	Khurdha, Odisha
65.	FV219	Kalakaincha	Khurdha, Odisha
66.	FV221	Dhusura	Khurdha, Odisha
67.	FV269	Luchei	Jashpur , Chattisgarh
68.	FV299	B.Hunar	Kalahandi, Odisha
69.	FV307	Chinamali-K	Kalahandi, Odisha
70.	FV310	Dal	Kalahandi, Odisha

Table 3.2. Description of qualitative characters of rice

S. No	Character	States	Note	Stage of observation
1.	Basal leaf: sheath colour	Green Light purple Purple lines Uniform Purple	1 2 3 4	Booting
2.	Flag leaf: attitude of blade (Late observation)	Erect Semi-erect Horizontal Deflexed	1 3 5 7	Ripening
3.	Lemma: anthocyanin colouration of apex	Absent Weak Medium Strong Very Strong	1 3 5 7 9	Middle of anthesis
4.	Spikelet: colour of stigma	White Light green Yellow Light purple Purple	1 2 3 4 5	Middle of anthesis
5.	Stem: anthocyanin colouration of nodes	Absent Present	1 9	Milking stage
6.	Panicle: exertion	Partly exerted Mostly exerted Well exerted	3 5 7	Ripening

Table 3.4. Description of grain quality characters according to Rao *et al.*, 2013

S. No	Character	States	Note	Stage of observation
1.	Decorticated grain: length	Short (<5.50)	1	Caryopsis hard
		Medium (5.51-6.50)	3	
		Long (6.51-7.50)	5	
		Extra Long (>7.50)	9	
2.	Decorticated grain: width	Narrow (<2.0 mm)	3	Caryopsis hard
		Medium (2.0-2.5 mm)	5	
		Broad (>2.5 mm)	7	
3.	Decorticated grain: shape	Short slender	1	Caryopsis hard
		Short bold	2	
		Medium slender	3	
		Long slender	4	
		Long bold	5	
		Extra long slender	6	
4.	Decorticated grain: colour	White	1	Caryopsis hard
		Light brown	2	
		Variegated brown	3	
		Dark brown	4	
		Light red	5	
		Red	6	
		Variegated purple	7	
		Purple	8	
		Dark purple	9	
5.	Amylose content (%)	Very low (<10%)	1	Caryopsis hard
		Low (10-19%)	3	
		Medium (20-25%)	5	
		High (26-30%)	7	
		Very high (>30%)	9	



Plate 3.1. General view of the experimental plot at DRR farm, ICRISAT campus, Patancheru.

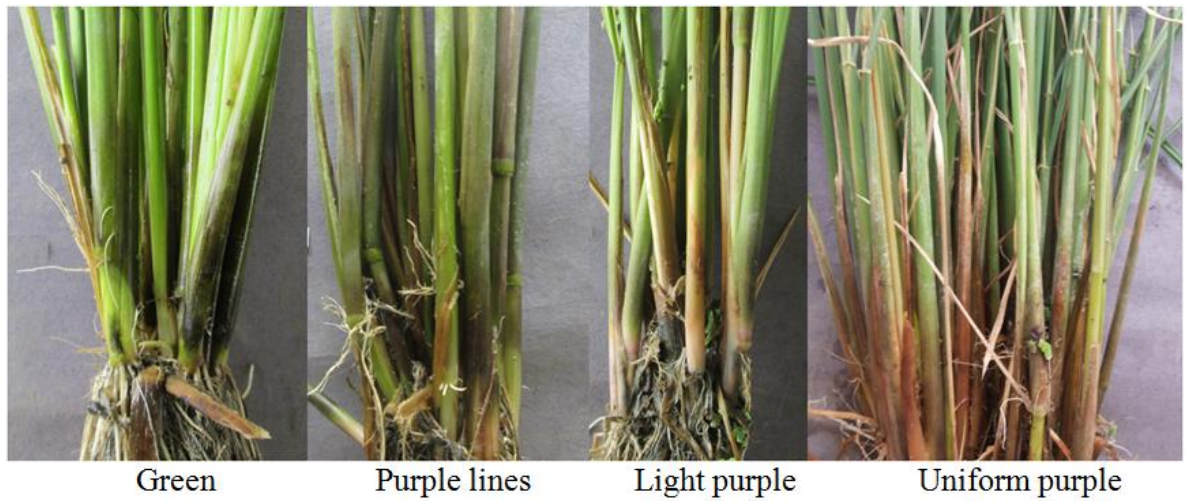


Plate 4.1. Variability observed for basal leaf: sheath colour.



Plate 4.2. Variability observed for lemma: anthocyanin colouration of apex.



White



Purple

Plate 4.3. Variability observed for colour of stigma.

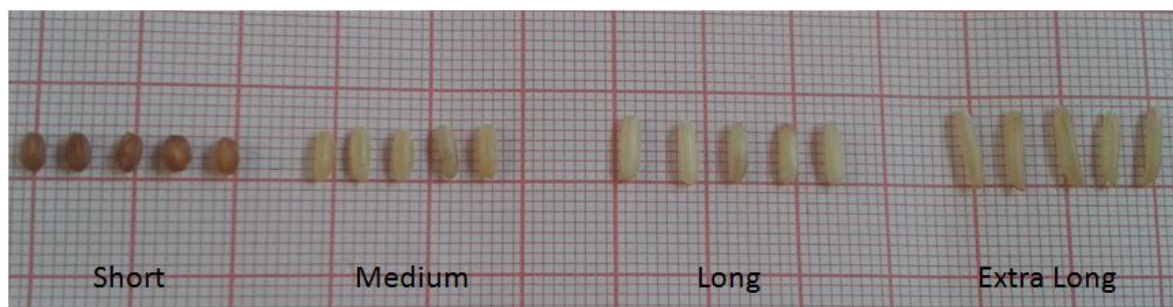


Plate 4.4. Variability observed for decorticated grain: length.

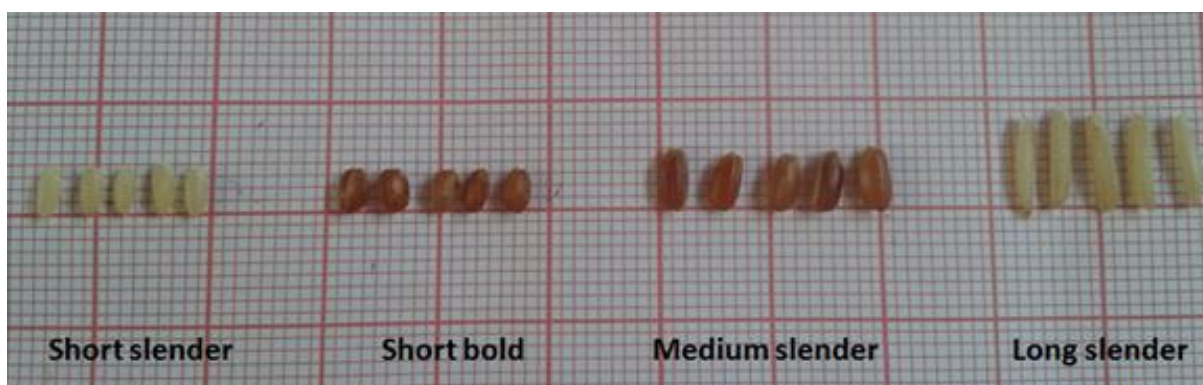


Plate 4.5. Variability observed for decorticated grain: shape.



Plate 4.6. Variability observed for decorticated grain: colour.



Plate 4.7. Variability observed for gel consistency.

Chapter IV

RESULTS AND DISCUSSION

The present investigation is intended to evaluate seventy landraces of rice using agro-morphological and quality traits in order to reveal the amount of variability and genetic diversity present in the experimental material and also to work out the correlation between yield, its contributing characters and grain quality parameters. The experimental findings obtained from the present study are furnished under the following heads and the available information on various aspects of the investigation has been discussed subsequently.

- 4.1 Morphological characterization
- 4.2 Analysis of variance
- 4.3 Mean performance, genetic variability, heritability and genetic advance
- 4.4 Genetic divergence
- 4.5 Character association
- 4.6 Path coefficient analysis

4.1 MORPHOLOGICAL CHARACTERIZATION

India has a rich and diverse genetic wealth of rice. To meet the continuously expanding needs of varietal improvement, the assemblage, evaluation, preservation and characterization of the entire existing germplasm are essential for more rewarding breeding efforts. Until a collection has been properly evaluated, it has little practical use. Characterization of variety is useful to identify and avoid duplication. Characterization should eventually lead to a system of recording and storing useful data that can be readily retrieved and made available to others and help in planning breeding programmes.

Being signatory to the General Agreement on Trade and Tariffs (GAAT), Government of India has enacted its *Sui generis* system, Protection of Plant Varieties and Farmers' Right Act (PPV&FRA), 2001 for providing protection to plant varieties based on Distinctiveness, Uniformity and Stability (DUS) test, apart from novelty. Therefore, the characterization of a variety is a prerequisite and identification of plant varieties of common knowledge is essential for the protection of new plant varieties and determining varietal purity. The uniqueness of a variety from existing varieties is to be established by following standard DUS testing guidelines.

Characterization consists of recording those characters which are highly heritable, can easily be seen by the eye and are expressed in all environments. Qualitative traits being more stable over generations are reliable for characterization of varieties.

In the present study, seventy landraces were characterized by using nine agro-morphological characters including six qualitative and three quantitative traits viz., basal leaf sheath colour, flag leaf attitude of blade (late observation), time of heading (50 % plants with panicles), lemma anthocyanin colouration of apex, spikelet colour of stigma, stem length (excluding panicle), stem anthocyanin colouration of node, panicle exertion and panicle length (Table 4.1) and five grain quality characters namely decorticated grain length, width, shape, colour and amylose content (Table 4.2) as per the norms of national DUS test guide lines. These descriptors are highly heritable, unambiguous and easily identifiable. The rice landraces under study showed wide range of variability for all the morphological traits studied. Frequency distribution for all the characters under study were computed (Table 4.3). The graphical representation of agro-morphological and grain quality traits were shown in Fig. 4.1 and 4.2, respectively.

4.1.1 Basal Leaf: Sheath Colour

Characterization of seventy landraces, on the basis of basal leaf sheath colour revealed that 50 landraces exhibited green basal leaf sheath colour, eight showed light purple, eight were having purple lines and remaining four landraces had uniform purple basal leaf sheath colour.

4.1.2 Flag Leaf: Attitude of Blade (Late Observation)

The experimental material possessed four different states of flag leaf attitude viz., erect, semi-erect, horizontal and deflexed. Among the seventy landraces under study, nineteen were having erect flag leaf attitude, thirty two were having semi-erect state, while horizontal flag leaf attitude was exhibited by eighteen landraces and finally only single landrace expressed deflexed flag leaf attitude.

4.1.3 Time of Heading (50 % Plants with Panicles)

The seventy landraces were grouped into four groups viz., very early (< 71 days), early (71-90 days), medium (91-110 days) and late (111-130 days) based on time of heading. Majority of the genotypes were grouped under medium (35) followed by early (26) categories, while eight and one genotypes were categorized as late and very early types, respectively. None of the landraces were found to be very late.

4.1.4 Lemma: Anthocyanin Colouration of Apex

Based on this criterion, all the landraces were grouped into five groups namely absent, weak, medium, strong and very strong with each group having 38, 1, 3, 12 and 16 landraces, respectively.

4.1.5 Spikelet: Colour of Stigma

Forty two rice landraces exhibited white stigma colour, three showed light purple stigma and twenty five landraces had purple stigma.

4.1.6 Stem Length (Excluding Panicle)

Based on stem length seventy landraces were characterized into three groups namely very short (<91 cm), short (91-110 cm) and medium (111-130 cm), which comprised of thirty two, twenty eight and ten landraces, respectively. None of the genotypes exhibited long (131-150 cm) and very long (>150 cm) stem length, which is generally not preferable as it leads to lodging of the plants.

4.1.7 Stem: Anthocyanin Colouration of Node

Majority (53) of the landraces expressed absence of node anthocyanin colouration and while 17 landraces exhibited anthocyanin colouration of node.

4.1.8 Panicle Exsertion

Four landraces showed partially exserted panicles, mostly exserted panicles were found in 8 landraces and 58 had well exserted panicles.

4.1.9 Panicle Length

Seventy landraces were classified as short (16-20 cm), medium (21-25 cm), long (26-30 cm) and very long (>30 cm) based on the panicle length. Most of landraces fall into medium (52), followed by long (11), short (5) and very long (2) panicle length categories. Very short (<16 cm) panicles were not found in any of the landraces under study.

4.1.10 Decorticated Grain: Length

Based on this trait the entire experimental material was characterized as short (<5.50), medium (5.51-6.50), long (6.51-7.50) and extra long (>7.50). Twenty nine landraces fall under short, 39 under medium and one genotype each under long and extra long grain types, respectively.

4.1.11 Decorticated Grain: Width

This character did not show any variation visually as the entire set of experimental material, exhibited only narrow type (< 2.0 mm) of decorticated grain width. None of the genotypes were under medium (2.0-2.5 mm) and broad (>2.5 mm) categories.

4.1.12 Decorticated Grain: Shape

Based on L/B ratio and decorticated grain length most of the landraces were classified as short slender (54) followed by long slender (11), then medium slender (4) and short bold (1). However, extra long slender type grains were not found in the experimental material under study.

4.1.13 Decorticated Grain: Colour

On the basis of decorticated grain colour, the experimental material was grouped into five categories viz., white (10), light brown (17), brown (5), light red (10) and red (27). However a special grain colour, which was not mentioned in DUS guidelines, i.e., black, was exhibited by a single landrace.

4.1.14 Amylose Content (%)

Based on the amylose content seventy landraces were characterized in to five groups viz., very low (< 10 %), low (10-19 %), medium (20-25 %), high (26-30 %) and very high (>30 %). 33 landraces had high, 22 landraces exhibited medium, 9 showed low, 4 had in very high and 2 showed very low amylose content.

Out of the 14 DUS characters recorded, stem anthocyanin colouration of node was dimorphic, spikelet colour of stigma, stem length and panicle exertion were trimorphic, basal leaf sheath colour, time of heading (50 % plants with panicles), flag leaf attitude (late observation), panicle length, decorticated grain length and shape were tetramorphic and lemma anthocyanin colouration of apex and amylose content showed five states of expression and based on decorticated grain colour highest number of groups i.e., six were made. Similar studies were conducted by Subbarao *et al.* (2006), Joshi *et al.*, (2007), Chakrabarty *et al.* (2012), Parikh *et al.* (2012), Tirkey *et al.* (2013) and Sinha and Mishra (2013).

4.2 ANALYSIS OF VARIANCE

The numerical data collected on nine agronomic and seven grain quality characters were statistically analysed and the analysis of variance (Table 4.4) showed significant differences among the landraces of rice under study for all the sixteen traits viz., time of heading (50% plants with panicles), stem length, total number of tillers per plant, number of productive tillers per plant, panicle length, total number of grains per panicle, spikelet fertility, 100-grain weight, single plant yield, decorticated grain length, width and L/B ratio, amylose content, gel consistency, grain iron and zinc concentrations, indicating the presence of considerable genetic variability among the experimental material under study.

4.3 MEAN PERFORMANCE, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The presence of adequate genetic variability and critical analysis of genetic variability are needed for initiating any crop improvement programme and for adopting of appropriate selection techniques. Greater variability in the initial breeding material ensures better chances of producing a desired form of a crop plant.

The genotypic coefficient of variation indicates the range of heritable variation present in the genotypes, while the phenotypic coefficient of variation measures the role of environment on the genotypes. 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. The magnitude of variation due to heritable component is very important because, it would be a guide for selection of parents for crop improvement programmes.

It is very difficult to judge whether observed variability is highly heritable or not. Heritability estimates provide authentic information about a particular genetic attribute which will be transmitted to the successive generations.

Again the heritable portion of the total variation might not be always due to additive gene action. Thus estimates of heritability alone will not give clear indication of the associating genetic progress that would result from selecting the best plants. It is also essential to find out the relative magnitude of additive and non-additive genetic variances with regard to the characters of concern. Therefore it should be combined with information

on genetic advance. Thus a character possessing high heritability along with high genetic advance will be valuable in the selection programme.

4.3.1 Mean Performance and Genetic Variability

The mean performance of seventy landraces of rice is presented in Table 4.5 and the mean values and genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as per cent of mean (Table 4.6) were calculated for yield and its contributing traits and grain quality parameters. The details of the results obtained in this regard are furnished below

4.3.1.1 Time of Heading (50% Plants with Panicles)

Among all the landraces, Karad was the earliest (70 days), while Bhulo was found to be late (120 days) with a general mean of 93.77 days. The phenotypic and genotypic coefficients of variation were moderate i.e., 11.94 and 11.85, respectively. These results are in conformity with the reports of Mohanty *et al.* (2012), Singh *et al.* (2012) and Bekele *et al.* (2013).

4.3.1.2 Stem Length (Excluding Panicle) (cm)

Stem length exhibited wide variability ranging from 52.65 to 122.44 cm with a general mean of 93.54 cm. Karad was the shortest (52.65), while Chenthadi was the tallest among the landraces under study. The estimates of phenotypic and genotypic coefficients of variation recorded for this trait were moderate i.e., 15.10 and 14.96, respectively. Similar results were obtained earlier by Padmaja *et al.* (2008), Kailashnath (2011), Lakshmi (2011), Singh *et al.* (2011), Sravan *et al.* (2012) and Vanisree *et al.* (2013) for plant height.

4.3.1.3 Total Number of Tillers per Plant

Total number of tillers per plant ranged from 8.33 (Makadhana) to 19.6 (Dal) with a general mean of 11.66. The observed phenotypic and genotypic coefficients of variation for this trait were moderate i.e., 19.92 and 18.24, respectively. These results were in accordance with those of Parray and Shikari (2008), Singh *et al.* (2011) and Dhanwani *et al.* (2013).

4.3.1.4 Number of Productive Tillers per Plant

The number of productive tillers per plant were found to be lowest in the landrace Adukkann (6.5) and highest in Dal (17.68) with a general mean of 10.41 tillers per plant. Phenotypic and genotypic coefficients of variations were high for this character i.e., 21.88

and 20.13, respectively. These results are in conformity with the findings of Suman (2005), Padmaja *et al.* (2008), Kailashnath (2011), Prasad *et al.* (2013) and Vanisree *et al.* (2013).

4.3.1.5 Panicle Length (cm)

The landraces Karad and Mullankayama exhibited lowest (19.35 cm) and highest (34.75 cm) panicle lengths, respectively with a general mean of 23.99 cm. The GCV and PCV for this trait were moderate, 11.29 and 10.43, respectively. These results are in trend with the findings of Singh *et al.* (2002), Parray and Shikari (2008), Yadav *et al.* (2010), Lakshmi (2011), Dhanwani *et al.* (2013), Gangashetty *et al.* (2013) and Singh *et al.* (2013).

4.3.1.6 Total Number of Grains per Panicle

Wide range of variability was obtained for total number of grains per panicle ranging from 75.22 (Baid Dulah) to 499.33 (Kayama) with a general mean of 174.70. High PCV and GCV values were observed for this trait i.e., 35.94 and 35.85, respectively. Similar results were reported by Suman (2003), Padmaja *et al.* (2008), Chandra *et al.* (2009a), Yadav *et al.* (2011), Basavaraja *et al.* (2013) and Singh *et al.* (2013).

4.3.1.7 Spikelet Fertility (%)

Spikelet fertility ranged from 79.98 % (Phondum) to 96.58% (Chandrakanta) with a general mean of 91.15 %. The estimates of phenotypic (4.59) and genotypic (4.28) coefficients of variability were found to be low. These results are in conformity with those of Kole *et al.* (2008), Saidaiah *et al.* (2010) and Pandey *et al.* (2012).

4.3.1.8 Single Plant Yield (g)

The general mean for single plant yield was 23.73 g and the landraces Kuttiveliyan and Jubaraj exhibited highest (36.71g) and lowest (12.58 g) single plant yields, respectively. High PCV (24.07) and GCV (23.28) were recorded for this trait. Suman (2003), Padmaja *et al.* (2008), Chandra *et al.* (2009a), Yadav *et al.* (2010), Kailashnath (2011), Lakshmi (2011), Singh *et al.* (2011), Singh *et al.* (2013) and Vanisree *et al.* (2013) also obtained similar results.

4.3.1.9 100-Grain Weight (g)

The general mean of 100-grain weight was 2.28 g and among all the landraces under study, Valichoori (3.33 g) recorded the highest 100-grain weight and was superior to all the genotypes tested and Danaguri (1.02 g) expressed lowest 100-grain weight. High phenotypic (22.30) and genotypic (22.16) coefficients of variation were obtained for this trait. Similar kind of results were reported by Chaubey and Singh (1994), Sawant *et al.* (1994), Mani *et al.* (1997) and Parikh *et al.* (2011).

4.3.1.10 Decorticated Grain: Length (mm)

The landraces, Kuruka (3.41 mm) and Surjeet Basmati 01 (8.18 mm), recorded minimum and maximum decorticated grain lengths, respectively with a mean value of 5.53 mm. Moderate phenotypic (12.24) and genotypic (12.19) coefficients of variation were observed for this trait. These results are in tune with those of Roy *et al.* (2009), Bekele *et al.* (2013) and Vanisree *et al.* (2013).

4.3.1.11 Decorticated Grain: Width (mm)

Minimum decorticated grain width was recorded by Kailash Rana (1.13 mm), while Thonnuran Thondi and Kurumottan exhibited maximum width (1.86 mm) with a general mean of 1.51 mm. Phenotypic (10.93) and genotypic (10.69) coefficients of variation recorded for this character were moderate. These findings were in accordance with those of Veerabhadhira *et al.* (2009).

4.3.1.12 Decorticated Grain: L/B ratio

The general mean observed for decorticated grain L/B ratio was 3.70 with a range of 1.99 (Kuruka) to 6.57 (Surjeet Basmati 01). Moderate phenotypic (16.23) and genotypic (15.99) coefficients of variation were reported for this character. Similar results were recorded by Veerabhadhira *et al.* (2009) and Dhanwani *et al.* (2013).

4.3.1.13 Amylose Content (%)

Wide variability, ranging from 6.32 % (Titabora) to 32.72 % (Rajahansa) was observed for this trait with a general mean of 24.7 %. The observed phenotypic and genotypic coefficients of variation were high for this trait i.e., 20.61 and 20.44, respectively. These results are in confirmity with the findings of Vanaja and Babu (2006) and Basavaraja *et al.* (2013).

4.3.1.14 Gel Consistency (mm)

Titabora (92.33 mm) exhibited high value for gel consistency, while five landraces viz., Bagh Jhapta, Onavattan, Gandeshwari, Dubraj and Akul-B had lowest (22 mm) gel consistency. The general mean for this trait was 40.98 mm. The PCV (35.63) and GCV (35.21) were found to be high for gel consistency. Similar results were reported by Veerabhadhira *et al.* (2009), Dhanwani *et al.* (2013) and Shejul *et al.* (2013).

Based on this trait, the landraces of rice were grouped into hard (26-40 mm), medium (41-60 mm) and soft (61-100 mm) gel consistency types with 36, 27 and 7 genotypes, respectively as indicated below:

S. No	Gel consistency range	Name of the landraces
1.	Hard (26-40 mm)	Nimisaal, Thuroodi, Kottathondi, Kankri, Banshpati, Kuruka, Chetuveliyan, Kayama, Surjeet Basmati 01, Jhuli, Baid Dulah, Baghjhapta, Adukkann, Valichoori, Onavattan, Nata, Lal Dhepa, Kunjootti Matta, Gandeshwari, Kurumottan, Nuapadapadampur-Assam chudi, Dubraj, Sapari, Koraput-Kundra-Assam chudi, Koraput-Kundra-Haldi chudi, Bhulo, Akul-B, Lalkain, , Jubaraj, Akula, Rajahansa, Kalakaincha, Dhusura, B.Hunar and Chinamali-K
2.	Medium (41-60 mm)	Danaguri, Chandrakanta, Krishna Kamod, Batiasora, Kuttiveliyan, Taothabi, Gandha Malati, Chenthadi, Kayama, Karad, Urunikayama, Marathondi, Mannuveliyan, Kailash Rana, Thonnuram Thondi, Kalamara, Kathidhan, Yubaraj, Majhali Jhuli, Ankul, Makadhana, Dhinkiasiali, Ganjamgedi, Champe Siali-C, Sagiri, Mayurkantha-K, Luche and Dal
3.	Soft (61-100 mm)	Chakhao Poirition, Moirangphou Yenthik, Srabanti-Sal, Phourelamuhi, Mullankayama, Titabora, Phondum

4.3.1.15 Grain Iron Concentration (mg/kg)

Iron concentration in decorticated grain ranged from 5.97 mg/kg in Chenthadi to 12.9 mg/kg in Kankri with a general mean of 9.67 mg/kg. Moderate phenotypic (17.54) and genotypic (15.78) coefficients of variation were observed for grain iron concentration. But Babu *et al.* (2012) and Gangashetty *et al.* (2013) observed high PCV and GCV values for this trait.

4.3.1.16 Grain Zinc Concentration (mg/kg)

Baid Dulah and Lal Dhepa recorded maximum (25.1 mg/kg) and minimum (8.97 mg/kg) zinc concentrations in decorticated grain, respectively with a general mean 19.14 mg/kg. Phenotypic and genotypic coefficients of variations were moderate i.e., 18.33 and 17.54, respectively for this trait. However, Bekele *et al.* (2013) and Gangashetty *et al.* (2013) reported high PCV and GCV values for grain zinc concentration.

The characters studied in the present investigation exhibited low, moderate and high phenotypic and genotypic coefficients of variation. Among all the metric characters under study, total number of grains per panicle exhibited highest PCV (35.94) and GCV (35.85), followed by single plant yield [PCV (24.07) and GCV (23.28)], whereas lowest PCV (4.59) and GCV (4.28) were recorded for spikelet fertility. Among all the grain quality characters gel consistency expressed highest of PCV (35.63) and GCV (35.21), while lowest PCV (10.93) and GCV (10.69) were obtained for decorticated grain width.

For all the characters under study, phenotypic coefficient of variation values are slightly higher than the genotypic coefficient of variation values indicating that the characters were less influenced by the environment. Therefore, response to direct selection may be effective in improving these traits.

4.3.2 Heritability and Genetic Advance

All the characters studied in the present investigation expressed high estimates of heritability in broad sense ranging from 80.99 to 99.51%. Among all metric characters, highest heritability was recorded for total number of grains per panicle (99.51%) followed by 100-grain weight (98.81 %), while decorticated grain length (99.11 %) and amylose content (98.32 %), among the grain quality parameters exhibited, highest heritability estimates.

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

Similar to heritability, genetic advance as a per cent of mean is also classified as low (less than 10 %), moderate (10-20 %) and high (more than 20 %). Among the metric characters spikelet fertility exhibited low (8.22%) genetic advance as a per cent of mean, panicle length had moderate (19.85%) genetic advance as a per cent of mean. Remaining all the traits exhibited high estimates of genetic advance as a per cent of mean, among them total number of grains per panicle (73.68%) acquired highest value. However all the grain quality parameters exhibited high values of genetic advance as a per cent of mean. Among them gel consistency recorded highest (71.67 %) value.

Among the all characters studied, spikelet fertility exhibited high heritability coupled with low genetic advance as a per cent of mean. Similar results were obtained earlier by Madhavalatha *et al.* (2005). High heritability coupled with low genetic advance as a per cent of mean indicates that the expression of the trait is under the control of non-additive type of gene action, and its response to selection would be poor. In such case hybridization programme is rewarded.

Panicle length expressed high heritability coupled with moderate genetic advance as a per cent of mean. This result is in accordance with the reports of Yadav *et al.* (2010), Parikh *et al.* (2011) and Singh *et al.* (2011). High heritability coupled with moderate genetic advance as per cent of mean, suggested that the expression of this trait was mostly influenced by additive type of gene action. Hence its response to selection would be effective in improving the seed yield.

All the remaining metric characters expressed high heritability coupled with high genetic advance, which indicated the preponderance of additive gene action in controlling of the traits. Hence direct selection of such characters would be effective in improving the seed yield. Similar results were observed by Madhavalatha (2002), Nayak *et al.* (2002), Sandhyakishore (2002) and Sankar *et al.* (2006) for time of heading; Sankar *et al.* (2006), Chandra *et al.* (2009a), Sravan *et al.* (2012) and Gangashetty *et al.* (2013) for plant height; Suman (2003) and Gangashetty *et al.* (2013) for total number of tillers per plant; Nayak *et al.* (2002), Suman (2003), Sankar *et al.* (2006), Gangashetty *et al.* (2013) and Kumar *et al.* (2013) for productive tillers per plant; Padmaja *et al.* (2008), Chandra *et al.* (2009a), Yadav *et al.* (2010), Singh *et al.* (2011) Kumar *et al.* (2013) and Singh *et al.* (2013) for total number of grains per panicle; Yadav *et al.* (2010), Parikh *et al.* (2011), Gangashetty *et al.* (2013), Kumar *et al.* (2013) and Singh *et al.* (2013) for single plant yield and Padmaja (2008) and Parikh *et al.* (2011) for 100-grain weight.

All the quality parameters exhibited high heritability coupled with high genetic advance as a per cent of mean. These results are in accordance with the findings of Patil *et al.* (2003) and Jaiswal *et al.* (2007) for decorticated grain length; Jaiswal *et al.* (2007) and Veerabhadhiran *et al.* (2009) for decorticated grain width; Veerabhadhiran *et al.* (2009) and Gangashetty *et al.* (2013) for decorticated L/B ratio; Amudha and Thiyagarajan (2008) for amylose content and gel consistency; Veerabhadhiran *et al.* (2009), Gangashetty *et al.* (2013) and Shejul *et al.* (2013) for grain iron and zinc concentration.

4.4 GENETIC DIVERSITY

Genetic improvement of any crop mainly depends upon the amount of genetic variability present in the population. In order to generate variability, hybridization between genotypes of diverse origin is suggested to unlock new recombinations. Genetic divergence has been used as an indirect parameter of moderate effectiveness in selecting parents to produce high yielding progenies.

Characterization and quantification of genetic diversity has long been a major goal in evolutionary biology and plant breeding. Information on genetic diversity within and among closely related crop germplasm is essential for rational use of genetic resources. Parents selected on the basis of such study would help in obtaining higher amount of heterotic expression in F_1 s and broad spectrum of variability in subsequent segregating generations for various quantitative characters and to study the genetic diversity among them so as to utilize them in the hybridization programme for the development of new lines with improved grain yield, quality and tolerance to stress conditions.

The quantitative assessment of genetic divergence among seventy landraces of rice was made by adopting Mahalanobis's D^2 statistic for yield, its contributing characters and grain quality parameters and the results obtained from the present study are presented below:

4.4.1 Wilk's 'V' Criterion Test

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

4.4.2 Mahalanobis's Generalized Distance D^2 Values

In order to assess the genetic diversity among 70 landraces of rice, D^2 statistic was used following the procedure given by Rao (1952). Since all the traits under study were correlated, they were transformed into uncorrelated linear combination through pivotal condensation method.

4.4.3 Grouping of Genotypes into Various Clusters

All landraces of rice under study were distributed into nine 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 presented in Table 4.7 and Figure 4.5. Out of nine clusters, cluster I was the largest comprising of fifty landraces, followed by cluster III with eight, cluster VI with four and cluster VII with three. Clusters II, IV, V, VIII and IX were monogenotypic clusters, suggesting the existence of high degree of heterogeneity among the genotypes.

Grouping of most of the landraces of Odisha into one cluster (cluster I) indicated genetic relatedness between these genotypes. This can be further explained by free flow of genes between these accessions. The clustering pattern also showed that the landraces originating from similar geographical regions were classified into different clusters, indicating that geographical diversity and genetic diversity were not related. Therefore, the kind of genetic diversity found among the genotypes belonging to same geographical region might be due to differences in adaptation, selection criteria, selection pressure and environmental conditions. These results are in confirmity with the findings of Ekka *et al.* (2012), Kar *et al.* (2013) and Manohara and Singh (2013).

4.4.4 Average Inter and Intra Cluster Distances

D^2 analysis is considered as the most effective method to measure the forces of differentiation at two levels namely, intra cluster and inter cluster levels.

The average intra and inter cluster D^2 values are presented in Table 4.8 Intra cluster D^2 values are minimum (0.000) in cluster II, IV, V, VIII, IX, as these were monogenotypic clusters and landraces falling in these clusters were more divergent and they could be utilized as parents for hybridization. Maximum intra cluster distance was observed in cluster VI (451.93), followed by cluster III (297.74), cluster I (280.18) and cluster VII (155.19), indicating that some genetic divergence still existed among the genotypes within each of these clusters. Selection within such clusters might be executed based on maximum mean value for the desirable characters.

The inter cluster distance was higher than intra cluster distance (Table 4.8), indicating the presence of wide genetic diversity among the landraces under study. Maximum inter cluster distance was exhibited between clusters VIII and IX (5280.51)

followed by clusters V and IX (3881.73), clusters VII and IX (3362.39) and clusters I and IX (2849.05). The greater the distance between two clusters, the wider the genetic diversity among the genotypes of those clusters. Such highly divergent, high performing genotypes would be of great use in recombination breeding programme in order to get high heterotic recombinants. The lowest inter cluster divergence was noticed between clusters II and VI (309.20) followed by clusters IV and VII (357.50) and clusters II and IV (360.13), indicating that the landraces included in them were closely related. Avoidance of selection of parents from genetically homogeneous clusters should be preferred to maintain relatively broad genetic base. Keeping this in view, it could be concluded that landraces from clusters VIII (Surjeet Basmati 01) and IX (Kayama), clusters V (Karad) and IX (Kayama), clusters VII (Chakaho Poirition, Phourelamuhi, Titabora) and IX (Kayama) may be used as parents in the hybridization programme to generate breeding material with high diversity to get encouraging results.

4.4.5 Cluster Means of the Characters

The cluster means for each of 16 characters are presented in Table 4.9. From the data it can be inferred that considerable differences existed for all the traits studied among the clusters. Cluster I exhibited highest mean value for number of productive tillers per plant (10.77). Cluster II was characterized by having highest mean values for four traits viz., single plant yield (34.60 g), 100-grain weight (3.18 g), decorticated grain width (1.86 mm) and amylose content (26.68 %) and lowest mean values were observed for total number tillers per plant (9.53), spikelet fertility (82.40 %), decorticated grain L/B ratio (2.99) and grain iron concentration (7.93 mg/kg). Landraces in cluster IV expressed lowest mean value of grain zinc concentration (17.21 mg/kg). Cluster V recorded maximum mean values for total number tillers per plant (13.15 tillers), spikelet fertility (94.23 %) and grain iron concentration (12.70 mg/kg) and minimum mean values for time of heading (70.00 days), stem length (52.65 cm), panicle length (19.35 cm) and single plant yield (19.00 g). Cluster VI exhibited highest mean value for time of heading (113.25 days) and minimum mean value for total number of productive tillers per plant (8.39). Cluster VII had highest and lowest mean values for gel consistency (74.33 mm) and amylose content (9.21), respectively. Landraces which were present in cluster VIII recorded highest mean values for decorticated grain length (8.18 mm) and L/B ratio (6.57) and lowest mean values for total number of grains per panicle (106.90), decorticated grain width (1.25 mm) and gel

consistency (24.00 mm). Finally cluster IX expressed highest mean values for stem length (114.63 cm), panicle length (31.30 cm), total number of grains per panicle (499.33) and grain zinc concentration (24.21 mg/kg) and lowest mean values for two traits viz., 100-grain weight (1.17) and decorticated grain length (4.28 mm).

A critical appraisal of the observations indicated that none of the clusters contained genotypes with all the desirable traits which could be directly selected and utilized. Therefore, hybridization between the selected genotypes from divergent clusters is essential to judiciously combine all the targeted traits.

The cluster I had highest mean value for productive tillers per plant, cluster II exhibited highest mean values for single plant yield, 100 grain weight, decorticated grain width and amylose content, cluster V for total number of grains per panicle, spikelet fertility and grain iron concentration, cluster VII showed maximum mean values for time of heading, cluster VIII for decorticated grain length, L/B ratio and gel consistency and cluster IX recorded highest mean values for stem length, panicle length, total number of grains per panicle and grain zinc concentration. The promising landraces from these clusters with high mean values for different traits may be directly used for adaptation or may be used as parents in future hybridization, depending upon the objective of the breeding programme to derive superior transgressive segregants.

4.4.6 Relative Contribution of Characters towards Genetic Divergence

The utility of D^2 statistics as a potential tool to quantify the extent of divergence in biological populations at genetic level is further enhanced by its applicability to estimate the relative contribution of the various plant characters to total genetic divergence. Number of times that each of the 16 characters appeared in first rank and its respective per cent contribution towards genetic divergence is presented in Table 4.10.

The results showed that the contribution of grains per panicle towards genetic divergence was highest (28.86 %) by taking 697 times ranking first, followed by decorticated grain length (17.89) by 432 times, 100-grain weight (14.24) by 344 times, amylose content (12.55) by 303 times, time of heading (11.51) by 278 times, stem length (9.11) by 220 times, gel consistency (3.35) by 81 times, decorticated grain width (0.87) by 21 times, grain zinc concentration (0.66) by 16 times, single plant yield (0.46) by 11 times, then spikelet fertility (0.21) and total number of tillers per plant (0.21) by ranking 5 times each, lastly decorticated grain L/B ratio (0.04) and grain iron concentration (0.04) by

ranking one time each. Number of productive tillers per plant and panicle length did not contribute towards genetic divergence among landraces of rice. These results are in conformity with the findings of Gahalain (2004), Thayumanavan *et al.* (2009) and Padmaja *et al.* (2010) who reported major contribution to diversity through total number of grains per panicle; Raju (2002) and Lakshmi (2011) through kernel length; Pandey *et al.* (1999) and Mahalingam *et al.* (2012) through 100-grain weight; Padmaja *et al.* (2010), Umadevi *et al.* (2010) and Lakshmi (2011) through number of productive tillers per plant and Umadevi *et al.* (2010) and Garg *et al.* (2011) through panicle length.

Out of the sixteen characters studied, six characters namely total number of grains per panicle, decorticated grain length, 100-grain weight, amylose content, time of heading and stem length together contributed maximum (94.16 %) to the total genetic divergence. Thus, it is suggested that these traits should be given importance in further breeding programmes i.e., during hybridization and selection of segregating populations, using this particular set of landraces, so far not utilized in breeding programs, which have potential for use in future rice improvement programmes aiming at the development of rice varieties or hybrids with high yield and better grain quality.

4.5 CHARACTER ASSOCIATION

Character association studies primary importance is to know the suitability of various characters for selection, because selection of a particular trait may induce desirable or undesirable changes in the associated characters. Generally, direct selection for yield was not aimed at, as it is a most complex trait, the result of the interaction of a number of components and highly influenced by environment.

If the association of characters is due to manifold effects of a gene or genes, it is difficult to separate these characters by selecting a particular character so related. If the correlation is due to linkage it is possible to reverse the correlation, provided the linkage is not very close. Hence, it is important to establish genetic basis of correlations before launching any breeding programme. Further, the component characters of yield exhibit different associations among themselves and also with yield. Unfavourable associations between the desired attributes under selection may limit genetic advance. Therefore, knowledge on the magnitude of association between the yield and its attributing characters is essential for planning sound breeding programme.

Phenotypic and genotypic correlations between yield, its contributing traits and grain quality parameters were estimated, are presented in Table 4.11. In general, for most of the characters under study the genotypic correlation coefficients were higher than phenotypic correlation coefficients. High genotypic correlations as compared to their phenotypic counterparts indicated strong inherent association between the characters.

4.5.1 Time of Heading (50% Plants with Panicles)

This trait registered highly positive significant association both at phenotypic and genotypic levels with single plant yield (0.1988**/0.2051**), total number of grains per panicle (0.2596**/0.2631**), 100-grain weight (0.2846**/0.886**), decorticated grain width (0.2750**/0.2848**) and amylose content (0.1443*/0.1452*), which were in agreement with the findings of Suman (2003), Sankar *et al.* (2006), Nandan *et al.* (2010), Ekka *et al.* (2011) and Reddy *et al.* (2013) for single plant yield, Padmaja *et al.* (2011) and Nagesh *et al.* (2013) and Reddy *et al.* (2013) for total number of grains per panicle, Yolanda and Das (1995) for 100-grain weight, Basavaraja *et al.* (2011) for amylose content. Panicle length exhibited positive significant association (0.1369*) with this trait only at genotypic level.

Total number of tillers per plant (-0.1698*/-0.1852**), number of productive tillers per plant (-0.2428**/ -0.2680**), decorticated grain L/B ratio (-0.1487*/-0.1531*), gel consistency (-0.1393*/-0.1422*), grain iron concentration (-0.3753**/ 0.4183**) and grain zinc concentration (-0.2720**/-0.2869**) recorded negative significant association at both the levels. Similar results were reported by Lakshmi (2011), Padmaja *et al.* (2011) and Babu *et al.* (2012) for number of productive tillers per plant and Yadav *et al.* (2012) for decorticated grain L/B ratio.

From the results it was evident that increased time of heading increased the vegetative phase which in turn helped to accumulate more photosynthates, leading to increased single plant yield.

4.5.2 Stem Length (Excluding Panicle) (cm)

This trait showed positive significant correlation with single plant yield (0.4852**/0.5056**), panicle length (0.6480**/0.6965**), total number of grains per panicle (0.3395**/0.3431**), 100-grain weight (0.1632*/0.1656*), gel consistency (0.2059**/ 0.2112**) and grain zinc concentration (0.2726**/0.2922**). Negative significant association was exhibited by total number of tillers per plant (-0.2772**/

-0.3076**), number of productive tillers per plant (-0.2239**/-0.2445**), amylose content (-0.3707**/-0.3778**) and grain iron concentration (-0.2017**/-0.2116**).

These findings are in accordance with the results of Suman (2003), Sravan *et al.* (2012) and Reddy *et al.* (2013) for single plant yield, total number of grains of per panicle and panicle length, Suman *et al.* (2006) for 100-grain weight, Gangashetty *et al.* (2013) for grain zinc concentration and Suman (2003) and Padmaja *et al.* (2011) for total number of tillers and productive tillers per plant.

4.5.3 Total Number of Tillers per Plant

Total number of tillers per plant exhibited positive significant association with number of productive tillers per plant (0.8890**/0.9143**), spikelet fertility (0.1379*/0.1556*), amylose content (0.1729*/0.1907**) and grain iron concentration (0.1513*/0.2278**). Negative significant correlation was reported with single plant yield (-0.2234**/-0.2587**), panicle length (-0.2221**/-0.2768**), total number of grains per panicle (-0.3042**/-0.3330*) and decorticated grain width (-0.1524*/-0.1814**).

These results are in tune with the results of Reddy *et al.* (2008), Padmaja *et al.* (2011) and Bekele *et al.* (2013) for productive tillers per plant, Gangashetty *et al.* (2013) for grain iron concentration, Suman (2003) and Yadav *et al.* (2011) for panicle length and Suman (2003) for total number of grains per panicle. Reddy *et al.* (2008) observed negative but non-significant association of single plant yield and total number of tillers per plant.

4.5.4 Number of Productive Tillers per Plant

This trait had a positive significant correlation with spikelet fertility (0.1548*/0.1653*), amylose content (0.1809*/0.1968**), grain iron concentration (0.1487*/0.2238**) and grain zinc concentration (0.1872**/0.2157**), while negative significant association was recorded with panicle length (-0.2273**/-0.2868**), total number of grains per panicle (-0.3198**/-0.3441**), decorticated grain width (-0.2150**/-0.2412**) and gel consistency (-0.2324**/-0.2464**). It showed negative but non-significant association with single plant yield (-0.0633/-0.0774).

These results are in confirmity with the findings of Sravan *et al.* (2012) and Hasan *et al.* (2013) for spikelet fertility, Gangashetty *et al.* (2013) for grain iron concentration, Suman (2003) and Babu *et al.* (2012) for panicle length, Satyavathi *et al.* (2001) for total number of grains per panicle and Nandan *et al.* (2010) and Bekele *et al.* (2013) for single plant yield.

4.5.5 Panicle Length (cm)

Panicle length expressed significant positive association with single plant yield (0.3748**/0.4125**), total number of grains per panicle (0.3696**/0.4028**) and grain zinc concentration (0.1727*/0.1992**). But traits viz., spikelet fertility (-0.1297*/-0.1555*) and amylose content (-0.2744**/-0.2915**) at both phenotypic and genotypic levels and grain iron concentration (-0.1240/-0.1555*) at only genotypic level exhibited negative significant correlation.

Chandra *et al.* (2009b), Yadav *et al.* (2011), Sravan *et al.* (2012) and Reddy *et al.* (2013) recorded similar reports for single plant yield, Chandra *et al.* (2009b) and Padmaja *et al.* (2011) for total number of grains per panicle and Sharma *et al.* (2012) for spikelet fertility.

From this result it can be concluded that panicle length would always increase the single plant yield by accommodating more number of grains per panicle.

4.5.6 Total Number of Grains per Panicle

This character registered positive significant association with single plant yield (0.3780**/0.3915**) which confirms the findings of Reddy *et al.* (2008), Chandra *et al.* (2009b), Nandan *et al.* (2010), Sravan *et al.* (2012) and Nagesh *et al.* (2013). This result is quite expected that more number of grains per panicle had direct contribution to the single plant yield. Negative significant association was reported with spikelet fertility (-0.2091**/-0.2212**), 100-grain weight (-0.3072**/-0.3093**), decorticated grain length (-0.4597**/-0.4634**) and decorticated grain L/B ratio (-0.3173**/-0.3236**). Padmaja *et al.* (2011) reported similar results for spikelet fertility.

4.5.7 Spikelet Fertility (%)

Spikelet fertility exhibited positive significant association with decorticated grain: length (0.1375*/0.1563*) and width (0.1430*/0.1572*) and positive but non-significant association was observed with single plant yield (0.0482/0.0325). These results are in confirmity with the earlier work of Yolanda and Das (1995).

4.5.8 100-Grain Weight (g)

This trait had positive significant correlation with single plant yield (0.2964**/0.3094**), decorticated grain length (0.5776**/0.5833**), decorticated grain width (0.6335**/0.6517**) and gel consistency (0.2496**/0.2533**) while negative significant correlation was observed with grain iron concentration (-0.3958**/-0.4495**).

These results are in conformity with the findings of Padmaja *et al.* (2011) for single plant yield and Ekka *et al.* (2011) for single plant yield, decorticated grain length and decorticated grain width.

100-grain weight had positive significant association with single plant yield indicating that increase in 100-grain weight would ultimately increase the single plant yield.

4.5.9 Decorticated Grain: Length (mm)

It showed positive significant association with decorticated grain L/B ratio (0.7387**/0.7506**) and negative significant association with amylose content (-0.1521*/-0.1536*) and grain iron concentration (-0.1477*/-0.1657*). Negative but non-significant association was observed with single plant yield (-0.0124/-0.0173).

These results are in accordance with the findings of Khatun *et al.* (2003) and Shivani *et al.* (2008) for amylose content and Subudhi *et al.* (2007), Kailashnath (2011), Nandan *et al.* (2011) and Mohanty *et al.* (2012) for decorticated grain L/B ratio.

4.5.10 Decorticated Grain: Width (mm)

This character recorded positive significant association with single plant yield (0.3967**/0.4169**) and gel consistency (0.1771*/0.1800**). Kailashnath (2011) observed positive significant association with single plant yield only at genotypic level. Negative significant correlation was reported with decorticated grain L/B ratio (-0.5861**/-0.5795**) similar to the findings of Khatun *et al.* (2003). Grain iron concentration (-0.2490**/-0.2897**) also recorded negative significant correlation with this trait. Anuradha *et al.* (2012) reported negative non-significant association of this trait with grain iron concentration.

4.5.11 Decorticated Grain: L/B ratio

This trait registered negative significant correlation with single plant yield (-0.2692**/-0.2811**) and amylose content (-0.1447*/-0.1498*). Similar findings were obtained by Kailashnath (2012) for single plant yield. Shivani *et al.* (2007) got negative but non-significant association of decorticated grain L/B ratio with amylose content.

4.5.12 Amylose Content (%)

Amylose content had negative significant association with gel consistency (-0.7485**/-0.7623**) as reported by Khatun *et al.* (2003) and negative but non-significant

correlation with single plant yield (-0.0517/-0.0514). These results are in conformity with the findings of Petchiammal and Kumar (2007).

4.5.13 Gel Consistency (mm)

Gel consistency exhibited negative non significant association with single plant yield (-0.0287/-0.0215).

4.5.14 Grain Iron Concentration (mg/kg)

This character associated significant and positively with grain zinc concentration (0.2602**/0.2681**) and negatively with single plant yield (-0.2856**/-0.3264**). Similar results were obtained by Nagesh *et al.* (2013).

4.5.15 Grain Zinc Concentration (mg/kg)

This trait recorded positive significantly correlation with single plant yield (0.2115**/0.2298**). Patil (2008) reported positive but non significant association of this trait with single plant yield.

4.5.16 Single Plant Yield (g)

Single plant yield registered positive significant association with time of heading (0.1988**/0.2051**), stem length (0.4852**/0.5056**), panicle length (0.3748**/0.4125**), total number of grains per panicle (0.3780**/0.3915**) and 100-grain weight (0.2964**/0.3094**), indicating that these characters were important for yield improvement. Decorticated grain width (0.3967**/0.4169**) and grain zinc concentration (0.2115**/0.2298**) also exhibited positive significant association with single plant yield, revealing that these traits could also be considered to achieve better results for improving yield as well as grain quality. Positive but non significant association of single plant yield was observed with spikelet fertility (0.0482/0.0325).

Negative significant association was exhibited with total number of tillers per plant (-0.2234**/-0.2587**), decorticated grain L/B ratio (-0.2692**/-0.2811**) and grain iron concentration (-0.2856**/-0.3264**). Negative but non-significant correlation was reported with number of productive tillers per plant (-0.0633/-0.0774), decorticated grain length (-0.0124/-0.0173), amylose content (-0.0517/-0.0514) and gel consistency (-0.0287/-0.0215).

According to NeWall and Eberhart (1961) when two characters show negative phenotypic and genotypic correlation it would be difficult to exercise simultaneous selection for these characters in the development of a variety. Hence, under such situations, judicious selection programme might be formulated for simultaneous improvement of such important developmental and component characters.

4.6 PATH COEFFICIENT ANALYSIS

The genetic architecture of grain yield is based on the balance or overall net effect produced by various yield components interacting with one another. 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 its component characters may be some times misleading, as it might be an over-estimate or under-estimate because of its association with other characters. If relationship is due to multiple effects of gene(s) it is difficult to separate these effects by selecting a particular character. Hence, indirect selection by correlated response may not be some times fruitful.

When many characters are affecting a given character, splitting total correlation into direct and indirect effects of cause as devised by Wright (1921) would provide more meaningful interpretation to the cause of association between the dependent variable like yield and independent variables like yield component characters. This kind of information will be helpful in formulating the selection criteria.

If the correlation coefficient between caused factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and direct selection of this trait will be effective. The correlation coefficient is positive and the direct effects are negative or negligible, the indirect effects seem to be the cause of correlation. In such situations the other factors influencing the trait have to be considered simultaneously. Correlation coefficients may be negative but the direct effect may be positive and high. Under these conditions a restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effects.

With this background, in present investigation the direct and indirect effects of different yield contributing traits and grain quality parameters on yield were estimated using genotypic and phenotypic correlation coefficients and are presented in Table 4.12. The cause-effect relationships at phenotypic and genotypic levels are diagrammatically

represented in Figure 4.6 and Figure 4.7, respectively. As discussed in character association here also the results of both phenotypic and genotypic path coefficient analysis of yield, its contributing characters and grain quality parameters are discussed here under.

4.6.1 Time of Heading (50% Plants with Panicles)

The direct contribution of this character to single plant yield was negative (-0.0623/-0.0253) at phenotypic and genotypic levels, respectively. These results are in agreement with the findings of Garg *et al.* (2010), Kailashnath (2011), Lakshmi (2011) and Babu *et al.* (2012).

The positive significant correlation of time of heading (0.1988**/0.2051**) with single plant yield was mainly due to indirect positive effects of this trait *via* total number of tillers per plant (0.0106/0.0047), number of productive tillers per plant (0.0151/0.0068), decorticated grain L/B ratio (0.0093/0.0039), gel consistency (0.0087/0.0036), grain iron concentration (0.0234/0.0106) and grain zinc concentration (0.0170/0.0072) at genotypic and phenotypic levels.

This trait exhibited negative indirect effects on single plant yield both at phenotypic and genotypic levels through stem length (-0.0057/-0.0023), panicle length (-0.0078/-0.0035), total number of grains per panicle (-0.0162/-0.0066), spikelet fertility (-0.0007/-0.0001), 100-grain weight (-0.0177/-0.0073), decorticated grain length (-0.0031/-0.0012), decorticated grain width (-0.0171/-0.0072) and amylose content (-0.0090/-0.0037).

4.6.2 Stem Length (Excluding Panicle) (cm)

Stem length had positive direct effect on single plant yield (0.1960/0.1349) both at phenotypic and genotypic levels. Garg *et al.* (2010), Kailashnath (2011), Lakshmi (2011), Babu *et al.* (2012) and Nagaraju *et al.* (2013) also recorded similar results for plant height. This trait exhibited positive significant (0.4852**/0.5056**) correlation with grain yield. The direct effect and correlation coefficients were positive. It is clearly indicated that direct selection of this trait would be effective in improving single plant yield, as it nullifies the negative indirect effects.

This trait recorded positive indirect effects on single plant *via* other component characters viz., time of heading (0.0180/0.0125), panicle length (0.1270/0.0939), total number of grains per panicle (0.0665/0.0463), 100-grain weight (0.0320/0.0223), decorticated grain length (0.0025/0.0018), decorticated grain width (0.0121/0.0084), gel consistency (0.0403/0.0285) and grain zinc concentration (0.0534/0.0394).

This trait expressed negative indirect effects on yield through total number of tillers per plant (-0.0543/-0.0415), number of productive tillers per plant (-0.0439/-0.0330), spikelet fertility (-0.0005/-0.0004), decorticated grain L/B ratio (-0.0026/-0.0017), amylose content (-0.0727/-0.0510) and grain iron concentration (-0.0395/-0.0285).

4.6.3 Total Number of Tillers per Plant

The direct contribution of this trait on plant yield was negative (-0.6965/-1.0718) both at phenotypic and genotypic levels. These results are in conformity with the findings of Suman *et al.* (2005), Garg *et al.* (2010) and Padmaja *et al.* (2011). Total number of tillers per plant exhibited negative significant (-0.2234**/-0.2587**) association with single plant yield mainly due to negative direct and indirect effects.

It also expressed positive indirect effects on single plant yield *via* time of heading (0.1183/0.1985), stem length (0.1931/0.3297), panicle length (0.1547/0.2967), total number of grains per panicle (0.2119/0.3569), 100-grain weight (0.0876/0.1414), decorticated grain length (0.0248/0.0451), decorticated grain width (0.1062/0.1945) and gel consistency (0.1369/0.2223).

Negative indirect effects were observed through number of productive tillers per plant (-0.6192/-0.9800), spikelet fertility (-0.0961/-0.1668), decorticated grain L/B ratio (-0.0357/-0.0620), amylose content (-0.1205/-0.2044), grain iron concentration (-0.1054/-0.2441) and grain zinc concentration (-0.0629/-0.1216) on single plant yield.

4.6.4 Number of Productive Tillers per Plant

Number of productive tillers per plant had positive direct effect (0.8115/1.2268) on single plant yield, which is in agreement with the findings of Chandra *et al.* (2009b), Kailashnath (2011), Padmaja *et al.* (2011), Babu *et al.* (2012), Gangashetty *et al.* (2013) and Nagesh *et al.* (2013).

This trait showed positive indirect effects on single plant yield through total number of tillers per plant (0.7214/1.1217), spikelet fertility (0.1256/0.2028), decorticated grain length (0.0008/0.0032), decorticated grain L/B ratio (0.1017/0.1656), amylose content (0.1468/0.2415), grain iron concentration (0.1207/0.2745) and grain zinc concentration (0.1519/0.2646).

It had negative non-significant association with single plant yield (-0.0633/-0.0774), which might result from the negative indirect effects manifested through other components *viz.*, time of heading (-0.1970/-0.3288), stem length (-0.1817/-0.299), panicle length

(-0.1845/-0.3518), total number of grains per panicle (-0.2595/-0.4222), 100-grain weight (-0.0971/-0.1539), decorticated grain width (-0.1744/-0.2959) and gel consistency (-0.1885/-0.3022).

4.6.5 Panicle Length (cm)

Panicle length had positive direct effect on single plant yield (0.1173/0.1935), which is in trend with the results of Suman (2003), Ekka *et al.* (2011), Babu *et al.* (2012), Mohanty *et al.* (2012) and Gangashetty *et al.* (2013). This trait exhibited positive significant correlation (0.3748**/0.4125**) with single plant yield. Hence, simple selection would be more effective for improving single plant yield based on this trait.

Panicle length had positive indirect effects on single plant yield *via* time of heading (0.0147/0.0265), stem length (0.0760/0.1348), total number of grains per panicle (0.0433/0.0779), 100 grain weight (0.0036/0.0069), decorticated grain length (0.0035/0.0072), decorticated grain width (0.0016/0.0021), decorticated grain L/B ratio (0.0053/0.0097), gel consistency (0.0146/0.0257) and grain zinc concentration (0.0203/0.0385).

This trait expressed negative indirect effects on single plant yield through total number of tillers per plant (-0.0261/-0.0536), number of productive tillers per plant (-0.0267/-0.0555), spikelet fertility (-0.0152/-0.0301), amylose content (-0.0322/-0.0564) and grain iron concentration (-0.0145/-0.0301).

4.6.6 Total Number of Grains per Panicle

This trait had positive direct effect on single plant yield (0.4025/0.3848), which is in agreement with the findings of Sandhyakishore (2005), Garg *et al.* (2010), Mohanty *et al.* (2012), Sharma *et al.* (2012) and Nagaraju *et al.* (2013). Total number of grains per panicle expressed positive significant association (0.3780**/0.3915**). So, direct selection of this trait would be effective in improving single plant yield.

This trait recorded positive indirect effects on single plant yield through time of heading (0.1045/0.1013), stem length (0.1367/0.1320), panicle length (0.1487/0.1550) and grain zinc concentration (0.0124/0.0121).

Negative direct effects of this trait on single plant yield were manifested through total number of tillers per plant (-0.1224/-0.0128), number of productive tillers per plant (-0.1287/-0.1324), spikelet fertility (-0.0841/-0.0851), 100-grain weight (-0.1236/-0.1190), decorticated grain length (-0.1850/-0.1783), decorticated grain width (-0.0282/-0.0272),

decorticated grain L/B ratio (-0.1277/-0.1245), amylose content (-0.0204/-0.0191), gel consistency (-0.0044/-0.0044) and grain iron concentration (-0.0250/-0.0260).

4.6.7 Spikelet Fertility (%)

Spikelet fertility recorded positive direct effect (0.0167/0.0014) on single plant yield, which is in confirmity with the findings of Padmaja *et al.* (2011) and Sharma *et al.* (2012). Correlation studies revealed that it had positive non-significant association with single plant yield (0.0482/0.0325).

This trait expressed positive indirect effects through time of heading (0.0002/0.000), total number of tillers per plant (0.0023/0.0002), number of productive tillers per plant (0.0026/0.0002), 100-grain weight (0.0019/0.0002), decorticated grain length (0.0023/0.0002), decorticated grain width (0.0024/0.0002), amylose content (0.0006/0.0000), grain iron concentration (0.0010/0.001) and grain zinc concentration (0.0010/0.001). Negative indirect effects of this trait on single plant yield were observed *via* panicle length (-0.0022/-0.0022), total number of grains per panicle (-0.0035/-0.0003), decorticated grain L/B ratio (-0.0001/0.0000) and gel consistency (-0.0013/-0.0001).

4.6.8 100-Grain Weight (g)

100-grain weight exhibited positive direct effect (0.1353/0.0784) on single plant yield, which is in confirmity with the findings of Suman (2003), Sankar *et al.* (2006) and Padmaja *et al.* (2011). It had positive significant association with single plant yield (0.2964**/0.3094**). Hence, selection based on this character for the improvement of single plant yield would be effective.

Positive indirect effects of this character on single plant yield were recorded *via* time of heading (0.0385/0.0226), stem length (0.0221/0.01330), panicle length (0.0041/0.0028), spikelet fertility (0.0151/0.0100), decorticated grain length (0.0781/0.0457), decorticated grain width (0.0857/ 0.0511), decorticated grain L/B ratio (0.0051/0.0028), gel consistency (0.0338/0.0198) and grain zinc concentration (0.0057/0.0035).

Negative indirect effects were observed through total number of tillers per plant (-0.0170/-0.0103), number of productive tillers per plant (-0.0162/-0.0098), total number of grains per panicle (-0.0416/-0.0242), amylose content (-0.0083/-0.0049) and grain iron concentration (-0.0535/-0.0352).

4.6.9 Decorticated Grain: Length (mm)

Direct contribution of this trait to single plant yield was positive (0.4510/0.5283). Lakshmi (2011), Singh *et al.* (2011) and Mohanty *et al.* (2012) also got similar results. This trait showed negative non-significant association (-0.0124/-0.0173) with single plant yield.

Decorticated grain length exhibited positive indirect effects *via* time of heading (0.0224/0.0258), stem length (0.0057/0.0071), number of productive tillers per plant (0.0004/0.0014), panicle length (0.0136/0.0197), spikelet fertility (0.0620/0.0826), 100-grain weight (0.2605/0.3082), decorticated grain width (0.0387/0.0479), decorticated grain L/B ratio (0.3332/0.3966) and gel consistency (0.0583/0.0700).

Negative indirect effects of this trait on single plant yield were observed through total number of tillers per plant (-0.0223/-0.0131), total number of grains per panicle (-0.2073/-0.2448), amylose content (-0.0686/-0.0812), grain iron concentration (-0.0666/-0.0876) and grain zinc concentration (-0.0067/-0.0075).

4.6.10 Decorticated Grain: Width (mm)

This trait had positive direct effect on single plant yield (0.0858/0.0817), which is in accordance with the findings of Bhattacharyya *et al.* (2007), Krishna *et al.* (2008), Ekka *et al.* (2011) and Yadav and Kumar (2012). It had positive significant correlation (0.3967**/0.4169**) with single plant yield.

Positive indirect effects of decorticated grain width on single plant yield were exhibited through time of heading (0.0236/0.0233), stem length (0.0053/0.0051), panicle length (0.0012/0.0009), spikelet fertility (0.0123/0.128), 100-grain weight (0.0543/0.0533), decorticated grain length (0.0074/0.0074), amylose content (0.0028/0.0030) and gel consistency (0.0152/0.0147).

Decorticated grain width had negative indirect effects *via* total number of tillers per plant (-0.0131/-0.0148), number of productive tillers per plant (-0.0184/-0.0197), total number of grains per panicle (-0.0060/-0.0058), decorticated grain L/B ratio (-0.0503/-0.0474), grain iron concentration (-0.0214/-0.0237) and grain zinc concentration (-0.0016/0.0020).

4.6.11 Decorticated Grain: L/B ratio

It had negative direct effect (-0.5370/-0.6512) on single plant yield, as reported by Garg *et al.* (2010). Decorticated grain L/B ratio exhibited negative significant (-0.2692**/-0.2811**) association with single plant yield.

Time of heading (0.0798/0.0997), stem length (0.0070/0.0082), total number of grains per panicle (0.1704/0.2108), decorticated grain width (0.3147/0.3774), amylose content (0.0777/0.0976) and gel consistency (0.0180/0.0208) were the component characters through which decorticated grain L/B ratio exhibited positive indirect effects.

Negative indirect effects of this trait were expressed through total number of tillers per plant (-0.0275/-0.0377), number of productive tillers per plant (-0.0673/-0.0879), panicle length (-0.0243/-0.0325), 100-grain weight (-0.0201/-0.0233), decorticated grain length (-0.3967/-0.4888), grain iron concentration (-0.0180/-0.0298) and grain zinc concentration (-0.0163/-0.0220). However, through spikelet fertility this trait expressed indirect effects, which were positive (0.0021) and negative (-0.0009) at phenotypic and genotypic levels, respectively.

4.6.12 Amylose Content (%)

Amylose content had negative direct effect (-0.1554/-0.1607) on single plant yield, which is in accordance with the findings of Garg *et al.* (2010) and it had negative non-significant association (-0.0517/-0.0514) with single plant yield.

This trait recorded positive indirect effects *via* stem length (0.0576/0.0607), panicle length (0.0426/0.0468), total number of grains per panicle (0.0079/0.0080), 100-grain weight (0.0095/0.0100), decorticated grain length (0.0236/0.0247), decorticated grain L/B ratio (0.0225/0.0241), gel consistency (0.1163/0.1225), grain iron concentration (0.0144/0.0171) and grain zinc concentration (0.0020/0.0029). Negative indirect effects were resulted through time of heading (-0.0224/-0.0233), total number of tillers per plant (-0.0269/-0.0306), number of productive tillers per plant (-0.0281/-0.0316), spikelet fertility (-0.0056/-0.0044) and decorticated grain width (-0.0051/-0.0059).

4.6.13 Gel Consistency (mm)

This trait had negative direct effect (-0.2665/-0.2314) on single plant yield, which is in unison with the findings of Garg *et al.* (2010). It had recorded negative non-significant association (-0.0287/-0.0215) with single plant yield.

Positive indirect effects were recorded *via* time of heading (0.0371/0.0329), total number of tillers per plant (0.0524/0.0480), number of productive tillers per plant (0.0619/0.0570), total number of grains per panicle (0.0029/0.0026), spikelet fertility (0.0199/0.0172), decorticated grain L/B ratio (0.0090/0.0074) and amylose content (0.1994/0.1764).

Negative indirect effects were resulted through stem length (-0.0549/-0.0489), panicle length (-0.0330/-0.0308), 100-grain weight (-0.0665/-0.0586), decorticated grain length (-0.0344/-0.0307), decorticated grain width (-0.0472/-0.0417) and grain iron concentration (-0.0213/-0.0194).

4.6.14 Grain Iron Concentration (mg/kg)

Grain iron concentration had negative direct effect (-0.0894/-0.1106) on single plant yield, which is in confirmity with the findings of Nagesh *et al.* (2013). This trait had negative significant correlation (-0.2856**/-0.3264**) with single plant yield.

Positive indirect effects of this trait were manifested through time of heading (0.0335/0.0463), stem length (0.0180/0.0234), panicle length (0.0111/0.0172), total number of grains per panicle (0.0055/0.0075), 100-grain weight (0.0354/0.0497), decorticated grain length (0.0132/0.0183), decorticated grain width (0.0223/0.0320) and amylose content (0.0083/0.0118).

Total number of tillers per plant (-0.0135/-0.0252), number of productive tillers per plant (-0.0133/-0.0248), spikelet fertility (-0.0056/-0.0081), decorticated L/B ratio (-0.0030/-0.0051), gel consistency (-0.0071/-0.0093) and grain zinc concentration (-0.0233/-0.0297) expressed negative indirect effects of this trait on single plant yield.

4.6.15 Grain Zinc Concentration (mg/kg)

This trait had positive direct effect (0.0368/0.0237) on single plant yield. This finding is in agreement with the report of Bekele *et al.* (2013). It had recorded positive significant association (0.2115**/0.2298**) with single plant yield.

Positive indirect effects of this trait were exhibited *via* stem length (0.0100/0.0069), total number of tillers per plant (0.0033/0.0027), number of productive tillers per plant (0.0069/0.0051), panicle length (0.0064/0.0047), total number of grains per panicle (0.0011/0.0007), spikelet fertility (0.0022/0.0016), 100-grain weight (0.0016/0.0011), decorticated grain L/B ratio (0.0011/0.0008) and grain iron concentration (0.0096/0.0064).

Negative indirect effects of this trait were observed through time of heading (-0.0100/-0.0068), decorticated grain length (-0.0050/-0.0003), decorticated grain width (-0.0007/-0.0006), amylose content (-0.0005/-0.0004) and gel consistency (-0.0030/-0.0021).

Path coefficient analysis revealed that number of productive tillers per plant exerted the highest positive direct effect on grain yield followed by decorticated grain length, total number of grains per panicle, stem length, panicle length, 100-grain weight, decorticated grain width, grain zinc concentration and spikelet fertility, indicating that the selection for these characters was likely to bring about an overall improvement in single plant yield directly. Therefore, it is suggested that preference should be given to these characters in the selection programme to isolate superior lines with genetic potentiality for high yield in rice genotypes. Negative direct effects on grain yield were exhibited by total number of tillers per plant, decorticated grain L/B ratio, gel consistency, amylose content, grain iron concentration and time of heading in decreasing order, respectively.

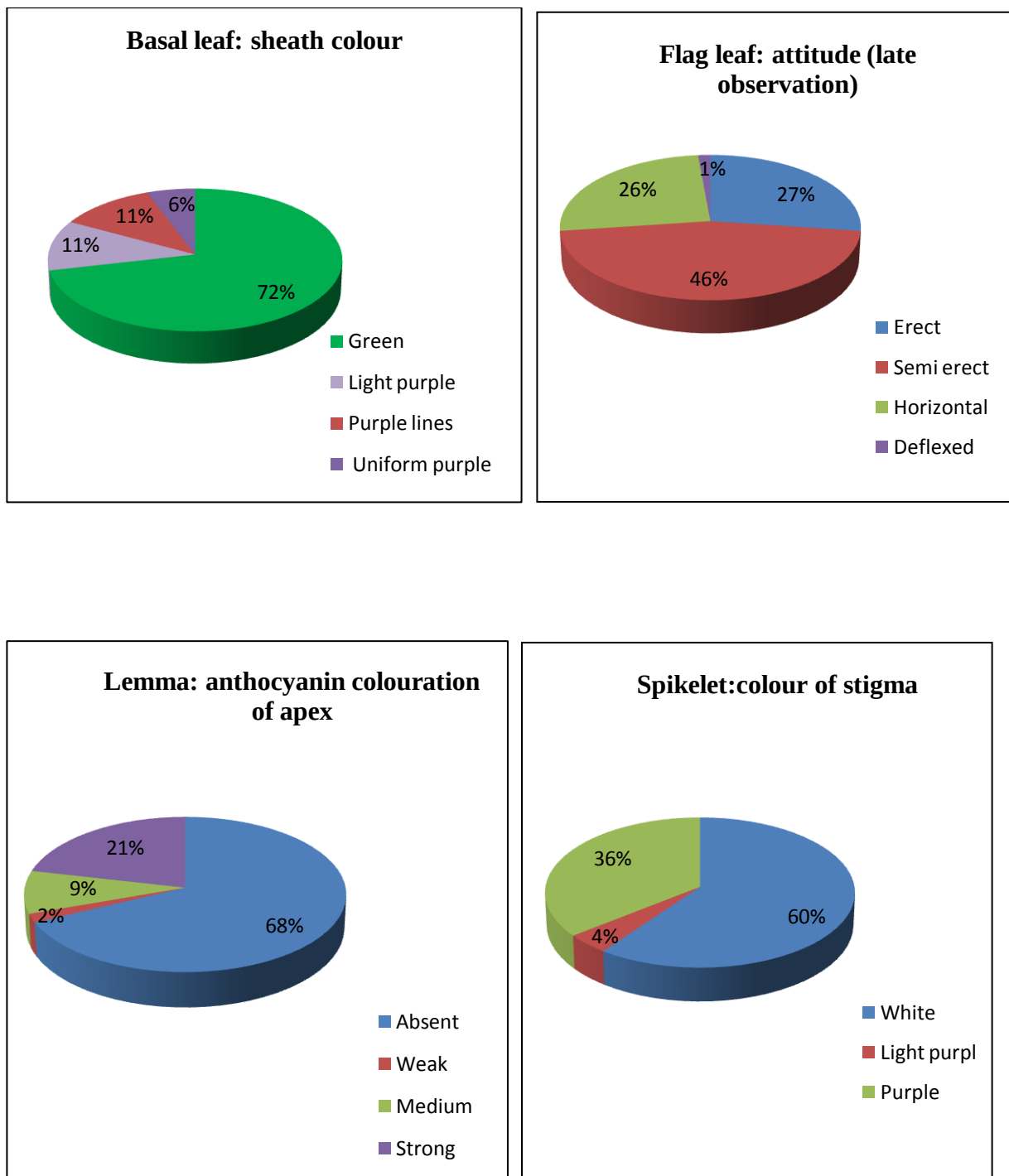


Figure 4.1. Frequency distribution of 70 landraces of rice for basal leaf sheath colour, flag leaf attitude (late observation), lemma anthocyanin colouration of apex and colour of stigma.

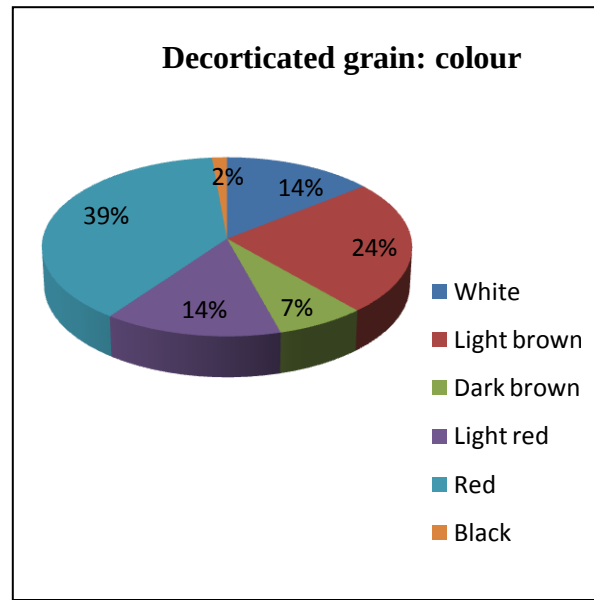
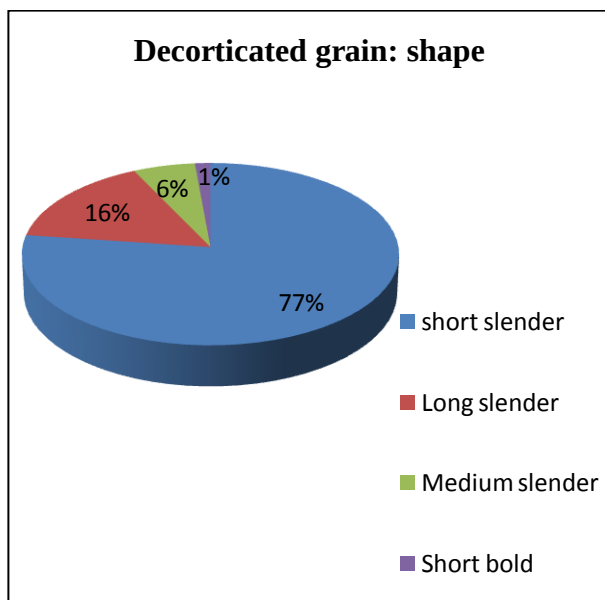
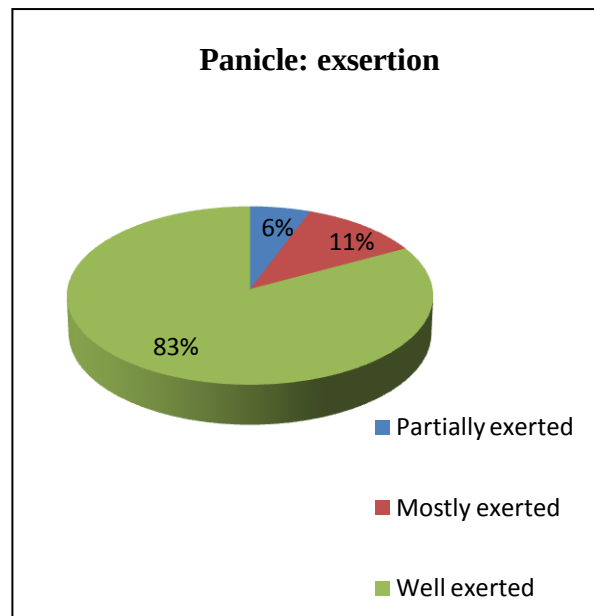
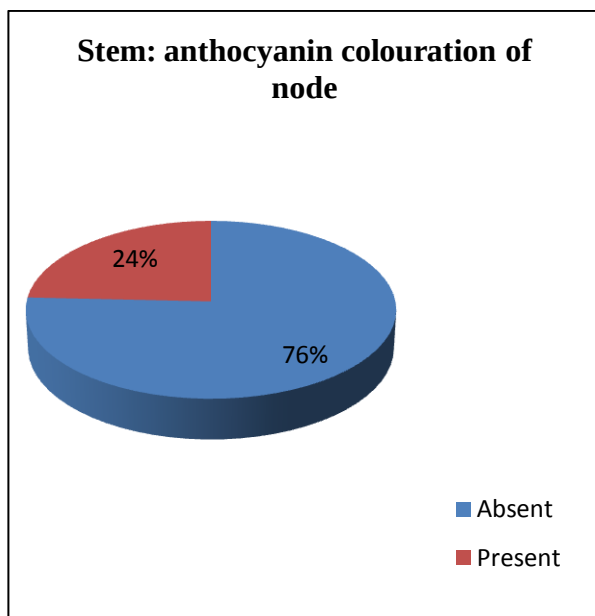


Figure 4.1 (cont.). Frequency distribution of 70 landraces of rice for anthocyanin colouration of node, panicle exsertion, decorticated grain shape and colour.

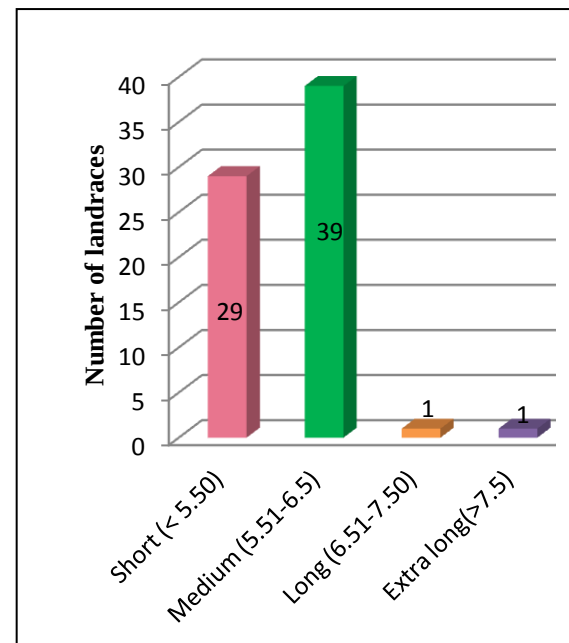
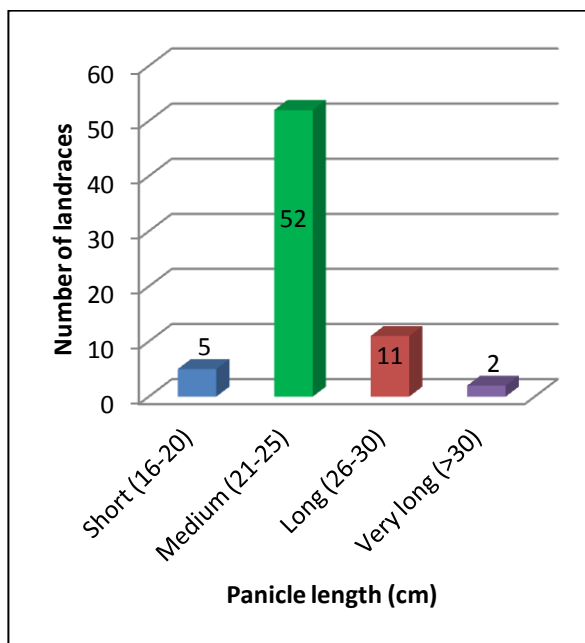
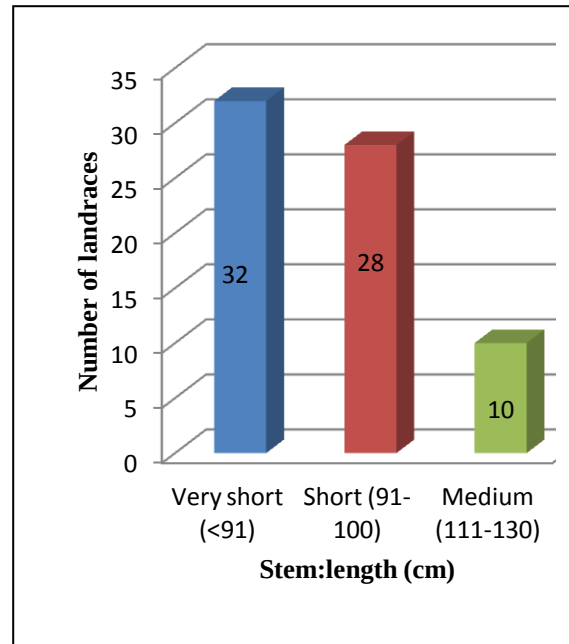
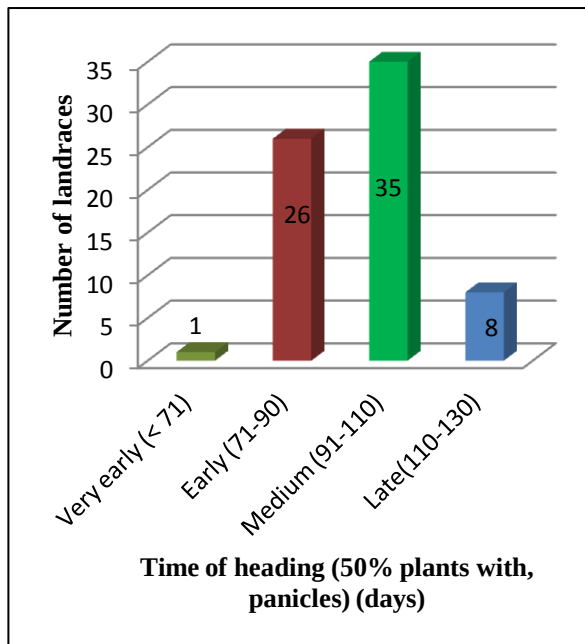


Figure 4.2. Frequency distribution of 70 landraces of rice for time of heading, stem length, panicle length and decorticated grain length.

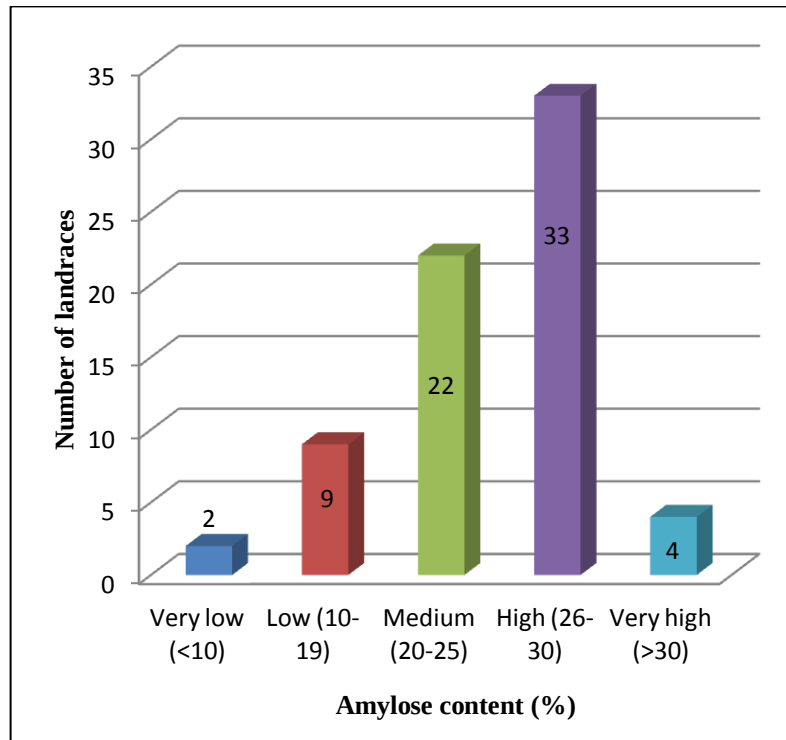


Figure 4.2 (cont.) Frequency distribution of 70 landraces of rice for amylose content.

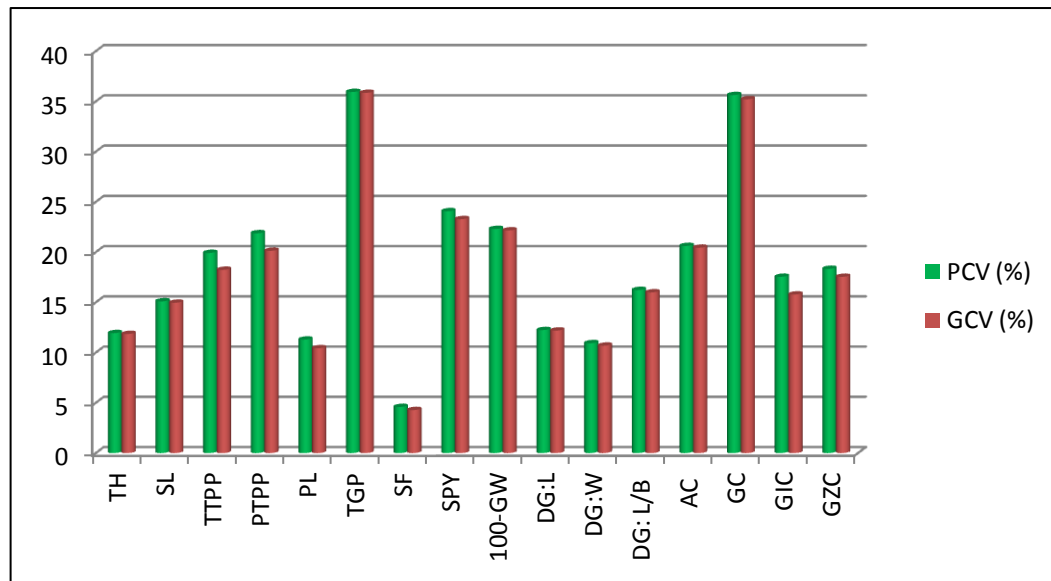


Figure 4.3. Graphical representation of phenotypic and genotypic coefficients of variation for various characters in landraces of rice.

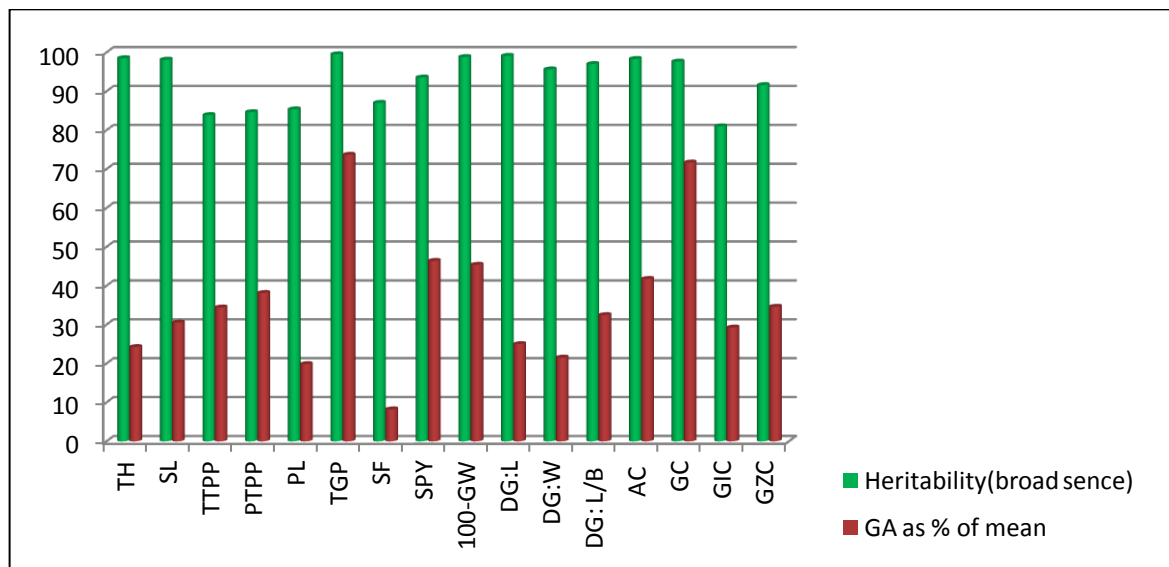


Figure 4.4. Graphical representation of heritability (broad scene) and genetic advance as a per cent of mean (5 %) for various characters in landraces of rice.

TH - Time of heading; SL - Stem length; TPP - Total number of tillers per plant; PTP - Number of productive tillers per plant; PL - Panicle length; TGP - Total number of grains per panicle; SF - Spikelet fertility; 100-GW - 100-grain weight; DGL - Decorticated grain length; DGW - Decorticated grain width; DG: L/B - Decorticated grain L/B ratio; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

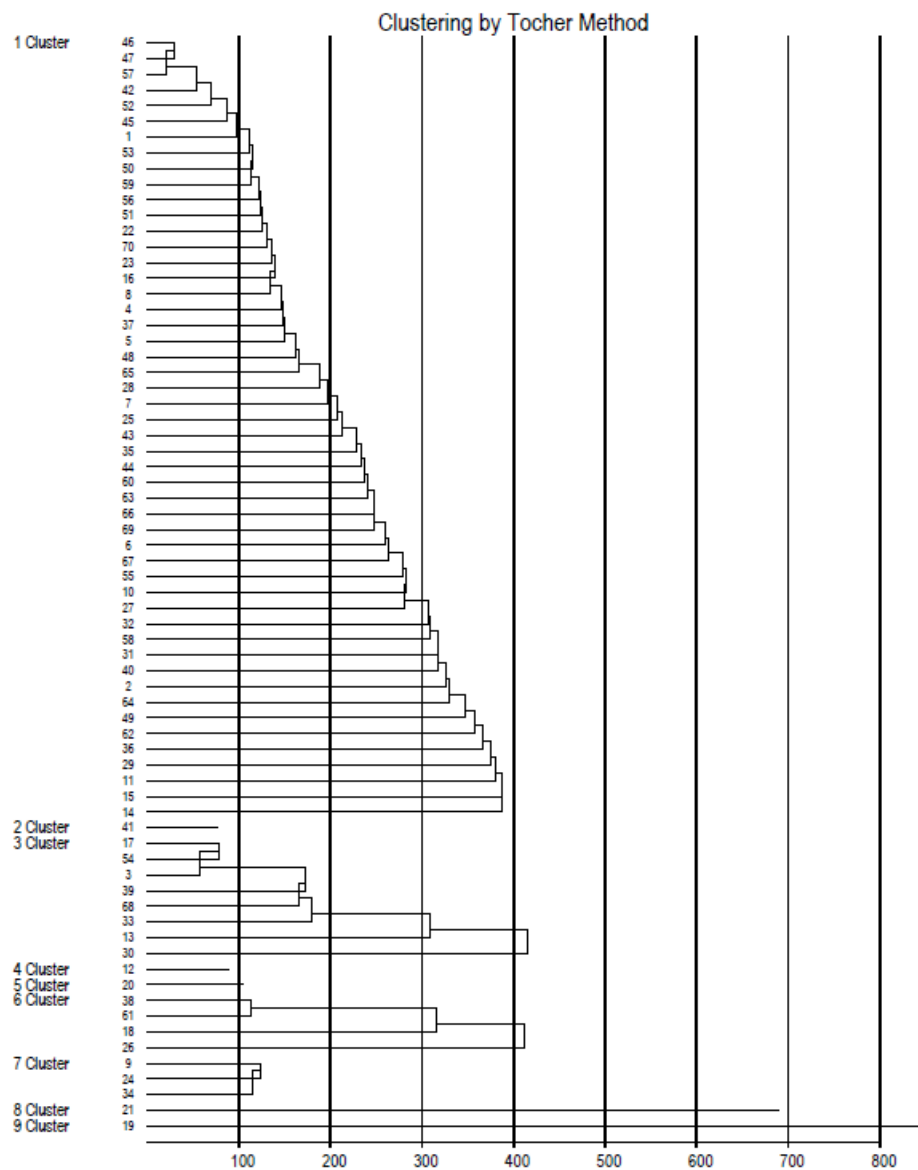


Figure 4.5. Clustering pattern by Tocher's method.

Table 4.2. Characterization of landraces of rice based on grain quality parameters

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Decorticated grain: shape	Decorticated grain: colour	Amylose content (%)
Nimisaal	Short	Narrow	Short slender	Red	Very high
Thuroodi	Medium	Narrow	Short slender	Red	Very high
Danaguri	Short	Narrow	Short slender	Light brown	Medium
Kottathondi	Medium	Narrow	Short slender	Red	Medium
Kankri	Medium	Narrow	Long slender	Light brown	High
Chandrakanta	Medium	Narrow	Long slender	Light red	Medium
Krishna Kamod	Medium	Narrow	Short slender	Light brown	Medium
Banshpati	Medium	Narrow	Short slender	Red	High
Chakhao Poiretion	Medium	Narrow	Short slender	Black	Very low
Batiasora	Short	Narrow	Short slender	White	Medium
Moirangphou Yenthik	Medium	Narrow	Long slender	White	Low
Srabanti Sal	Medium	Narrow	Long slender	Light red	Low
Kuruka	Short	Narrow	Short bold	Red	High
Chetuvelian	Medium	Narrow	Short slender	Red	Very high
Kuttivelian	Short	Narrow	Medium slender	Red	High
Taothabi	Medium	Narrow	Short slender	Red	High
Gandha Malati	Short	Narrow	Medium slender	White	Medium
Chenthadi	Medium	Narrow	Short slender	Light red	Low

Table 4.2 (cont.).

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Decorticated grain: shape	Decorticated grain: colour	Amylose content (%)
Kayama	Short	Narrow	Short slender	White	Medium
Karad	Medium	Narrow	Short slender	Red	Medium
Surjeet Basmati 01	Extra long	Narrow	Long slender	Light brown	Medium
Jhuli	Short	Narrow	Short slender	Brown	High
Urunikayama	Medium	Narrow	Short slender	Light red	Medium
Phourelamubi	Long	Narrow	Long slender	White	Low
Baid Dulah	Short	Narrow	Short slender	Red	High
Mullankayama	Short	Narrow	Short slender	Light brown	Low
Bagh Jhapta	Medium	Narrow	Long slender	Light brown	High
Adukkann	Short	Narrow	Medium slender	Red	High
Valichoori	Medium	Narrow	Long slender	Light red	Medium
Onavattan	Short	Narrow	Short slender	Red	High
Marathondi	Short	Narrow	Short slender	Light red	Low
Mannuvelian	Medium	Narrow	Short slender	Red	High
Kailash Rana	Short	Narrow	Short slender	Light brown	Medium
Titabora	Medium	Narrow	Short slender	White	Very low
Nata	Medium	Narrow	Short slender	Red	High
Phoudum	Short	Narrow	Short slender	White	Low
Lal Dhepa	Medium	Narrow	Short slender	Red	High

Table 4.2 (cont.).

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Decorticated grain: shape	Decorticated grain: colour	Amylose content (%)
Kunjootti Matta	Short	Narrow	Short slender	Red	High
Gandeshwari	Short	Narrow	Short slender	White	Medium
Thonnuran Thondi	Medium	Narrow	Short slender	Red	Medium
Kurumottan	Medium	Narrow	Medium slender	Red	High
Nuapada-padampur- Assam chudi	Short	Narrow	Short slender	Red	High
Dubraj	Short	Narrow	Short slender	Dark brown	Medium
Sapari	Medium	Narrow	Short slender	White	High
Kalamara	Medium	Narrow	Short slender	Light red	High
Koraput-Kundra- Assam chudi	Medium	Narrow	Long slender	Red	High
Koraput-Kundra- Haldi chudi	Medium	Narrow	Short slender	Light brown	High
Kathi Dhan	Short	Narrow	Short slender	Red	Medium
Bhulo	Medium	Narrow	Long slender	Red	High
Yubaraj	Medium	Narrow	Short slender	Dark brown	Medium
Akul-B	Short	Narrow	Short slender	Light brown	High
Lalkain	Short	Narrow	Short slender	Light brown	High
Ganthia Sikila	Short	Narrow	Short slender	Light brown	High
Majhali Jhuli	Short	Narrow	Short slender	Light brown	High
Jubaraj	Medium	Narrow	Short slender	Light brown	High

Table 4.2 (cont.).

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Decorticated grain: shape	Decorticated grain: colour	Amylose content (%)
Ankul	Short	Narrow	Short slender	Light brown	Medium
Akula	Medium	Narrow	Short slender	Light red	High
Makadhana	Medium	Narrow	Long slender	Red	Medium
Dhinkiasiali	Short	Narrow	Short slender	Red	Medium
Ganjamgedi	Short	Narrow	Short slender	White	Medium
Rajahansa	Medium	Narrow	Short slender	Light brown	Very high
Champe Siali-C	Medium	Narrow	Short slender	Red	High
Sagiri	Medium	Narrow	Short slender	Light red	Low
Mayurkantha-K	Medium	Narrow	Short slender	Light brown	Low
Kalakaincha	Short	Narrow	Short slender	Brown	High
Dhusura	Medium	Narrow	Short slender	Light brown	High
Luchei	Medium	Narrow	Short slender	Red	Medium
B.Hunar	Short	Narrow	Short slender	Light brown	High
Chinamali-K	Medium	Narrow	Short slender	Light red	High
Dal	Medium	Narrow	Short slender	Red	High

Table 4.4. ANOVA for yield, its contributing characters and grain quality parameters in different landraces of rice

S. No	Character	Mean sum of squares		
		Replications (d.f.=2)	Treatments (d.f.=69)	Error (d.f.=138)
1.	Time of heading (50% of plants with panicles)	0.171	374.34**	1.862
2.	Stem length (excluding panicle) (cm)	1.459	590.82**	3.735
3.	Total number of tillers per plant	0.067	14.43**	0. 869
4.	Number of productive tillers per plant	0.457	13.96**	0.797
5.	Panicle length (cm)	1.672	19.86**	1.075
6.	Total number of grains per panicle	12.078	11789. 45**	19.349
7.	Spikelet fertility (%)	0.641	47.89**	2.268
8.	Single plant yield (g)	0.385	93.63**	2.108
9.	100-grain weight (g)	0.007	0.77**	0.003
10.	Decorticated grain: length (mm)	0.004	1.37**	0.004
11.	Decorticated grain: width (mm)	0.0002	0.08**	0.001
12.	Decorticated grain: L/B ratio	0.001	1.06**	0.011
13.	Amylose content (%)	0.674	76.89**	0.435
14.	Gel consistency (mm)	5.233	629.62**	5.040
15.	Grain iron concentration (mg/kg)	0.381	7.54**	0.547
16.	Grain zinc concentration (mg/kg)	0.945	34.84**	1.033

** Significant at 1 percent level of significance

*Significant at 5 percent level of significance

Table 4.5. Mean performance of various landraces of rice for yield, its contributing characters and grain quality parameters

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1	95.33	106.58	14.37	13.93	23.94	158.22	94.29	23.37	2.40	5.45	1.39	3.93	31.63	29.00	8.63	15.80
FV 2	93.33	93.41	10.24	9.33	22.56	208.22	95.27	33.54	2.86	5.59	1.69	3.27	31.53	30.33	7.30	19.07
FV 3	92.67	99.66	10.88	10.11	25.11	308.66	81.86	26.25	1.02	4.11	1.26	3.25	22.91	43.33	9.92	16.90
FV 6	93.33	92.92	11.00	9.55	24.15	146.00	89.81	24.94	2.76	5.82	1.74	3.37	25.61	38.00	8.66	22.21
FV 7	84.67	81.20	12.11	11.78	20.11	105.55	93.89	22.54	2.36	6.01	1.58	3.80	27.31	26.33	12.90	22.27
FV 8	94.33	106.66	12.00	11.50	26.59	146.00	96.58	28.97	2.42	6.26	1.44	4.34	20.41	48.33	9.90	20.07
FV 9	85.33	99.35	12.89	12.11	23.68	135.58	85.84	20.15	1.71	5.70	1.37	4.16	21.74	45.67	10.91	24.56
FV 10	87.00	96.11	13.00	12.89	25.00	117.11	91.57	26.84	2.23	5.95	1.59	3.75	29.23	31.00	9.60	23.90
FV 11	84.00	118.36	10.41	9.44	25.42	214.22	94.39	27.81	2.12	5.99	1.34	4.46	8.94	67.33	11.50	22.60
FV 12	76.67	112.05	10.02	7.67	25.76	210.83	94.01	21.92	2.24	5.47	1.51	3.63	22.09	43.00	10.00	22.00
FV 15	94.67	77.07	9.00	7.50	22.96	167.33	89.31	24.07	2.63	6.24	1.70	3.67	17.06	78.00	8.10	11.19

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV16	93.00	103.00	9.67	8.55	22.77	231.93	88.40	27.92	2.98	6.22	1.74	3.63	17.90	65.00	10.57	17.21
FV17	104.67	89.11	10.78	10.55	22.00	254.66	96.11	32.02	1.51	3.41	1.73	1.99	29.22	22.67	7.77	17.20
FV18	107.33	111.94	10.11	9.77	24.85	217.66	90.46	29.45	2.91	5.51	1.62	3.40	30.76	34.67	6.80	18.20
FV20	84.00	112.88	10.05	9.77	26.88	194.33	92.87	36.71	3.07	5.35	1.84	2.91	29.09	44.67	8.60	24.50
FV21	85.33	99.61	11.00	10.66	22.00	114.04	96.55	26.99	2.25	5.58	1.49	3.76	28.88	36.00	10.59	24.10
FV22	94.33	99.88	12.44	9.55	28.33	257.33	83.09	23.89	1.48	4.20	1.44	2.92	23.41	52.67	11.40	15.09
FV23	109.67	122.44	9.89	9.33	26.22	237.66	92.31	32.36	2.83	5.69	1.55	3.67	18.53	48.67	5.97	22.00
FV24	99.33	114.63	9.94	9.33	31.30	499.33	92.43	31.54	1.17	4.28	1.31	3.27	24.19	27.00	10.53	24.21
FV25	70.00	52.65	13.15	10.56	19.35	114.89	94.23	19.00	2.33	5.67	1.64	3.45	23.15	52.33	12.70	19.20
FV26	92.67	87.08	9.78	9.67	28.50	106.90	85.91	22.64	2.56	8.18	1.25	6.57	23.91	24.00	8.00	19.10
FV27	82.00	88.72	14.85	14.66	21.61	132.00	92.84	23.23	1.75	5.40	1.37	3.95	28.64	25.33	11.83	22.10
FV29	97.00	89.61	11.97	10.66	24.61	107.11	96.12	24.34	2.34	5.58	1.56	3.56	25.62	47.33	11.30	16.22

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV30	83.67	113.55	11.37	11.23	24.97	161.27	93.22	24.49	2.41	6.58	1.43	4.83	12.38	63.33	11.00	23.18
FV33	87.33	85.93	17.00	16.44	23.86	75.22	95.69	22.05	2.22	5.42	1.43	3.80	27.78	23.33	9.50	25.10
FV34	111.00	121.77	10.80	7.67	34.78	161.00	95.56	25.39	2.33	5.20	1.72	3.03	16.29	62.33	10.60	19.52
FV36	91.00	108.63	11.22	10.66	27.16	188.22	89.74	29.86	2.21	6.40	1.36	4.70	28.10	22.00	8.93	22.48
FV37	90.33	97.98	11.33	6.50	25.19	158.67	91.45	15.32	2.71	5.23	1.83	2.96	26.29	29.67	7.80	23.10
FV39	111.33	100.31	9.66	9.22	26.22	167.33	86.91	36.32	3.33	6.23	1.63	3.82	24.22	33.00	6.77	19.80
FV40	87.00	88.27	9.44	8.44	23.67	150.55	89.01	20.28	1.13	5.02	1.54	3.27	28.69	22.00	7.60	10.48
FV41	93.33	111.78	11.33	11.00	24.89	148.44	91.13	29.85	2.61	5.24	1.59	3.29	15.57	52.00	7.40	22.72
FV42	102.00	108.88	8.77	7.55	24.41	178.00	93.47	27.66	3.14	5.85	1.55	3.76	26.51	56.33	7.67	19.20
FV43	81.67	102.44	10.83	10.00	26.55	221.95	88.78	22.50	1.19	4.65	1.13	4.10	23.35	38.00	12.70	23.00
FV44	82.00	103.46	10.10	8.94	25.67	171.55	94.33	23.78	2.48	5.91	1.55	3.83	6.32	92.33	8.29	16.20
FV45	75.67	73.52	14.55	14.33	21.58	85.67	95.41	25.10	2.43	5.61	1.66	3.37	27.21	34.00	11.30	23.40

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV46	73.33	107.12	10.50	10.00	22.14	162.00	79.98	20.94	2.17	5.13	1.35	3.93	19.05	65.00	10.30	21.10
FV47	96.67	84.97	13.78	12.88	23.77	137.11	91.74	28.82	2.57	5.98	1.53	3.91	26.50	23.67	7.00	8.97
FV48	116.67	88.87	10.02	7.33	23.77	258.33	87.38	33.45	2.46	5.41	1.64	3.30	29.59	35.00	6.60	16.10
FV49	94.33	99.18	10.44	9.33	25.29	205.00	88.76	25.58	1.76	4.43	1.39	3.19	23.02	22.00	11.60	17.30
FV50	88.33	113.78	11.60	11.00	26.12	149.52	92.78	35.56	3.00	5.91	1.86	3.17	24.21	52.67	11.60	23.60
FV51	107.00	96.91	9.53	8.66	26.55	211.55	82.40	34.60	3.18	5.56	1.86	2.99	26.68	29.67	7.93	19.62
FV32-1	92.67	89.91	11.33	10.47	22.02	211.99	93.36	23.02	2.20	5.43	1.55	3.51	27.94	36.00	11.63	21.60
FV33-1	96.00	89.12	11.15	9.91	20.53	187.09	90.56	21.68	1.67	5.07	1.35	3.76	24.07	22.00	10.03	18.18
FV34-1	100.33	58.09	11.24	10.55	20.41	93.21	92.97	14.36	2.21	5.63	1.33	4.23	28.06	33.67	10.60	19.61
FV59	84.33	96.21	10.44	9.44	27.71	204.00	82.81	19.09	2.56	5.68	1.47	3.88	26.87	51.00	9.65	20.20
FV66	91.00	87.67	11.96	10.33	24.87	187.87	95.82	23.90	2.02	6.06	1.43	4.24	27.33	33.67	11.07	17.90
FV67	92.33	85.62	10.78	10.11	25.41	201.46	86.51	19.59	2.05	5.90	1.35	4.37	27.21	35.67	10.00	19.20

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV93	93.00	92.03	9.11	8.67	23.30	115.11	86.85	16.46	2.64	5.12	1.57	3.27	24.69	49.33	10.00	19.40
FV98	120.00	83.03	9.85	8.00	22.07	174.64	95.22	14.97	2.31	6.29	1.42	4.42	27.47	34.33	9.70	17.40
FV108	87.00	78.04	12.55	10.06	22.07	135.20	85.89	19.86	2.01	5.71	1.43	4.00	25.88	45.33	9.70	17.60
FV115	84.00	83.18	11.11	9.67	22.88	123.73	92.96	17.44	1.96	5.47	1.37	4.00	26.50	22.00	10.00	17.00
FV120	95.67	94.99	10.33	9.50	22.85	158.66	94.26	18.05	2.25	5.40	1.36	3.99	30.69	28.67	9.20	16.00
FV125	91.00	84.86	13.09	12.08	21.31	132.36	92.80	20.11	1.97	5.45	1.33	4.09	27.00	35.00	10.93	15.60
FV126	86.33	81.98	12.44	10.33	23.67	277.28	85.46	19.54	1.30	4.01	1.27	3.16	26.35	45.33	11.90	19.40
FV133	75.00	98.66	14.89	11.67	23.67	97.18	93.55	12.58	2.04	5.96	1.42	4.20	28.69	33.67	9.80	17.33
FV136	84.67	83.46	14.26	12.78	22.02	140.19	87.58	16.34	1.92	5.31	1.32	4.03	23.37	43.00	9.00	17.24
FV142	92.67	80.48	10.44	9.63	22.91	175.89	92.87	22.45	2.00	5.69	1.44	3.96	27.24	38.67	10.18	18.40
FV151	100.33	93.40	8.33	7.78	23.45	184.93	96.43	22.39	2.95	6.19	1.62	3.81	22.60	58.00	8.90	14.60
FV154	88.00	80.02	12.00	10.22	20.79	140.03	94.36	18.79	2.42	5.39	1.46	3.69	25.42	50.00	8.50	16.41

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV170	92.33	61.73	10.00	9.10	21.32	153.66	88.91	18.41	2.13	4.84	1.60	3.02	24.22	55.33	11.40	19.90
FV171	115.67	80.59	11.11	9.22	21.34	242.83	94.76	23.96	2.01	5.72	1.75	3.28	32.72	28.00	10.40	17.20
FV182	112.67	91.07	9.11	8.05	22.96	208.86	86.14	19.98	2.86	5.55	1.75	3.18	26.54	46.67	9.20	16.47
FV201	102.33	100.52	10.07	8.22	22.27	115.08	93.93	18.16	2.49	5.71	1.58	3.61	19.31	50.67	10.78	13.39
FV217	103.00	95.49	14.77	12.44	24.11	228.33	94.31	24.27	2.47	5.68	1.58	3.60	16.99	42.00	10.20	17.60
FV219	103.00	91.63	14.70	13.22	22.91	161.03	92.86	23.85	2.31	5.07	1.49	3.40	26.78	31.33	9.20	21.90
FV221	114.33	93.11	12.66	9.33	23.34	175.61	91.12	15.67	2.47	5.83	1.34	4.38	27.21	31.33	8.20	19.20
FV269	113.33	90.06	15.44	13.11	22.69	111.89	89.66	17.93	2.37	5.92	1.59	3.72	20.90	56.33	9.60	16.69
FV299	85.00	81.12	13.33	12.02	21.00	208.15	91.48	22.90	1.71	4.52	1.38	3.26	27.53	33.33	9.77	22.29
FV307	109.67	84.80	18.00	15.00	22.17	155.49	88.26	24.91	2.90	5.80	1.63	3.55	29.49	31.67	10.70	19.81
FV310	85.00	74.35	19.61	17.68	22.68	150.66	92.85	18.25	2.45	5.56	1.48	3.75	26.51	49.67	8.63	17.42
Mean	93.77	93.54	11.66	10.41	23.99	174.70	91.15	23.73	2.28	5.53	1.51	3.70	24.70	40.98	9.67	19.14

Table 4.5 (cont.).

Genotype	Timing of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorticated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
C.V (%)	1.46	2.07	8.00	8.58	4.32	2.52	1.65	6.12	2.43	1.16	2.28	2.81	2.67	5.48	7.65	5.31
S.E	0.79	1.12	0.54	0.52	0.60	2.54	0.87	0.84	0.03	0.04	0.02	0.06	0.38	1.30	0.43	0.59
C.D (5%)	2.20	3.12	1.50	1.44	1.67	7.10	2.43	2.34	0.09	0.10	0.06	0.17	1.07	3.62	1.19	1.64

AC - Amylose content, GC - Gel Consistency

FV 1 - Nimisaal; FV 2 - Thuroodi; FV 3 - Danaguri; FV 6 - Kottathondi; FV 7 - Kankri; FV 8 - Chandrakanta; FV 9 - Krishna Kamod; FV10 - Bansapati; FV11 - Chakhao Poirition; FV12 - Batiasora; FV15 - Moirangphou Yenthik; FV16 - Srabanti-Sal; FV17 - Kuruka; FV18 - Chetuviliyan; FV20 - Kuttuviliyan; FV21 - Taothabi; FV22 - Gandha Malati; FV23 - Chenthadi; FV24 - Kayama; FV25 - Karad; FV26 - Surjeet Basmati 01; FV27 - Jhuli; FV29 - Urunikayama; FV30 - Phourelamuhi; FV33 - Baid Dulah; FV34 - Mullankayama; FV36 - Bagh Jhapta; FV37 - Adukan; FV39 - Valichoori; FV40 - Onavattan; FV41 - Marathondi; FV42 - Mannuviliyan; FV43 - Kailash Rana; FV44 - Jitabora; FV45 - Nata; FV46 - Phondum; FV47 - Lal Dhepa; FV48 - Kunjootti Matta; FV49 - Gandeshwari; FV50 - Thonnuram Thondi; FV51 - Kurumottan; FV32-1 - Nuapada-padampur-Assam chudi; FV33-1 - Dubraj; FV34-1 - Sapari; FV59 - Kalamara; FV66 - Koraput-Kundra-Assam chudi; FV67 - Koraput-Kundra-Haldi chudi; FV93 - Kathidhan; FV98 - Bhulo; FV108 - Yubaraj; FV115 - Akul-B; FV120 - Lalkain; FV125 - Ganthia Sikila; FV126 - Majhali Jhuli; FV133 - Jubaraj; FV136 - Ankul; FV142 - Akula; FV151 - Makadhana; FV154 - Dhinkiasiali; FV170 - Ganjamgedi; FV171 - Rajahansa; FV182 - Champe Siali-C; FV201 - Sagiri; FV217 - Mayurkantha-K; FV219 - Kalakaincha; FV221 - Dhusura; FV269 - Luchei; FV299 - B.Hunar; FV307 - Chinamali-K and FV310 - Dal.

Table 4.3. Frequency distribution of landraces of rice for various DUS characters

S. No	Character	State of expression	Number of genotypes	Frequency distribution (%)
1	Basal: leaf sheath colour	Green	50	71.43
		Light purple	8	11.43
		Purple lines	8	11.43
		Purple	4	5.71
2	Flag leaf: attitude of blade (late observation)	Erect	19	27.14
		Semi erect	32	45.71
		Horizontal	18	25.71
		Deflexed	1	1.43
3.	Time of heading (50 % plants with panicles)	Very early	1	1.43
		Early	26	37.14
		Medium	35	50.00
		Late	8	11.43
4.	Lemma: anthocyanin colouration of apex	Absent	38	54.29
		Weak	1	1.43
		Medium	3	4.29
		Strong	12	17.14
		Very strong	16	22.86
5.	Spikelet: colour of stigma	White	42	60.00
		Light purple	3	4.29
		Purple	25	35.71
6.	Stem length (excluding panicle)	Very short	32	45.71
		Short	28	40.00
		Medium	10	14.28
7	Stem: anthocyanin colouration of node	Absent	53	75.71
		Present	17	24.29
8.	Panicle: exertion	Partially exerted	4	5.71
		Mostly exerted	8	11.43
		Well exerted	58	82.86
9.	Panicle length	Short	5	7.14

Table 4.3 (cont.).

S. No	Character	State of expression	Number of genotypes	Frequency distribution (%)
		Medium	52	74.28
		Long	11	15.71
		Very long	2	2.86
10.	Decorticated grain: length	Short	29	41.43
		Medium	39	55.71
		Long	1	1.43
		Extra long	1	1.45
11.	Decorticated grain: width	Narrow	70	100.00
12.	Decorticated grain: shape	Short slender	54	77.14
		Short bold	1	1.43
		Medium slender	4	5.71
		Long slender	11	15.71
13.	Decorticated grain: colour	White	10	14.28
		Light brown	17	24.28
		Dark brown	5	7.14
		Light red	10	14.28
		Red	27	38.57
		Black	1	1.43
14.	Amylose content	Very low	2	2.86
		Low	9	12.86
		Medium	22	31.43
		High	33	47.14
		Very high	4	5.71

Table 4.6. Estimation of variability, heritability and genetic advance for yield, its contributing characters and grain quality parameters in landraces of rice

S. No	Character	Mean	Range		Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability in broad sense (h^2) (%)	GA	GA as percent of mean
			Min	Max							
1.	Time of heading (50% of plants with panicles)	93.77	70.00	120.00	125.36	123.49	11.94	11.85	98.51	22.72	24.23
2.	Stem length (cm)	93.54	52.65	122.44	199.43	195.69	15.10	14.96	98.13	28.55	30.52
3.	Total no. of tillers per plant	11.66	8.33	19.61	5.39	4.52	19.92	18.24	83.88	4.01	34.41
4.	No. of productive tillers per plant	10.41	6.50	17.68	5.19	4.39	21.88	20.13	84.63	3.97	38.14
5.	Panicle length (cm)	23.99	19.35	34.75	7.34	6.26	11.29	10.43	85.35	4.76	19.85
6.	Total no. of grains per panicle	174.70	75.22	499.33	3942.72	3923.37	35.94	35.85	99.51	128.72	73.68
7.	Spikelet fertility (%)	91.15	79.98	96.58	17.48	15.21	4.59	4.28	87.02	7.49	8.22
8.	Single plant yield (g)	23.73	12.58	36.71	32.62	30.51	24.07	23.28	93.54	11.01	46.38
9.	100-grain weight (g)	2.28	1.02	3.33	0.26	0.26	22.30	22.16	98.81	1.04	45.38
10.	Decorticated grain: length (mm)	5.53	3.41	8.18	0.46	0.46	12.24	12.19	99.11	1.38	25.00
11.	Decorticated grain: width (mm)	1.51	1.13	1.86	0.03	0.03	10.93	10.69	95.64	0.33	21.53
12.	Decorticated grain: L/B ratio	3.70	1.99	6.57	0.36	0.35	16.23	15.99	97.01	1.20	32.44
13.	Amylose content (%)	24.70	6.32	32.72	25.92	25.48	20.61	20.44	98.32	10.31	41.75
14.	Gel consistency (mm)	40.98	22.00	92.33	213.23	208.19	35.63	35.21	97.64	29.37	71.67
15.	Grain iron concentration (mg/kg)	9.67	5.97	12.9	2.88	2.33	17.54	15.78	80.99	2.83	29.26
16.	Grain zinc concentration (mg/kg)	19.14	8.97	25.1	12.30	11.27	18.33	17.54	91.60	6.62	34.59

Min.-Minimum, Max.-Maximum

PCV- Phenotypic Coefficient of Variation; GCV- Genotypic Coefficient of Variation; GA – Genetic Advance

Table 4.7. Clustering pattern among 70 landraces of rice under study (Tocher's method)

Cluster No.	No. of land races	Name of the land races
I	50	Nimisaal, Thuroodi, Kottathondi, Kankri, Chandrakanta, Krishna Kamod, Banshpati, Batiasora, Moirangphou Yenthik, Chetuveliyen, Kuttiveliyen, Taothabi, Jhuli, Urunikayama, Baid Dulah, Baghjhapta, Adukkann, Valichoori, Marathondi, Mannuveliyen, Nata, Phondum, Lal Dhepa, Thonnuram Thondi, Nuapada-padampur-Assam chudi, Dubraj, Sapari, Kalamara, Koraput-Kundra-Assam chudi, Koraput-Kundra-Haldi chudi, Kathidhan, Bhulo, Yubaraj, Akul-B, Lalkain, Ganthia Sikila, Jubaraj, Ankul, Akula, Makadhana, Dhinkiasiali, Ganjamgedi, Champe Siali-C, Sagiri, Mayurkantha-K, Kalakaincha, Dhusura, Luchei, Chinamali-K and Dal
II	1	Kurumottan
III	8	Danaguri, Kuruka, Gandha Malati, Onavattan, Kailash Rana, Majhali Jhuli, Gandeshwari and B.Hunar
IV	1	Srabanti-Sal
V	1	Karad
VI	4	Chenthadi, Mullankayama, Kunjootti Matta and Rajahansa
VII	3	Chakhao Poiretion , Phourelamuhi and Titabora
VIII	1	Surjeet Basmati 01
IX	1	Kayama

Table 4.10. Relative contribution of different traits to genetic diversity in 70 landraces of rice

S. No	Character	Times ranked 1st	Per cent contribution	Rank
1.	Time of heading (50% of plants with panicles)	278	11.51	5
2.	Stem length (excluding panicle) (cm)	220	9.11	6
3.	Total number of tillers per plant	5	0.21	11
4.	Number of productive tillers per plant	0	0.00	-
5.	Panicle length (cm)	0	0.00	-
6.	Total number of grains per panicle	697	28.86	1
7.	Spikelet fertility (%)	5	0.21	11
8.	Single plant yield (g)	11	0.46	10
9.	100-grain weight (g)	344	14.24	3
10.	Decorticated grain: length (mm)	432	17.89	2
11.	Decorticated grain: width (mm)	21	0.87	8
12.	Decorticated grain: L/B ratio	1	0.04	12
13.	Amylose content (%)	303	12.55	4
14.	Gel consistency (mm)	81	3.35	7
15.	Grain iron concentration (mg/kg)	1	0.04	12
16.	Grain zinc concentration (mg/kg)	16	0.66	9

Table 4.8. Intra (diagonal) and inter-cluster average D^2 values of 70 landraces of rice (Tocher's method)

Table 4.9. Cluster means for various agro-morphological and grain quality parameters in 70 landraces of rice

Cluster No.	Time of heading (50% plants with panicles)	Stem length (cm)	Total no. of tillers per plant	No. of productive tillers per plant	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	Single plant yield (g)	100-grain weight (g)	Decorated grain: length (mm)	Decorticated grain: width (mm)	Decorticated grain: L/B ratio	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
I	93.47	92.05	11.99	10.77	23.46	154.69	91.61	22.82	2.40	5.65	1.52	3.76	25.68	39.89	9.60	19.23
II	107.00	96.91	9.53	8.66	26.55	211.55	82.40	34.60	3.18	5.56	1.86	2.99	26.68	29.67	7.93	19.62
III	90.75	92.70	11.32	10.04	24.45	235.45	88.07	24.12	1.39	4.29	1.39	3.14	25.56	34.92	10.33	17.71
IV	93.00	103.00	9.67	8.55	22.77	231.93	88.40	27.92	2.98	6.22	1.74	3.63	17.90	65.00	10.57	17.21
V	70.00	52.65	13.15	10.56	19.35	114.89	94.23	19.00	2.33	5.67	1.64	3.45	23.15	52.33	12.70	19.20
VI	113.25	103.42	10.46	8.39	26.53	224.95	92.50	28.79	2.41	5.50	1.67	3.32	24.28	43.50	8.39	18.70
VII	83.22	111.79	10.62	9.87	25.35	182.35	93.98	25.36	2.34	6.16	1.44	4.37	9.21	74.33	10.26	20.66
VIII	92.67	87.08	9.78	9.67	28.50	106.90	85.91	22.64	2.56	8.18	1.25	6.57	23.91	24.00	8.00	19.10
IX	99.33	114.63	9.94	9.33	31.30	499.33	92.43	31.54	1.17	4.28	1.31	3.27	24.19	27.00	10.53	24.21

AC – Amylose content, GC - Gel consistency

AC – Amylose content, GC - Gel consistency

Table 4.11. Estimates of phenotypic and genotypic correlation coefficients among yield, its contributing characters and grain quality parameters in 70 landraces of rice

TRAIT		TH	SL	TTPP	PTP	PL	TGPP	SF	100-GW	DG: L	DG: W	DG: L/B	AC	GC	GIC	GZC	SPY
TH	P	1.0000	0.0918	-0.1698*	-0.2428**	0.1251	0.2596**	0.0115	0.2846**	0.0497	0.2750**	-0.1487*	0.1443*	-0.1393*	-0.3753**	-0.2720**	0.1988**
	G	1.0000	0.0930	-0.1852**	-0.2680**	0.1369*	0.2631**	0.0052	0.2886**	0.0488	0.2848**	-0.1531*	0.1452*	-0.1422*	-0.4183**	-0.2869**	0.2051**
SL	P		1.0000	-0.2772**	-0.2239**	0.6480**	0.3395**	-0.0024	0.1632*	0.0126	0.0620	-0.0131	-0.3707**	0.2059**	-0.2017**	0.2726**	0.4852**
	G		1.0000	-0.3076**	-0.2445**	0.6965**	0.3431**	-0.0026	0.1656*	0.0134	0.0622	-0.0125	-0.3778**	0.2112**	-0.2116**	0.2922**	0.5056**
TTPP	P			1.0000	0.8890**	-0.2221**	-0.3042**	0.1379*	-0.1258	-0.0357	-0.1524*	0.0512	0.1729*	-0.1966**	0.1513*	0.0904	-0.2234**
	G			1.0000	0.9143**	-0.2768**	-0.3330**	0.1556*	-0.1319	-0.0421	-0.1814**	0.0579	0.1907**	-0.2074**	0.2278**	0.1135	-0.2587**
PTP	P				1.0000	-0.2273**	-0.3198**	0.1548*	-0.1197	0.0010	-0.2150**	0.1253	0.1809**	-0.2324**	0.1487*	0.1872**	-0.0633
	G				1.0000	-0.2868**	-0.3441**	0.1653*	-0.1254	0.0026	-0.2412**	0.1350	0.1968**	-0.2464**	0.2238**	0.2157**	-0.0774
PL	P					1.0000	0.3694**	-0.1297*	0.0303	0.0302	0.0135	0.0452	-0.2744**	0.1240	-0.1240	0.1727*	0.3748**
	G					1.0000	0.4028**	-0.1555*	0.0356	0.0372	0.0111	0.0499	-0.2915**	0.1329	-0.1555*	0.1992**	0.4125**
TGPP	P						1.0000	-0.2091**	-0.3072**	-0.4597**	-0.0701	-0.3173**	-0.0506	-0.0109	-0.0621	0.0308	0.3780**
	G						1.0000	-0.2212**	-0.3093**	-0.4634**	-0.0706	-0.3236**	-0.0497	-0.0114	-0.0675	0.0315	0.3915**
SF	P							1.0000	0.1113	0.1375*	0.1430*	-0.0039	0.0360	-0.0748	0.0627	0.0606	0.0482
	G							1.0000	0.1273	0.1563*	0.1572*	0.0014	0.0277	-0.0744	0.0732	0.0659	0.0325
100 - GW	P								1.0000	0.5776**	0.6335*	0.0374	-0.0611	0.2496**	-0.3958**	0.0422	0.2964**
	G								1.0000	0.5833**	0.6517**	0.0357	-0.0622	0.2533**	-0.4495**	0.0452	0.3094**
DG: L	P									1.0000	0.0857	0.7387**	-0.1521*	0.1292	-0.1477*	-0.0149	-0.0124
	G									1.0000	0.0906	0.7506**	-0.1536*	0.1325	-0.1657*	-0.0141	-0.0173
DG: W	P										1.0000	-0.5861**	0.0326	0.1771*	-0.2490**	-0.0190	0.3967**
	G										1.0000	-0.5795**	0.0366	0.1800**	-0.2897**	-0.0249	0.4169**
DG:L/B	P											1.0000	-0.1447*	-0.0336	0.0336	0.0304	-0.2692**
	G											1.0000	-0.1498*	-0.0320	0.0458	0.0338	-0.2811**
AC	P												1.0000	-0.7485**	-0.0926	-0.0127	-0.0517
	G												1.0000	-0.7623**	-0.1063	-0.0179	-0.0514
GC	P													1.0000	0.0799	-0.0821	-0.0287
	G													1.0000	0.0837	-0.0882	-0.0215
GIC	P														1.0000	0.2602**	-0.2856**
	G														1.0000	0.2681**	-0.3264**
GZC	P															1.0000	0.2115**
	G															1.0000	0.2298**

**Significant at 1 per cent level of significance, * Significant at 5 % level of significance; P - Phenotypic correlation coefficient; G - Genotypic correlation coefficient

*TH - Time of heading; SL - Stem length; TTPP - Total number of tillers per plant; PTP - Number of productive tillers per plant; PL - Panicle length; TGPP - Total number of grains per panicle; SF - Spikelet fertility; 100-GW - 100-grain weight; DGL - Decorticated grain length; DGW- Decorticated grain width; DG: L/B - Decorticated grain L/B ratio; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

*TH - Time of heading; SL - Stem length; TTPP - Total number of tillers per plant; PTP - Number of productive tillers per plant; PL - Panicle length; TGPP - Total number of grains per panicle; SF - Spikelet fertility; 100-GW - 100-grain weight; DGL - Decorticated grain length; DGW- Decorticated grain width; DG: L/B - Decorticated grain L/B ratio; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

Table 4.12. Estimates of direct and indirect effects of yield contributing traits and grain quality parameters on yield in 70 landraces of rice

TRAIT		TH	SL	TTPP	PTP	PL	TGPP	SF	100-GW	DG: L	DG: W	DG: L/B	AC	GC	GIC	GZC	SPY
TH	P	-0.0623	-0.0057	0.0106	0.0151	-0.0078	-0.0162	-0.0007	-0.0177	-0.0031	-0.0171	0.0093	-0.0090	0.0087	0.0234	0.0170	0.1988**
	G	-0.0253	-0.0023	0.0047	0.0068	-0.0035	-0.0066	-0.0001	-0.0073	-0.0012	-0.0072	0.0039	-0.0037	0.0036	0.0106	0.0072	0.2051**
SL	P	0.0180	0.1960	-0.0543	-0.0439	0.1270	0.0665	-0.0005	0.0320	0.0025	0.0121	-0.0026	-0.0727	0.0403	-0.0395	0.0534	0.4852**
	G	0.0125	0.1349	-0.0415	-0.0330	0.0939	0.0463	-0.0004	0.0223	0.0018	0.0084	-0.0017	-0.0510	0.0285	-0.0285	0.0394	0.5056**
TTPP	P	0.1183	0.1931	-0.6965	-0.6192	0.1547	0.2119	-0.0961	0.0876	0.0248	0.1062	-0.0357	-0.1205	0.1369	-0.1054	-0.0629	-0.2234**
	G	0.1985	0.3297	-1.0718	-0.9800	0.2967	0.3569	-0.1668	0.1414	0.0451	0.1945	-0.0620	-0.2044	0.2223	-0.2441	-0.1216	-0.2587**
PTP	P	-0.1970	-0.1817	0.7214	0.8115	-0.1845	-0.2595	0.1256	-0.0971	0.0008	-0.1744	0.1017	0.1468	-0.1885	0.1207	0.1519	-0.0633
	G	-0.3288	-0.2999	1.1217	1.2268	-0.3518	-0.4222	0.2028	-0.1539	0.0032	-0.2959	0.1656	0.2415	-0.3022	0.2745	0.2646	-0.0774
PL	P	0.0147	0.0760	-0.0261	-0.0267	0.1173	0.0433	-0.0152	0.0036	0.0035	0.0016	0.0053	-0.0322	0.0146	-0.0145	0.0203	0.3748**
	G	0.0265	0.1348	-0.0536	-0.0555	0.1935	0.0779	-0.0301	0.0069	0.0072	0.0021	0.0097	-0.0564	0.0257	-0.0301	0.0385	0.4125**
TGPP	P	0.1045	0.1367	-0.1224	-0.1287	0.1487	0.4025	-0.0841	-0.1236	-0.1850	-0.0282	-0.1277	-0.0204	-0.0044	-0.0250	0.0124	0.3780**
	G	0.1013	0.1320	-0.0128	-0.1324	0.1550	0.3848	-0.0851	-0.1190	-0.1783	-0.0272	-0.1245	-0.0191	-0.0044	-0.0260	0.0121	0.3915**
SF	P	0.0002	0.0000	0.0023	0.0026	-0.0022	-0.0035	0.0167	0.0019	0.0023	0.0024	-0.0001	0.0006	-0.0013	0.0010	0.0010	0.0482
	G	0.0000	0.0000	0.0002	0.0002	-0.0002	-0.0003	0.0014	0.0002	0.0002	0.0002	0.0000	0.0000	-0.0001	0.0001	0.0001	0.0325
100-GW	P	0.0385	0.0221	-0.0170	-0.0162	0.0041	-0.0416	0.0151	0.1353	0.0781	0.0857	0.0051	-0.0083	0.0338	-0.0535	0.0057	0.2964**
	G	0.0226	0.0130	-0.0103	-0.0098	0.0028	-0.0242	0.0100	0.0784	0.0457	0.0511	0.0028	-0.0049	0.0198	-0.0352	0.0035	0.3094**
DG: L	P	0.0224	0.0057	-0.0161	0.0004	0.0136	-0.2073	0.0620	0.2605	0.4510	0.0387	0.3332	-0.0686	0.0583	-0.0666	-0.0067	-0.0124
	G	0.0258	0.0071	-0.0223	0.0014	0.0197	-0.2448	0.0826	0.3082	0.5283	0.0479	0.3966	-0.0812	0.0700	-0.0876	-0.0075	-0.0173
DG: W	P	0.0236	0.0053	-0.0131	-0.0184	0.0012	-0.0060	0.0123	0.0543	0.0074	0.0858	-0.0503	0.0028	0.0152	-0.0214	-0.0016	0.3967**
	G	0.0233	0.0051	-0.0148	-0.0197	0.0009	-0.0058	0.0128	0.0533	0.0074	0.0817	-0.0474	0.0030	0.0147	-0.0237	-0.0020	0.4169**
DG: L/B	P	0.0798	0.0070	-0.0275	-0.0673	-0.0243	0.1704	0.0021	-0.0201	-0.3967	0.3147	-0.5370	0.0777	0.0180	-0.0180	-0.0163	-0.2692**
	G	0.0997	0.0082	-0.0377	-0.0879	-0.0325	0.2108	-0.0009	-0.0233	-0.4888	0.3774	-0.6512	0.0976	0.0208	-0.0298	-0.0220	-0.2811**
AC	P	-0.0224	0.0576	-0.0269	-0.0281	0.0426	0.0079	-0.0056	0.0095	0.0236	-0.0051	0.0225	-0.1554	0.1163	0.0144	0.0020	-0.0517
	G	-0.0233	0.0607	-0.0306	-0.0316	0.0468	0.0080	-0.0044	0.0100	0.0247	-0.0059	0.0241	-0.1607	0.1225	0.0171	0.0029	-0.0514
GC	P	0.0371	-0.0549	0.0524	0.0619	-0.0330	0.0029	0.0199	-0.0665	-0.0344	-0.0472	0.0090	0.1994	-0.2665	-0.0213	0.0219	-0.0287
	G	0.0329	-0.0489	0.0480	0.0570	-0.0308	0.0026	0.0172	-0.0586	-0.0307	-0.0417	0.0074	0.1764	-0.2314	-0.0194	0.0204	-0.0215
GIC	P	0.0335	0.0180	-0.0135	-0.0133	0.0111	0.0055	-0.0056	0.0354	0.0132	0.0223	-0.0030	0.0083	-0.0071	-0.0894	-0.0233	-0.2856**
	G	0.0463	0.0234	-0.0252	-0.0248	0.0172	0.0075	-0.0081	0.0497	0.0183	0.0320	-0.0051	0.0118	-0.0093	-0.1106	-0.0297	-0.3264**
GZC	P	-0.0100	0.0100	0.0033	0.0069	0.0064	0.0011	0.0022	0.0016	-0.0050	-0.0007	0.0011	-0.0005	-0.0030	0.0096	0.0368	0.2115**
	G	-0.0068	0.0069	0.0027	0.0051	0.0047	0.0007	0.0016	0.0011	-0.0003	-0.0006	0.0008	-0.0004	-0.0021	0.0064	0.0237	0.2298**

Phenotypic residual effect= 0.60, Genotypic residual effect = 0.49; P - Phenotypic level; G - Genotypic level; **Bold values**- direct effects Normal values-indirect effects

** Significant at 1 percent level of significance *Significant at 5 percent level of significance

*TH - Time of heading; SL - Stem length; TTPP - Total number of tillers per plant; PTP - Number of productive tillers per plant; PL - Panicle length; TGPP - Total number of grains per panicle; SF - Spikelet fertility; 100-GW - 100-grain weight; DGL - Decorticated grain length; DGW - Decorticated grain width; DG: L/B - Decorticated grain L/B ratio; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

*TH - Time of heading; SL - Stem length; TTPP - Total number of tillers per plant; PTP - Number of productive tillers per plant; PL - Panicle length;
TGPP - Total number of grains per panicle; SF - Spikelet fertility; 100-GW - 100-grain weight; DGL - Decorticated grain length; DGW - Decorticated grain width;
DG: L/B - Decorticated grain L/B ratio; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

Chapter V

SUMMARY AND CONCLUSIONS

Among cereals, rice is undoubtedly the most important cereal of the world, which is the staple food for more than half of the world's population. It has shaped the cultures, diets and economies of billions of people living in Asia where it has a long history of cultivation and is deeply ingrained in the daily lives of Asian people. Landraces of rice harbour a great deal of useful traits and played a very important role in the local food security and sustainable development of agriculture, in addition to their significance as genetic resource for the improvement of rice cultivars.

The present investigation entitled "Evaluation of landraces of rice (*Oryza sativa* L.) for genetic diversity" was conducted with seventy landraces obtained from Directorate of Rice Research, Rajendranagar, Hyderabad, with the main objectives of studying the genetic variability among the landraces of rice for agro-morphological and grain quality parameters, estimating the genetic diversity among these genotypes using Mahalanobis D^2 analysis, identifying the promising genotypes possessing desirable traits and studying the extent of association among yield, its component traits and grain quality parameters and determining the direct and indirect effects of these characters on yield.

The experiment was carried out in Randomized Block Design, with three replications during *kharif* 2013. Visual observations were recorded on single plant basis on ten randomly selected plants in each genotype at appropriate growth stages as per the norms of national test guidelines for Distinctness, Uniformity and Stability (DUS) on six qualitative characters *viz.*, basal leaf sheath colour, flag leaf attitude (late observation), lemma anthocyanin colouration of apex, stigma colour, stem anthocyanin colouration of node and panicle exertion.

Data on seven metric parameters *viz.*, stem length, total number of tillers per plant, number of productive tillers per plant, panicle length, total number of grains per panicle, spikelet fertility and single plant yield were recorded on five randomly selected plants in each plot. Time of heading (50 % plants with panicles) was recorded on plot basis. 100-grain weight was recorded per replication in each genotype. Grain quality and nutritional traits including decorticated grain length, decorticated grain width, decorticated grain L/B ratio, decorticated grain shape, decorticated grain colour, amylose content, gel consistency, grain iron and grain zinc concentrations were also recorded as per the standard procedures.

To meet the continuously expanding needs of varietal improvement, the assemblage, evaluation, preservation and characterization of the entire existing germplasm are essential to more rewarding breeding efforts. Characterization consists of recording those characters which are highly heritable, can easily be seen by the eye and are expressed in all environments. Out of the fourteen DUS characters recorded, stem anthocyanin colouration of node was dimorphic, spikelet colour of stigma, stem length and panicle exertion were trimorphic, basal leaf sheath colour, time of heading (50 % plants with panicles), flag leaf attitude (late observation), panicle length, decorticated grain length and shape were tetramorphic and lemma anthocyanin colouration of apex and amylose content showed five states of expression and based on decorticated grain colour highest number of groups i.e., six were made.

Analysis of variance revealed the presence of significant differences among the landraces of rice under study for all the sixteen traits viz., time of heading (50% plants with panicles), stem length, total number of tillers per plant, number of productive tillers per plant, panicle length, total number of grains per panicle, spikelet fertility, 100-grain weight, single plant yield, decorticated grain length, width and L/B ratio, amylose content, gel consistency, grain iron and zinc concentrations indicating the presence of considerable genetic variation in the experimental material.

A perusal of genetic parameters viz., phenotypic and genotypic coefficients of variation revealed less influence of environment on the characters under study. Therefore, response to direct selection may be effective in improving these traits. Among all the characters under study, total number of grains per panicle exhibited highest PCV and GCV values followed by single plant yield, whereas lowest PCV and GCV values were reported for spikelet fertility. Among all the grain quality characters, gel consistency expressed highest values of PCV and GCV.

All the characters under study except spikelet fertility and panicle length exhibited high heritability coupled with high genetic advance as a per cent of mean, which indicated the preponderance of additive gene action in controlling these traits. Hence direct selection of these characters would be effective in improving the seed yield. Panicle length had high heritability coupled with moderate genetic advance as per cent of mean suggesting that the expression of this trait was mostly influenced by additive type of gene action. Hence its response to selection would be effective in improving the seed yield. While, spikelet fertility had high heritability coupled with low genetic advance as per cent of mean

indicating that the expression of this trait was under the control of non-additive type of gene action, hence its response to selection would be poor.

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 landraces of rice under study were distributed into nine clusters based on D^2 values using Tocher's method such that the genotypes belonging to same cluster had an average smaller D^2 values than those belonging to different clusters. Out of nine clusters, cluster I was the largest comprising of fifty landraces, followed by cluster III with eight, cluster VI with four and cluster VII with three landraces. Cluster II, IV, V, VIII and IX were monogenotypic clusters suggesting the existence of high degree of heterogeneity among the genotypes.

Grouping of most of the landraces of Odisha into one cluster (cluster I) indicated genetic relatedness between these genotypes. This can be further explained by free flow of genes between these accessions. The clustering pattern showed that the landraces originating from similar geographical regions were categorized into different clusters, indicating that geographical diversity and genetic diversity were not related. Therefore, the kind of genetic diversity found among the genotypes belonging to same geographical region might be due to differences in adaptation, selection criteria, selection pressure and environmental conditions.

Maximum intra cluster distance was observed in cluster VI, followed by cluster III, cluster I and cluster VII indicating that some genetic divergence still existed among the genotypes within each of these clusters. Selection within such clusters might be executed based on maximum mean values for the desirable characters. Maximum inter cluster distance was exhibited between clusters VIII and IX followed by clusters V and IX, clusters VII and IX and clusters I and IX. The greater the distance between two clusters, the wider the genetic diversity among the genotypes of those clusters. Such highly divergent, high performing genotypes would be of great use in recombination breeding programme in order to get high heterotic recombinants.

The cluster I was having highest mean value for productive tillers per plant, cluster II had highest mean values for single plant yield, 100 grain weight, decorticated grain width and amylose content, cluster V recorded maximum mean values for total number of grains per panicle, spikelet fertility and grain iron concentration, cluster VII showed maximum mean values for time of heading, cluster VIII had highest mean value for

decorticated grain length, L/B ratio and gel consistency and cluster IX recorded highest mean values for stem length, panicle length, total number of grains per panicle and grain zinc concentration. The promising landraces from these clusters with high mean values for different traits may be directly used for adaptation or may be used as parents in future hybridization, depending upon the objective of the breeding programme to derive superior transgressive segregants.

Based on the inter cluster distance, it is suggested that hybridization between the landraces from clusters VIII (Surjeet Basmati 01) and IX (Kayama), clusters V (Karad) and IX (Kayama), clusters VII (Chakhao Poirition, Phourelamuhi and Titabora) and IX (Kayama) may produce encouraging results.

Out of the sixteen characters studied, six characters namely total number of grains per panicle, decorticated grain length, 100-grain weight, amylose content, time of heading (50 % plants with heads) and stem length together contributed maximum (94.16 %) to the total genetic divergence. Thus, it is suggested that these traits should be given importance in further breeding programmes i.e., during hybridization and selection of segregating populations, in this particular set of landraces to develop high yielding rice varieties/hybrids with superior grain quality.

Character association studies revealed that the genotypic correlation coefficients were higher than phenotypic correlation coefficients indicating strong inherent association between the characters. Single plant yield registered positive significant association with time of heading (50 % plants with panicles), stem length, panicle length, total number of grains per panicle and 100-grain weight indicating that these characters were important for yield improvement. Decorticated grain width and grain zinc concentration could also exhibited positive significant association with single plant yield indicating that these characters could also be considered to achieve better results for improving yield as well as grain quality. Positive but non-significant association of single plant yield was observed with spikelet fertility.

Path coefficient analysis revealed that number of productive tillers per plant exerted highest positive direct effect on grain yield followed by decorticated grain length, total number of grains per panicle, stem length, panicle length, 100-grain weight, decorticated grain width, grain zinc concentration and spikelet fertility indicating that selection for these characters was likely to bring about an overall improvement in single plant yield directly.

Critical analysis of results obtained from character association and path analysis indicated that the number of productive tillers per plant exerted the highest positive direct effect on single plant yield but it had negative-non significant association with yield which might be due to the negative indirect effects manifested through other component traits. But stem length, panicle length, total number of grains per panicle, 100-grain weight, decorticated grain width and grain zinc concentration displayed significant positive correlation as well as positive direct effect on single plant yield. The positive direct effect of these traits on yield resulted in strong genetic correlation. Hence, due emphasis should be given to these traits in formulating selection criteria to bring yield as well as grain quality improvement.

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*Original not seen

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