

**STUDIES ON GENETIC AND
BIOCHEMICAL ANALYSIS OF LAND
RACES OF RICE (*Oryza sativa* L.)**

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B.Sc. (Ag.)

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



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ANALYSIS OF LANDRACES OF RICE**
(*Oryza sativa* L.)

BY
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B.Sc. (Ag.)

**THESIS SUBMITTED TO THE PROFESSOR JAYASHANKAR
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CHAIRMAN: Dr. K. KANAKA DURGA



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2017**

DECLARATION

I, **CHINTALA RADHIKA RANI** hereby declare that the thesis entitled **“Studies on Genetic and Biochemical Analysis of Landraces of Rice (*Oryza sativa* L.)”** submitted to the **Professor Jayashankar Telangana State Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Hyderabad

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CERTIFICATE

Mrs. CHINTALA RADHIKA RANI has satisfactorily prosecuted the course of research and that the thesis entitled “**Studies on Genetic and Biochemical Analysis of Landraces of Rice (*Oryza sativa* L.)**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

(Dr. K. KANAKA DURGA)

Chairman

Date:

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON GENETIC AND BIOCHEMICAL ANALYSIS OF LAND RACES OF RICE (*Oryza sativa* L.)**” submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture of the Professor Jayashankar Telangana State Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Mrs. C. RADHIKA RANI** under our guidance and supervision.

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

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SYMBOLS AND ABBREVIATIONS

%	Per cent
σ^2_p	Phenotypic variance
σ^2_g	Genotypic variance
ANOVA	Analysis of variance
Cm	Centimeter
CD	Critical difference
D ²	Genetic distance
DUS	Distinctiveness, Uniformity and Stability
<i>et al.</i>	And others
Fig.	Figure
G	Gram
GA	Genetic advance
GAM	Genetic advance as per cent of mean
GCV	Genotypic coefficient of variation
h ²	Heritability in broad sense
Ha	Hectare
i.e.,	That is
M ha	Million hectare
mm	Millimeter
m.t.	Million tones
No.	Number
PCV	Phenotypic coefficient of variation
PPV & FRA	Protection of Plant Varieties and Farmers' Rights Authority
RBD	Randomized Block Design
viz.,	Namely

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ABSTRACT

In the present investigation, seventy six landraces of rice were evaluated to study the extent of genetic variability among these genotypes for agro-morphological, nutritional 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. Further, based on the D^2 analysis 12 land races falling in six different clusters were selected to investigate the biochemical analysis (proximate principles).

The experiment was conducted in a Randomized block design with three replications during *kharif* 2016 and the data was recorded on 22 agro-morphological and grain quality traits. Characterization of the experimental material was carried out based on seventeen DUS characters. Among these characters, stem anthocyanin colouration of node and internodes and decorticated grain width were dimorphic, basal leaf sheath colour, leaf blade length and width, time of heading (50% plants with panicles), spikelet density of pubescence on lemma, stem length and thickness, panicle exertion, number of productive tillers per plant were trimorphic; culm attitude, stigma colour, panicle length, flag leaf attitude (late observation), decorticated grain length and amylose content were tetramorphic and lemma anthocyanin colouration of apex, attitude of branches of panicle and 1000-grain weight showed five states of expression and based on colour of lemma and palea highest number of groups i.e., nine were made.

Analysis of variance indicated the existence of significant differences among the landraces under study for all the seventeen 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 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. Spikelet fertility 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.

Based on the relative magnitude of D^2 values, landraces of rice under study were distributed into six clusters by using Tocher's method. Out of six clusters, cluster I was the largest comprising of forty nine landraces, followed by cluster III with fourteen, cluster II with seven and cluster IV with four. Clusters V and VI were monogenotypic clusters, suggesting the existence of high degree of heterogeneity among the genotypes. Stem length, grain zinc concentration, gel consistency, amylose content, spikelet fertility and grain iron concentration together contributed maximum (97.33 %) to the total genetic divergence.

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

Cluster I exhibited highest mean value for panicle length, total number of grains per panicle and spikelet fertility, Cluster II had highest mean values for leaf blade length, stem thickness, stem length, time of heading and decorticated grain width. Cluster IV recorded maximum mean values for spikelet fertility. Cluster V exhibited highest mean value for single plant yield, amylose content and gel consistency. Cluster VI had highest mean values for leaf blade thickness, number of productive tillers per plant, 1000-grain weight, grain iron 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 non significant association with time of heading, stem length, panicle length, total number of grains per panicle and spikelet fertility indicating that these characters were important for yield improvement.

A critical analysis of the results by path analysis revealed that total number of grains per panicle exhibited the highest positive direct effect on single plant yield followed by stem length, gel consistency, spikelet fertility, stem thickness and 1000-grain weight. Hence, these traits must be considered as important attributes in formulating selection criteria for achieving desired targets in future breeding programmes.

The biochemical analysis has revealed that the selected landraces were rich proximate, i.e., crude protein, total fat and fibre, which can be utilized in future breeding programmes to improve nutritional value of existing high yielding rice varieties.

This study further throws light on useful traits of vast genetic resources of this country. Therefore, it is suggested that the proper characterization and evaluation of the land races would greatly benefit the farmers, breeders to tailor the breeding programme to develop high yielding, nutritionally rich and quality rice and finally to the consumers.

Chapter I

INTRODUCTION

“Rice is life” was the famous theme of International Year of Rice, 2004 denoting its overwhelming importance as an item of staple 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).

Global paddy production in 2016 reached 751.9 million tonnes (499.2 m.t., milled basis). The upturn was made possible by a normal climatic unfolding of the season, which permitted various northern-hemisphere producers that had been struck by adverse weather in the previous two years to reclaim lands for paddy cultivation. This was especially the case in Asia, which is set to lead the global recovery, garnering a record of 680.1 million tonnes (Food and Agricultural Organisation of United Nations, April 2017).

In India, rice is cultivated in an area of nearly 43.97 million hectares with an annual production of 105.23 million tones and productivity of 2461 kg ha⁻¹, while in Telangana, rice is grown in an area of 2.2 million hectares with an annual production and productivity of 6.62 million tonnes and 1334 kg ha⁻¹, respectively (Directorate of Economics and Statistics, Ministry of Agriculture, India, 2015-16).

Rice is grown under diverse eco-geographical conditions in various tropical and subtropical countries. 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 23 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 for this useful traits.

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 rich variability of complex quantitative traits with respect to maturity, growing adaptation and with respect to their physico-chemical 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 rationale 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 diversity for yield and yield components including nutritional and quality parameters of land races of rice.
2. To correlate the character association of yield, nutritional cum quality parameters.
3. To investigate the biochemical properties (proximate principles) of selected land races having variability for yield, nutritional and quality traits.

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. 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 pleiotropy 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., days to 50% flowering, plant height, panicle number per hill, grain weight per panicle 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 important 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 the 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 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 *et al.*, 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 number of 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. 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 farmer's 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. Thirty 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 ten 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, physico-chemical properties of milled rice of 60 farmer's 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.

Seven hundred eighty two rice germplasm accessions were characterized using morpho-agronomic descriptors according to DUS guidelines (Sarawgi *et al.* (2013). 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) characterized 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.

Roy and Sharma (2014) characterized 84 landraces collected from various agro-ecological regions of West Bengal and adjoining areas based on qualitative and quantitative agro-morphological descriptors along with zinc (Zn) and iron (Fe) content. Dendrogram showed that there is enough genetic diversity among these landraces by grouping them into five major clusters and this information can be helpful

to the breeders to choose the right parent for crop improvement.

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

Anjan Kumar Sinha *et al.* (2015) found a wide variation of grain morphological characters like grain size and shape, anthocyanin colouration of lemma-palea and kernel, presence or absence of aroma, awning characteristics among 55 traditional rice varieties of West Bengal mostly from the lateritic region.

Keshavulu *et al.* (2015) characterized 24 elite Indian rice varieties based on 24 agro-morphological traits into five major clusters. Cluster analysis based on both phenotype and SSR marker data did not show perfect congruence between the two measures of genetic diversity. However, the correlation between morphological and molecular diversity was positive and significant ($r = 0.36$ $P < 10^{-4}$) indicating usefulness in classification of rice varieties.

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) Rita Bisne <i>et al.</i> (2009) Seyoum <i>et al.</i> (2012)
	Moderate	Moderate	Singh <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Sravan <i>et al.</i> (2014) Shrivastava <i>et al.</i> (2015)
	Low	Low	Sinha <i>et al.</i> (2004) Patil <i>et al.</i> (2005) Vijayalakshmi <i>et al.</i> (2008) Manoj kumar <i>et al.</i> (2011) Sravan <i>et al.</i> (2012) Prasad <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Suresh <i>et al.</i> (2014b) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)
Stem length (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)
	Low	Low	Kole <i>et al.</i> (2008) Pandey <i>et al.</i> (2012) Prasad <i>et al.</i> (2013)

Character	Coefficient of variation		References
	PCV	GCV	
Panicle length (cm)	High	High	Tripathi <i>et al.</i> (1999) Nayudu <i>et al.</i> (2007) Rahman <i>et al.</i> (2014) Sachan <i>et al.</i> (2015)
	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) Rahman <i>et al.</i> (2014)
Panicle length (cm)	Low	Low	Kole <i>et al.</i> (2008) Padmaja <i>et al.</i> (2008) Singh <i>et al.</i> (2011) Manoj kumar <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) Sravan <i>et al.</i> (2014) Suresh <i>et al.</i> (2014b) Gampala <i>et al.</i> (2015) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015).

Character	Coefficient of variation		References
	PCV	GCV	
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) Dhurai <i>et al.</i> (2014) suresh <i>et al.</i> (2014a) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015)
	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)
Spikelet fertility (%)	High	High	Saravan and Senthil (1997)
	Low	Low	Kole <i>et al.</i> (2008) Saidaiah <i>et al.</i> (2010) Pandey <i>et al.</i> (2012)

Character	Coefficient of variation		References
	PCV	GCV	
Single plant yield (g)	High	High	Suman (2003) Nayudu <i>et al.</i> (2007) Padmaja <i>et al.</i> (2008) Anbanandan <i>et al.</i> (2009) Chandra <i>et al.</i> (2009a) Garg <i>et al.</i> (2010) 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) Suresh <i>et al.</i> (2014a) Allam <i>et al.</i> (2015) Bhati <i>et al.</i> (2015) Gampala <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Karande <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015)
	Moderate to high	Moderate to high	Saidaiah <i>et al.</i> (2010) Pandey <i>et al.</i> (2012) Sameera <i>et al.</i> (2015)
Single plant yield (g)	Moderate	Moderate	Kole <i>et al.</i> (2008) Parray and Shikari (2008) Adilakshmi <i>et al.</i> (2012)
	Low	Low	Babu <i>et al.</i> (2012)

Character	Coefficient of variation		References
	PCV	GCV	
1000-grain weight (g)	High	High	Chaubey and Singh (1994) Sawant <i>et al.</i> (1994) Mani <i>et al.</i> (1997) Patil and Sarawgi (2003) Nayudu <i>et al.</i> (2007) Parikh <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)
	Moderate	Moderate	Dhurai <i>et al.</i> (2014) Suresh <i>et al.</i> (2014)a Shekawat <i>et al.</i> (2015)
	Low	Low	Satyavathi <i>et al.</i> (2001) Sravan <i>et al.</i> (2014)
Decorticated grain: length (mm)	High	High	Singh <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)
	Moderate	Moderate	Roy <i>et al.</i> (2009) Bekele <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013)
	Low	Low	Veerabhadhiran <i>et al.</i> (2009) Sala <i>et al.</i> (2015)
Decorticated grain: width (mm)	High	High	Singh <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013)
	Moderate	Moderate	Veerabhadhiran <i>et al.</i> (2009)
	Low	Low	Vanisree <i>et al.</i> (2013) Sala <i>et al.</i> (2015)
Amylose content (%)	High	High	Vanaja and Babu (2006) Basavaraja <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Allam <i>et al.</i> (2015)

Character	Coefficient of variation		References
	PCV	GCV	
	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	Subudhi <i>et al.</i> (2009) Rajeswari <i>et al.</i> (2010) Devi <i>et al.</i> (2015)
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 here under

Character	Range		References
	Heritability	Genetic advance	
Time of heading (50% plants with panicles)	High	High	Madhavalatha (2002) Nayak <i>et al.</i> (2002) Sandhyakishore (2005) Sankar <i>et al.</i> (2006) Bharadwaj <i>et al.</i> (2007) Kishore <i>et al.</i> (2008) Gampala <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)
	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)
Stem length (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)
	High	Moderate	Nayak <i>et al.</i> (2002) Suman (2003) Parikh <i>et al.</i> (2011)

Character	Range		References
	Heritability	Genetic advance	
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) Dhurai <i>et al.</i> (2014) Karande <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)
	Moderate	Moderate	Anbanandan <i>et al.</i> (2009) Nandan <i>et al.</i> (2010) Immanuel Selvaraj <i>et al.</i> (2011) Singh <i>et al.</i> (2011) Gangashetty <i>et al.</i> (2013)
	Low	Low	Rajendar reddy <i>et al.</i> (2013) Singh <i>et al.</i> (2013) Mohan <i>et al.</i> (2015)
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)

Character	Range		References
	Heritability	Genetic advance	
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) Dhurai <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Karande <i>et al.</i> (2015)
	Moderate	Moderate	Singh <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012)
Spikelet fertility (%)	High	High	Satyanarayana <i>et al.</i> (2005)
	High	Moderate	Saravan and Senthil (1997)
	High	Low	Madhavalatha <i>et al.</i> (2005)

Character	Range		References
	Heritability	Genetic advance	
Single plant yield (g)	High	High	Nayudu <i>et al.</i> (2007) Anbanandan <i>et al.</i> (2009) Garg <i>et al.</i> (2010) Yadav <i>et al.</i> (2010) Parikh <i>et al.</i> (2011) Mohanty <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) Dhurai <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Karande <i>et al.</i> (2015)
Single plant yield (g)	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) Mohan <i>et al.</i> (2015)
1000 - grain weight (g)	High	High	Parikh <i>et al.</i> (2011) Fiyaz <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012) Dhurai <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Gampala <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015)
	High	Moderate	Suman (2003)

Character	Range		References
	Heritability	Genetic advance	
	Moderate	Moderate	Seyoum <i>et al.</i> (2012)
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)
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)
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)
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)

Character	Range		References
	Heritability	Genetic advance	
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 D^2 statistics (Mahalanobis, 1936), 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 rainfed rice and grouped them into five clusters. Plant height and grain yield contributed considerably (85 %) to the total divergence. The geographical diversity was not found to be related to genetic diversity.

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 per panicle and grain yield per plant, while cluster VI scored highest value for productive tillers per plant and panicle length.

Sardana *et al.* (1997) evaluated the genetic divergence in eighty two local rice varieties of Tripura, using D^2 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 D^2 statistics 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. Clusters 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 D^2 statistics 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 divergence among 45 genotypes 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, Himalayas. On the basis of D^2 values, they were grouped into twelve clusters. The highest contribution towards total divergence was rendered by total grains per panicle, followed by fertile grains per panicle, 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 statistics. 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 clusters 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 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 had desired mean for characters like hulling %, milling %, head rice recovery and panicle length; cluster VII had high value for kernel length and L/B ratio and cluster V with 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 ten clusters. The cluster I had highest cluster mean for head rice recovery, while cluster IX exhibited highest L/B ratio and lowest kernel breadth. They concluded that 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 statistics. 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 per panicle, number of panicles per plant, biomass index and grain yield contributed considerably towards total divergence.

Mohanty *et al.* (2010) studied 40 rice genotypes using Mahalanobis D^2 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 per panicle 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 D^2 statistics. On the basis of D^2 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 D^2 statistics (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.

Narendra pratap *et al.* (2011) assessed the genetic divergence in 104 genotypes of rice comprising aromatic as well as non-aromatic germplasm lines by using Non-hierarchical Euclidean cluster analysis. The 104 genotypes were grouped into 11 distinct clusters. Clustering pattern of genotypes showed lack of relationship between geographic origin and genetic diversity. The crossing between superior genotypes of above diverse cluster pairs may provide desirable transgressive segregants for developing high yielding rice varieties of aromatic and non-aromatic rice types.

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 farmer's 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 (2013) evaluated 51 landraces of rice based on 18 agro-morphological and 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 to 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 between clusters III and 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.

Anuradha *et al.* (2012) analyzed brown rice of 126 accessions including seven accessions of two wild species for iron and zinc concentration. Iron concentration ranged from 6.2 ppm to 71.6 ppm and zinc from 26.2 ppm to 67.3 ppm. Zinc concentration and grain elongation (-0.25) were significantly correlated. The wild accessions had the highest iron and zinc.

Jagadeesh *et al.* (2013) conducted a trial for three seasons in the same location with nine cultures including one local check. Obvious differences in Fe and Zn contents were noticed among the genotypes tested, suggesting the role of genetic potential in increasing the content of these micronutrients in rice grains without any negative impact on yield.

Kumar *et al.* (2013) grouped 73 genotypes of rice into nine 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 D^2 analysis, the 24 rice genotypes were grouped into six clusters. Grouping of most of the landraces of Goa

and few improved cultivars of rice into one cluster i.e., 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.

Subbarao *et al.* (2014) studied the genetic divergence in 57 farmers' varieties from the eastern region of the country using Mahalanobis D^2 statistics. The genotypes were grouped into 12 clusters, of which cluster I, III, II were the major clusters. Cluster III showed maximum intra cluster divergence while inter cluster divergence was maximum between clusters IX and X. Traits viz., gelatinization temperature, grain aroma, endosperm content of amylose, presence of amylose and decorticated grain colour were the major contributors to genetic divergence.

Lingaiah *et al.* (2014) studied sixty four mid early group genotypes of rice for genetic diversity for yield and yield contributing characters and grouped into 11 clusters. The pattern of distribution of genotypes into different clusters was at random. Plant height contributed maximum towards genetic divergence followed by days to 50% flowering. The maximum inter cluster distance was observed between clusters IV and VII (182.08) followed by clusters I and IV (169.94).

Sindhumole *et al.* (2015) studied sixty four mid early rice genotypes of diverse origin, with three check varieties viz., IR 64 (National), MTU 1010 (Southern Regional) and Jyothi (Local), under irrigated wet land conditions. The highest heritability was observed for plant height (96.71) followed by panicle length (90.57). However, grain yield exhibited the lowest heritability (54.74) among all the traits. Positive association existed among all the traits. Grain yield was highly associated with plant height and panicle length. The top yielding genotypes identified in the study were MTU 1155, UPRI 2012-18, HKR 08-62 and RNR 10294.

Mohan *et al.* (2015) evaluated 43 genotypes derived through pedigree method

of breeding involving 11 divergent parents using D^2 studies. Highest inter cluster distance (8.69) was observed between clusters II & V followed by clusters II & III (7.87) suggesting wide diversity between traits. Among the traits studied, test weight and days to flowering contributed the highest. They concluded that the genotypes grouped in cluster II could be crossed with the genotypes, JGL 21002 and JGL 21005 of cluster III to derive transgressive segregants for improvement of seed yield, number of grains per panicle and test weight.

Devi *et al.* (2015) evaluated 92 rice cultivars using Mahalanobis D^2 statistics. Based on cluster analysis, the genotypes were grouped into ten clusters of which clusters VII and IX were the largest clusters consisting of 16 genotypes each, while cluster V was the smallest with only a single genotype. The maximum intra cluster distance ($D = 14066.5$) was found in cluster VI consisting of two traditional varieties AS 100 and Chittimutyalu. The most divergent clusters found were clusters V and VI. Minimum inter cluster distance ($D = 5144.43$) was found between clusters VIII and IX. Amylose content, gel consistency, 1000 grain weight and head rice recovery were found to be the most contributing traits towards genetic diversity.

Rao *et al.* (2015) studied genetic relatedness among 57 farmers' varieties of rice from the eastern region of the country using 48 distinct rice microsatellite markers. Cluster analysis was done based on molecular markers and morphological characteristics separately. Dendrogram based on molecular markers revealed three major groups among 57 farmers' varieties which are again sub clustered into small groups. The genotype Samudra Bali was found to be in a distant cluster from the rest of the genotypes. The study helped to understand the extent of genetic diversity among the farmers' varieties which are a potential source that can be exploited.

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

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) Rashid <i>et al.</i> (2014) Islam <i>et al.</i> (2015)
	Positive non- significant	Madhavalatha <i>et al.</i> (2005) Chandra <i>et al.</i> (2009b) Satish <i>et al.</i> (2009) Nandan <i>et al.</i> (2010) Rao <i>et al.</i> (2014) Kishore <i>et al.</i> (2015)
	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) Anil <i>et al.</i> (2015)
	Negative non-significant	Meenakshi <i>et al.</i> (1999) Nagaraju <i>et al.</i> (2013)

Character	Nature of association	Reference
Stem length (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)
	Positive non-significant	Suman (2003) Madhavalatha <i>et al.</i> (2005) Karad and Pol (2008) Nandan <i>et al.</i> (2010) Kishore <i>et al.</i> (2015)
	Negative significant	Satyavathi <i>et al.</i> (2001) Mahto <i>et al.</i> (2003) Babu <i>et al.</i> (2012) Sharma <i>et al.</i> (2012) Nagaraju <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Rao <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Anil <i>et al.</i> (2015)
	Negative non-significant	Meenakshi <i>et al.</i> (1999) Chandra <i>et al.</i> (2009b) Satish <i>et al.</i> (2009) Seyoum <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	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) Patel <i>et al.</i> (2014) Rao <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Anil <i>et al.</i> (2015) Biswash <i>et al.</i> (2015) Madakemohekar <i>et al.</i> (2015) Sala <i>et al.</i> (2015) Vijay kumar (2015a)
	Positive non-significant	Suman (2003) Madhavalatha <i>et al.</i> (2005) Seyoum <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)
	Negative non-significant	Satish <i>et al.</i> (2009) Nandan <i>et al.</i> (2010) Seyoum <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Rahman <i>et al.</i> (2014)

Character	Nature of association	Reference
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) Patel <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Rao <i>et al.</i> (2014) Biswash <i>et al.</i> (2015) Madakemohekar <i>et al.</i> (2015) Vijay kumar (2015b)
	Positive non-significant	Suman (2003) Madhavalatha <i>et al.</i> (2005) Krishna <i>et al.</i> (2008) Seyoum <i>et al.</i> (2012) Kishore <i>et al.</i> (2015)
	Negative significant	Nandan <i>et al.</i> (2010) Sharma <i>et al.</i> (2012) Rahman <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Anil <i>et al.</i> (2015)
	Negative non-significant	Sandhyakishore (2005) Rao <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Rashid <i>et al.</i> (2014)

Character	Nature of association	Reference
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) Patel <i>et al.</i> (2014) Rao <i>et al.</i> (2014) Islam <i>et al.</i> (2015) Kishore <i>et al.</i> (2015)
	Positive non-significant	Madhavalatha <i>et al.</i> (2005) Nandan <i>et al.</i> (2010) Rahman <i>et al.</i> (2014) Rashid <i>et al.</i> (2014)
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)

Character	Nature of association	Reference
1000 - grain weight (g)	Positive significant	Ekka <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2011) Zulqarnainhaidr and Zia (2012) Patel <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Rao <i>et al.</i> (2014) Rashid <i>et al.</i> (2014) Anil <i>et al.</i> (2015) Madakemohekar <i>et al.</i> (2015) Sala <i>et al.</i> (2015)
	Positive non-significant	Suman (2003) Madhavalatha <i>et al.</i> (2005) Rahman <i>et al.</i> (2014) Kishore <i>et al.</i> (2015)
	Negative significant	Suman (2003) Islam <i>et al.</i> (2015)
	Negative non-significant	Seyoum <i>et al.</i> (2012) Singh <i>et al.</i> (2014)
Decorticated grain: length (mm)	Positive significant	Mohanty <i>et al.</i> (2012)
	Negative significant	Krishna <i>et al.</i> (2008)
Decorticated grain: width (mm)	Negative significant	Krishna <i>et al.</i> (2008).
Amylose content (%)	Positive significant	Basavaraja <i>et al.</i> (2012)
	Positive non-significant	Bhattacharyya <i>et al.</i> (2007)
	Negative significant	Garg <i>et al.</i> (2010)
	Negative non-significant	Petchiammal and Kumar (2007)

Character	Nature of association	Reference
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
Stem length (cm)	Positive significant	Madhavalatha (2002) Babu <i>et al.</i> (2012) Anil <i>et al.</i> (2015)
	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) Rao <i>et al.</i> (2014)
Number of productive tillers per plant	Positive significant	Sawant <i>et al.</i> (1995) Sakthivel (2001) Rao <i>et al.</i> (2014)
	Positive non-significant	Raju (2002) Chandra <i>et al.</i> (2009b) Satish <i>et al.</i> (2009)
	Negative significant	Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Lakshmi (2012) Hasan <i>et al.</i> (2013) Reddy <i>et al.</i> (2013)

Character	Nature of association	Reference
Number of productive tillers per plant	Negative non-significant	Yolanda and Das (1995) Meenakshi <i>et al.</i> (1999) Madhavalatha (2002) Babu <i>et al.</i> (2012)
Panicle length (cm)	Positive significant	Madhavalatha (2002) Suman (2003) Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012) Anil <i>et al.</i> (2015)
	Positive non-significant	Sawant <i>et al.</i> (1995) Kavitha and Reddi (2001)
	Negative significant	Nandan <i>et al.</i> (2010) Rao <i>et al.</i> (2014)
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) Rao <i>et al.</i> (2014)
	Positive non-significant	Yolanda and Das (1995) Satish <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)
	Negative significant	Yadav and Kumar (2012)
	Negative non-significant	Meenakshi <i>et al.</i> (1999)
1000 - grain weight (g)	Positive significant	Yolanda and Das (1995)
	Positive non-significant	Roy <i>et al.</i> (1995)
	Negative significant	Nayak <i>et al.</i> (2001) Sakthivel (2001) Rao <i>et al.</i> (2014)
	Negative non-significant	Satish <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)
Spikelet fertility (%)	Positive significant	Hasan <i>et al.</i> (2013)

Character	Nature of association	Reference
	Positive non-significant	Rao and Shrivastav (1999)
Spikelet fertility (%)	Negative significant	Yolanda and Das (1995)
	Negative non-significant	Madhavalatha (2002)
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)
Amylose content (%)	Positive significant	Basavaraja <i>et al.</i> (2011)

2.5.3. Association of the yield component traits and grain quality parameters with stem length

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Sakthivel (2001) Raju (2002) Chandra <i>et al.</i> (2009b)
	Positive non-significant	Rao <i>et al.</i> (2014)
	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) Biswash <i>et al.</i> (2015)

Character	Nature of association	Reference
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) Kishore <i>et al.</i> (2015) Anil <i>et al.</i> (2015) Vijay kumar (2015b)
	Positive non- significant	Raju (2002)
Panicle length (cm)	Negative significant	Bala (2001) 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) Rahman <i>et al.</i> (2014)
	Positive non-significant	Meenakshi <i>et al.</i> (1999) Kavitha and Reddi (2001) Abdus <i>et al.</i> (2009)
	Negative significant	Raju (2002) Akhtar <i>et al.</i> (2011) Rao <i>et al.</i> (2014)
	Negative non-significant	Nandan <i>et al.</i> (2010)
Spikelet fertility (%)	Negative significant	Padmaja <i>et al.</i> (2011)
1000-seed weight (g)	Positive significant	Suman (2003) Yogameenakshi <i>et al.</i> (2004) Anil <i>et al.</i> (2015) Biswash <i>et al.</i> (2015)
	Positive non-significant	Satish <i>et al.</i> (2009)

Character	Nature of association	Reference
	Negative significant	Padmaja <i>et al.</i> (2011) Rao <i>et al.</i> (2014) Rahman <i>et al.</i> (2014)
	Negative non-significant	Nayak <i>et al.</i> (2001)
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)	Positive significant	Krishna <i>et al.</i> (2008)
Grain iron and zinc concentrations (mg/kg)	Positive significant	Gangashetty <i>et al.</i> (2013)

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

Character	Nature of association	Reference
Panicle length	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) Satish <i>et al.</i> (2009) Rao <i>et al.</i> (2014)
	Negative significant	Suman (2003) Babu <i>et al.</i> (2012) Rahman <i>et al.</i> (2014) Anil <i>et al.</i> (2015)
	Negative non-significant	Abdus <i>et al.</i> (2009)

Character	Nature of association	Reference
Stem length (cm)	Positive significant	Meenakshi <i>et al.</i> (1999) Janardhanam <i>et al.</i> (2001) Sakthivel (2001) Rahman <i>et al.</i> (2014) Sala <i>et al.</i> (2015)
	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) Suman (2003) Rao <i>et al.</i> (2014)
	Negative non-significant	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Satish <i>et al.</i> (2009)
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)
1000 - grain weight (g)	Positive significant	Suryanarayana (2000) Sakthivel (2001) Anil <i>et al.</i> (2015)
	Positive non-significant	Kavitha and Reddi (2001) Satyavathi <i>et al.</i> (2001)
	Negative significant	Nayak <i>et al.</i> (2001) Padmaja <i>et al.</i> (2011) Rahman <i>et al.</i> (2014)
	Negative non-significant	Sathish <i>et al.</i> (2009) Babu <i>et al.</i> (2012)

Character	Nature of association	Reference
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)

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

Character	Nature of association	Reference
Number of productive tillers per plant	Positive significant	Bala (2001) Rajendarreddy <i>et al.</i> (2013)
	Negative significant	Babu <i>et al.</i> (2012) Rahman <i>et al.</i> (2014) Biswash <i>et al.</i> (2015)
Total number of grains per panicle	Positive significant	Chandra <i>et al.</i> (2009b) Padmaja <i>et al.</i> (2011) Vijay kumar (2015b)
	Positive non-significant	Satyavathi <i>et al.</i> (2001) Rahman <i>et al.</i> (2014)
	Negative significant	Rao <i>et al.</i> (2014)
	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)
1000 – grain weight (g)	Positive significant	Meenakshi <i>et al.</i> (1999) Yogameenakshi <i>et al.</i> (2004) Babu <i>et al.</i> (2012) Prem kumar <i>et al.</i> (2015)

Character	Nature of association	Reference
	Positive non-significant	Kavitha <i>et al.</i> (2001) Satish <i>et al.</i> (2009) Nandan <i>et al.</i> (2010)
	Negative significant	Rao <i>et al.</i> (2014)
	Negative non-significant	Nayak <i>et al.</i> (2001)
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)
Gel consistency (mm)	Positive significant	Sravan <i>et al.</i> (2012)

2.5.6 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)
1000-grain weight (g)	Positive significant	Meenakshi <i>et al.</i> (1999) Rao <i>et al.</i> (2014)
	Positive non-significant	Satish <i>et al.</i> (2009) Rao <i>et al.</i> (2014)
	Negative significant	Nayak <i>et al.</i> (2001) Menaka and Ibrahim (2015)
	Negative non-significant	Kavitha and Reddi (2001) Nandan <i>et al.</i> (2010)

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

Character	Nature of association	Reference
1000- grain weight (g)	Positive significant	Padmaja <i>et al.</i> (2011)

2.5.8 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)
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)

2.5.9 Association of grain quality parameters with decorticated grain: width

Character	Nature of association	Reference
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 amylose content (%)

Character	Nature of association	Reference
Gel consistency (mm)	Positive non-significant	Shivani <i>et al.</i> (2008)
	Negative significant	Khatun <i>et al.</i> (2003)

2.4.11 Association of yield component traits with grain zinc concentration

Character	Nature of association	Reference
1000 - grain weight (g)	Positive non-significant	Bekele <i>et al.</i> (2013)

2.5.12 Association of grain iron concentration with grain zinc concentration

Character	Nature of association	Reference
Grain zinc concentration (mg/kg)	Positive significant	Patil (2008)
	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
Stem: length (excluding panicle)	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) Mohanty <i>et al.</i> (2012) Seyoum <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Rahman <i>et al.</i> (2014) Kishore <i>et al.</i> (2015) Islam <i>et al.</i> (2015)	Satyavathi <i>et al.</i> (2001) Suman (2003) Karad and Pol (2008) Chandra <i>et al.</i> (2009b) Akhtar <i>et al.</i> (2011) Thirumala rao <i>et al.</i> (2014)
Number of productive tillers per plant	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) Rao <i>et al.</i> (2014) Lingaiah <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) ThirumalarRao <i>et al.</i> (2014) Anil <i>et al.</i> (2015)	Kavitha and Reddi (2001) Yadav <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012)

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) Kishore <i>et al.</i> (2015)	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) Patel <i>et al.</i> (2014) Rao <i>et al.</i> (2014)
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) Lingaiah <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Thirumala Rao <i>et al.</i> (2014) Anil <i>et al.</i> (2015) Madakemohekar <i>et al.</i> (2015)	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) Patel <i>et al.</i> (2014) Kishore <i>et al.</i> (2015)
Total number of grains per panicle	Nandan <i>et al.</i> (2010) Padmaja <i>et al.</i> (2011) Yadav <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Nagaraju <i>et al.</i> (2013) Rao <i>et al.</i> (2014) Menaka and Ibrahim (2015) Kishore <i>et al.</i> (2015) Islam <i>et al.</i> (2015)	Akhtar <i>et al.</i> (2011) Babu <i>et al.</i> (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)
1000-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) Rahman <i>et al.</i> (2014) Menaka and Ibrahim (2015) Kishore <i>et al.</i> (2015)	Karad and Pol (2008) Garg <i>et al.</i> (2010) Basavaraja <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012) Babu <i>et al.</i> (2012) Patel <i>et al.</i> (2014)
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 <i>et al.</i> (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)	---
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) Sala <i>et al.</i> (2015)	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
Stem length (cm)	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) Ekka <i>et al.</i> (2015)
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) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	Meenakshi <i>et al.</i> (1999) Kavitha and Reddi (2001) Padmaja <i>et al.</i> (2011) Basavaraja <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) Ekka <i>et al.</i> (2015)	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) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	Satish <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Yadav and Kumar (2012)
Spikelet fertility (%)	---	Madhavalatha (2002)
1000 - grain weight (g)	Madhavalatha (2002) Rahman <i>et al.</i> (2014)	Satish <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011)
Decorticated grain: Length (mm)	Yadav and Kumar (2012)	Nayak <i>et al.</i> (2001) Bhadru <i>et al.</i> (2012)
Decorticated grain: Width (mm)	Yadav and Kumar (2012)	-

2.6.2.2 Indirect effects of stem length 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) Ekka <i>et al.</i> (2015)	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) Ekka <i>et al.</i> (2015)	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) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	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) Rahman <i>et al.</i> (2014)	Kole <i>et al.</i> (2008) Pandey <i>et al.</i> (2012) Yadav and Kumar (2012)
Spikelet fertility (%)	Madhavalatha (2002)	---

Character	Positive indirect effect	Negative indirect effect
1000-grain weight (g)	Satish <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	Nayak <i>et al.</i> (2001) Suman (2003) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012)
Decorticated grain: length (mm)	Mohanty <i>et al.</i> (2012) Yadav and Kumar (2012)	---
Decorticated grain: width (mm)	Yadav and Kumar (2012)	---

2.6.2.3 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>	Kavitha and Reddi (2001) Yadav <i>et al.</i> 2010) Babu <i>et al.</i> (2012)
Stem length (cm)	Janardhanam <i>et al.</i> (2001) Madhavalatha (2002) Yadav <i>et al.</i>	Chandra <i>et al.</i> (2009b) Babu <i>et al.</i> (2012)
Panicle length (cm)	Madhavalatha (2002) Padmaja <i>et al.</i> (2011) Basavaraja <i>et al.</i> (2011) Gangashetty <i>et al.</i> (2013)	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Yadav <i>et al.</i> 2010) Babu <i>et al.</i> (2012) Ekka <i>et al.</i> 2015)
Total number of grains per panicle	Satyavathi <i>et al.</i> (2001) Sandhyakishore (2005) Satish <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Mulugetasyoum <i>et al.</i> (2012)	Nayak <i>et al.</i> (2001) Madhavalatha 2002) Yadav <i>et al.</i> (2010) Babu <i>et al.</i> (2012)
Spikelet fertility (%)	Madhavalatha (2002)	---
1000-grain weight (g)	Nagajyothi (2001) Satyavathi <i>et al.</i> (2001)	Madhavalatha (2002) Satish <i>et al.</i> (2009) Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012)
Decorticated grain: length (mm)	Mohanty <i>et al.</i> (2012) Yadav and Kumar (2012)	Madavilatha (2002)
Decorticated grain: width (mm)	Mohanty <i>et al.</i> (2012) Yadav and Kumar (2012)	-----

2.6.2.4 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) Satish <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)	Padmaja <i>et al.</i> (2011)
Stem length (cm)	Satish <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)	Janardhanam <i>et al.</i> (2001) Satyavathi <i>et al.</i> (2001) Yadav <i>et al.</i> (2010) Ekka <i>et al.</i> (2015)
Number of productive tillers per plant	Nayak <i>et al.</i> (2001) Sankar <i>et al.</i> (2006) Padmaja <i>et al.</i> (2011) Mohanty <i>et al.</i> (2012) Reddy <i>et al.</i> (2013) Rahman <i>et al.</i> (2014)	Satyavathi <i>et al.</i> (2001) Madhavalatha (2002) Babu <i>et al.</i> (2012) Bhadru <i>et al.</i> (2012)
Total number of grains per panicle	Satyavathi <i>et al.</i> (2001) Madhavalatha (2002) Sankar <i>et al.</i> (2006) Yadav <i>et al.</i> (2010) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	Kole <i>et al.</i> (2008) Satish <i>et al.</i> (2009) Pandey <i>et al.</i> (2012) Reddy <i>et al.</i> (2013)
Spikelet fertility (%)	Madhavalatha (2002)	---
1000 - grain weight (g)	Nagajyothi (2001) Madhavalatha (2002) Basavaraja <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)	Nayak <i>et al.</i> (2001) Satish <i>et al.</i> (2009) Ekka <i>et al.</i> (2015)
Decorticated grain: length (mm)	Mohanty <i>et al.</i> (2012)	---

2.6.2.5. 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)	Madhaviatha (2002) Sandhyakishore 2005) Sankar <i>et al.</i> (2006) Kole <i>et al.</i> (2008) Padmaja <i>et al.</i> (2011) Sharma <i>et al.</i> (2012) Ekka <i>et al.</i> (2015)	Kavitha and Reddi (2001) Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011) Bhadru <i>et al.</i> (2012)
Stem length (cm)	Nayak <i>et al.</i> (2001) Madhaviatha (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) Ekka <i>et al.</i> (2015)
Number of productive tillers per plant	Akhtar <i>et al.</i> (2011) Rahman <i>et al.</i> (2014)	Nayak <i>et al.</i> (2001) Madhaviatha (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) Rajamadhan <i>et al.</i> (2011) Rahman <i>et al.</i> (2014) Ekka <i>et al.</i> (2015)	Nayak <i>et al.</i> (2001) Madhaviatha (2002) Kole <i>et al.</i> (2008) Bhadru <i>et al.</i> (2012)
Spikelet fertility (%)	Madhaviatha (2002)	---
Decorticated grain: length (mm)	Madaviatha (2002)	Nayak <i>et al.</i> (2001)
1000-grain weight (g)	Akhtar <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Rahman <i>et al.</i> (2014)	Satyavathi <i>et al.</i> (2001) Ekka <i>et al.</i> (2015)

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

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

2.6.2.7 Indirect effects of 1000-grain weight on single plant yield through

Character	Positive indirect effect	Negative indirect effect
Time of heading (Days to 50% flowering)	Nayak <i>et al.</i> (2001) Satish <i>et al.</i> (2009)	Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012)
Stem length (cm)	Nagajyothi (2001) Rajamadhan <i>et al.</i> (2011) Babu <i>et al.</i> (2012) Rahman <i>et al.</i> (2014)	Satish <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)
Number of productive tillers per plant	Nagajyothi (2001) Satyavathi <i>et al.</i> (2001) Rahman <i>et al.</i> (2014)	Satish <i>et al.</i> (2009) Rajamadhan <i>et al.</i> (2011) Padmaja <i>et al.</i> (2011) Babu <i>et al.</i> (2012)
Panicle length (cm)	Padmaja <i>et al.</i> (2011) Rajamadhan <i>et al.</i> (2011) Rahman <i>et al.</i> (2014)	Satish <i>et al.</i> (2009) Babu <i>et al.</i> (2012)
Total number of grains per panicle	Satish <i>et al.</i> (2009) Padmaja <i>et al.</i> (2011)	Nayak <i>et al.</i> (2001) Rajamadhan <i>et al.</i> (2011)

2.6.2.8. 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)	Madavilatha (2002) Krishna <i>et al.</i> (2008) Yadav and Kumar (2012)	---
Stem length (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)

2.6.2.9 Indirect effects of grain iron concentration on single plant yield through

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

2.7 PROXIMATE COMPOSITION

Proximate analysis is defined by H. Bennett in the *Concise Chemical and Technical Dictionary* as the “determination of a group of closely related components together, e.g. total protein, fat.” It conventionally includes determinations of the amount of water (moisture content), protein, fat (ether extract), ash and fiber, with nitrogen-free extract (sometimes termed Nifext) being estimated by subtracting the sum of these five percentages from 100. In order to emphasize the group nature of the percentage of protein, fat and fiber, many chemists use the word “crude” before these three terms.

Moisture, crude protein, total fat, fiber and ash are commonly referred to as proximates since their sum totals approximately 100% of many feed stuffs. Missing from this approximation are several carbohydrates and other minor components.

Deka (1998) analyzed the nutritional characteristics of rice varieties and reported that moisture content varied from 11.15 to 11.29, protein 7.86 to 8.41, crude fibre 0.46 to 0.92, fat 1.15 to 1.21 and ash 0.96 to 1.14 per cent. Cameron and Wang (2005) recorded the per cent composition of milled rice cultivars in the range of 6.6 to 9.3, 0.18 to 0.51 and 9.0 to 11.0 for crude protein, crude fat and moisture c

Chapter III

MATERIAL AND METHODS

The present experiment to study the genetic diversity among the landraces of rice was carried out during *kharif*, 2016-2017 at IIRR farm, ICRISAT campus, Patancheru, Hyderabad, India, situated at 17.53⁰ N latitude, 78.27⁰ E longitude and an altitude of 545 m above mean sea level. The material used, experimental design adopted, the mode of data collected and the statistical procedures followed in the present study are outlined below.

3.1 EXPERIMENTAL MATERIAL

The experimental material used in the present investigation comprised of seventy six landraces of rice obtained from the Plant Breeding Division, Crop Improvement Section, ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad. The details of landraces are furnished in Table 3.1.

3.2 METHODS

Seventy six 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 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 packages of practices were adopted besides providing necessary prophylactic plant protection measures to raise a good crop.

3.3 RECORDING OF OBSERVATIONS

Thirty characteristics which include eleven qualitative, eleven quantitative, five grain quality and nutritional traits and three biochemical parameters 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).

Eleven qualitative characters recorded were viz., basal leaf sheath colour, flag leaf attitude (late observation), culm attitude, lemma anthocyanin colouration of apex, stigma colour, stem anthocyanin colouration of nodes and internodes, density of pubescence, attitude of branches, panicle exertion and lemma and palea colour. A description of qualitative characters observed is given in Table 3.2.

3.3.2 Quantitative Traits

Data on eleven 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 per cent of plants in each plot and in each replication were in heading was recorded.

3.3.2.2 Stem thickness (cm)

Stem thickness was measured in centimeters at second node in each plant at the time of harvest with a vernier callipers.

3.3.2.3 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.

3.3.2.4 Panicle length (cm)

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

3.3.2.5. Number of productive tillers per plant

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

3.3.2.6. Leaf length (cm)

Leaf length was measured in centimetres from base of the leaf to the tip of the leaf in each plant at the time of booting stage with a measuring scale.

3.3.2.7 Leaf width (cm)

Leaf width was measured in centimetres at midpoint of the leaf at the time of booting stage with a measuring scale.

3.3.2.8. Total number of grains per panicle

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

3.3.2.9. 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.

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

3.3.2.10 1000-grain weight (g)

One thousand 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.

3.3.2.11 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) Early (71-90 days) Medium (91-110 days) Late (111-130 days) Very late (>130 days)	1 3 5 7 9	Half of inflorescence emerged
2.	Stem: length (excluding panicle; excluding floating rice)	Very short (<91 cm) Short (91-110 cm) Medium (111-130 cm) Long (131-150 cm) Very long (>150)	1 3 5 7 9	Milking stage
3.	Panicle length	Very short (<16 cm) Short (16-20 cm) Medium (21-25 cm) Long (26-30 cm) Very long (>30 cm)	1 3 5 7 9	Milking to ripening stage

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 millimeters 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 millimeters using dial micrometer.

3.3.3.3 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 1 ml 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 up to 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 six landraces of rice were classified into different groups as indicated in Table 3.4.

3.3.3.4 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 10 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 temperatures of 0-2⁰C for 20 minutes. Then the culture tubes were removed from the ice bath and laid horizontally 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

3.3.3.5 Grain iron and zinc concentrations (mg/kg)

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.

3.3.4 Biochemical Parameters (Proximate Principles)

Data on three biochemical properties (proximate) were collected as mentioned below.

3.3.4.1 Crude protein (%)

Estimation of crude protein was done by AOAC 992.23 - Generic combustion method using Leco FP-528 Nitrogen analyser.

3.3.4.2 Total fat (%)

Total fat was analysed by Gerhardt soxthern fat analyser by the method

described by Nancy J Thiex (2003) in Journal of AOAC International i.e., AOAC 2003.06.

3.3.4.3 Fibre (%)

Fibre was analysed by using AOAC official method 962.09 (Ceramic fibre filter method).

3.4 MORPHOLOGICAL CHARACTERIZATION AND STATISTICAL ANALYSIS

Morphological characterization of seventy six landraces of rice was carried out using seventeen DUS characters namely basal leaf sheath colour, length of leaf blade, width of leaf blade, flag leaf attitude (late observation), culm attitude, time of heading (50 % plants with panicles), lemma anthocyanin colouration of apex, stigma colour, stem length, stem anthocyanin colouration of nodes and internodes, density of pubescence, attitude of branches, panicle exertion, lemma and palea colour, decorticated grain length, width and amylose content and statistical analysis was carried out for using seventeen traits viz., length of leaf blade, width of leaf blade, stem thickness, stem length, number of productive tillers per plant, time of heading, panicle length, total number of grains per panicle, spikelet fertility, 1000-grain weight, single plant yield, decorticated grain length and decorticated grain width, amylose content, gel consistency, grain iron concentration and grain zinc concentration.

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 (Panse and Sukhatme, 1985)
2. Genotypic and phenotypic coefficients of variation (Falconer, 1981)
3. Heritability and genetic advance (Allard, 1960)
4. Estimation of genetic divergence using Mahalanobis's Generalized Distance (D^2)
5. Estimation of extent of association (Falconer, 1981).
6. Path coefficient analysis (Wright, 1921 and Dewey and Lu, 1959)

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
Replications	(r-1)	M's	M's/M'e
Treatments	(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,

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

3.4.2 Genotypic and Phenotypic Coefficients of Variance

The genotypic and phenotypic coefficients of variance 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).

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

Where,

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

σ^2_g = genotypic variance

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

σ^2_e = environmental variance

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

Low	:	0-30 %
Medium	:	30-60%
High	:	above 60 %

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).

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

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 per cent of mean was computed.

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

The range of genetic advance as per cent 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

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 were 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,

‘V’ = Wilk’s criterion

W = Determinant of error matrix and

S = Determinant of error + variety matrix

The significance of ‘V’ was tested by

$$P+Q+1$$

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

Where,

$$m = n - (p + q + 1)/2$$

p = number of characters (or) variables

q = number of genotypes-1 (or) degrees of freedom for population

n = degrees of freedom for error + genotypes at base of

natural log = 2.7183

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

3.4.4.2 Transformation of Correlated Variables

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

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

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

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 an 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 $\Sigma D^2/n$

Where,

ΣD^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:

NX100

$$\text{Percent contribution of character (X)} = \frac{\text{-----}}{M}$$

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).

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

Where,

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

$\text{Cov. } (x_i, x_j)_g$ 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

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

Where,

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

$\text{Cov. } (x_i, x_j)_p$ 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.

$$\begin{array}{rcl}
 r_{1y} & = & P_{1y}r_{11} + P_{2y}r_{12} + P_{3y}r_{13} \dots\dots\dots + P_{ny}r_{1n} \\
 r_{2y} & = & P_{1y}r_{21} + P_{2y}r_{22} + P_{3y}r_{23} \dots\dots\dots + P_{ny}r_{2n} \\
 \cdot & & \cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \quad \cdot \quad \quad \quad \cdot \\
 & & \\
 : & & : \quad \quad : \quad \quad : \quad \quad : \quad \quad : \\
 r_{ny} & = & P_{1y}r_{n1} + P_{2y}r_{n2} + P_{3y}r_{n3} \dots\dots\dots + P_{ny}r_{nn}
 \end{array}$$

Where;

1, 2 n = Independent variables y

= Dependant variable

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

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

The above equations can be written in matrix form as:

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

Then

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

Direct effects were as follows:

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

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

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

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

Where,

p_{ny} = Direct effect of x_n on Y

r_{ny} = Correlation coefficient of x_n on Y

p_{ny} = Direct effect of x_n on Y

r_{ny} = Correlation coefficient of x_n on Y

Chapter IV

RESULTS AND DISCUSSION

The present investigation is intended to evaluate seventy six 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 *Suis 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, easily 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 six landraces were characterized by using eighteen agro-morphological characters including eleven qualitative and eight quantitative traits viz., basal leaf sheath colour, flag leaf attitude (late observation), culm attitude, lemma anthocyanin colouration of apex, stigma colour, stem anthocyanin colouration of nodes and internodes, density of pubescence, attitude of branches, panicle exertion and lemma and palea colour, leaf blade length and width, time of heading (50% plants with panicles), stem length and thickness, panicle length, productive tillers per plant, 1000-grain weight (Table 4.1) and four grain quality characters namely decorticated grain length, width, gel consistency 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 Figs. 4.1 and 4.2, respectively.

4.1.1 Basal : leaf sheath colour

Characterization of seventy six landraces, on the basis of basal leaf sheath colour revealed that 55 landraces exhibited green basal leaf sheath colour, 17 showed light purple and remaining 4 landraces had uniform purple basal leaf sheath colour.

4.1.2 Leaf: length of blade (cm)

Seventy six landraces were classified as short (<30 cm), medium (30-45 cm) and long (>45 cm) based on the length of leaf blade. Most of landraces fall into long (45) followed by medium (20) and short (11) length of leaf blade categories.

4.1.3 Leaf: width of blade (cm)

Based on width of leaf blade seventy six landraces were characterized into three groups namely narrow (<1 cm), medium (1-2 cm) and broad (>2 cm), which comprised of twenty, fifty one and five landraces, respectively.

4.1.4 Flag leaf: attitude of the blade (late observation)

Experimental material possessed four different states of flag leaf attitude viz., erect, semi erect, horizontal and deflexed. Among the seventy six landraces under study, six were having erect flag leaf attitude, thirty three were having semi erect flag leaf attitude, while horizontal flag leaf attitude was exhibited by thirty five and finally only two landraces expressed deflexed flag leaf attitude.

4.1.5 Culm: attitude

Seventy six landraces were classified as erect, semi-erect, open and spreading based on the culm attitude. Most of landraces fall into semi-erect (46), followed by open (17), erect (9) and spreading (4) culm attitude categories.

4.1.6 Time of heading (50 % plants with panicles) (days)

The seventy six landraces were grouped into three groups viz., 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 late (36) followed by medium (34) categories, while 6 genotypes were categorized as early types, respectively. None of the landraces were found to be very early and very late.

4.1.7 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 49, 10, 10, 4 and 3 landraces, respectively.

4.1.8 Spikelet: colour of stigma

Forty eight rice landraces exhibited white stigma colour, sixteen showed yellow stigma, four showed light purple stigma and eight landraces had purple stigma.

4.1.9 Stem: thickness (cm)

Based on stem thickness seventy six landraces were characterized into three groups namely thin (<0.4 cm), medium (0.40 – 0.55 cm) and thick (>0.55 cm), which comprised of twenty eight, forty and eight landraces, respectively.

4.1.10 Stem: length (excluding panicle)

Based on stem length seventy six landraces were characterized into three groups namely very short (<91 cm), short (91-110 cm) and medium (111-130 cm), which

comprised of twenty eight, forty three and five 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.

4.1.11 Stem: anthocyanin colouration of node

Majority (63) of the landraces expressed absence of node anthocyanin colouration while 13 landraces exhibited anthocyanin colouration of node.

4.1.12 Stem: anthocyanin colouration of internodes

Sixty eight rice landraces expressed absence of internodes anthocyanin colouration, and eight landraces exhibited anthocyanin colouration of internodes.

4.1.13 Panicle: length of main axis (cm)

Seventy six landraces were classified as very short (< 16 cm), 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 (35), followed by short (33), very short (6) and long (2) panicle length categories. Very long panicles were not found in any of the landraces under study.

4.1.14 Panicle: number of productive tillers per plant

Based on number of productive tiller per plant landraces were classified as few (<11), medium (11-20) and many (>20). Most of landraces fall into medium (63), followed by few (11) and many (2) productive tillers per plant categories.

4.1.15 Spikelet: density of pubescence on lemma

On the basis of density of pubescence on lemma thirty nine landraces possessed medium pubescence on lemma, twenty two possessed weak and remaining fifteen landraces possessed strong pubescence on lemma.

4.1.16 Lemma and palea: colour

The seventy six landraces were grouped into nine groups viz. straw (38), gold and gold furrows on straw background (2), brown spots on straw (3), brown furrows on straw (8), brown (tawny) (4), purple spots on straw (6), purple furrows on straw (2), purple (5) and black (8) based on colour of lemma and palea .

4.1.17 Panicle: attitude of branches

Based on this criterion, all the landraces were grouped into five groups namely

erect, erect to semi erect, semi erect, semi erect to spreading and spreading. In this 76 landraces most of them fall into semi erect to spreading (43), followed by erect to semi erect (20), semi erect (7), erect (3) and spreading (3).

4.1.18 Panicle: exertion

Three landraces showed partly exerted panicles. Mostly exerted panicles were found in 32 landraces and 41 had well exerted panicles.

4.1.19 Grain: weight of 1000 fully developed grains (g)

The entire experimental material was characterized as very low (<15 g), low (15-20 g), medium (5.51-6.50), high (26-30 g) and very high(>30g) based on the weight of 1000 fully developed grains. In this seventy six land races, two landraces fall under very low, 16 under low, 18 under medium, 30 under high and ten genotypes under very high categories, respectively.

4.1.20 Decorticated grain: length (mm)

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 eight landraces fall under short, forty three under medium, four long and one genotype under extra long grain types, respectively.

4.1.21 Decorticated grain: width (mm)

Seventy six landraces were classified as narrow (< 2.0 mm) and medium (2.0-2.5 mm) based on the width of decorticated grain. Most of landraces fall into narrow (71) and remaining are medium (5). None of the genotypes were under broad (>2.5 mm) categories.

4.1.22 Amylose content (%)

Based on the amylose content seventy six landraces were characterized into five groups viz., very low (< 10 %), low (10-19 %), medium (20-25 %), high (26-30 %) and very high (>30 %). 23 landraces had high, 42 landraces exhibited medium, 7 showed low and 4 showed very low amylose content. None of the land race exhibited very high amylose content.

4.1.23 Gel consistency (%)

Based on the gel consistency seventy six landraces were characterized

into three groups viz., soft (61-100mm), medium (40-60 mm), medium (20-25 %) and hard (26-40 mm). 36 landraces had soft, 29 landraces exhibited medium and 11 showed hard gel consistency.

Out of the 22 DUS characters recorded, stem anthocyanin colouration of node and internodes and decorticated grain width were dimorphic; basal leaf sheath colour, leaf blade length and width, time of heading (50% plants with panicles), spikelet density of pubescence on lemma, stem length and thickness, panicle exertion, number of productive tillers per plant were trimorphic; culm attitude, stigma colour, panicle length, flag leaf attitude (late observation), decorticated grain length and amylose content were tetramorphic and lemma anthocyanin colouration of apex, attitude of branches of panicle and 1000-grain weight showed five states of expression and based on colour of lemma and palea highest number of groups i.e., nine 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 eleven agronomic and six 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 seventeen traits viz., leaf blade length, width, time of heading (50% plants with panicles), stem length, thickness, panicle length, productive tillers per plant, total number of grains per panicle, spikelet fertility, 1000-grain weight, single plant yield, decorticated grain length, width and 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 appropriate selection techniques. Greater variability in the initial breeding material ensures better chances of producing a desired ideotype.

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 six landraces of rice is presented in Table 4.5 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 Leaf: length of blade (cm)

The landraces Katharibhog and Sati exhibited lowest (24.10 cm) and highest (69.16 cm) leaf blade lengths, respectively with a general mean of 49.51 cm. The GCV and PCV for this trait were high, 20.25 and 20.43, respectively. These results were in trend with the findings of Thimmanna *et al.* (2000) and Chakrabarthy *et al.* (2012).

4.3.1.2 Leaf: width of blade (cm)

Minimum leaf blade width was recorded by Joha (0.58 cm), while Dharmaphool exhibited maximum width (1.78 cm) with a general mean of 1.08 cm. Phenotypic (20.19) and genotypic (19.97) coefficients of variation recorded for this character were moderate. These findings were in accordance with the results of Thimmanna *et al.* (2000) and Chakrabarthy *et al.* (2012).

4.3.1.3 Stem: thickness (cm)

The general mean observed for stem thickness was 0.43 cm with a range of 0.24 cm (Phool pakri) to 0.70 (Sati). High phenotypic (20.60) and moderate genotypic (19.10) coefficients of variations were reported for this character. Similar results were recorded by Chaudhary and Sahai (1993).

4.3.1.4 Stem: length (excluding panicle) (cm)

Stem length exhibited wide variability ranging from 17.73 to 120.16 cm with a general mean of 89.22 cm. Katharibhog was the shortest (17.73 cm), while Baku was the tallest (120.16 cm) among the landraces under study. The estimates of phenotypic and genotypic coefficients of variation recorded for this trait were moderate i.e., 19.45 and 19.45, 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 stem length.

4.3.1.5 Number of productive tillers per plant

The number of productive tillers per plant were found to be lowest in the landrace Betho and Samkene (9.0) and highest in Jashyopa (22.00) with a general mean of 13.01 tillers per plant. Phenotypic and genotypic coefficients of variations were high for this character i.e., 22.18 and 21.54, respectively. These results were in confirmity with the findings of Suman (2005), Padmaja *et al.* (2008), Prasad *et al.* (2013) and Vanisree *et al.* (2013).

4.3.1.6 Time of heading (50 % plants with panicles) (days)

Among all the landraces, Kotki was the earliest (79 days), while Jashyopa was found to be late (129.33 days) with a general mean of 110.39 days. The phenotypic and genotypic coefficients of variation were low i.e., 9.86 and 9.80, respectively. These results were in confirmity with the reports of Gangashetty *et al.* (2013), Mohan *et al.* (2015) and Sameera *et al.* (2015).

4.3.1.7 Panicle length (cm)

The landraces Kathari bhog and k a d a m f u l exhibited lowest (11.30 cm) and highest (31.40 cm) panicle lengths, respectively with a general mean of 24.18 cm. The GCV and PCV for this trait were moderate, 12.47 and 12.79, respectively. These results were in trend with the findings of Parray and Shikari (2008), Yadav *et al.* (2010), Lakshmi (2011), Dhanwani *et al.* (2013), Gangashetty *et al.* (2013) and Singh *et al.*

(2013).

4.3.1.8 Total number of grains per panicle

Wide range of variability was obtained for total number of grains per panicle ranging from 42.00 (Kathari bhog) to 355.66 (Mihigandheswari) with a general mean of 160.50. High PCV and GCV values were observed for this trait i.e., 48.70 and 48.16, 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 Shekawat *et al.* (2015).

4.3.1.9 Spikelet fertility (%)

Spikelet fertility ranged from 62.77 % (Jhingesal) to 97.63% (Sathi-P) with a general mean of 88.55%. The estimates of phenotypic (7.05) and genotypic (7.02) coefficients of variability were found to be low. These results were in conformity with those of Kole *et al.* (2008), Saidaiah *et al.* (2010) and Pandey *et al.* (2012).

4.3.1.10 1000 - grain weight (g)

The general mean of 1000-grain weight was 24.93 g and among all the landraces under study, Balangir-saria (36.33 g) recorded the highest 1000-grain weight and was superior to all the genotypes tested and Jashyopa (13.00 g) expressed lowest 1000-grain weight. High phenotypic (23.84) and genotypic (23.16) coefficients of variation were obtained for this trait. Similar kind of results are reported by Chaubey and Singh (1994), Sawant *et al.* (1994), Mani *et al.* (1997), Parikh *et al.* (2011) and Gampala *et al.* (2015).

4.3.1.11 Single plant yield (g)

The general mean for single plant yield was 37.38 g and the landraces Kartik khas exhibited highest (70.83 g) and Biroi exhibited lowest (16.97 g) single plant yields, respectively. High PCV (28.18) and GCV (28.05) were recorded for this trait. Suman (2003), Padmaja *et al.* (2008), Chandra *et al.* (2009a), Yadav *et al.* (2010), Lakshmi (2011), Singh *et al.* (2011), Singh *et al.* (2013) and Vanisree *et al.* (2013) also obtained similar results.

4.3.1.12 Decorticated grain: length (mm)

The landraces, Kadamful (3.87 mm) and Jhumka basmati (8.22 mm), recorded minimum and maximum decorticated grain lengths, respectively with a mean value

of 5.60 mm. Moderate phenotypic (14.79) and genotypic (14.71) 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).

4.3.1.13 Decorticated grain: width (mm)

Minimum decorticated grain width was recorded by Kartik khas (1.23 mm), while Baku exhibited maximum width (2.21 mm) with a general mean of 1.69 mm. Phenotypic (12.20) and genotypic (12.00) coefficients of variation recorded for this character were moderate. These findings were in accordance with those of Veerabhadhiran *et al.* (2009).

4.3.1.14 Amylose content (%)

Wide variability, ranging from 3.23 % (Kaike) to 29.32% (Khama) was observed for this trait with a general mean of 22.61%. The observed phenotypic and genotypic coefficients of variation were high for this trait i.e., 24.87 and 24.72, respectively. These results are in conformity with the findings of Vanaja and Babu (2006), Basavaraja *et al.* (2013) and Allam *et al.* (2015).

4.3.1.15 Gel consistency (mm)

Hetomari and Dudhkalam (22.00 mm) exhibited lowest value for gel consistency, while five landraces viz., Binni, Jonroibuna, Bonnidhan, Gochi and Balangir-saria had highest (100 mm) gel consistency. The general mean for this trait was 62.81 mm. The PCV (37.98) and GCV (37.92) were found to be high for gel consistency and is in accordance with the findings of Veerabhadhiran *et al.* (2009), Dhanwani *et al.* (2013), Shejul *et al.* (2013) and Gampala *et al.* (2015).

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 11, 29 and 36 genotypes, respectively as indicated below:

S.No.	Gel Consistency	Name of the landraces
1.	Hard (26-40 mm)	Hetomari, Sathia, Phool pakri, Kukurjali, Mangamuthi, Jashoya selection-1, Dudhkalam motajashya, Sugandha-II Govind bhog-1, Dadghani, Jhumka basmati
2.	Medium (41-60 mm)	Sati, Kele, Khama, Murgi balam, Jhingesal, Kotki, Katarybhog, Kalo bochi, Jaldhyapa, Dudhkalam-1, Kashiya binni, Kajal ghorya, Dhyapa, Kalshepa, Jaldhyapa-3, Biroi, Kauka, Dhusuri baratee, Bitti, Mihigandheswari, Paramananda, Chaturmukhi, Kashiyabinni, Dhan sirhatti, Gandheswari, Meghi, Kartik khas, Kadamful, Balangir-kutumdola-kala krushna
3.	Soft (61-100 mm)	Harinakhuri, Harinkajali, Baigonmachua, Binni, Jonroibuna, Dharmaphool, Kalodhyapa, Paharibochi selection-1, Radhatilak selection-1, Khaiyamadhan, Betho, Kaike, Bochi, Jhagrikartick, Bonnidhan, Serha-5, Katharibhog, Gochi, Shyam, Chingrifuli, Jabsal-1, Baku, Sathi-P, Kalaheeradhan, Kalogandheswari, Samkene, Motibas, Joha, Khajurchari-III, Angl-digipadar- chinamali, Magara-B, Bharati, Godikaberi, Nbr-assanchudi, Mbj-basumati, Balangir-Saria.

4.3.1.16 Grain iron concentration (mg/kg)

Iron concentration in decorticated grain ranged from 5.50 mg/kg in Samkene to 14.10 mg/kg in Balangir-kutumdola-kalakrushna with a general mean of 9.50 mg/kg. Moderate phenotypic (15.01) and genotypic (14.93) coefficients of variation were observed for grain iron concentration. However, high PCV and GCV values for this trait were reported by Babu *et al.* (2012) and Gangashetty *et al.* (2013).

4.3.1.17 Grain zinc concentration (mg/kg)

Khajal ghorya and Mbj-basumati recorded maximum (25.80 mg/kg) and minimum (10.20 mg/kg) zinc concentrations in decorticated grain, respectively with a general mean 17.56 mg/kg. Phenotypic and genotypic coefficients of variations were moderate i.e., 17.80 and 17.78, respectively for this trait. However, Bekele *et al.* (2013)

and Gangashetty *et al.* (2013) reported high PCV and GCV values for grain zinc concentration.

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.

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 (48.70) and GCV (48.16) whereas lowest PCV (7.05) and GCV (7.02) were recorded for spikelet fertility. Among all the grain quality characters gel consistency expressed highest PCV (37.98) and GCV (37.92), while lowest PCV (12.2) and GCV (12.00) were obtained for decorticated grain width. The difference between genotypic and phenotypic coefficients of variation was less for all characters studied except stem length, 1000-grain weight and no. of productive tillers per plant, indicating the influence of the environment over these three characters. The slight difference between GCV and PCV was also reported by Kole *et al.* (2008) and Seyoum *et al.* (2012).

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 86% to 100 %. Among all metric characters, highest heritability was recorded for stem length (100%) followed by spikelet fertility (99.2 %), while grain zinc content (99.70%) and gel consistency (99.60 %) exhibited highest heritability estimates among the grain quality parameters. 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 moderate (14.40%) 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 (98.10%) 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 (77.97 %) value.

Among all the characters studied, spikelet fertility exhibited high heritability coupled with moderate genetic advance as a per cent of mean. Similar results were obtained earlier by Sankar *et al.* (2006). High heritability coupled with moderate genetic advance as a per cent of mean indicates that the expression of the trait is under the control of 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 indicate the preponderance of additive gene action in controlling the traits. Hence, direct selection of such characters would be effective in improving the seed yield. Similar results were observed by Madhavilatha (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; 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 1000-grain weight.

All the quality parameters exhibited high heritability coupled with high genetic advance as 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 Veerabathiran *et al.* (2009) for decorticated grain width; Amudha and Thiagarajan (2008) for amylose content and gel consistency; Gangashetty *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 six landraces of rice was made by adopting Mahalanobis D^2 statistics 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 1275 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 Generalized Distance D^2 Values

In order to assess the genetic diversity among 76 landraces of rice, D^2 statistics 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 six 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 six clusters, cluster I was the largest comprising of forty nine landraces, followed by cluster III with fourteen, cluster II with seven and cluster IV with four. Clusters V and VI were monogenotypic clusters, suggesting the existence of high degree of heterogeneity among the genotypes.

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 V and VI 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 II (1689.04), followed by cluster III (1671.21), cluster I (1574.26) and cluster IV (934.52), 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 II and VI (78134.90) followed by clusters I and VI (50066.82), clusters V and VI (46381.34) and clusters II and IV (34426.11). 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 I and V (2569.95) followed by clusters I and II (4745.76) and clusters III and IV (5112.24), 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.

4.4.5 Cluster Means of the Characters

The cluster means for each of 17 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 panicle length (25.02 cm) total number of grains per panicle (171.16) and spikelet fertility (89.14 %) and lowest for decorticated grain length (5.50 cm). Cluster II was characterized by having

highest mean values for five traits viz., leaf blade length (58.87 cm), stem thickness (0.50 cm) and length (113.77 cm), time of heading (119 days) decorticated grain width (1.91 mm) and lowest for amylose content (20.89%). Landraces in cluster III expressed medium mean value for all characters. Cluster IV recorded maximum mean values for spikelet fertility (89.87 %) and minimum mean values for leaf width (0.98 cm) and gel consistency (54.54 mm). Cluster V exhibited highest mean value for single plant yield (47.30 g), amylose content (28.77 %) and gel consistency (99.00 mm) and minimum mean value for number of productive tillers per plant (11.33), spikelet fertility (79.78 %), 1000 grain weight (24.00 g), grain iron concentration (6.10 mg/kg) and grain zinc concentration (10.30 mg/kg). Cluster VI had highest mean values for leaf blade width (1.18 cm), number of productive tillers per plant (18.67), grain iron concentration (10.40 mg/kg) and grain zinc concentration (19.20 mg/kg) and lowest leaf blade length (24.10 cm), stem thickness (0.35 cm), time of heading (98.67 days), panicle length (11.30 cm), total number of grains per panicle (42.00), single plant yield (18.77 g) and decorticated grain width (1.65 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 II and VI had highest mean value for five and four agromorphological and grain parameters and cluster V exhibited highest mean value for single plant yield. 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 17 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 stem length towards genetic divergence was highest (6642.11%) and it ranked first 1893 times, followed by Grain

zinc concentration (mg/kg) (1273.68) by 363 times, gel consistency (1045.61) by 298 times, single plant yield (g) (210.53) by 60 times, amylose content (189.96) by 54 times, spikelet fertility and grain iron concentration (mg/kg) (185.96) by 53 times, decorticated grain length (112.28) by 32 times, time of heading (94.74) by 27 times, leaf blade width (24.56) by 7 times, Total no. of grains per panicle (17.54) by 5 times leaf blade length (14.04) by 4 times, decorticated grain width (3.51) by ranking one time each. Stem thickness (cm), number of productive tillers per plant, panicle length and 1000-grain weight (g) did not contribute towards genetic divergence among landraces of rice.

Out of the seventeen characters studied, six characters namely stem length (66.42%), grain zinc concentration (12.73%), gel consistency (10.45%), amylose content (1.89%), spikelet fertility (1.85%) and grain iron concentration (1.85%) together contributed maximum (95.19 %) to the total genetic divergence. Thus, it is suggested that these traits should be given importance in future breeding programmes i.e., during hybridization and selection of segregating populations. Using these particular set of landraces, which are not utilized in breeding programs so far and have potential for use in future rice improvement programmes, can develop rice varieties or hybrids with high yield and better grain quality.

4.5 CHARACTER ASSOCIATION

Character association studies are important 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 and it is highly influenced by environment, the result of the interaction of a number of components.

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 association 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 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 indicate strong inherent association between the characters.

4.5.1 Leaf: length of blade (cm)

This trait registered positive significant association at phenotypic levels with leaf blade width (0.1307*), stem thickness (0.2985***), stem length (0.5389***), time of heading (0.4842***), panicle length (0.4638***), total grains per plant (0.1850**) and decorticated grain width (0.1826**). Similar results were reported by Lakshmi (2011), Padmaja *et al.* (2011) and Babu *et al.* (2012) for number of productive tillers per plant. Positive non-significant association at genotypic level was reported with leaf blade width (0.1331), stem thickness (0.3231), stem length (0.5436), time of heading (0.4917), panicle length (0.4823), total grains per plant (0.1867) and decorticated grain width (0.1857) at both phenotypic and genotypic levels with total number of productive tillers per plant (0.0382/0.0418), which were in agreement with the findings of Chakrabarthy *et al.* (2012) for single plant yield, Padmaja *et al.* (2011) and Nagesh *et al.* (2013) for total number of grains per panicle, Yolanda and Das (1995) for 1000-grain weight.

Single plant yield (-0.0154/-0.0168), 1000- grain weight (-0.1859**/-0.1952), spikelet fertility (-0.3186/-0.3224), decorticated grain length (-0.1041/-0.1049**), amylose content (-0.0654/-0.0667), gel consistency (-0.1563*/- 0.1578), grain iron content(-0.1371/ -0.1373) and grain zinc content (-0.0252/-0.0257) recorded negative significant association at both the levels, 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, Yolanda and Das (1995) for 1000-grain weight, Basavaraja *et al.* (2011) for amylose content.

4.5.2 Leaf: width of blade (cm)

This trait registered high significant positive association at phenotypic level with stem thickness (0.3018***), 1000-grain weight (0.2162**), decorticated grain width (0.4335***) and grain zinc content (0.4294***), which were in agreement with the findings of Suman (2003), Chakrabarthy *et al.* (2012) for single plant yield, Padmaja *et al.* (2011) and Nagesh *et al.* (2013) for total number of grains per panicle, Yolanda and Das (1995) for 1000-grain weight. Positive non- significant association at genotypic

level was reported with stem thickness (0.3307), 1000-grain weight (0.2231), decorticated grain width (0.4462), and grain zinc content (0.4336). The results 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), Nagesh *et al.* (2013) and Reddy *et al.* (2013) for total number of grains per panicle, Yolanda and Das (1995) for 1000-grain weight, Basavaraja *et al.* (2011) for amylose content. Positive non-significant association both at phenotypic and genotypic levels were observed with stem length (0.0863/0.0874), time of heading (0.0161/0.0165), decorticated grain length (0.0607/0.0608), gel consistency (0.0757/0.0767) and grain iron concentration (0.0390/0.0382), 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), Nagesh *et al.* (2013) and Reddy *et al.* (2013) for total number of grains per panicle, Yolanda and Das (1995) for 1000-grain weight and Basavaraja *et al.* (2011) for amylose content.

Total number of grains per panicle (-0.2562***/0.2596) and amylose content (-0.1929**/-0.1971) recorded negative significant association at phenotypic level and negative non-significant relationship at genotypic level with the trait. Similar results were reported by Lakshmi (2011), Padmaja *et al.* (2011) and Babu *et al.* (2012) for number of productive tillers per plant. Number of productive tillers per plant (-0.1043/-0.1133), panicle length (-1216/0.1232), spikelet fertility (-0.0643/-0.0643) and single plant yield (-0.1589/-0.1625) registered negative non-significant association with this trait 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.

4.5.3 Stem thickness (cm)

This trait showed significant positive correlation at phenotypic level and non-significant relationship at genotypic level with stem length (0.3718***/0.4009), time of heading (0.2273***/0.2517) and decorticated grain width (0.1887**/0.2070). However non-significant positive correlation at both the levels was noticed with panicle length (0.0805/0.0865), 1000-grain weight (0.0313/0.0393), amylose content (0.1257/0.1362), gel consistency (0.1016/0.1089), grain zinc concentration (0.0589/0.0652) and single plant yield (0.0333/0.0352). Negative significant association at phenotypic level and non-significant at genotypic level was exhibited by number of productive tillers per plant (-0.2048**/-0.2260) and spikelet fertility with stem thickness (-0.2570***/-0.2791); negative non-significant

association at both the levels was exhibited by total number of grains per panicle (0.0011/0.0048), decorticated grain length (-0.1117/-0.1218) and grain iron concentration (-0.0303/-0.0652).

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 per panicle and panicle length, Suman *et al.* (2006) for 1000-grain weight, Gangashetty *et al.* (2013) for grain zinc concentration and Suman (2003) and Padmaja *et al.* (2011) for productive tillers per plant.

4.5.4 Stem length (excluding panicle) (cm)

This trait showed positive significant association at phenotypic and non-significant at genotypic level with panicle length (0.5170***/0.5306), time of heading (0.2292***/0.2306) and total number of grains per panicle (0.2192**/0.2212). Positive non-significant association of this trait with single plant yield (0.2333/0.2344), decorticated grain width (0.0674/0.0686) and gel consistency (0.117/0.1172) at both the levels was noticed.

Negative significant association at phenotypic and non-significant at genotypic level was exhibited by total number of productive tillers per plant (-0.1625*/-0.1671), decorticated grain length (-0.1310*/-0.1317) and amylose content (-0.1621*/-0.1633) and negative non-significant association was exhibited by spikelet fertility (-0.0845/-0.0850), 1000-grain weight (-0.0816/0.0840), grain iron concentration (-0.0640/-0.0645) and grain zinc concentration (-0.0380/-0.0381) at both the levels.

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 per panicle and panicle length, Nayak *et al.* (2001) for 1000-grain weight and decorticated grain length, Gangashetty *et al.* (2013) for grain zinc concentration and Suman (2003) for total grains per panicle, and Padmaja *et al.* (2011) for productive tillers per plant.

4.5.5 Number of productive tillers per plant

The character showed a positive significant (0.1617*) and positive non-significant (0.1692) correlation with decorticated grain length at phenotypic and genotypic levels, respectively, with grain zinc concentration (0.0102/0.0105) it showed non-significant positive association at phenotypic and genotypic level.

Negative significant association at phenotypic and non-significant at genotypic

level was recorded with panicle length (-0.2590***/-0.2769), total number of grains per panicle (-0.2522***/-0.2578), 1000-grain weight (-0.1829**/-0.1870), decorticated grain width (-0.1319*/-0.1369) and gel consistency (-0.2892***/-0.2971). However negative but non-significant association was noticed with time of heading (-0.0749/-0.0744), spikelet fertility (-0.0239/-0.0261), amylose content (-0.0386/-0.0389), grain iron concentration (-0.0249/0.0257) and single plant yield (-0.1834/-0.1926).

These results are in confirmity with the findings of Petchiammal and Kumar (2007) for spikelet fertility, Babu *et al.* (2012) for panicle length, Satyavathi *et al.* (2001) for total number of grains per panicle and Satish *et al.* (2009) and Rahaman *et al.* (2014) for single plant yield.

4.5.6 Time of heading (50% plants with panicles) (days)

Positive significant association at phenotypic and non-significant association at genotypic levels was registered by this trait with total number of grains per panicle (0.1693*/0.1743) and decorticated grain width (0.1515*/0.1563). Non-significant correlation at both the levels with panicle length (0.1125/0.1147), decorticated grain length (0.0771/0.0785), gel consistency (0.0915/0.0919) and single plant yield (0.0195/0.0215) was witnessed. These results were in agreement with the findings of Madhavilatha *et al.* (2005), Rao *et al.* (2014) and Kishore *et al.* (2015) for single plant yield, Padmaja *et al.* (2011), Nagesh *et al.* (2013) and Reddy *et al.* (2013) for total number of grains per panicle.

spikelet fertility (-0.1922**/-0.1931) and grain iron concentration (-0.3443***/-0.3498) recorded negative significant association at phenotypic level and non-significant at genotypic level. 1000-grain weight (-0.0866/-0.0872), amylose content (-0.0394/-0.0413) and grain zinc concentration (-0.0451/-0.0454) recorded negative non-significant association at both the levels. Similar results were reported by Satish *et al.* (2009), Nandan *et al.* (2010) for 1000-grain weight and Nayak *et al.* (2001) for decorticated grain length.

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.

4.5.7 Panicle length (cm)

Panicle length expressed significant positive association at phenotypic level and

non-significant at genotypic level with total number of grains per panicle (0.4542***/0.4737) but non-significant with spikelet fertility (0.0171/0.0207) and single plant yield (0.1818/0.1889) at both phenotypic and genotypic levels. 1000-grain weight (-0.3257***/-0.3449), decorticated grain length (-0.2257***/-0.2333), decorticated grain width (-0.1791**/-0.1836), amylose content (-0.1708**/-0.1765) and grain zinc concentration (-0.2820***/-0.2891) exhibited negative significant correlation at only phenotypic level but gel consistency (-0.0851/-0.0897) and grain iron concentration (-0.0745/-0.0764) were found non significant at both the levels.

Suman (2003), Seyoum *et al.* (2012) and Kishore *et al.* (2015) recorded similar reports for single plant yield, Chandra *et al.* (2009b) and Padmaja *et al.* (2011) for total number of grains per panicle and 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.

4.5.8 Total number of grains per panicle

This character registered positive non-significant association with single plant yield (0.4067/0.4140), spikelet fertility (0.0445/0.0459) and grain iron concentration (0.0821/0.0848) at both the levels which confirms the findings of Yolanda and Das (1995), and Madhaviatha *et al.* (2001). This result is quite expected that more number of grains per panicle had direct contribution to the single plant yield. 1000-grain weight (-0.4251***/-0.4406), decorticated grain length (-0.5642***/-0.5741), decorticated grain width (-0.3947***/-0.4066), amylose content (-0.1317*/-0.1335), gel consistency (-0.1301*/-0.1307) and grain zinc concentration (-0.4660***/-0.4714) were negative but significant at phenotypic level only.

4.5.9 Spikelet fertility (%)

Spikelet fertility exhibited positive significant association with 1000- grain weight (0.2055**/0.2112) and gel consistency (0.2066**/0.2076) at phenotypic level only. At genotypic level, the relationship was non-significant but positive. Positive but non-significant association was observed with single plant yield (0.1369/0.1383), decorticated grain length (0.0741/0.0737), decorticated grain width (0.0806/0.0811) and grain iron concentration (0.1114/0.1116) at both the levels. These results are in confirmity with the earlier work of Padmaja *et al* (2011).

Amylose content (-0.2503***/-0.2523) exhibited negative significant

association with this trait at phenotypic level only. However, negative non-significant association at both the levels was reported with grain zinc concentration (-0.0255/-0.0256).

4.5.10 1000-grain weight (g)

This trait had positive significant correlation at phenotypic level for four traits namely decorticated grain length (0.4506***/0.4677), decorticated grain width (0.4613***/0.4866), gel consistency (0.2937***/0.3020) and grain zinc concentration (0.3240***/0.3334) and non-significant but positive genotypic correlation. Negative non-significant correlation at both the levels was observed with grain iron concentration (-0.0617/-0.0637). These results are in conformity with the findings of Suman 2003 and Islam *et al.* (2015) for single plant yield. 1000-grain weight had negative non-significant association with single plant yield indicating that increase in 1000-grain weight would ultimately decrease the single plant yield.

4.5.11 Decorticated grain: length (mm)

The trait showed positive significant association at phenotypic level and non-significant association at genotypic level with decorticated grain width (0.1678*/0.1690) and grain zinc content (0.2287***/0.2304) and negative significant association with grain iron concentration (-0.3195***/-0.3226) at phenotypic level only. Negative but non-significant association at both the levels was observed with single plant yield (-0.2038/-0.2058) and amylose content (-0.0503/-0.0502). These results are in accordance with the findings of Krishna *et al.* (2008) for decorticated grain width.

4.5.12 Decorticated grain: width (mm)

This character recorded positive significant association with gel consistency (0.2014**/0.2052) and grain zinc content (0.3871***/0.3934). Kailashnath (2011) observed positive significant association with single plant yield only at genotypic level. Negative significant correlation was reported with grain iron concentration (-0.1575*/-0.1624) at phenotypic level only which was similar to the findings of Anuradha *et al.* (2012) where this trait reported negative non-significant association with grain iron concentration.

4.5.13 Amylose content (%)

Amylose content had negative non-significant association with gel consistency

(-0.0522/-0.0530), grain iron concentration (-0.0447/-0.0466), grain zinc concentration (-0.0027/-0.0035) and single plant yield (-0.1427/-0.1421) at both levels. These results are in conformity with the findings of Khatum *et al* (2003) where amylose content reported negative significant association with gel consistency.

4.5.14 Gel consistency (mm)

Gel consistency exhibited positive non significant association with single plant yield (0.2028/0.2057) and grain zinc concentration (0.0162/0.0158) and negative non significant relationship with grain iron concentration (-0.1078/- 0.1085).

4.5.15 Grain iron concentration (mg/kg)

This character associated significant and positively with grain zinc concentration (0.2666***/0.2681) at phenotypic level only and was non-significant but positive at genotypic level. It was negatively non significant with single plant yield (-0.2695/-0.2717) at both levels. Similar results were obtained by Nagesh *et al.* (2013).

4.5.16 Grain zinc concentration (mg/kg)

This trait recorded negative non significant correlation with single plant yield (-0.3843/-0.3863). Similar results were obtained by Nagesh *et al.* (2013).

4.5.17 Single plant yield (g)

None of traits has significant association with single plant yield. This trait had positive with time of heading (0.0195/0.0215), stem thickness (0.0333/0.0352), stem length (0.2333/0.2344), panicle length (0.1818/0.1889), total number of grains per panicle (0.4067/0.4140), spikelet fertility (0.1369/0.1383) and gel consistency (0.2028/0.2057) at both levels, indicating that these characters were important for yield improvement.

Negative association at both levels was exhibited with leaf blade length (-0.0154/-0.0168), leaf blade width (-0.1589/-0.1625), number of productive tillers per plant (-0.1834/-0.1926), 1 000 -grain weight (-0.0303/-0.0326), decorticated grain length (-0.2038/-0.2058), decorticated grain width (-0.1105/-0.1133), amylose content (-0.1427/-0.1421), grain iron concentration (-0.2695/-0.2717) and grain zinc concentration (-0.3843/-0.3863).

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 causal 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. If 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 the 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 Leaf: length of the blade (cm)

The direct contribution of this character to single plant yield was negative (-0.0504/-0.031) 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 negative significant correlation of length of leaf blade (-0.0154/-0.0168) with single plant yield was mainly due to indirect negative effects of this trait *via* leaf blade width (-0.0066/-0.0041), stem thickness (-0.015/-0.01), stem length (-0.0272/-0.0168), number of productive tillers per plant (-0.0019/-0.0013), time of heading (-0.0244/-0.0152), panicle length (-0.0234/-0.0149), total number of grains per plant (-0.0093/-0.0058) and decorticated grain width (-0.0094/-0.0060) at genotypic and phenotypic levels.

This trait exhibited positive indirect effects on single plant yield both at phenotypic and genotypic levels through spikelet fertility (0.0161/0.01), 1000- grain weight (0.0094/0.006), decorticated grain length (0.0052/0.0033), amylose content (0.0033/0.0021), gel consistency (0.0079/0.0049), grain iron content (0.0069/0.0043) and grain zinc content (0.0013/0.0008).

4.6.2 Leaf: width of the blade (cm)

The direct contribution of this character to single plant yield was negative (-0.0913/-0.1056) 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 negative significant correlation of leaf blade width (-0.1589/-0.1625) with single plant yield was mainly due to indirect negative effects of this trait *via* leaf blade length (-0.0119/-0.0141), stem thickness (-0.0276/-0.0349), stem length (-0.0079/-0.0092), time of heading (-0.0015/-0.0017), 1000-grain weight (-0.0197/-0.0236), decorticated grain length (-0.0055/-0.0064), decorticated grain width (-0.0396/-0.0471), gel consistency (-0.0069/-0.0081), grain iron content (-0.0036/-0.004) and grain zinc content (-0.0392/-0.0458) at genotypic and phenotypic levels.

This trait exhibited positive indirect effects on single plant yield both at phenotypic and genotypic levels through number of productive tillers per plant (0.0095/0.0120), spikelet fertility (0.0059/0.0068), panicle length (0.0111/0.013), total number of grains per panicle (0.0234/0.0274) and amylose content (0.0176/0.0208).

4.6.3 Stem thickness (cm)

Stem thickness had positive direct effect on single plant yield (0.0383/0.0498), which is in tune with the findings of Suman (2003), Ekka *et al.* (2011), Babu *et al.* (2012), Mohanty *et al.* (2012) and Gangashetty *et al.* (2013). This trait exhibited positive correlation (0.0333/0.0352) with single plant yield. Hence, simple selection would be more effective for improving single plant yield based on this trait.

Stem thickness had positive indirect effects on single plant yield *via* leaf blade length (0.0114/0.0161), leaf blade width (0.0116/0.0165), stem length (0.0143/0.0199), time of heading (0.0087/0.0125), panicle length (0.0031/0.0043), 1000 grain weight (0.0012/0.0020), decorticated grain width (0.0072/0.0103), amylose content (0.0048/0.0068), gel consistency (0.0039/0.0054) and grain zinc concentration (0.0023/0.0032) at both levels.

This trait expressed negative indirect effects on single plant yield through number of productive tillers per plant (-0.0078/-0.0112), total no. of grains per plant (-0.0002), spikelet fertility (-0.0098/-0.0139), decorticated grain length (-0.0043/-0.0061) and grain iron concentration (-0.0012/-0.0016).

4.6.4 Stem length (excluding panicle) (cm)

Stem length had positive direct effect on single plant yield (0.2151/0.2116) both at phenotypic and genotypic levels. Garg *et al.* (2010), Babu *et al.* (2012), Nagaraju *et al.* (2013), Kishore *et al.* (2015) and Islam *et al.* (2015). This trait exhibited positive (0.2333/0.2344) 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., leaf blade length (0.1159/0.1150), leaf blade width (0.0186/0.0185), stem thickness (0.0800/0.0848), time of heading (0.0493/0.0488), panicle length (0.1112/0.1123), total number of grains per panicle (0.0471/0.0468), decorticated grain width (0.0145/0.0145) and gel consistency (0.0252/0.0248). It expressed negative

indirect effects on yield through number of productive tillers per plant (-0.0350/-0.0353), spikelet fertility (-0.0182/-0.0180), 1000 grain weight (-0.0176/-0.0178), decorticated grain length (-0.0282/-0.0279), amylose content (-0.0349/-0.0346), grain iron concentration (-0.0138/-0.0136) and grain zinc concentration (-0.0082/-0.0081).

4.6.5 Number of productive tillers per plant

Number of productive tillers per plant had negative direct effect (- 0.0263/-0.0334) on single plant yield, which is in agreement with the findings of Kavita and Reddi (2001), Yadav *et al.* (2011) and Seyoum *et al.* (2012).

The trait had negative non-significant association with single plant yield (-0.1834/-0.1926), which might result from the negative indirect effects manifested through other components viz., leaf blade length (-0.0010/-0.0014), decorticated grain length (-0.0042/-0.0057) and grain zinc concentration (- 0.0003/0.0004).

This trait showed positive indirect effects on single plant yield through leaf blade width (0.0027/0.0038), stem thickness (0.0054/0.0076), stem length (0.0043/0.0056), time of heading (0.0020/0.0025), panicle length (0.006/0.0093), total number of grains per panicle (0.0066/0.0086), spikelet fertility (0.0006/0.0009), 1000 grain weight (0.0048/0.0062), decorticated grain width (0.0035/0.0046), amylose content (0.0010/0.0013), gel consistency (0.0076/0.0099) and grain iron concentration (0.0007/0.0009).

4.6.6 Time of heading (50% plants with panicles) (days)

The direct contribution of this character to single plant yield was negative (-0.2067/-0.2265) at phenotypic and genotypic levels, respectively. These results were in agreement with the findings of Garg *et al.* (2010), Kailashnath (2011) and Babu *et al.* (2012).

It had positive non-significant association with single plant yield (0.0195/0.0215), which might result from the positive indirect effects manifested through other components viz., leaf blade length (0.1001/0.1114), number of productive tillers per plant (0.0155/0.0169), spikelet fertility (0.0397/0.0437), 1000 grain weight (0.0179/0.0198), decorticated grain length (0.0159/0.0178), amylose content (0.0081/0.0094), grain iron concentration (0.0712/0.0792) and grain zinc concentration (0.0093/0.0103).

This trait exhibited negative indirect effects on single plant yield both at

phenotypic and genotypic levels through leaf blade width (-0.0033/-0.0037), stem length (-0.0470/-0.0570), stem length (-0.0474/-0.0522), panicle length (-0.0233/-0.0260), total number of grains per panicle (-0.0350/-0.0395), decorticated grain width (-0.0313/-0.0354) and gel consistency (-0.0189/-0.0208).

4.6.7 Panicle length (cm)

Panicle length had negative direct effect on single plant yield (-0.1400/-0.1608), which is in trend with the results of Nayak *et al.* (2001), Kole *et al.* (2008), Padmaja *et al.* (2011) and Koshore *et al.* (2015). This trait exhibited positive correlation (0.1818/0.1889) 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 leaf blade width (0.017/0.0198), total number of productive tillers per plant (0.0363/0.0445), 1000 grain weight (0.0456/0.0555), decorticated grain length (0.0316/0.0375), decorticated grain width (0.0251/0.0295), amylose content (0.0239/0.0284), gel consistency (0.0119/0.0144), grain iron concentration (0.0104/0.0123) and grain zinc concentration (0.0395/0.0465).

This trait expressed negative indirect effects on single plant yield through leaf blade length (-0.0649/-0.0776), stem thickness (-0.0113/-0.0139), stem length (-0.0724/-0.0853), time of heading (-0.0158/-0.0184), total no. of grains per panicle (-0.0636/-0.0762) and spikelet fertility (-0.0024/-0.0033).

4.6.8 Total number of grains per panicle

This trait had positive direct effect on single plant yield (0.3622/0.3825), which is in agreement with the findings of Rao *et al.* (2014), Menaka and Ibrahim (2015) and Islam *et al.* (2015). Total number of grains per panicle expressed positive association (0.4067/0.4140) with grain yield. 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 leaf blade length (0.0670/0.0714), stem length (0.0794/0.0846), time of heading (0.0613/0.0667), panicle length (0.1645/0.1812), spikelet fertility (0.0161/0.0176) and grain iron concentration (0.0297/0.0324).

Negative indirect effects of this trait on single plant yield were manifested through leaf blade width (-0.0928/-0.0993), stem thickness (-0.0004/-0.0018),

number of productive tillers per plant (-0.0914/-0.0986), 1000-grain weight (-0.1540/-0.1685), decorticated grain length (-0.2043/- 0.2196), decorticated grain width (-0.1430/-0.1555), amylose content (-0.0477/- 0.0511), gel consistency (-0.0471/-0.0500) and grain zinc concentration (- 0.1688/-0.1803).

4.6.9 Spikelet fertility (%)

Spikelet fertility recorded positive direct effect (0.0489/0.0522) 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 (0.1369/0.1383).

This trait expressed positive indirect effects through panicle length (0.0008/0.0011), total no. of grains per panicle (0.0022/0.0024), 1000-grain weight (0.0101/0.0110), decorticated grain length (0.0036/0.0038), decorticated grain width (0.0039/0.0042), gel consistency (0.0101/0.0108) and grain iron concentration (0.0055/0.0058). Negative indirect effects of this trait on single plant yield were observed via leaf blade length (-0.0156/-0.0168), leaf blade width (-0.0031/-0.0034), stem thickness (-0.0126/-0.0146), stem length (-0.0041/-0.0044), total productive tillers per plant (-0.0012/-0.0014), time of heading (-0.0094/-0.0101), amylose content (-0.0123/-0.0132) and grain zinc concentration (-0.0012/-0.0013).

4.6.10 1000-grain weight (g)

1000-grain weight exhibited positive direct effect (0.1630/0.1744) on single plant yield, which is in confirmity with the findings of Sankar *et al.* (2006), Padmaja *et al.* (2011) and Kishore *et al* (2015). It had negative association with single plant yield (-0.0303/0.0326). Positive indirect effects of this character on single plant yield were recorded via leaf blade width (0.0352/0.0389), stem thickness (0.0051/0.0069), spikelet fertility (0.0335/0.0368), decorticated grain length (0.0734/0.0816), decorticated grain width (0.0752/ 0.0849), amylose content (0.0205/0.0229), gel consistency (0.0479/0.0527) and grain zinc concentration (0.0528/0.0581). Negative indirect effects were observed through leaf blade length (-0.0303/- 0.0340), stem length (-0.0133/-0.0146), number of productive tillers per plant (- 0.0298/-0.0326), time of heading (-0.0141/-0.0152), panicle length (-0.0531/- 0.0602), total number of grains per panicle (-0.0693/-0.0768) and grain iron concentration (-0.0101/-0.0111).

4.6.11 Decorticated grain: length (mm)

Direct contribution of this trait to single plant yield was negative (- 0.1947/- 0.2008) and was in agreement with the findings of Madhavilatha *et al.* (2002). This trait showed negative non-significant association (-0.2038/- 0.2058) with single plant yield. Decorticated grain length exhibited positive indirect effects *via* leaf blade length (0.0203/0.0211), stem thickness (0.0218/0.0245), stem length (0.0255/0.0264), time of heading (0.0150/0.0158), panicle length (0.0439/0.0469), total number of grains per panicle (0.1098/0.1153), amylose content (0.0098/0.0101) and grain iron concentration (0.0622/0.0648).

Negative indirect effects of this trait on single plant yield were observed through leaf blade width (-0.0118/-0.0122), total number of productive tillers per plant (-0.0315/-0.0340), spikelet fertility (-0.0144/-0.0148), 1000- grain weight (-0.0877/-0.0939), decorticated grain width (-0.0327 /-0.0339), gel consistency (-0.0080/-0.0081) and grain zinc concentration (-0.0445/-0.0463).

4.6.12 Decorticated grain: width (mm)

This trait had negative direct effect on single plant yield (-0.0142/- 0.0222), 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 negative correlation (-0.1105/- 0.1133) with single plant yield.

Positive indirect effects of decorticated grain width on single plant yield were exhibited through number of productive tillers per plant (0.0019/0.0030), panicle length (0.0025/0.0041), total number of grains per panicle (0.0056/0.0090) and grain iron concentration (0.0022/0.0036).

Decorticated grain width had negative indirect effects on, leaf blade length (-0.0026/-0.0041), leaf blade width (-0.0061/-0.0099), stem thickness (- 0.0027/- 0.0046), stem length (-0.0010/-0.0015), time of heading (-0.0021/- 0.0035), spikelet fertility (-0.0011/-0.0018), 1000-grain weight (-0.0065/-0.0108), decorticated grain length (-0.0024/-0.0037), decorticated grain width (-0.0142/- 0.0222), amylose content (-0.0010/-0.0016), gel consistency (-0.0029/-0.0045) and grain zinc concentration (-0.0055/-0.0087).

4.6.13 Amylose content (%)

Amylose content had negative direct effect (-0.1473/-0.1564) on single plant yield, which is in accordance with the findings of Garg *et al.* (2010) and it had negative

non-significant association (-0.1427/-0.1421) with single plant yield.

This trait recorded positive indirect effects *via* leaf blade length (0.0096/0.0104), leaf blade width (0.0284/0.0308), stem length (0.0239/0.0255), number of productive tillers per plant (0.0057/0.0061), time of heading (0.0058/0.0065), panicle length (0.0252/0.0276), total number of grains per panicle (0.0194/0.0209), spikelet fertility (0.0369/0.0395), decorticated grain length (0.0074/0.0078), gel consistency (0.0077/0.0083), grain iron concentration (0.0066/0.0073) and grain zinc concentration (0.0004/0.0005). Negative indirect effects were resulted through stem thickness (-0.0185/-0.0213), 1000 grain weight (-0.0185/-0.0206) and decorticated grain width (-0.0101/-0.0112).

4.6.14 Gel consistency (mm)

This trait had positive direct effect (0.1242/0.1233) on single plant yield, which is in line with the findings of Garg *et al.* (2010). It had recorded positive non-significant association (0.2028/0.2057) with single plant yield.

Positive indirect effects were recorded *via* leaf blade width (0.0094/0.0095), stem thickness (0.0126/0.0134), stem length (0.0145/0.0144), time of heading (0.0114/0.0113), spikelet fertility (0.0257/0.0256), 1000 grain weight (0.0365/0.0372), decorticated grain length (0.0051/0.005), decorticated grain width (0.0250/0.0253) and grain zinc concentration (0.002/0.0019).

Negative indirect effects were resulted through leaf blade length (-0.0194/0.0195), number of productive tillers per plant (-0.0359/-0.0366), panicle length (-0.0106/-0.0111), total number of grains per panicle (-0.0162/-0.0161), amylose content (-0.0065/-0.0065) and grain iron concentration (-0.0134/-0.0134).

4.6.15 Grain iron concentration (mg/kg)

Grain iron concentration had negative direct effect (-0.3909/-0.4097) on single plant yield, which is in confirmity with the findings of Nagesh *et al.* (2013). This trait had negative non significant correlation (-0.2695/-0.2717) with single plant yield.

Positive indirect effects of this trait were manifested through leaf blade length (0.0536/0.0562), stem thickness (0.0122/0.0135), stem length (0.0250/0.0264), number of productive tillers per plant (0.0097/0.0105), time of heading (0.1346/0.1433), panicle length (0.0291/0.0313), 1000-grain weight (0.0241/0.0261), decorticated grain length (0.1249/0.1322), decorticated grain width (0.0616/0.0665), amylose content

(0.0175/0.0191) and gel consistency (0.0422/0.0445). Leaf blade width (-0.0152/-0.0156), total grains per panicle (-0.0321/-0.0348), spikelet fertility (-0.0436/-0.0457) and grain zinc concentration (-0.1042/-0.1099) expressed negative indirect effects of this trait on single plant yield.

4.6.16 Grain zinc concentration (mg/kg)

This trait had negative direct effect (-0.1199/-0.1071) on single plant yield, which is in conformity with the findings of Bakele *et al.* (2013). This trait had negative non significant correlation (-0.3843/-0.3863) with single plant yield.

Positive indirect effects of this trait were manifested through leaf blade length (0.0030/0.0027), stem length (0.0046/0.0041), time of heading (0.0054/0.0049), panicle length (0.0338/0.0310), total no. of grains per panicle (0.0559/0.0505), spikelet fertility (0.0031/0.0027) and amylose content (0.0003/0.0004).

Negative indirect effects of this trait were observed through leaf blade width (-0.0515/-0.0464), stem thickness (-0.0071/-0.0070), number of productive tillers per plant (-0.0012/-0.0011), 1000 grain weight (-0.0389/-0.0357), decorticated grain length (-0.0274/-0.0247), decorticated grain width (-0.0464/-0.0421), gel consistency (-0.0019/-0.0017) and grain iron concentration (-0.0320/-0.0287).

Path coefficient analysis revealed that total no. of grains per panicle exhibited the highest positive direct effect on single plant yield followed by stem length, gel consistency, spikelet fertility, stem thickness and 1000-grain weight, 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 decorticated grain width, no. of productive tillers per plant, leaf blade length, leaf blade width, grain zinc concentration, panicle length, amylose content, decorticated grain length, time of heading, grain iron concentration in decreasing order, respectively.

4.7 Biochemical parameters (proximate principles)

Based on the D² analysis twelve land races from six different clusters were selected to investigate the biochemical analysis (proximate principles). Out of six clusters, four land races (Khama, Murgi balam, Jonnroi buna and Chaturmukhi) from

cluster I, two land races (Binni and Joshyopa) from Cluster II, two land races (Kele and Jhingesal) from cluster III, two land races (Sathia and Jaldhyap) from cluster IV, one of each V (Bharati) and VI (Katharibhog), which were monogenic, are selected.

Out of 5 components of proximate principles three major parameters, namely, crude protein, total fat and fibre were analysed.

The results obtained for proximal composition of these land races investigated in this study are depicted in Table 4.13.

4.5.1 Crude protein (%)

Protein content for these land races ranged from 8.14% to 11.91% with a general mean of 9.81%. The landrace Jonroibuna from cluster I exhibited highest protein content (11.91%) while Jaldhyapa from cluster IV was with lowest (8.14%) among the landraces that are selected for analysis.

4.5.2 Total fat (%)

The general mean for total fat was 1.3% and the landraces Chaturmukhi and Jonroibuna from cluster I exhibited highest (1.3% and lowest (0.48%) total fat.

4.5.3 Fibre (%)

Binni from cluster II and Jhingesal from cluster III have exhibited highest (1.74%) and lowest (0.78%) fibre content with a mean 1.11% among the selected landraces.

The biochemical analysis has revealed that the selected landraces were rich proximate, i.e., crude protein, total fat and fibre. The landraces Kele, Sathia, Jonroibuna, Katharibhog, Chaturmukhi and Bharati were rich in protein content (>10.35%), which can be utilised in future breeding programmes to improve nutritional value of existing high yielding rice varieties.

From ancient period, due to their low yields these landraces were cultivated in small areas by farmers. So, preservation of these germplasm lines is essential for more rewarding breeding efforts to improve our varieties.

India has reached the food security by producing self sufficient food grains. But, now also pulses production and consumption is very low in our country. Due to

which, we are observing deficiencies of major vitamins, micro-nutrients, proteins etc. So, now our target has changed to become nutritionally secured i.e., food grains are to be enriched with these vitamins, micro nutrients, proteins etc. Iron content in some of the landraces were very poor but zinc content in most of the landraces was promising containing 25.80 mg per kg in Kajol ghorya and 24.3 mg per kg in Dhusuri baratee. Most of the commercial indica and japonica rice cultivars are deficient in iron and zinc compared to the other staple food crops such as wheat and maize (Gregorio et al., 2000). Zinc deficiency is probably the most widespread micronutrient deficiency in cereals. Since rice is the principal food of the Asian continent, a lot of efforts are being made to develop nutritionally improved genotypes of rice. Breeding for enhancing bio-available minerals in edible portions through increasing the concentrations of metal-binding proteins have been studied by many researchers (Zang *et al.*, 2005). The first pre-requisite for initiating a breeding program to develop protein and micronutrient-rich genotypes, is to screen the available germplasm and identify the source of the genetic variation for the target trait, which can be used in crosses, genetic studies and to understand the basis of enhanced micronutrient and protein accumulation.

There are about 94,000 rice germplasm accessions present in our gene bank. But characterisation of all accessions is not done. Characterization of accessions is an indispensable tool for selecting good varieties or lines based on agronomical, morphological, nutritional and quality characters to reach the nutritional security. This study has evaluated 76 landraces through morphological, quality and nutritional, which revealed that many landraces are rich in nutrients like iron, zinc, protein, fibre etc., So, these can be utilised in breeding to enrich our high yielding varieties nutritionally.

This study further throws light on useful traits of vast genetic resources of this country. Therefore, it is suggested that the proper characterization and evaluation of the land races would greatly benefit the farmers, breeders to tailor the breeding programme to develop high yielding, nutritionally rich and quality rice and finally to the consumers.

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 “Studies on genetic and biochemical analysis of landraces of rice (Oryza sativa)” was conducted with seventy ix landraces obtained from Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad, with the main objective of studying the genetic variability among the landraces of rice for agro-morphological, grain nutritional and 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. From clusters selected land races having variability for yield, nutritional and quality traits were investigated on biochemical properties (Proximate principles).

The experiment was carried out in Randomized block design, with three replications during *kharif* 2016 of 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 eleven qualitative characters viz., basal leaf sheath colour, flag leaf attitude (late obseravtion), culm attitude, lemma anthocyanin colouration of apex, stigma colour, stem anthocyanin colouration of nodes and internodes, density of pubescence, attitude of branches, panicle exsertion and lemma and palea colour.

Data on eleven metric parameters viz., leaf blade length, leaf blade width, stem thickness, stem length, 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. 1000- grain weight was recorded per replication in each genotype. Grain quality and nutritional traits including decorticated grain length, decorticated grain width, 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 twenty two DUS characters recorded on seventy six genotypes, green basal leaf sheath were observed in 55 genotypes (71.43%), leaf blade length long in 45 genotypes (59.21%), leaf blade width medium in 51 genotypes (67.11%), culm attitude semi-erect in 46 genotypes (60.53%), time of heading medium in 34 (44.74%) and late in 36 (47.37%), pubescence of spikelet lemma mostly fall in medium with 39 genotypes (51.32%), 48 genotypes with stigma colour (63.16%), 43 genotypes with short stem (56.58%), 40 genotypes with medium thick stems (52.63%), panicle length medium in 40 genotypes (52.63%), 33 and 35 genotypes with semi-erect and horizontal attitude of flag leaf (late observation) respectively, 63 genotypes with medium number of productive tillers per plant, 43 genotypes with semi erect to spreading type of branches in panicle, 41 and 32 genotypes with well exerted and mostly exerted type of panicles, respectively, 30 genotypes with high weight of 1000 fully developed grains, 43 and 71 genotypes with medium decorticated grain length and width, respectively, 42 genotypes are with medium amylose content and 29 genotypes are medium in gel consistency.

In quantitative traits, among all seventy six genotypes, the Sati exhibited highest leaf blade length, Dharmaphool exhibited maximum leaf blade width, Sati has thick stem, Baku has 120.16 cm long stem. The number of productive tillers per plant were found to highest in Jashyopa, while time of heading was found earlier in Kotki and late in Jashyopa. Kadamful exhibited highest panicle length, Mihigandheswari has highest total number of grains per panicle, spikelet fertility ranged from 62.77 % (Jhingesal) to 97.63% (Sathi-P) with lowest and highest, respectively.

Balangir-Saria recorded the highest 1000-grain weight and was superior to all the genotypes tested and the landraces Kartikkhas exhibited highest single plant yields. The landrace Jhumka basmati recorded maximum decorticated grain lengths while Baku exhibited maximum width. Khama has highest amylose content while five

landraces viz., Binni, Jonroibuna, Bonnidhan, Gochi and Balangir-saria had highest gel consistency.

Iron concentration in decorticated grain was found maximum in Balangir-kutumdola-kalakrushna and khajal ghorya recorded maximum zinc concentrations in decorticated grain.

Analysis of variance revealed the presence of significant differences among the landraces of rice under study for all the seventeen traits viz., leaf blade length, width, time of heading (50% plants with panicles), stem length, thickness, panicle length, productive tillers per plant, total number of grains per panicle, spikelet fertility, 1000-grain weight, single plant yield, decorticated grain length, decorticated grain width and amylose content, gel consistency, grain iron concentration and grain zinc concentration, indicating the presence of considerable genetic variability among 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 exhibited high heritability coupled with high genetic advance as a per cent of mean, which indicate the preponderance of additive gene action in controlling these traits. Hence direct selection of these characters would be effective in improving the seed yield. Spikelet fertility 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.

Divergence studies through D^2 statistics 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 six 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 six

clusters, cluster I was the largest comprising of forty nine landraces, followed by cluster III with fourteen, cluster II with seven and cluster IV with four. Clusters V and VI were monogenotypic clusters, suggesting the existence of high degree of heterogeneity among the genotypes.

Maximum intra cluster distance was observed in cluster II (1689.04), followed by cluster III (1671.21), cluster I (1574.26) and cluster IV (934.52) 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.

Maximum inter cluster distance was exhibited between clusters II and VI followed by clusters I and IV, clusters V and VI and clusters II and IV. 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 I and V (2569.95) followed by clusters I and II (4745.76) and clusters III and IV (5112.24), 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.

The cluster I, II III and V was having highest mean value for total number of grains per panicle, cluster IV and VI had highest mean values for time of heading. 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.

The cluster II and VI had highest mean value for five and four morphological and grain parameters and cluster V and I exhibited highest mean values for single plant yield. 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 I (Sati) and IV (Jaldhyapa), clusters II (Kalaogandheswari) and

VI (Katharibhog), clusters III (Mihigandheswari) and IV (Kala heera dhan), cluster V (Bharati) and VI (Katharibhog) may produce encouraging results.

Out of the seventeen characters studied, six characters namely stem length, grain zinc concentration, gel consistency, amylose content, spikelet fertility and grain iron concentration together contributed maximum (97.33 %) 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 association with time of heading (50 % plants with panicles), stem thickness, spikelet fertility, panicle length, stem length and total number of grains per panicle indicating that these characters were important for yield improvement. Gel consistency also exhibited positive 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.

Path coefficient analysis revealed that total number of grains per panicle exerted the highest positive direct effect on grain yield followed by stem length, gel consistency, panicle length, spikelet fertility, stem thickness and time of heading, indicating that the selection for these characters is 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 total number of grains per panicle 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, spikelet fertility, stem thickness and time of heading is played 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.

The biochemical analysis of 12 selected landraces has revealed that the genotypes Jonroi buna, Bharathi, Chaturmukhi are rich in crude protein,

Chaturmukhi, Kele are rich in total fat and Binni, Kathatibhog and Khama are rich in total fibre. Therefore these landraces may be utilised in breeding to improve the existing cultivated high yielding varieties to attain nutritional security.

This study further throws light on useful traits of vast genetic resources of this country. Therefore, it is suggested that the proper characterization and evaluation of the land races would greatly benefit the farmers, breeders to tailor the breeding programme to develop high yielding, nutritionally rich and quality rice and finally to the consumers.

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*Original not seen

The pattern of “Literature Cited” presented above is in accordance with the Thesis format guidelines, 2017, Professor Jayashankar Telangana State Agricultural University, Hyderabad.

Table 3.1 Details of landraces of rice used in the present study and source of material

S. No.	Code. No.	Name of the landrace	S. No.	Code. No.	Name of the landrace
1	FV 1602	Sati	30	FV 1632	Khaiyam dhan
2	FV 1604	Kele	31	FV 1633	Jaldhyapa-3
3	FV 1605	Khama	32	FV 1634	Dudhkalam motajashya
4	FV 1606	Murgibalam	33	FV 1635	Biroi
5	FV 1607	Hetomari	34	FV 1638	Kauka
6	FV 1608	Jhingesal	35	FV 1639	Betho
7	FV 1609	Harina khuri	36	FV 1640	Kaike
8	FV 1610	Sathia	37	FV 1641	Bochi
9	FV 1611	Kotki	38	FV 1642	Jhagrikartick
10	FV 1612	Katarybhog	39	FV 1643	Dhusuri baratee
11	FV 1613	Harinkajali	40	FV 1644	Bonnidhan
12	FV 1614	Baigon machua	41	FV 1645	Bitti
13	FV 1615	Phool pakri	42	FV 1647	Sugandha-II
14	FV 1616	Binni	43	FV 1648	Mihigandheswari
15	FV 1617	Kalo bochi	44	FV 1649	Paramananda
16	FV 1618	Jaldhyapa	45	FV 1650	Govind bhog-1
17	FV 1619	Dudhkalam-1	46	FV 1651	Serha-5
18	FV 1620	Kashiya binni	47	FV 1652	Katharibhog
19	FV 1621	Jonroi buna	48	FV 1654	Gochi
20	FV 1622	Kukurjali	49	FV 1655	Chaturmukhi
21	FV 1623	Dharmaphool	50	FV 1656	Shyam
22	FV 1624	Kajal ghorya	51	FV 1657	Chingri fuli
23	FV 1625	Dhyapa	52	FV 1658	Dadghani
24	FV 1626	Kalo dhyapa	53	FV 1659	Kashiyabinni
25	FV 1627	Mangamuthi	54	FV 1660	Jabsal-1
26	FV 1628	Paharibochi selection-1	55	FV 1661	Dhan sirhatti
27	FV 1629	Jashoya	56	FV 1663	Baku
28	FV 1630	Kalshepa	57	FV 1664	Gandheswari
29	FV 1631	Radhatilak selection-1	58	FV 1667	Sathi-P

S. No.	Code. No.	Name of the landrace
59	FV 1669	Kala heera dhan
60	FV 1670	Meghi
61	FV 1671	Kalo gandheswari
62	FV 1672	Kartik khas
63	FV 1674	Samkene
64	FV 1675	Moti bas
65	FV 1676	Joha
66	FV 1677	Khajurchari-III
67	FV 1680	Angl-digipadar-chinamali
68	FV 1681	Jhumka Basmati
69	FV 1682	Magara-B
70	FV 1684	Kadamful
71	FV 1685	Balangir-kutumdola-kala krushna
72	FV 1686	Bharati
73	FV 1687	Godi kaberi
74	FV 1688	Nbr-assanchudi
75	FV 1689	Mbj-basumati
76	FV 1690	Balangir-saria

❖ **Place of collection :** ICAR-IIRR, Hyderabad

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.	Culm: attitude	Erect Semi-erect Open Spreading	1 3 5 7	Booting
4.	Lemma: anthocyanin colouration of apex	Absent Weak Medium Strong Very Strong	1 3 5 7 9	Middle of anthesis
5.	Spikelet: colour of stigma	White Light green Yellow Light purple Purple	1 2 3 4 5	Middle of anthesis
6.	Stem: anthocyanin colouration of nodes	Absent Present	1 9	Milking stage
7.	Stem: anthocyanin colouration of internodes	Absent Present	1 9	Milking stage
8.	Spiklet: density of pubescence	Absent Weak Medium Strong Very strong	1 3 5 7 9	Ripening

S. No.	Character	States	Note	Stage of observation
9	Lemma and Palea colour	Straw Gold and gold furrows on straw back ground Brown spots on straw Brown furrows on straw Brown (tawny) Reddish to light purple Purple spots on straw Purple furrows on straw Purple Black	0 1 2 3 4 5 6 7 8 9	Ripening
10.	Panicle : attitude of branching	Erect Erect to semi-erect Semi-erect Semi-erect to spreading Spreading	1 3 5 7 9	Ripening
11.	Panicle: exertion	Partly exerted Mostly exerted Well exerted	3 5 7	Ripening

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) Early (71-90 days) Medium (91-110 days) Late (111-130 days) Very late (>130 days)	1 3 5 7 9	Half of inflorescence emerged
2.	Stem: length (excluding panicle; excluding floating rice)	Very short (<91 cm) Short (91-110 cm) Medium (111-130 cm) Long (131-150 cm) Very long (>150 cm)	1 3 5 7 9	Milking stage
3.	Panicle length	Very short (<16 cm) Short (16-20 cm) Medium (21-25 cm) Long (26-30 cm) Very long (>30 cm)	1 3 5 7 9	Milking to ripening stage

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 (mm)	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 (mm)	Narrow (<2.0 mm)	3	Caryopsis hard
		Medium (2.0-2.5 mm)	5	
		Broad (>2.5 mm)	7	
3.	Amylose content (%)	Very low (<10%)	1	Caryopsis hard
		Low (10-19%)	3	
		Medium (20-25%)	5	
		High (26-30%)	7	
		Very high (>30%)	9	

Table 4.1 (cont.).

Table 4.1 Agro-morphological characterization of landraces of rice

Name of the landrace	Basal: leaf sheath colour	Leaf: length of blade	Leaf: width of blade	Flag leaf: attitude of blade	Culm : attitude	Time of heading	Lemma: anthocyanin colouration of apex	Spikelet: colour of stigma	Stem: thickness	Stem: length	Stem: anthocyanin colouration of node
Sati	Green	Long	Medium	Horizontal	Open	Late	Absent	White	Thick	Short	Absent
Kele	Light Purple	Medium	Medium	Semi-erect	Semi-erect	Early	Weak	Light Purple	Thin	Very short	Absent
Khama	Green	Long	Medium	Horizontal	Erect	Early	Absent	White	Medium	Short	Absent
Murgibalam	Light Purple	Long	Medium	Semi-erect	Semi-erect	Late	Medium	Purple	Medium	Short	Absent
Hetomari	Purple	Medium	Narrow	Semi-erect	Open	Late	Medium	Purple	Thin	Very short	Absent
Jhingesal	Green	Medium	Narrow	Erect	Semi-erect	Late	Absent	White	Medium	Very short	Absent
Harina khuri	Green	Short	Narrow	Semi-erect	Semi-erect	Medium	Medium	Yellow	Medium	Very short	Absent
Sathia	Green	Medium	Medium	Semi-erect	Semi-erect	Early	Absent	White	Medium	Very short	Absent
Kotki	Light purple	Medium	Narrow	Semi-erect	Erect	Early	Weak	Yellow	Medium	Very short	Absent
Katarybhog	Green	Long	Medium	Semi-erect	Erect	Medium	Absent	White	Medium	Short	Absent
Harinkajali	Light purple	Medium	Medium	Semi-erect	Open	Early	Absent	Light purple	Thin	Very short	Absent
Baigon machua	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Thin	Very short	Absent
Phool pakri	Green	Long	Narrow	Semi-erect	Open	Late	Absent	Yellow	Thin	Very short	Absent
Binni	Green	Long	Medium	Semi-erect	Semi-erect	Late	Absent	White	Thin	Short	Absent
Kalo bochi	Green	Medium	Narrow	Horizontal	Semi-erect	Medium	Absent	Yellow	Thin	Very short	Absent
Jaldhyapa	Light purple	Long	Medium	Horizontal	Semi-erect	Late	Medium	Purple	Thin	Very short	Absent

Table 4.1 (cont.).

Name of the landrace	Basal: leaf sheath colour	Leaf: length of blade	Leaf: width of blade	Flag leaf: attitude of blade	Culm : attitude	Time of heading	Lemma: anthocyanin colouration of apex	Spikelet: colour of stigma	Stem: thickness	Stem: length	Stem: anthocyanin colouration of node
Dudhkalam-1	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	Yellow	Medium	Short	Absent
Kashiya binni	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Thin	Short	Absent
Jonroi buna	Purple	Medium	Medium	Horizontal	Semi-erect	Medium	Medium	White	Medium	Short	Absent
Kukurjali	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Thin	Short	Absent
Dharmaphool	Green	Long	Medium	Semi-erect	Erect	Late	Absent	Yellow	Medium	Very short	Absent
Kajal ghorya	Purple	Long	Medium	Horizontal	Semi-erect	Early	Very strong	Purple	Medium	Short	Present
Dhyapa	Green	Long	Medium	Semi-erect	Semi-erect	Late	Absent	Yellow	Medium	Short	Absent
Kalo dhyapa	Light Purple	Long	Medium	Erect	Semi-erect	Medium	Strong	White	Medium	Short	Present
Mangamuthi	Light Purple	Long	Medium	Semi-erect	Semi-erect	Late	Medium	Purple	Medium	Medium	Absent
Paharibochi	Green	Long	Medium	Horizontal	Semi-erect	Medium	Absent	White	Medium	Medium	Absent
Jashoya selection-1	Green	Long	Medium	Horizontal	Spreading	Late	Medium	Light purple	Thick	Medium	Absent
Kalshepa	Light Purple	Long	Medium	Horizontal	Semi-erect	Late	Weak	Yellow	Medium	Short	Present
Radhatilak selection-1	Green	Short	Broad	Horizontal	Open	Late	Absent	White	Thin	Very short	Absent
Khaiyam dhan	Light Purple	Short	Broad	Semi-erect	Semi-erect	Medium	Weak	White	Medium	Short	Present
Jaldhyapa-3	Light Purple	Short	Broad	Horizontal	Open	Late	Weak	Light purple	Medium	Short	Present
Dudhkalam motajashya	Green	Short	Broad	Horizontal	Semi-erect	Late	Absent	White	Medium	Short	Absent

Table 4.1 (cont.).

Name of the landrace	Basal: leaf sheath colour	Leaf: length of blade	Leaf: width of blade	Flag leaf: attitude of blade	Culm : attitude	Time of heading	Lemma: anthocyanin colouration of apex	Spikelet: colour of stigma	Stem: thickness	Stem: length	Stem: anthocyanin colouration of node
Biroi	Green	Short	Broad	Horizontal	Open	Late	Medium	White	Medium	Very short	Absent
Kauka	Green	Short	Medium	Erect	Open	Medium	Absent	White	Thin	Very short	Absent
Betho	Purple	Short	Medium	Semi-erect	Semi-erect	Medium	Medium	White	Medium	Short	Present
Kaike	Green	Short	Medium	Erect	Semi-erect	Medium	Absent	White	Thin	Very short	Absent
Bochi	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Medium	Short	Absent
Jhagrikartick	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Medium	Very short	Absent
Dhusuri baratee	Green	Long	Medium	Semi-erect	Semi-erect	Medium	Weak	White	Medium	Very short	Absent
Bonnidhan	Light Purple	Long	Medium	Semi-erect	Semi-erect	Medium	Strong	Yellow	Medium	Short	Present
Bitti	Light Purple	Medium	Medium	Semi-erect	Semi-erect	Medium	Weak	White	Thick	Short	Present
Sugandha-II	Green	Long	Narrow	Horizontal	Semi-erect	Late	Absent	White	Medium	Short	Absent
Mihigandheswari	Green	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Medium	Very short	Absent
Paramananda	Green	Long	Medium	Horizontal	Semi-erect	Medium	Absent	Yellow	Medium	Short	Absent
Govind bhog-1	Green	Medium	Medium	Semi-erect	Semi-erect	Medium	Absent	Yellow	Thin	Short	Absent
Serha-5	Green	Medium	Medium	Semi-erect	Semi-erect	Late	Absent	White	Medium	Short	Absent
Katharibhog	Green	Short	Medium	Semi-erect	Spreading	Medium	Weak	Purple	Thin	Short	Present
Gochi	Light purple	Long	Medium	Horizontal	Semi-erect	Late	Absent	White	Thick	Short	Present

Table 4.1 (cont.).

Name of the landrace	Basal: leaf sheath colour	Leaf: length of blade	Leaf: width of blade	Flag leaf: attitude of blade	Culm : attitude	Time of heading	Lemma: anthocyanin colouration of apex	Spikelet: colour of stigma	Stem: thickness	Stem: length	Stem: anthocyanin colouration of node
Chaturmukhi	Green	Long	Narrow	Horizontal	Semi-erect	Medium	Absent	White	Medium	Very short	Absent
Shyam	Green	Long	Narrow	Horizontal	Semi-erect	Late	Absent	White	Medium	Short	Absent
Chingri fuli	Green	Medium	Narrow	Semi-erect	Semi-erect	Medium	Absent	White	Thick	Short	Absent
Dadghani	Green	Long	Medium	Deflexed	Semi-erect	Late	Absent	White	Medium	Short	Absent
Kashiyabinni	Green	Long	Narrow	Deflexed	Open	Medium	Absent	Yellow	Medium	Short	Absent
Jabsal-1	Green	Long	Medium	Semi-erect	Erect	Medium	Weak	White	Thin	Short	Absent
Dhan sirhatti	Green	Long	Medium	Erect	Semi-erect	Late	Absent	White	Medium	Very short	Absent
Baku	Green	Long	Medium	Semi-erect	Spreading	Late	Absent	White	Thick	Medium	Absent
Gandheswari	Light purple	Long	Narrow	Horizontal	Erect	Medium	Absent	White	Medium	Very short	Absent
Sathi-P	Green	Medium	Medium	Semi-erect	Open	Medium	Absent	White	Thin	Very short	Absent
Kala heera dhan	Green	Short	Narrow	Erect	Spreading	Late	Strong	White	Thin	Very short	Absent
Meghi	Green	Long	Narrow	Semi-erect	Open	Medium	Absent	White	Thin	Short	Absent
Kalo gandheswari	Green	Long	Narrow	Horizontal	Open	Late	Absent	White	Thick	Medium	Absent
Kartik khas	Green	Long	Narrow	Horizontal	Semi-erect	Medium	Absent	White	Thin	Short	Absent
Samkene	Light purple	Long	Narrow	Semi-erect	Semi-erect	Late	Medium	Purple	Thin	Short	Present
Moti bas	Green	Medium	Narrow	Semi-erect	Semi-erect	Medium	Absent	White	Thin	Short	Absent

Table 4.1 (cont.).

Name of the landrace	Basal: leaf sheath colour	Leaf: length of blade	Leaf: width of blade	Flag leaf: attitude of blade	Culm : attitude	Time of heading	Lemma: anthocyanin colouration of apex	Spikelet: colour of stigma	Stem: thickness	Stem: length	Stem: anthocyanin colouration of node
Joha	Green	Medium	Medium	Semi-erect	Semi-erect	Medium	Strong	White	Thin	Short	Absent
Khajurchari-III	Green	Long	Medium	Semi-erect	Open	Late	Absent	White	Thick	Short	Absent
Angl-digipadar-chinamali	Green	Medium	Narrow	Horizontal	Open	Late	Absent	White	Thin	Very short	Absent
Jhumka Basmati	Green	Medium	Narrow	Semi-erect	Erect	Medium	Absent	White	Thin	Very short	Absent
Magara-B	Green	Long	Medium	Horizontal	Open	Medium	Weak	Purple	Medium	Very short	Absent
Kadamful	Green	Long	Medium	Semi-erect	Open	Medium	Very strong	White	Thin	Short	Present
Balangir-kutumdola-kala	Green	Long	Medium	Horizontal	Erect	Medium	Very strong	Yellow	Thin	Short	Absent
Bharati	Green	Medium	Medium	Horizontal	Erect	Late	Absent	Yellow	Medium	Short	Absent
Godi kaberi	Light purple	Long	Medium	Horizontal	Open	Medium	Absent	White	Thin	Short	Present
Nbr-assanchudi	Green	Medium	Medium	Horizontal	Semi-erect	Medium	Absent	Yellow	Medium	Short	Absent
Mbj-basumati	Green	Long	Medium	Horizontal	Semi-erect	Medium	Absent	Yellow	Medium	Short	Absent
Balangir-saria	Light purple	Medium	Medium	Semi-erect	Semi-erect	Medium	Absent	White	Medium	Very short	Absent

Table 4.1 (cont.).

Name of the landrace	Stem: anthocyanin colouration of internode	Panicle: length of the main axis	Panicle: productive tillers per plant	Spikelet: density of pubescence	Lemma and palea colour	Panicle: attitude of branching	Panicle: exertion	Grain : weight of the 1000 fully developed grains (g)
Sati	Absent	Medium	Medium	Medium	Straw	Erect to semi-erect	Mostly exerted	Very high
Kele	Absent	Short	Medium	Medium	Black	Erect to semi-erect	Mostly exerted	High
Khama	Absent	Medium	Medium	Medium	Brown (tawny)	Erect to semi-erect	Well exerted	Low
Murgibalam	Absent	Short	Medium	Medium	Brown (tawny)	Erect to semi-erect	Well exerted	High
Hetomari	Absent	Short	Medium	Medium	Straw	Erect to semi-erect	Mostly exerted	Medium
Jhingesal	Absent	Very short	Medium	Medium	Straw	Semi-erect to spreading	Mostly exerted	Medium
Harina khuri	Absent	Short	Medium	Medium	Purple spots on Straw	Semi-erect to spreading	Well exerted	Low
Sathia	Absent	Short	Medium	Medium	Straw	Erect to semi-erect	Mostly exerted	High
Kotki	Absent	Short	Medium	Medium	Straw	Erect to semi-erect	Well exerted	Medium
Katarybhog	Absent	Short	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	Low
Harinkajali	Absent	Short	Medium	Medium	Black	Erect to semi-erect	Well exerted	High
Baigon machua	Absent	Medium	Medium	Medium	Straw	Semi-erect	Well exerted	Very low
Phool pakri	Absent	Short	Medium	Medium	Brown furrows on Straw	Spreading	Well exerted	Medium
Binni	Absent	Short	Medium	Strong	Brown furrows on Straw	Erect	Well exerted	High
Kalo bochi	Absent	Medium	Many	Strong	Straw	Erect to semi-erect	Mostly exerted	Very high
Jaldhyapa	Absent	Medium	Medium	Medium	Straw	Semi-erect	Mostly exerted	High

Table 4.1 (cont.).

Name of the landrace	Stem: anthocyanin colouration of internode	Panicle: length of the main axis	Panicle: productive tillers per plant	Spikelet: density of pubescence	Lemma and palea colour	Panicle: attitude of branching	Panicle: exertion	Grain : weight of the 1000 fully developed grains (g)
Dudhkalam-1	Absent	Medium	Medium	Strong	Straw	Spreading	Well exerted	Medium
Kashiya binni	Absent	Medium	Medium	Strong	Brown spots on Straw	Semi-erect to spreading	Mostly exerted	High
Jonroi buna	Present	Medium	Medium	Strong	Purple	Erect to semi-erect	Mostly exerted	High
Kukurjali	Absent	Medium	Medium	Medium	Purple spots on straw	Semi-erect to spreading	Well exerted	Medium
Dharmaphool	Absent	Short	Medium	Strong	Straw	Semi-erect to spreading	Partly exerted	High
Kajal ghorya	Present	Medium	Medium	Medium	Purple furrows on straw	Semi-erect to spreading	Mostly exerted	Very high
Dhyapa	Absent	Short	Medium	Medium	Straw	Semi-erect	Mostly exerted	Medium
Kalo dhyapa	Absent	Very short	Medium	Medium	Purple spots on straw	Erect to semi-erect	Well exerted	High
Mangamuthi	Absent	Short	Few	Weak	Straw	Semi-erect to spreading	Well exerted	High
Paharibochi	Absent	Medium	Medium	Medium	Brown (tawny)	Semi-erect to spreading	Well exerted	Medium
Jashoya selection-1	Absent	Medium	Many	Medium	Black	Semi-erect to spreading	Well exerted	High
Kalshepa	Absent	Medium	Medium	Strong	Purple spots on straw	Erect to semi-erect	Well exerted	High
Radhatilak selection-1	Absent	Medium	Medium	Medium	Straw	Semi-erect	Mostly exerted	Low
Khaiyam dhan	Present	Short	Medium	Strong	Purple spots on straw	Semi-erect to spreading	Well exerted	Very high
Jaldhyapa-3	Present	Medium	Medium	Medium	Straw	Semi-erect to spreading	Mostly exerted	Very high
Dudhkalam motajashya	Absent	Medium	Medium	Medium	Straw	Semi-erect to spreading	Well exerted	High

Table 4.1 (cont.).

Name of the landrace	Stem: anthocyanin colouration of internode	Panicle: length of the main axis	Panicle: productive tillers per plant	Spikelet: density of pubescence	Lemma and palea colour	Panicle: attitude of branching	Panicle: exertion	Grain : weight of the 1000 fully developed grains (g)
Biroi	Absent	Medium	Medium	Weak	Black	Semi-erect	Well exerted	Low
Kauka	Absent	Very short	Medium	Strong	Brown furrows on straw	Semi-erect to spreading	Well exerted	Very high
Betho	Present	Short	Few	Strong	Purple furrows on straw	Erect to semi-erect	Mostly exerted	Very high
Kaike	Absent	Very short	Medium	Strong	Brown furrows on straw	Erect to semi-erect	Well exerted	High
Bochi	Absent	Medium	Medium	Strong	Brown furrows on straw	Semi-erect to spreading	Mostly exerted	High
Jhagrikartick	Absent	Medium	Medium	Medium	Straw	Semi-erect	Well exerted	High
Dhusuri baratee	Absent	Short	Medium	Medium	Straw	Erect to semi-erect	Mostly exerted	High
Bonnidhan	Present	Short	Medium	Strong	Black	Semi-erect to spreading	Mostly exerted	Low
Bitti	Present	Short	Medium	Medium	Straw	Semi-erect to spreading	Mostly exerted	Medium
Sugandha-II	Absent	Medium	Medium	Weak	Straw	Semi-erect	Well exerted	Low
Mihigandheswari	Absent	Medium	Few	Weak	Straw	Semi-erect to spreading	Mostly exerted	Low
Paramananda	Absent	Medium	Few	Medium	Brown furrows on straw	Erect to semi-erect	Well exerted	High
Govind bhog-1	Absent	Short	Medium	Medium	Straw	Semi-erect to spreading	Well exerted	Low
Serha-5	Absent	Short	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	Low
Katharibhog	Present	Short	Medium	Strong	Purple	Erect	Partly exerted	High
Gochi	Absent	Medium	Medium	Weak	Straw	Erect	Mostly exerted	High

Table 4.1 (cont.).

Name of the landrace	Stem: anthocyanin colouration of internode	Panicle: length of the main axis	Panicle: productive tillers per plant	Spikelet: density of pubescence	Lemma and palea colour	Panicle: attitude of branching	Panicle: exertion	Grain : weight of the 1000 fully developed grains (g)
Chaturmukhi	Absent	Medium	Medium	Medium	Straw	Semi-erect to spreading	Well exerted	Low
Shyam	Absent	Medium	Few	Weak	Straw	Semi-erect to spreading	Mostly exerted	Medium
Chingri fuli	Absent	Short	Medium	Medium	Straw	Semi-erect to spreading	Mostly exerted	Very high
Dadghani	Absent	Long	Medium	Medium	Gold and gold furrows on straw	Semi-erect to spreading	Mostly exerted	Medium
Kashiyabinni	Absent	Long	Medium	Medium	Brown furrows on straw	Semi-erect to spreading	Mostly exerted	Very high
Jabsal-1	Absent	Short	Few	Medium	Straw	Erect to semi-erect	Mostly exerted	High
Dhan sirhatti	Absent	Very short	Medium	Weak	Black	Erect to semi-erect	Partly exerted	Medium
Baku	Absent	Short	Few	Weak	Straw	Erect to semi-erect	Well exerted	Very high
Gandheswari	Absent	Medium	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	Low
Sathi-P	Absent	Short	Medium	Medium	Black	Erect to semi-erect	Well exerted	Medium
Kala heera dhan	Absent	Very short	Medium	Weak	Purple	Semi-erect to spreading	Mostly exerted	Medium
Meghi	Absent	Short	Medium	Weak	Gold and gold furrows on straw	Semi-erect to spreading	Well exerted	Low
Kalo gandheswari	Absent	Medium	Medium	Weak	Straw	Semi-erect to spreading	Mostly exerted	High
Kartik khas	Absent	Medium	Medium	Medium	Straw	Semi-erect to spreading	Well exerted	Low
Samkene	Absent	Short	Few	Weak	Brown spots on straw	Semi-erect to spreading	Well exerted	High
Moti bas	Absent	Short	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	Very low

Table 4.1 (cont.).

Name of the landrace	Stem: anthocyanin colouration of internode	Panicle: length of the main axis	Panicle: productive tillers per plant	Spikelet: density of pubescence	Lemma and palea colour	Panicle: attitude of branching	Panicle: exertion	Grain : weight of the 1000 fully developed grains (g)
Joha	Absent	Short	Medium	Medium	Purple	Semi-erect to spreading	Well exerted	Medium
Khajurchari-III	Absent	Short	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	High
Angl-digipadar-chinamali	Absent	Medium	Medium	Weak	Straw	Semi-erect to spreading	Well exerted	High
Jhumka Basmati	Absent	Short	Medium	Weak	Straw	Semi-erect to spreading	Mostly exerted	High
Magara-B	Absent	Medium	Few	Medium	Brown(tawny)	Semi-erect to spreading	Well exerted	Medium
Kadamful	Absent	Short	Medium	Weak	Purple spots on straw	Spreading	Well exerted	Medium
Balangir- kutumdola-kala krushna	Absent	Medium	Medium	Medium	Black	Semi-erect to spreading	Well exerted	Low
Bharati	Absent	Medium	Many	Weak	Purple	Semi-erect to spreading	Mostly exerted	Medium
Godi kaberi	Absent	Medium	Medium	Strong	Brown furrows on straw	Semi-erect to spreading	Well exerted	High
Nbr-assanchudi	Absent	Medium	Few	Medium	Brown spots on straw	Semi-erect to spreading	Mostly exerted	High
Mbj-basumati	Absent	Medium	Medium	Weak	Straw	Semi-erect to spreading	Mostly exerted	Low
Balangir-saria	Absent	Short	Few	Medium	Straw	Semi-erect to spreading	Mostly exerted	High

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

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Amylose content (%)	Gel consistency (mm)
Sati	Medium	Narrow	High	Medium
Kele	Medium	Narrow	High	Medium
Khama	Medium	Narrow	High	Medium
Murgibalam	Medium	Narrow	High	Medium
Hetomari	Medium	Narrow	Medium	Hard
Jhingesal	Medium	Narrow	High	Medium
Harina khuri	Medium	Narrow	Medium	Soft
Sathia	Medium	Narrow	Medium	Hard
Kotki	Medium	Narrow	High	Medium
Katarybhog	Medium	Narrow	Medium	Medium
Harinkajali	Medium	Narrow	High	Soft
Baigon machua	Short	Narrow	Medium	Soft
Phool pakri	Medium	Narrow	Medium	Hard
Binni	Long	Narrow	Very low	Soft
Kalo bochi	Medium	Narrow	Medium	Medium
Jaldhyapa	Short	Medium	High	Medium
Dudhkalam-1	Medium	Narrow	Medium	Medium
Kashiya binni	Medium	Narrow	High	Medium
Jonroi buna	Medium	Narrow	Very low	Soft
Kukurjali	Short	Narrow	Medium	Hard
Dharmaphool	Medium	Narrow	Low	Soft
Kajal ghorya	Short	Narrow	Medium	Medium
Dhyapa	Medium	Narrow	Medium	Medium
Kalo dhyapa	Medium	Narrow	Medium	Soft
Mangamuthi	Medium	Narrow	Medium	Hard
Paharibochi selection-1	Medium	Medium	Medium	Soft
Jashoya	Short	Narrow	Medium	Hard
Kalshepa	Medium	Narrow	Medium	Medium

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Amylose content (%)	Gel consistency (mm)
Radhatilak selection-1	Short	Narrow	Low	Soft
Khaiyam dhan	Long	Narrow	Low	Soft
Jaldhyapa-3	Medium	Medium	Medium	Medium
Dudhkalam motajashya	Long	Narrow	Medium	Hard
Biroi	Medium	Narrow	Low	Medium
Kauka	Medium	Narrow	Medium	Medium
Betho	Medium	Narrow	Medium	Soft
Kaike	Medium	Narrow	Very low	Soft
Bochi	Short	Narrow	Low	Soft
Jhagrikartick	Short	Narrow	Medium	Soft
Dhusuri baratee	Short	Narrow	Medium	Medium
Bonnidhan	Medium	Narrow	Very low	Soft
Bitti	Short	Narrow	Medium	Medium
Sugandha-II	Short	Narrow	Medium	Hard
Mihigandheswari	Short	Narrow	Medium	Medium
Paramananda	Short	Medium	Medium	Medium
Govind bhog-1	Short	Narrow	Low	Hard
Serha-5	Medium	Narrow	Low	Soft
Katharibhog	Medium	Narrow	Medium	Soft
Gochi	Medium	Narrow	High	Soft
Chaturmukhi	Short	Narrow	Medium	Medium
Shyam	Short	Narrow	Medium	Soft
Chingri fuli	Medium	Narrow	High	Soft
Dadghani	Medium	Narrow	Medium	Hard
Kashiyabinni	Medium	Narrow	Medium	Medium
Jabsal-1	Medium	Narrow	Medium	Soft
Dhan sirhatti	Short	Narrow	Medium	Medium
Baku	Short	Medium	High	Soft
Gandheswari	Short	Narrow	Medium	Medium
Sathi-P	Medium	Narrow	High	Soft

Name of the landrace	Decorticated grain: length	Decorticated grain: width	Amylose content (%)	Gel consistency (mm)
Kala heera dhan	Short	Narrow	High	Soft
Meghi	Medium	Narrow	Medium	Medium
Kalo gandheswari	Short	Narrow	High	Soft
Kartik khas	Short	Narrow	Medium	Medium
Samkene	Medium	Narrow	High	Soft
Moti bas	Short	Narrow	Medium	Soft
Joha	Medium	Narrow	Medium	Soft
Khajurchari-III	Medium	Narrow	High	Soft
Angl-digipadar-chinamali	Short	Narrow	High	Soft
Jhumka Basmati	Very long	Narrow	Medium	Hard
Magara-B	Short	Narrow	Medium	Soft
Kadamful	Short	Narrow	Medium	Medium
Balangir-kutumdola-kala krushna	Short	Narrow	Medium	Medium
Bharati	Medium	Narrow	High	Soft
Godi kaberi	Medium	Narrow	High	Soft
Nbr-assanchudi	Long	Narrow	High	Soft
Mbj-basumati	Short	Narrow	Medium	Soft
Balangir-saria	Medium	Narrow	High	Soft

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	55	71.43
		Light purple	17	11.43
		Purple	4	5.71
2	Leaf : length of the blade	Short	11	14.47
		Medium	20	26.32
		Long	45	59.21
3	Leaf : width of the blade	Narrow	20	26.32
		Medium	51	67.11
		Broad	5	6.58
4	Flag leaf: attitude of blade (late observation)	Erect	6	7.89
		Semi erect	33	43.42
		Horizontal	35	46.05
		Deflexed	2	2.64
5	Culm : attitude	Erect	9	11.84
		Semi erect	46	60.53
		Open	17	22.37
		Spreading	4	5.26
6	Time of heading (50 % plants with panicles)	Early	6	7.89
		Medium	34	44.74
		Late	36	47.37
7.	Lemma: anthocyanin colouration of apex	Absent	49	64.47
		Weak	10	13.16
		Medium	10	13.16
		Strong	4	5.26
		Very strong	3	3.95
8.	Spikelet: colour of stigma	White	48	63.16
		Yellow	16	21.05
		Light purple	4	5.26
		Purple	8	10.53
9.	Stem : thickness	Thin	28	36.84
		Medium	40	52.63
		Thick	8	10.53
10.	Stem : length (excluding panicle)	Very short	28	36.84
		Short	43	56.58
		Medium	5	6.58

S. No.	Character	State of expression	Number of genotypes	Frequency distribution (%)
11.	Stem: anthocyanin colouration of node	Absent	63	82.89
		Present	13	17.11
12.	Stem: anthocyanin colouration of internodes	Absent	68	89.47
		Present	8	10.53
13.	Panicle : length of main axis	Short	5	6.78
		Medium	40	52.63
		Long	30	39.47
		Very long	1	1.32
14	Panicle: no. of productive tillers per plant	Few	11	14.47
		Medium	63	82.90
		Many	2	2.63
15.	Spikelet: density of pubescence of lemma	Weak	22	28.95
		Medium	39	51.32
		Strong	15	19.73
16.	Lemma and palea : colour	Straw	38	50.00
		Gold and gold furrows on straw background	2	2.63
		Brown spots on straw	3	3.95
		Brown furrows on straw	8	10.53
		Brown (tawny)	4	5.26
		Purple spots on straw	6	7.90
		Purple furrows on straw	2	2.63
		Purple	5	6.58
17.	Panicle : attitude of branches	Black	8	10.52
		Erect	3	3.95
		Erect to semi erect	20	26.32
		Semi erect	7	9.21
		Semi erect to spreading	43	56.58
18.	Panicle: exertion	Spreading	3	3.94
		Partly exerted	3	3.94
		Mostly exerted	32	42.11
19.	Grain: weight of 1000 fully developed grains	Well exerted	41	53.95
		Very low	2	2.64
		Low	16	21.05
		Medium	18	23.68
		High	30	39.47
		Very high	10	13.16

S. No.	Character	State of expression	Number of genotypes	Frequency distribution (%)
20.	Decorticated grain: length	Short	28	36.85
		Medium	43	56.58
		Long	4	5.26
		Very long	1	1.31
21.	Decorticated grain: width	Narrow	71	93.42
		Medium	5	6.58
22.	Amylose content	Very low	4	5.26
		Low	7	9.21
		Medium	42	55.27
		High	23	30.26
23.	Gel consistency	Soft	36	47.37
		Medium	29	38.16
		Hard	11	14.47

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.=75)	Error (d.f.=227)
1.	Leaf : length of the blade (cm)	1.774	303.544***	1.746
2.	Leaf : width of the blade (cm)	0.002	0.141***	0.001
3.	Stem : thickness (cm)	0.001	0.021***	0.001
4.	Stem : length (cm)	0.092	903.872***	0.046
5.	Total number of productive tillers per plant	1.421	24.048***	0.470
6.	Time of heading (days)	2.855	352.397***	1.326
7.	Panicle length (cm)	0.738	27.754***	0.481
8.	Total number of grains per panicle	16.452	18059.880***	134.741
9.	Spikelet fertility (%)	0.765	116.263***	0.318
10.	1000-grain weight (g)	0.662	101.979***	1.973
11.	Single plant yield (g)	1.760	330.910***	1.041
12.	Decorticated grain: length (mm)	0.002	2.045***	0.008
13.	Decorticated grain: width (mm)	0.000	0.126***	0.001
14.	Amylose content (%)	0.466	94.081***	0.391
15.	Gel consistency (mm)	0.189	1703.645***	1.994
16.	Grain iron concentration (mg/kg)	0.001	6.061***	0.020
17.	Grain zinc concentration (mg/kg)	0.062	29.266***	0.026

*** Significant at 0.01 per cent level of significance

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

Genotype	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc -tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decori -cated grain: length (mm)	Decorti cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1602	69.16	1.05	0.7	100.23	14.66	128.66	23.40	90.33	86.47	24.33	23.40	5.89	1.90	27.78	54.67	10.63	21.13
FV 1604	39.66	1.04	0.30	78.26	20.66	87.33	21.80	44.66	92.98	28.33	31.60	5.65	1.76	26.11	50.00	10.50	13.87
FV 1605	62.53	1.02	0.49	96.26	15.00	89.00	27.60	51.66	79.72	18.67	32.27	5.90	1.53	29.32	45.50	8.53	15.07
FV 1606	51.23	1.00	0.54	100.50	13.66	115.00	24.50	121.00	83.68	26.33	30.70	6.07	1.35	27.94	51.00	9.00	16.23
FV 1607	35.00	0.91	0.36	61.06	14.00	119.00	18.70	102.66	87.88	23.00	30.57	5.94	1.51	23.04	22.00	10.00	19.37
FV 1608	41.80	0.84	0.39	72.50	14.66	112.66	21.80	92.00	62.77	23.67	30.77	6.58	1.61	28.51	58.50	7.27	15.57
FV 1609	48.60	0.91	0.45	67.96	14.66	107.33	27.00	144.33	92.21	21.00	29.90	5.99	1.53	21.97	67.17	10.00	14.77
FV 1610	32.20	1.08	0.47	48.20	11.66	86.00	20.50	97.00	89.49	30.00	39.03	5.74	1.69	24.41	34.50	10.07	14.23
FV 1611	32.20	0.90	0.43	74.06	15.66	79.00	21.46	74.00	90.54	26.33	28.87	5.81	1.60	28.48	59.00	12.07	19.13
FV 1612	51.86	1.02	0.40	100.30	17.66	105.66	20.56	174.00	89.63	19.00	23.60	6.12	1.38	23.19	52.33	9.37	16.50
FV 1613	32.80	1.03	0.35	75.93	13.00	82.33	21.80	56.33	87.98	29.33	39.33	6.60	1.58	26.49	65.33	10.50	21.23
FV 1614	55.70	1.01	0.36	80.53	12.66	115.00	25.93	234.00	82.05	14.00	33.67	4.40	1.49	25.82	73.00	9.50	18.23
FV 1615	52.66	0.90	0.24	90.26	17.00	113.66	24.86	136.66	92.80	21.67	31.07	5.60	1.45	24.00	23.00	8.57	15.50
FV 1616	62.83	1.10	0.28	105.16	18.66	126.00	22.90	110.00	88.58	30.00	26.93	7.20	1.76	3.91	100.00	10.53	20.63

Table 4.5 (cont.).

Genotype	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc- -tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decori- -cated grain: length (mm)	Decorti- cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1617	43.70	0.83	0.31	53.80	20.00	108.00	18.93	96.66	96.22	32.00	38.00	5.92	1.76	26.05	54.17	10.27	18.47
FV 1618	65.40	1.06	0.35	49.46	13.00	125.00	19.60	82.66	80.78	24.00	49.70	5.31	2.09	27.34	52.17	7.27	16.43
FV 1619	62.73	1.30	0.41	98.63	12.00	115.00	28.00	161.00	91.24	23.67	30.00	6.32	1.78	25.34	42.00	9.23	20.50
FV 1620	64.73	1.23	0.39	95.66	13.66	116.66	25.16	129.33	81.16	24.67	36.27	6.08	1.84	27.22	42.33	10.70	19.47
FV 1621	38.50	1.07	0.41	103.16	12.00	103.00	22.33	88.33	94.74	24.67	51.00	6.02	1.66	6.07	100.00	8.63	18.13
FV 1622	62.36	1.26	0.36	101.26	16.00	114.66	28.16	156.66	82.68	22.00	29.97	5.47	1.53	24.38	37.83	10.30	21.63
FV 1623	48.33	1.78	0.45	69.26	11.66	115.66	24.30	184.00	90.85	31.00	30.17	6.48	1.85	12.28	71.83	9.93	18.83
FV 1624	52.00	1.48	0.43	97.47	11.67	87.00	23.20	100.67	84.03	32.33	30.23	5.46	1.94	23.93	49.00	11.43	25.80
FV 1625	58.20	1.11	0.45	110.03	13.00	115.33	28.70	185.67	89.35	22.33	30.40	5.52	1.93	24.00	55.67	7.80	16.77
FV 1626	55.70	1.34	0.42	100.23	15.00	105.00	24.40	164.33	91.40	31.33	34.03	5.60	1.89	24.82	97.17	9.17	16.53
FV 1627	68.90	1.30	0.51	113.40	10.67	117.67	24.70	155.00	77.83	25.00	32.10	6.23	1.90	22.55	23.00	9.07	19.23
FV 1628	55.90	1.16	0.44	113.13	11.67	106.00	24.40	224.00	92.82	22.67	34.67	5.68	2.12	23.35	63.17	9.27	17.27
FV 1629	61.90	1.37	0.57	117.33	22.00	129.33	23.30	78.33	80.44	13.00	33.80	5.40	1.88	20.42	22.50	7.20	16.87
FV 1630	48.17	1.01	0.53	92.07	13.67	115.33	26.20	171.33	91.65	30.00	47.87	5.73	1.73	23.29	51.00	8.57	17.57

Table 4.5 (cont.).

Genotype	Leaf : ; length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc -tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decor -cated grain: length (mm)	Decorti cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1631	55.90	0.88	0.40	90.20	13.00	119.00	27.60	221.33	78.63	16.00	33.97	4.17	1.45	18.65	62.17	9.60	13.77
FV 1632	59.80	1.03	0.45	99.17	11.00	106.67	28.00	146.33	97.50	32.00	39.67	7.42	1.83	11.79	63.67	9.03	15.73
FV 1633	68.60	1.02	0.40	95.07	11.67	121.00	25.10	176.33	86.79	31.67	32.30	5.69	2.01	22.88	53.50	9.03	17.20
FV 1634	57.53	1.11	0.41	91.53	12.00	117.00	27.10	144.33	93.70	29.33	39.07	7.03	1.83	21.02	22.00	7.30	16.40
FV 1635	61.20	0.73	0.41	90.53	11.67	117.33	26.70	185.00	85.34	16.00	16.97	6.09	1.53	18.89	55.00	8.73	15.57
FV 1638	35.60	1.29	0.33	82.53	13.67	104.33	21.90	65.67	95.50	31.67	30.63	5.77	1.88	23.94	45.50	8.37	20.80
FV 1639	41.50	1.56	0.47	97.67	9.00	106.33	21.50	147.33	88.84	35.33	40.27	5.77	1.91	23.71	98.50	9.43	19.13
FV 1640	41.70	1.40	0.38	84.93	14.00	106.00	21.30	87.67	97.34	32.00	49.17	5.69	1.76	3.23	73.67	8.53	19.40
FV 1641	56.30	1.18	0.45	103.17	12.00	125.33	26.90	104.67	86.84	25.00	39.60	5.39	1.82	18.23	67.50	9.53	16.40
FV 1642	56.40	1.25	0.48	70.43	16.67	117.00	22.60	219.67	91.50	26.00	40.60	4.48	1.89	23.47	69.67	9.57	21.30
FV 1643	49.60	1.60	0.52	85.93	11.00	105.00	22.50	136.33	87.78	20.33	36.93	5.04	1.68	19.81	51.50	12.17	24.30
FV 1644	51.90	1.40	0.45	91.07	12.67	107.33	27.87	140.00	93.69	16.33	40.07	5.89	1.66	3.93	100.00	8.53	18.33
FV 1645	41.40	1.57	0.58	92.17	11.00	105.00	22.00	96.00	76.66	20.33	27.33	5.02	1.64	22.53	51.00	10.00	22.40
FV 1647	49.83	0.97	0.48	95.13	13.00	119.67	26.90	335.33	88.67	18.00	33.13	4.05	1.43	18.74	29.00	9.13	12.90

Table 4.5 (cont.).

Genotype	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc- tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decori- cated grain: length (mm)	Decorti- cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1648	47.70	1.21	0.44	78.33	10.67	114.00	26.80	355.67	87.46	19.00	32.13	4.59	1.51	21.94	41.50	9.37	13.30
FV 1649	45.23	1.13	0.45	96.07	11.00	106.00	21.80	129.33	94.28	31.67	36.17	5.40	2.06	19.68	55.33	10.83	14.77
FV 1650	41.03	1.10	0.34	96.50	10.00	103.00	25.40	302.33	94.68	16.00	49.63	4.49	1.43	19.03	26.50	11.73	15.50
FV 1651	46.30	0.92	0.39	104.07	11.67	114.67	26.70	235.33	90.80	19.33	49.93	5.76	1.39	17.75	87.50	8.87	15.07
FV 1652	24.10	1.18	0.35	17.73	18.67	98.67	11.30	42.00	88.48	26.00	18.77	6.76	1.65	24.90	64.83	10.40	19.20
FV 1654	66.07	1.30	0.53	98.07	13.67	129.00	27.80	99.67	87.81	25.00	41.70	5.51	1.89	27.69	100.00	7.63	20.43
FV 1655	57.90	0.95	0.39	83.27	11.00	106.33	27.60	348.00	87.99	18.00	44.37	4.36	1.58	21.80	46.50	9.93	15.77
FV 1656	53.80	0.91	0.54	91.93	9.67	124.33	24.20	273.00	86.50	22.00	33.50	4.31	1.47	25.15	63.50	11.00	13.27
FV 1657	43.20	0.85	0.49	96.17	11.00	101.67	26.00	103.33	94.91	32.00	30.00	5.87	1.68	26.21	87.50	9.33	21.50
FV 1658	52.53	1.09	0.46	100.00	17.00	112.33	23.70	171.00	85.34	22.00	35.63	5.82	1.78	24.01	23.00	9.37	21.47
FV 1659	51.63	0.91	0.38	95.67	16.00	107.67	23.00	146.00	77.94	32.00	26.00	5.96	1.64	22.92	55.83	10.20	21.67
FV 1660	49.77	1.22	0.37	95.07	10.00	120.00	23.50	77.33	94.43	31.33	27.87	5.65	1.85	25.35	87.50	10.00	21.33
FV 1661	45.60	1.01	0.39	72.90	10.33	123.00	20.30	211.67	89.03	32.67	24.17	5.26	1.83	24.98	50.17	9.83	21.90
FV 1663	52.00	1.32	0.65	120.17	9.67	115.67	24.40	129.33	79.49	34.67	53.57	5.59	2.21	26.11	92.50	9.50	20.10

Table 4.5 (cont.).

Genotype	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc- tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decor- -cated grain: length (mm)	Decorti- cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1664	56.60	0.93	0.43	89.90	11.67	101.33	26.30	309.00	77.53	20.33	49.47	4.30	1.41	22.36	48.33	10.07	13.40
FV 1667	38.93	1.01	0.37	84.87	14.00	105.33	21.67	52.00	97.63	21.00	18.80	5.86	1.86	28.16	99.00	12.57	19.40
FV 1669	25.40	0.94	0.32	52.93	10.67	126.00	22.77	126.67	92.97	22.67	30.60	5.37	1.83	25.68	77.33	9.00	19.83
FV 1670	48.23	0.79	0.39	98.93	12.00	105.00	26.87	320.33	93.52	21.33	59.63	5.68	1.65	19.65	50.00	11.07	16.53
FV 1671	52.37	0.83	0.58	117.17	12.00	123.00	23.10	240.67	90.38	31.33	59.43	4.44	1.56	25.87	98.00	9.90	14.20
FV 1672	49.10	0.82	0.33	96.07	18.00	106.67	23.50	313.67	94.60	16.00	70.83	5.15	1.23	20.02	48.83	9.13	13.20
FV 1674	49.83	0.99	0.38	95.87	9.00	123.00	23.07	145.33	85.79	30.33	63.00	5.76	1.89	25.96	98.00	5.50	16.77
FV 1675	43.90	0.77	0.35	91.80	15.00	103.00	24.80	262.67	92.68	14.00	47.37	4.09	1.82	20.80	64.33	8.90	17.17
FV 1676	39.90	0.58	0.37	102.87	11.67	107.00	26.67	149.67	91.51	24.00	41.33	6.05	1.53	19.68	63.33	10.27	19.53
FV 1677	56.70	1.16	0.59	101.17	10.67	124.33	19.60	156.33	85.45	26.00	40.70	5.51	1.61	27.41	98.33	10.07	16.20
FV 1680	39.57	0.92	0.37	86.13	11.67	116.67	23.97	238.00	92.26	29.67	45.40	5.37	1.44	28.78	98.83	9.50	14.53
FV 1681	38.23	0.84	0.32	60.77	14.00	104.67	25.60	131.33	92.97	30.00	38.60	8.22	1.52	25.03	30.17	7.57	16.93
FV 1682	45.50	1.00	0.42	81.13	9.33	106.33	25.00	178.00	95.06	22.00	34.33	4.47	1.99	25.28	98.50	9.83	17.30
FV 1684	51.30	1.03	0.36	94.33	11.33	102.00	31.40	214.33	93.41	23.00	35.67	3.87	1.62	21.99	53.33	11.50	12.20

Table 4.5 (cont.).

Genotype	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of produc -tive tillers per plant	Timing of heading (50% plants with panicles)	Panicle length (cm)	Total no.of grains per panicle	Spikelet fertility (%)	1000- grain weight (g)	Single plant yield (g)	Decor -cated grain: length (mm)	Decorti cated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
FV 1685	51.47	1.01	0.34	2.13	9.67	103.00	27.00	200.67	81.81	20.00	36.23	4.45	1.42	19.68	52.50	14.10	19.77
FV 1686	44.80	1.01	0.40	0.33	11.33	116.33	23.07	136.67	79.78	24.00	47.30	6.50	1.71	28.77	99.00	6.10	10.30
FV 1687	49.50	1.06	0.37	96.20	11.00	103.67	23.17	115.00	96.26	30.00	40.97	5.55	1.80	26.60	87.00	8.80	17.20
FV 1688	43.33	1.05	0.46	95.40	9.67	106.67	26.13	195.67	93.73	30.00	52.70	6.77	1.58	27.11	93.00	6.60	15.10
FV 1689	45.17	1.02	0.47	94.07	14.00	108.00	28.30	297.00	90.58	16.33	57.87	4.47	1.46	20.79	73.17	9.80	10.20
FV 1690	34.07	1.27	0.43	77.07	10.00	104.33	21.30	78.67	91.73	36.33	28.23	6.34	1.89	28.54	100.00	9.57	21.00
Mean	49.51	1.08	0.43	89.22	13.01	110.39	24.18	160.50	88.55	24.93	37.39	5.60	1.70	22.61	62.81	9.50	17.56
S.Em_±	0.76	0.02	0.02	0.12	0.40	0.66	0.40	6.70	0.33	0.81	0.59	0.05	0.02	0.36	0.82	0.08	0.09
C.D (5%)	2.13	0.05	0.05	0.35	1.11	1.86	1.12	18.73	0.91	2.27	1.65	0.14	0.06	1.01	2.28	0.23	0.26
C.V (%)	2.67	2.96	7.72	0.24	5.27	1.04	2.87	7.23	0.64	5.64	2.73	1.56	2.16	2.76	2.25	1.49	0.91

AC - Amylose content, GC - Gel
Consistency

FV 1602 – Sati, FV 1604 – Kele, FV 1605 – Khama, FV 1606 – Murgi balam, FV 1607 – Hetomari, FV 1608 – Jhingesal,
FV 1609 - Harina khuri, FV 1610 – Sathia, FV 1611 – Kotki, FV 1612 - Katarybhag, FV 1613 – Harinkajali, FV 1614 - Baigon machua,
FV 1615 - Phool pakri, FV 1616 – Binni, FV 1617 - Kalo bochi, FV 1618 - Jaldhyapa, FV 1619 - Dudhkalam-1,
FV 1620 - Kashiya binni, FV 1621 - Jonroi buna, FV 1622 – Kukurjali, FV 1623 – Dharmaphool, FV 1624 - Kajal ghorya,
FV 1625 – Dhyapa, FV 1626 – Kalo dhyapa, FV 1627 - Mangamuthi, FV 1628 - Paharibochi selection-1, FV 629 – Jashoya,
FV 1630 – Kalshepa, FV 1631- Radhatilak selection-1, FV 1632 - Khaiyam Dhan, FV 1633 - Jaldhyapa-3,
FV 1634 - Dudhkalam motajashya, FV 1635 – Biroi, FV 1638 – Kauka, FV 1639 – Betho, FV 1640 - Kaikhe, FV 1641 – Bochi,
FV 1642 – Jhagrikartick, FV 1643 - Dhusuri baratee, FV 1644 - Bonnidhan, FV 1645 - Bitti, FV 1647 - Sugandha-II,
FV 1648 – Mihigandheswari, FV 1649 – Paramananda, FV 1650 - Govind bhog-1, FV 1651 - Serha-5, FV 1652 - Katharibhog,
FV 1654 – Gochi, FV 1655 – Chaturmukhi, FV 1656 – Shyam, FV 1657 - Chingri fuli, FV 1658 – Dadghani, FV 1659 - Kashiyabinni,
FV 1660 - Jabsal-1, FV 1661 - Dhan sirhatti, FV 1663 – Baku, FV 1664 – Gandheswari, FV 1667 - Sathi-P, FV 1669 - Kala heera dhan,
FV 1670 – Meghi, FV 1671 - Kalo gandheswari, FV 1672 – Kartik khas, FV 1674 – Samkene, FV 1675 – Moti bas, FV 1676 – Joha,
FV 1677 - Khajurchari-III, FV 1680 - Angl-Digipadar chinamali, FV 1681 - Jhumka basmati, FV 1682 - Magara-B, FV 1684 – Kadamful,
FV 1685 - Balangir-kutumdola-kala krushna, FV 1686 – Bharati, FV 1687 - Godi kaberi, FV 1688 - Nbr-assanchudi,
FV 1689 - Mbj-basumati, FV 1690 - Balangir-saria.

Table 4.6. Estimation of variability, heritability and genetic advance for yield, its contributing characters and grain quality parameters in 76 landraces of rice

S. No.	Character	Mean	Range		Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability in broad sense (h^2) (%)	GA	GA as Per cent of mean
			Min.	Max.							
1.	Leaf blade length (cm)	49.51	24.10	69.16	102.35	100.60	20.43	20.26	98.30	20.49	41.37
2.	Leaf blade width (cm)	1.08	0.58	1.78	0.05	0.05	20.19	19.97	97.80	0.44	40.69
3.	Stem thickness (cm)	0.43	0.24	0.70	0.01	0.01	20.60	19.10	86.00	0.16	36.48
4.	Stem length (cm)	89.22	17.73	120.16	301.32	301.28	19.46	19.45	100.00	35.75	40.07
5.	No. of productive tillers per plant	13.01	9.00	22.00	8.33	7.86	22.18	21.54	94.40	5.61	43.11
6.	Time of heading (50% of plants with panicles) (days)	110.39	79.00	129.33	118.35	117.02	9.85	9.79	98.90	22.16	20.07
7.	Panicle length (cm)	24.18	11.30	31.40	9.57	9.09	12.79	12.46	95.00	6.05	25.03
8.	Total no. of grains per panicle	160.50	42.00	355.40	6109.79	5975.05	48.70	48.16	97.80	157.47	98.10
9.	Spikelet fertility (%)	88.55	62.77	97.63	38.97	38.65	7.05	7.02	99.20	12.75	14.40
10.	1000-grain weight (g)	24.92	13.00	36.33	35.31	33.34	23.84	23.16	94.40	11.56	46.37
11.	Single plant yield (g)	37.38	16.96	70.83	111.00	109.96	28.18	28.05	99.10	21.50	57.50
12.	Decorticated grain: length (mm)	5.60	3.87	8.22	0.69	0.68	14.79	14.71	98.90	1.69	30.14
13.	Decorticated grain: width (mm)	1.69	1.22	2.20	0.04	0.04	12.20	12.00	96.90	0.41	24.34
14.	Amylose content (%)	22.61	3.22	29.31	31.62	31.23	24.87	24.72	98.80	11.44	50.60
15.	Gel consistency (mm)	62.81	22.00	100.00	569.21	567.22	37.98	37.92	99.60	48.98	77.97
16.	Grain iron concentration (mg/kg)	9.50	5.50	14.10	2.03	2.01	15.01	14.93	99.00	2.91	30.61
17.	Grain zinc concentration (mg/kg)	17.56	10.20	25.80	9.77	9.75	17.80	17.78	99.70	6.42	36.58

Table 4.7 Clustering pattern among 76 landraces of rice (Tocher's method)

Cluster No.	No. of landraces	Name of the landraces
I	49	Sati, Khama, Murgi balam, Kataribhog, Phool pakri, Dudhkalam-1, Kashiya binni, Jonroi buna, Kukurjali, Kajalghorya, Kalo dhyapa, Kalshepa, Radhatilak selection-1, Khaiyam dhan, Jaldhyapa-3, Dudhkalam motajashya, Biroi, Kauka, Benthoo, Kaike, Bochi, Dhusuri bartee, Bonnidhan, Bitti, Sugandha-II, Paramananda, Govind bhog-1, Serha-5, Gochi, Chaturmukhi, Shyam, Chingri fuli, Dadghani, Kashiyabinni, Jabsal-1, Gandheswari, Sathi-P, Meghi, Kartik khas, Sankene, Moti bas, Joha, Khajurchari-III, Angl-digipadar-chinamali, Kadamful, Balangir-kutumdola-kala krushna, Godi kaberi, Nrb-assanchudi , Mbj-basumati
II	7	Binni, Dhyapa, Mangamuthi, Paharibochi selection-1, Jashoya, Baku, Kalo gandheswari
III	14	Kele, Hetomari, Jhingesal, Harina khuri, Kotki, Harinkajli, Baigan machua, Dharmaphool, Jhagrikartick, Mihigandheswari, Dhan sirhatti, Jhumka basmati, Magra-B, Balangir-saria
IV	4	Sathia, Kalo bochi, Jaldhyapa, Kala heera dhan
V	1	Bharati
VI	1	Kathari bhog

Table 4.10 Relative contribution of different traits to genetic diversity in 76 landraces of rice

S.No.	Character	Times ranked 1 st	Per cent contribution	Rank
1.	Leaf: length of blade (cm)	4	14.04	11
2.	Leaf : width of blade (cm)	7	24.56	9
3.	Stem: thickness (cm)	0	0.00	-
4.	Stem : length (cm)	1893	6642.11	1
5.	No. of productive tillers per plant	0	0.00	-
6.	Time of heading (50% of plants with panicles)	27	94.74	8
7.	Panicle : length of the main axis (cm)	0	0.00	-
8.	Total no. of grains per panicle	5	17.54	10
9.	Spikelet fertility (%)	53	185.96	6
10.	1000-grain weight (g)	0	00.00	-
11.	Single plant yield (g)	60	210.53	4
12.	Decorticated grain: length (mm)	32	112.28	7
13.	Decorticated grain: width (mm)	1	3.51	12
14.	Amylose content (%)	54	189.96	5
15.	Gel consistency (mm)	298	1045.61	3
16.	Grain iron concentration (mg/kg)	53	185.96	6
17.	Grain zinc concentration (mg/kg)	363	1273.68	2

Table 4.8 Intra (diagonal) and inter-cluster average D^2 values of 76 landraces of rice (Tocher's method)

Cluster	I	II	III	IV	V	VI
I	1574.26	4745.76	5618.50	17069.10	2569.95	50066.82
II		689.04	15977.65	34426.11	6891.92	78134.90
III			1671.21	5112.24	5311.22	25845.96
IV				934.52	15070.92	9859.29
V					0.00	46381.34
VI						0.00

Table 4.9 Cluster means for various agro-morphological and grain quality parameters in 76 landraces of rice

Cluster No.	Leaf : length of the blade (cm)	Leaf : width of the blade (cm)	Stem : thickness (cm)	Stem length (cm)	No. of productive tillers per plant	Timing of heading (50% plants with panicles) (days)	Panicle length (cm)	Total no. of grains per panicle	Spikelet fertility (%)	1000-grain weight (g)	Single plant yield (g)	Decorated grain: length (mm)	Decorated grain: width (mm)	AC (%)	GC (mm)	Grain iron conc. (mg/kg)	Grain zinc conc. (mg/kg)
I	51.30	1.08	0.43	94.93	12.61	110.39	25.02	171.16	89.14	24.37	38.66	5.50	1.66	21.90	62.86	9.60	17.52
II	58.87	1.17	0.50	113.77	13.95	119.00	24.50	160.43	85.56	25.57	38.70	5.72	1.91	20.89	64.98	9.04	17.87
III	42.97	1.07	0.40	72.87	13.43	106.26	23.17	150.50	88.22	25.90	32.35	5.77	1.68	24.43	61.20	9.68	18.05
IV	41.68	0.98	0.37	51.10	13.83	111.25	20.45	100.75	89.87	27.17	39.33	5.59	1.84	25.87	54.54	9.15	17.24
V	44.80	1.01	0.40	90.33	11.33	116.33	23.07	136.67	79.78	24.00	47.30	6.50	1.71	28.77	99.00	6.10	10.30
VI	24.10	1.18	0.35	17.73	18.67	98.67	11.30	42.00	88.48	26.00	18.77	6.76	1.65	24.90	64.83	10.40	19.20

Table 4.11 Estimates of phenotypic and genotypic correlation coefficients among yield, its contributing characters and grain quality parameters in 76 landraces of rice

TRAIT		LBL	LBW	ST	SL	PTP	TH	PL	TGPP	SF	1000 -GW	DGL	DGW	AC	GC	GIC	GZC	SPY
LBL	P	1.0000	0.1307 *	0.2985 ***	0.5389 ***	0.0382	0.4842 ***	0.4638 ***	0.1850 **	-0.3186	-0.1859 **	-0.1041	0.1826 **	-0.0654	-0.1563 *	-0.1371 *	-0.0252	-0.0154
	G	1.0000	0.1331	0.3231	0.5436	0.0418	0.4917	0.4823	0.1867	-0.3224	-0.1952	-0.1049	0.1857	-0.0667	-0.1578	-0.1373	-0.0257	-0.0168
LBW	P		1.0000	0.3018 ***	0.0863	-0.1043	0.0161	-0.1216	-0.2562 ***	-0.0643	0.2162 **	0.0607	0.4335 ***	-0.1929 **	0.0757	0.039	0.4294 ***	-0.1589
	G		1.0000	0.3307	0.0874	-0.1133	0.0165	-0.1232	-0.2596	-0.0643	0.2231	0.0608	0.4462	-0.1971	0.0767	0.0382	0.4336	-0.1625
ST	P			1.0000	0.3718 ***	-0.2048 **	0.2273 ***	0.0805	-0.0011	-0.2570 ***	0.0313	-0.1117	0.1887 **	0.1257	0.1016	-0.0313	0.0589	0.0333
	G			1.0000	0.4009	-0.226	0.2517	0.0865	-0.0048	-0.2791	0.0393	-0.1218	0.207	0.1362	0.1089	-0.0329	0.0652	0.0352
SL	P				1.0000	-0.1625 *	0.2292 ***	0.5170 ***	0.2192 ***	-0.0845	-0.0816	-0.1310 *	0.0674	-0.1621 *	0.117	-0.064	-0.038	0.2333
	G				1.0000	-0.1671	0.2306	0.5306	0.2212	-0.085	-0.084	-0.1317	0.0686	-0.1633	0.1172	-0.0645	-0.0381	0.2344
PTP	P					1.0000	-0.0749	-0.2590 ***	-0.2522 ***	-0.0239	-0.1829 **	0.1617 *	-0.1319 *	-0.0386	-0.2892 ***	-0.0249	0.0102	-0.1834
	G					1.0000	-0.0744	-0.2769	-0.2578	-0.0261	-0.187	0.1692	-0.1369	-0.0389	-0.2971	-0.0257	0.0105	-0.1926
TH	P						1.0000	0.1125	0.1693 *	-0.1922 **	-0.0866	0.0771	0.1515 *	-0.0394	0.0915	-0.3443 ***	-0.0451	0.0195
	G						1.0000	0.1147	0.1743	-0.1931	-0.0872	0.0785	0.1563	-0.0413	0.0919	-0.3498	-0.0454	0.0215
PL	P							1.0000	0.4542 ***	0.0171	-0.3257 ***	-0.2257 ***	-0.1791 **	-0.1708 **	-0.0851	-0.0745	-0.2820 ***	0.1818
	G							1.0000	0.4737	0.0207	-0.3449	-0.2333	-0.1836	-0.1765	-0.0897	-0.0764	-0.2891	0.1889
TGPP	P								1.0000	0.0445	-0.4251 ***	-0.5642 ***	-0.3947 ***	-0.1317 *	-0.1301 *	0.0821	-0.4660 ***	0.4067
	G								1.0000	0.0459	-0.4406	-0.5741	-0.4066	-0.1335	-0.1307	0.0848	-0.4714	0.414
SF	P									1.0000	0.2055 **	0.0741	0.0806	-0.2503 ***	0.2066 **	0.1114	-0.0255	0.1369
	G									1.0000	0.2112	0.0737	0.0811	-0.2523	0.2076	0.1116	-0.0256	0.1383
1000 -GW	P										1.0000	0.4506 ***	0.4613 ***	0.1256	0.2937 ***	-0.0617	0.3240 ***	-0.0303
	G										1.0000	0.4677	0.4866	0.1315	0.302	-0.0637	0.3334	-0.0326
DGL	P											1.0000	0.1678 *	-0.0503	0.0409	-0.3195 ***	0.2287 ***	-0.2038
	G											1.0000	0.169	-0.0502	0.0405	-0.3226	0.2304	-0.2058
DGW	P												1.0000	0.0688	0.2014 **	-0.1575 *	0.3871 ***	-0.1105
	G												1.0000	0.0714	0.2052	-0.1624	0.3934	-0.1133
AC	P													1.0000	-0.0522	-0.0447	-0.0027	-0.1427
	G													1.0000	-0.053	-0.0466	-0.0035	-0.1421
GC	P														1.0000	-0.1078	0.0162	0.2028
	G														1.0000	-0.1085	0.0158	0.2057
GIC	P															1.0000	0.2666 ***	-0.2695
	G															1.0000	0.2681	-0.2717
GZC	P																1.0000	-0.3843
	G																1.0000	-0.3863

*** Significant at 0.01 per cent level of significance **Significant at 1 per cent level of significance, * Significant at 5 % level of significance; P - Phenotypic correlation coefficient;

G - Genotypic correlation coefficient LBL – Leaf blade length; LBW – Leaf blade width; ST – Stem thickness; SL - Stem length; PTP - Number of productive tillers per plant; TH - Time of heading; PL - Panicle length;

TGPP – Total no. of grains per plant; SF – Spikelet fertility; 1000- GW – 1000 grains weight; DGL – Decorticated grain length; DGW – Decorticated grain width;

AC – Amylose content; GC – Gel consistency; GIC – Grain iron content; GZC – Grain zinc content; SPY – Single plant yield

Table 4.12 Estimates of direct and indirect effects of yield contributing traits and grain quality parameters on yield in 76 landraces of rice

TRAIT		LBL	LBW	ST	SL	PTP	TH	PL	TGPP	SF	1000 -GW	DGL	DGW	AC	GC	GIC	GZC	SPY
LBL	P	-0.0504	-0.0066	-0.015	-0.0272	-0.0019	-0.0244	-0.0234	-0.0093	0.0161	0.0094	0.0052	-0.0092	0.0033	0.0079	0.0069	0.0013	-0.0154
	G	-0.0310	-0.0041	-0.0100	-0.0168	-0.0013	-0.0152	-0.0149	-0.0058	0.0100	0.0060	0.0033	-0.0058	0.0021	0.0049	0.0043	0.0008	-0.0168
LBW	P	-0.0119	-0.0913	-0.0276	-0.0079	0.0095	-0.0015	0.0111	0.0234	0.0059	-0.0197	-0.0055	-0.0396	0.0176	-0.0069	-0.0036	-0.0392	-0.1589
	G	-0.0141	-0.1056	-0.0349	-0.0092	0.0120	-0.0017	0.0130	0.0274	0.0068	-0.0236	-0.0064	-0.0471	0.0208	-0.0081	-0.0040	-0.0458	-0.1625
ST	P	0.0114	0.0116	0.0383	0.0143	-0.0078	0.0087	0.0031	-	-0.0098	0.0012	-0.0043	0.0072	0.0048	0.0039	-0.0012	0.0023	0.0333
	G	0.0161	0.0165	0.0498	0.0199	-0.0112	0.0125	0.0043	-0.0002	-0.0139	0.0020	-0.0061	0.0103	0.0068	0.0054	-0.0016	0.0032	0.0352
SL	P	0.1159	0.0186	0.0800	0.2151	-0.0350	0.0493	0.1112	0.0471	-0.0182	-0.0176	-0.0282	0.0145	-0.0349	0.0252	-0.0138	-0.0082	0.2333
	G	0.1150	0.0185	0.0848	0.2116	-0.0353	0.0488	0.1123	0.0468	-0.0180	-0.0178	-0.0279	0.0145	-0.0346	0.0248	-0.0136	-0.0081	0.2344
PTP	P	-0.0010	0.0027	0.0054	0.0043	-0.0263	0.0020	0.0068	0.0066	0.0006	0.0048	-0.0042	0.0035	0.0010	0.0076	0.0007	-0.0003	-0.1834
	G	-0.0014	0.0038	0.0076	0.0056	-0.0334	0.0025	0.0093	0.0086	0.0009	0.0062	-0.0057	0.0046	0.0013	0.0099	0.0009	-0.0004	-0.1926
TH	P	0.1001	-0.0033	-0.0470	-0.0474	0.0155	-0.2067	-0.0233	-0.0350	0.0397	0.0179	0.0159	-0.0313	0.0081	-0.0189	0.0712	0.0093	0.0195
	G	0.1114	-0.0037	-0.0570	-0.0522	0.0169	-0.2265	-0.0260	-0.0395	0.0437	0.0198	0.0178	-0.0354	0.0094	-0.0208	0.0792	0.0103	0.0215
PL	P	-0.0649	0.0170	-0.0113	-0.0724	0.0363	-0.0158	-0.1400	-0.0636	-0.0024	0.0456	0.0316	0.0251	0.0239	0.0119	0.0104	0.0395	0.1818
	G	-0.0776	0.0198	-0.0139	-0.0853	0.0445	-0.0184	-0.1608	-0.0762	-0.0033	0.0555	0.0375	0.0295	0.0284	0.0144	0.0123	0.0465	0.1889
TGPP	P	0.0670	-0.0928	-0.0004	0.0794	-0.0914	0.0613	0.1645	0.3622	0.0161	-0.1540	-0.2043	-0.1430	-0.0477	-0.0471	0.0297	-0.1688	0.4067
	G	0.0714	-0.0993	-0.0018	0.0846	-0.0986	0.0667	0.1812	0.3825	0.0176	-0.1685	-0.2196	-0.1555	-0.0511	-0.0500	0.0324	-0.1803	0.4140
SF	P	-0.0156	-0.0031	-0.0126	-0.0041	-0.0012	-0.0094	0.0008	0.0022	0.0489	0.0101	0.0036	0.0039	-0.0123	0.0101	0.0055	-0.0012	0.1369
	G	-0.0168	-0.0034	-0.0146	-0.0044	-0.0014	-0.0101	0.0011	0.0024	0.0522	0.0110	0.0038	0.0042	-0.0132	0.0108	0.0058	-0.0013	0.1383
1000 -GW	P	-0.0303	0.0352	0.0051	-0.0133	-0.0298	-0.0141	-0.0531	-0.0693	0.0335	0.1630	0.0734	0.0752	0.0205	0.0479	-0.0101	0.0528	-0.0303
	G	-0.0340	0.0389	0.0069	-0.0146	-0.0326	-0.0152	-0.0602	-0.0768	0.0368	0.1744	0.0816	0.0849	0.0229	0.0527	-0.0111	0.0581	-0.0326
DGL	P	0.0203	-0.0118	0.0218	0.0255	-0.0315	0.0150	0.0439	0.1098	-0.0144	-0.0877	-0.1947	-0.0327	0.0098	-0.0080	0.0622	-0.0445	-0.2038
	G	0.0211	-0.0122	0.0245	0.0264	-0.0340	0.0158	0.0469	0.1153	-0.0148	-0.0939	-0.2008	-0.0339	0.0101	-0.0081	0.0648	-0.0463	-0.2058
DGW	P	-0.0026	-0.0061	-0.0027	-0.0010	0.0019	-0.0021	0.0025	0.0056	-0.0011	-0.0065	-0.0024	-0.0142	-0.0010	-0.0029	0.0022	-0.0055	-0.1105
	G	-0.0041	-0.0099	-0.0046	-0.0015	0.0030	-0.0035	0.0041	0.0090	-0.0018	-0.0108	-0.0037	-0.0222	-0.0016	-0.0045	0.0036	-0.0087	-0.1133
AC	P	0.0096	0.0284	-0.0185	0.0239	0.0057	0.0058	0.0252	0.0194	0.0369	-0.0185	0.0074	-0.0101	-0.1473	0.0077	0.0066	0.0004	-0.1427
	G	0.0104	0.0308	-0.0213	0.0255	0.0061	0.0065	0.0276	0.0209	0.0395	-0.0206	0.0078	-0.0112	-0.1564	0.0083	0.0073	0.0005	-0.1421
GC	P	-0.0194	0.0094	0.0126	0.0145	-0.0359	0.0114	-0.0106	-0.0162	0.0257	0.0365	0.0051	0.0250	-0.0065	0.1242	-0.0134	0.0020	0.2028
	G	-0.0195	0.0095	0.0134	0.0144	-0.0366	0.0113	-0.0111	-0.0161	0.0256	0.0372	0.0050	0.0253	-0.0065	0.1233	-0.0134	0.0019	0.2057
GIC	P	0.0536	-0.0152	0.0122	0.0250	0.0097	0.1346	0.0291	-0.0321	-0.0436	0.0241	0.1249	0.0616	0.0175	0.0422	-0.3909	-0.1042	-0.2695
	G	0.0562	-0.0156	0.0135	0.0264	0.0105	0.1433	0.0313	-0.0348	-0.0457	0.0261	0.1322	0.0665	0.0191	0.0445	-0.4097	-0.1099	-0.2717
GZC	P	0.0030	-0.0515	-0.0071	0.0046	-0.0012	0.0054	0.0338	0.0559	0.0031	-0.0389	-0.0274	-0.0464	0.0003	-0.0019	-0.0320	-0.1199	-0.3843
	G	0.0027	-0.0464	-0.0070	0.0041	-0.0011	0.0049	0.0310	0.0505	0.0027	-0.0357	-0.0247	-0.0421	0.0004	-0.0017	-0.0287	-0.1071	-0.3863

Phenotypic residual effect= 0.755, Genotypic residual effect = 0.746, P - Phenotypic level; G - Genotypic level; **Bold values**- direct effects Normal values-indirect effects

*** Significant at 0.01 per cent level of significance **Significant at 1 per cent level of significance, * Significant at 5 % level of significance;

P - Phenotypic correlation coefficient; G - Genotypic correlation coefficient

LBL – Leaf blade length; LBW – Leaf blade width; ST – Stem thickness; SL - Stem length; PTP - Number of productive tillers per plant; TH - Time of heading; PL - Panicle length; TGPP – Total no. of grains per plant; SF – Spikelet fertility; 1000- GW – 1000 grains weight; DGL – Decorticated grain length; DGW – Decorticated grain width; AC – Amylose content; GC – Gel consistency; GIC – Grain iron content; GZC – Grain zinc content; SPY – Single plant yield

**Table 4.13 Details of proximate composition of twelve landraces of rice
selected from six clusters**

S.No.	Code.No.	Name of the landrace	Crude protein (%)	Total fat (%)	Fibre (%)
1	FV 1604	Kele	10.92	1.17	0.83
2	FV 1605	Khama	8.70	0.71	1.22
3	FV 1606	Murgi balam	8.20	0.78	1.08
4	FV 1608	Jhingesal	7.93	0.58	0.78
5	FV 1610	Sathia	10.35	0.56	1.25
6	FV 1616	Binni	9.21	0.77	1.74
7	FV 1618	Jaldhyapa	8.14	0.62	0.94
8	FV 1621	Jonroi buna	11.91	0.48	1.01
9	FV 1629	Jashoya	8.50	0.56	1.13
10	FV 1652	Katharibhog	10.48	0.62	1.40
11	FV 1655	Chaturmukhi	11.63	1.30	0.98
12	FV 1686	Bharati	11.77	1.03	0.98
Mean			9.81	0.77	1.11
Range		Maximum	11.91	1.3	1.74
		Minimum	8.14	0.48	0.78

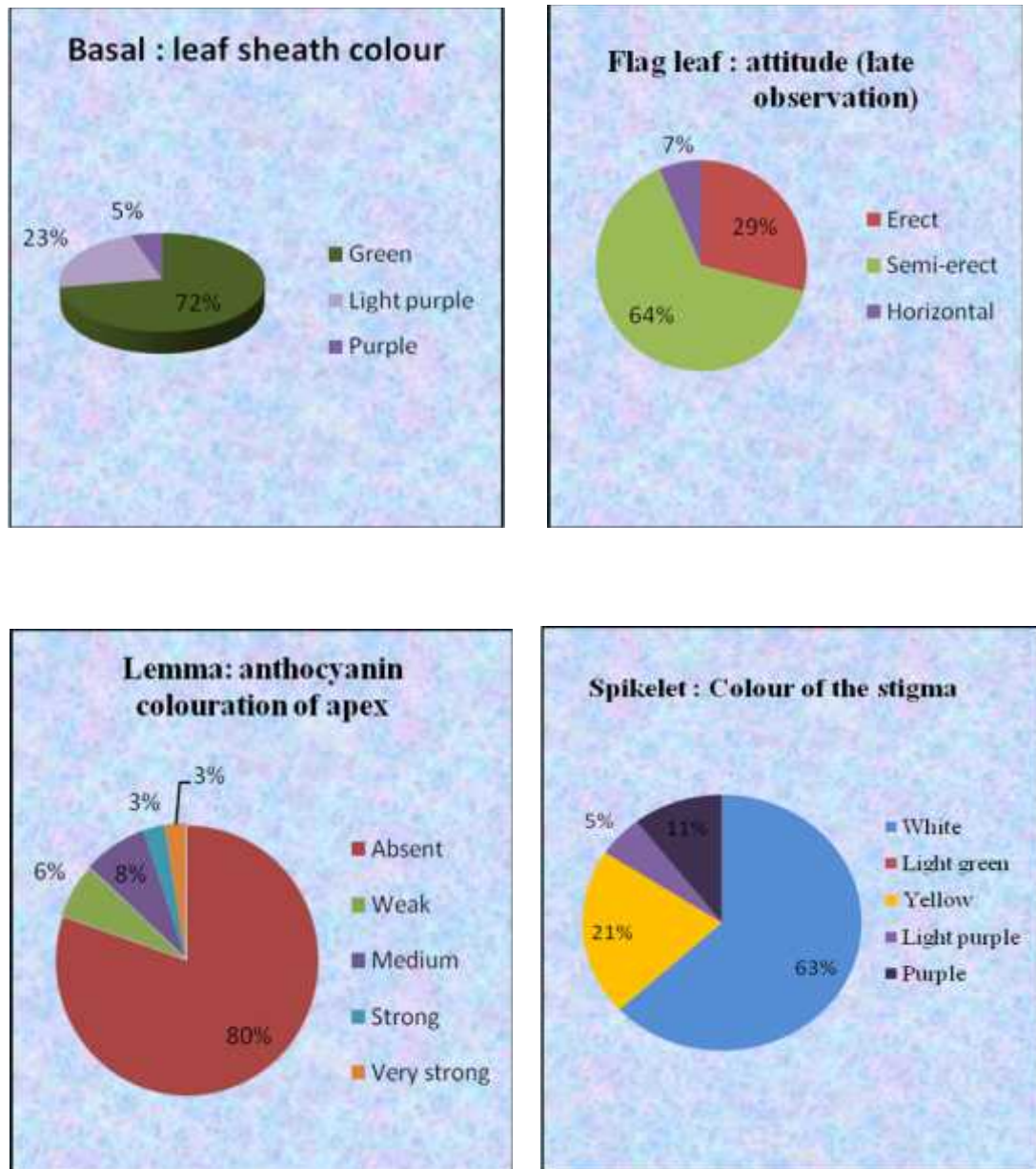


Figure 4.1 Frequency distribution of 76 landraces of rice for

- Basal: leaf sheath colour
- Flag leaf: attitude (late observation)
- Lemma: anthocyanin colouration of apex
- Spikelet: colour of stigma

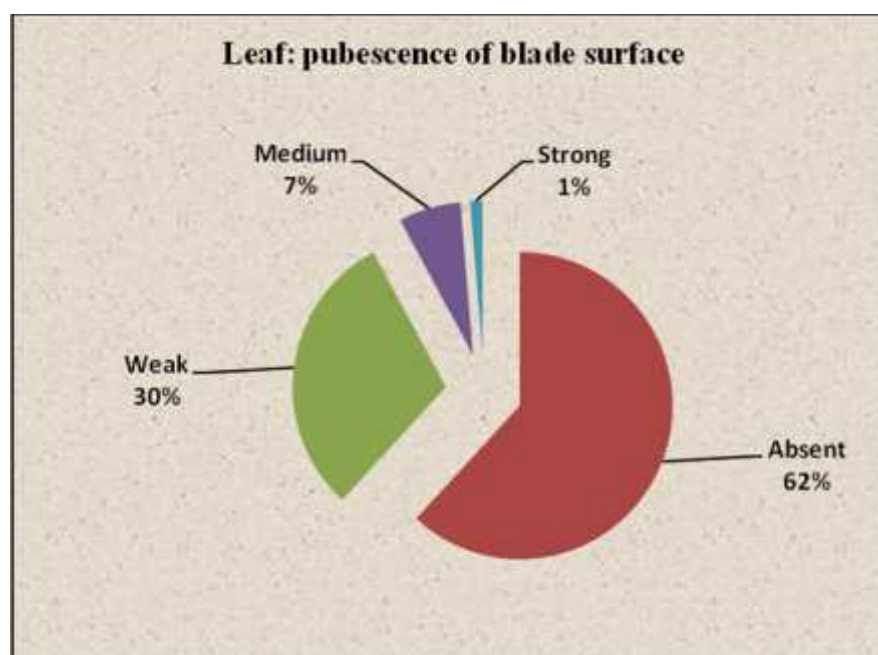
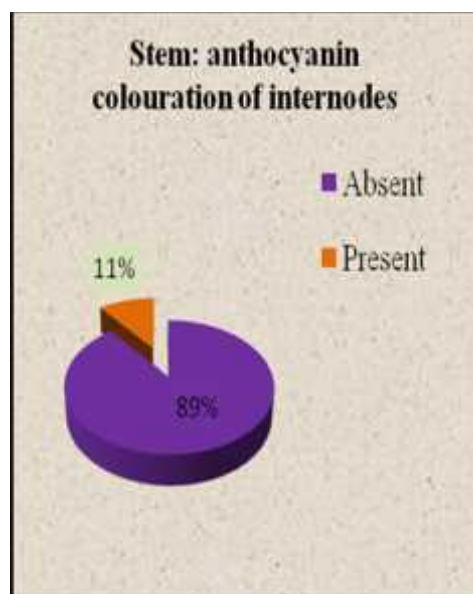
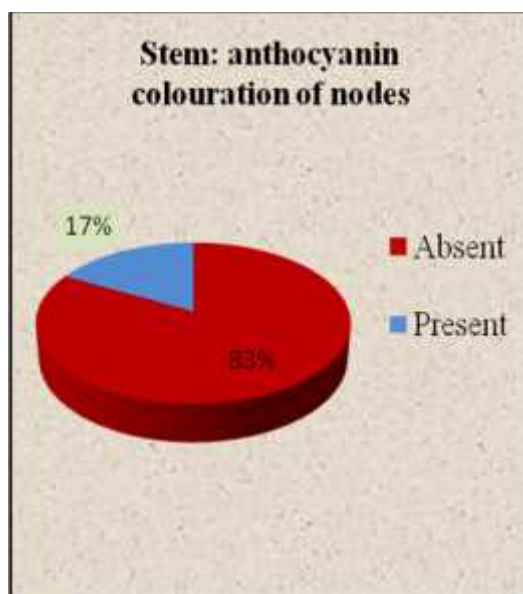


Figure 4.1 Frequency distribution of 76 landraces of rice for
a) Stem: anthocyanin colouration of nodes
b) Stem: anthocyanin colouration of internodes
c) Leaf: pubescence of blade surface

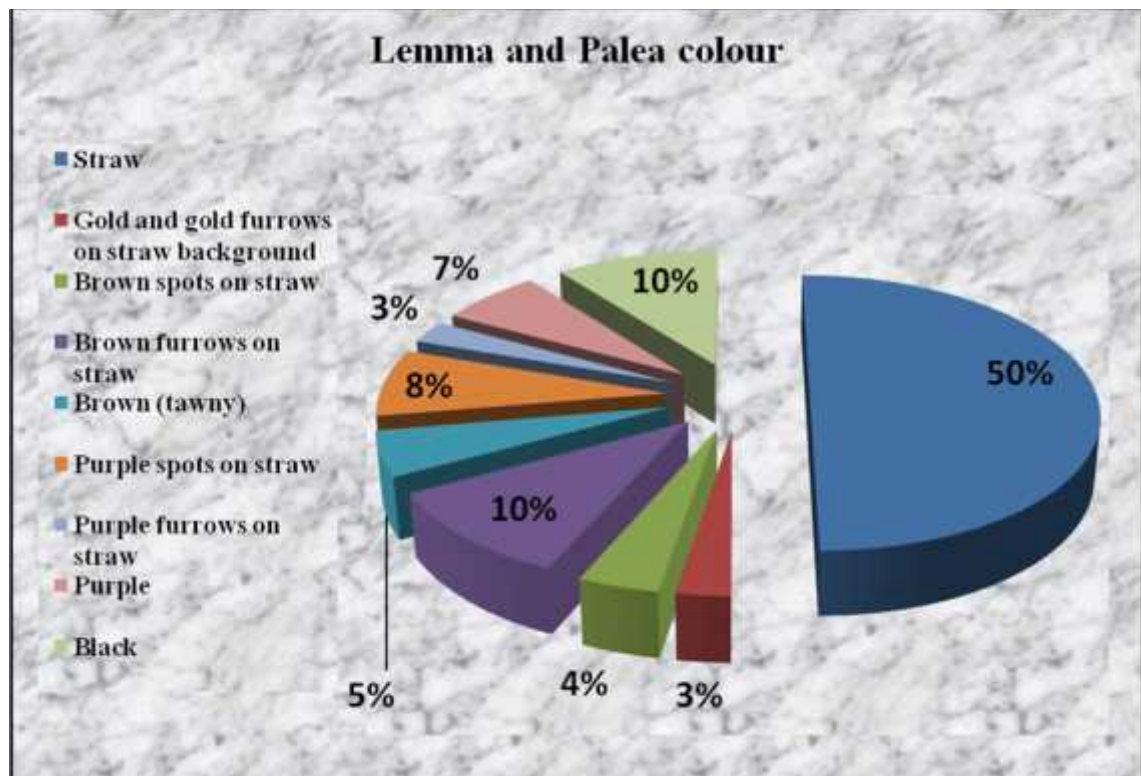


Figure 4.1 Frequency distribution of 76 landraces of rice for lemma and palea colour

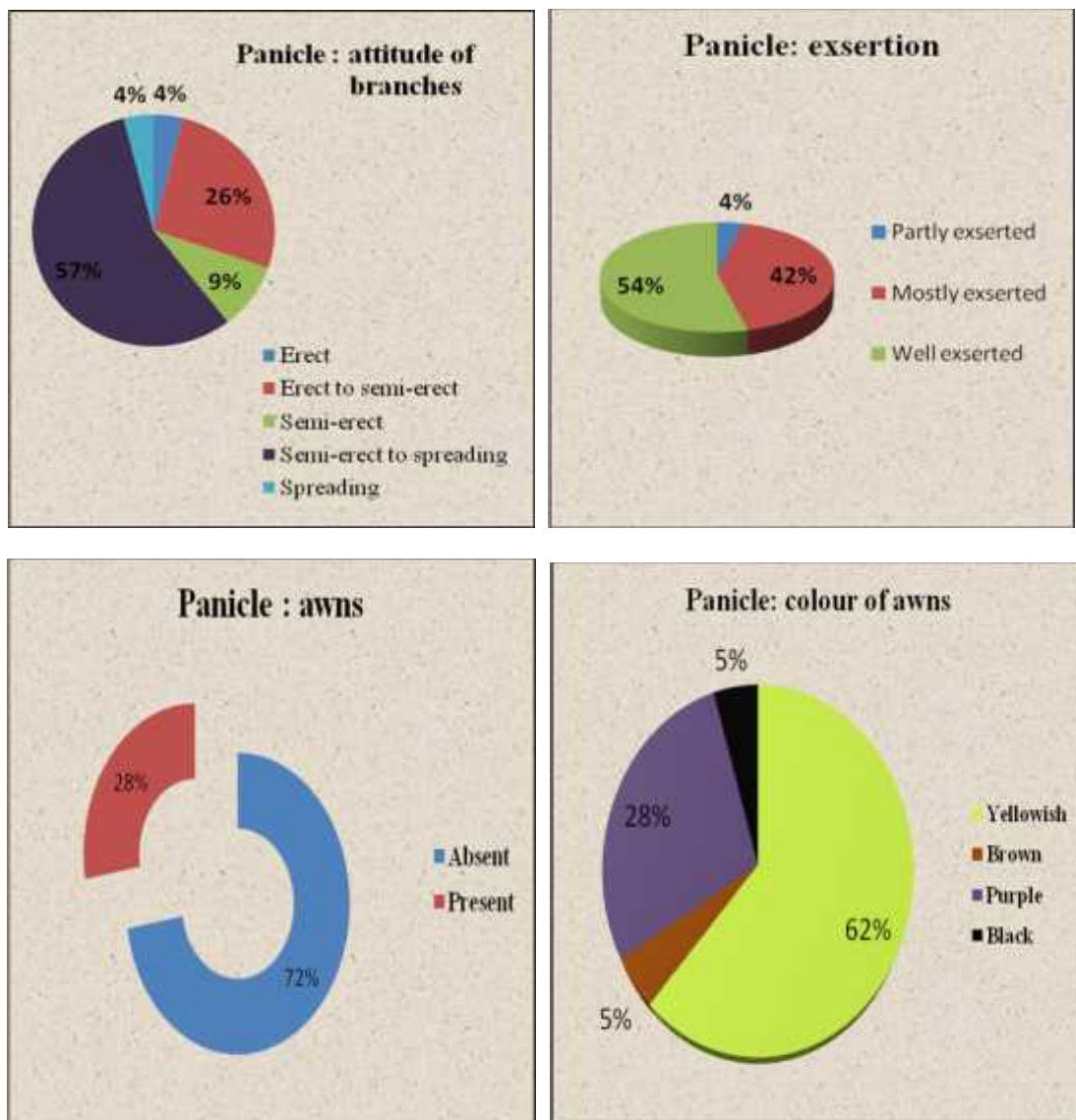


Figure 4.1 cont..Frequency distribution of 76 landraces of rice for
a) Panicle: attitude of branching
b) Panicle: exertion
c) Panicle: awns
d) Panicle: colour of the awn

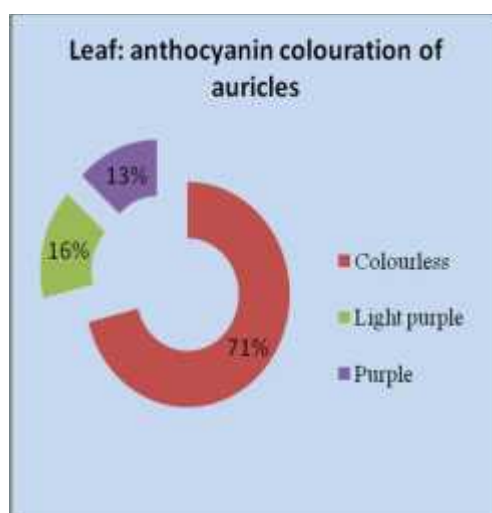
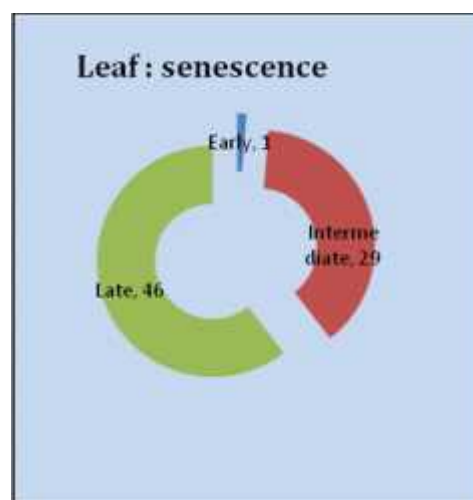
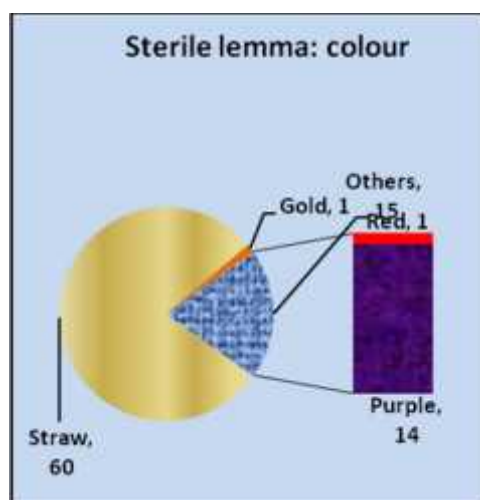


Figure 4.1 Cont...Frequency distribution of 76 landraces of rice for
a) Sterile lemma: colour
b) Leaf: senescence
c) Leaf: anthocyanin colouration of auricles
d) Leaf: colour of ligule

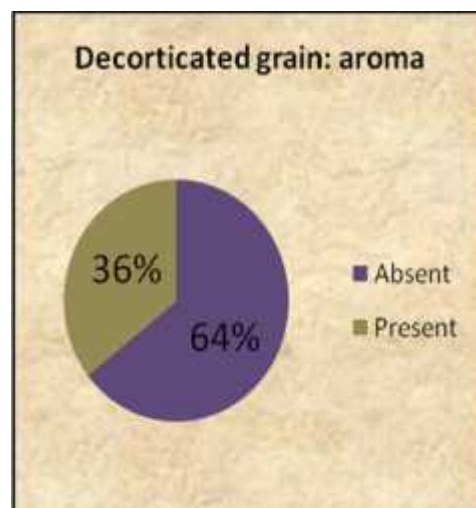
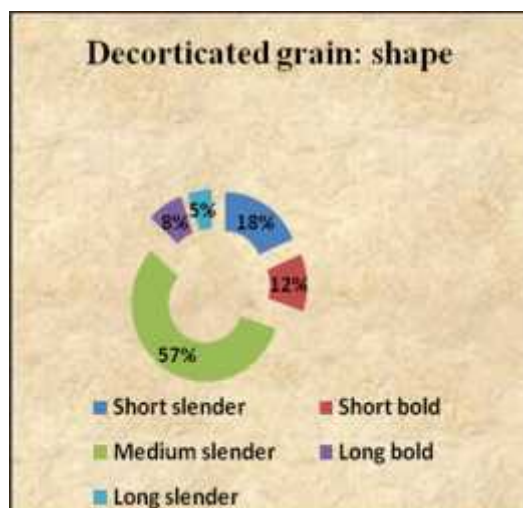
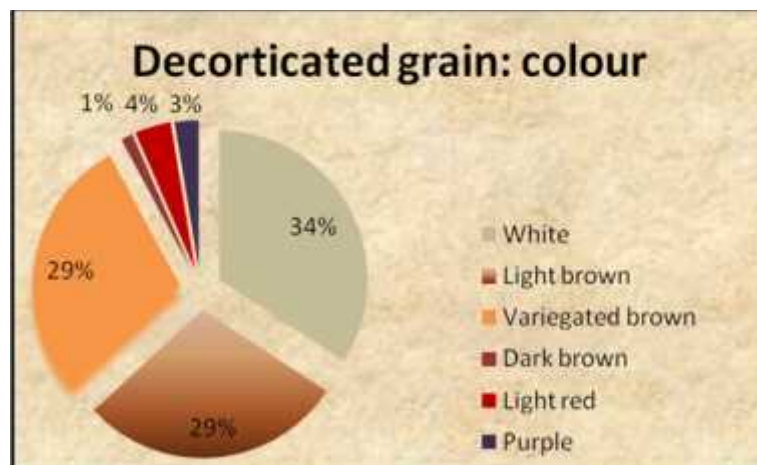


Figure 4.1Cont...Frequency distribution of 76 landraces of rice for
a) Decorticated grain: colour
b) Decorticated grain: shape
c) Decorticated grain: aroma

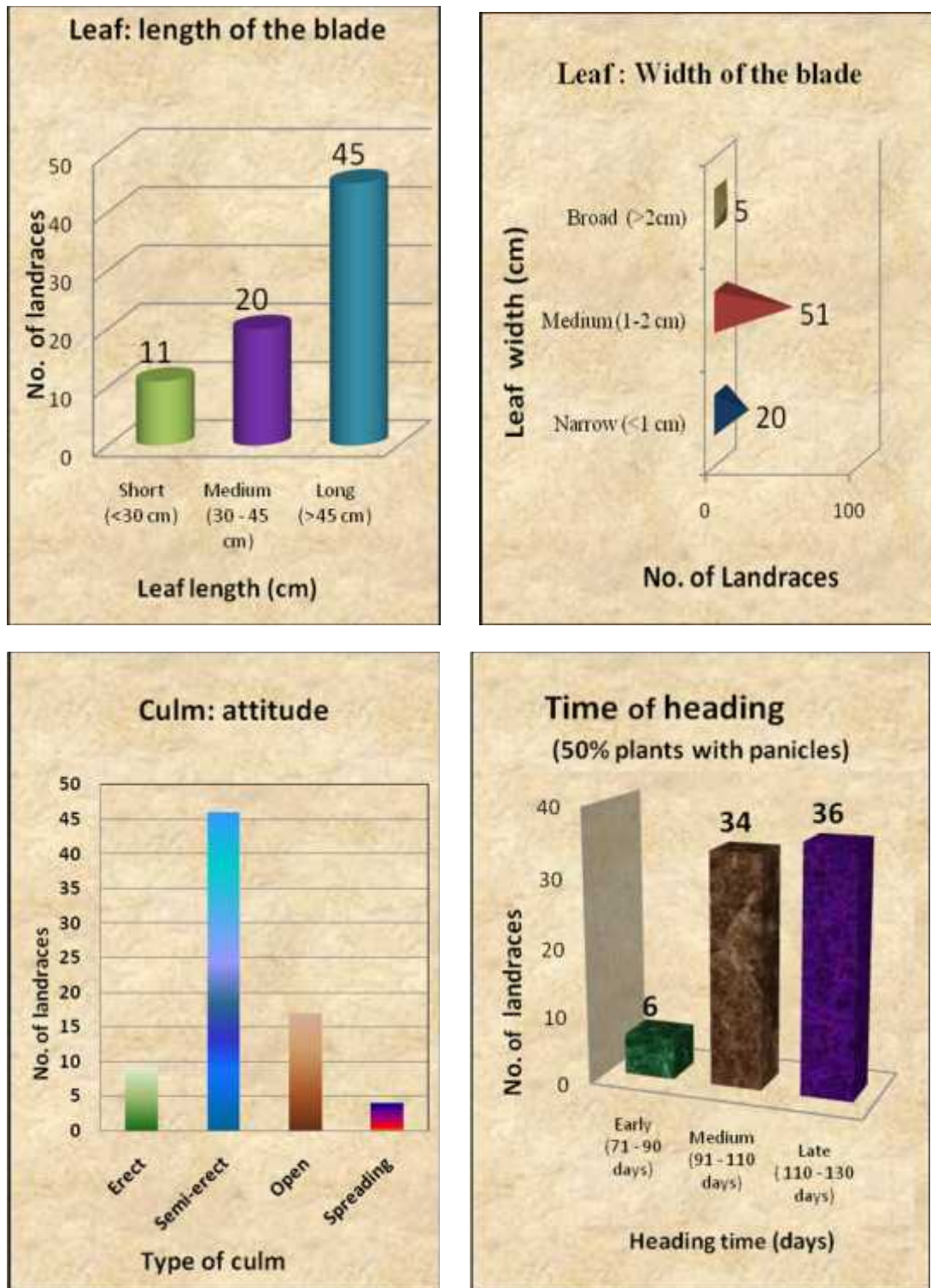


Figure 4.2 Frequency distribution of 76 landraces of rice for
 a) Leaf: length of the blade
 b) Leaf: width of the blade
 c) Culm: attitude
 d) Time of heading

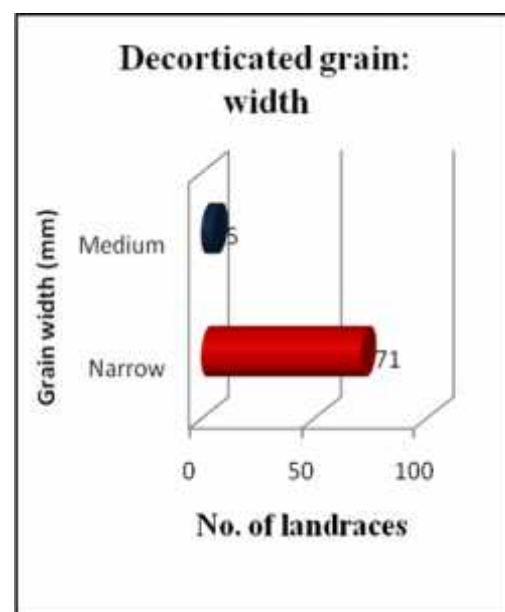
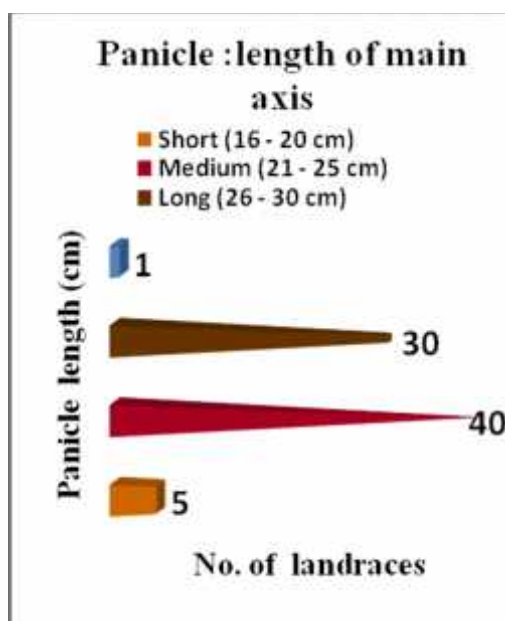
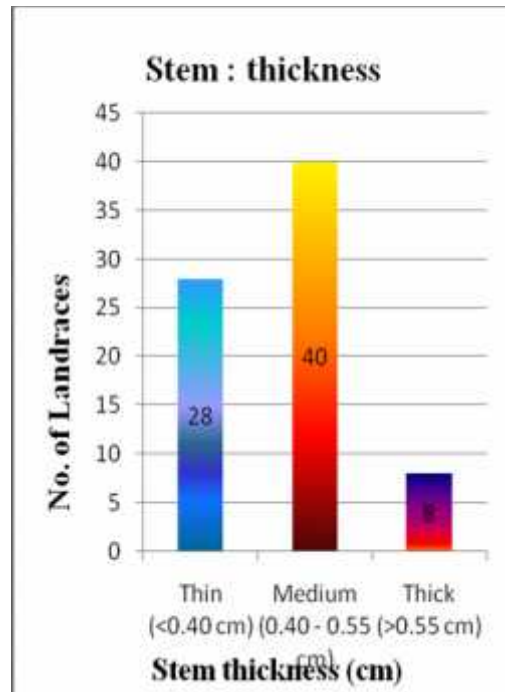
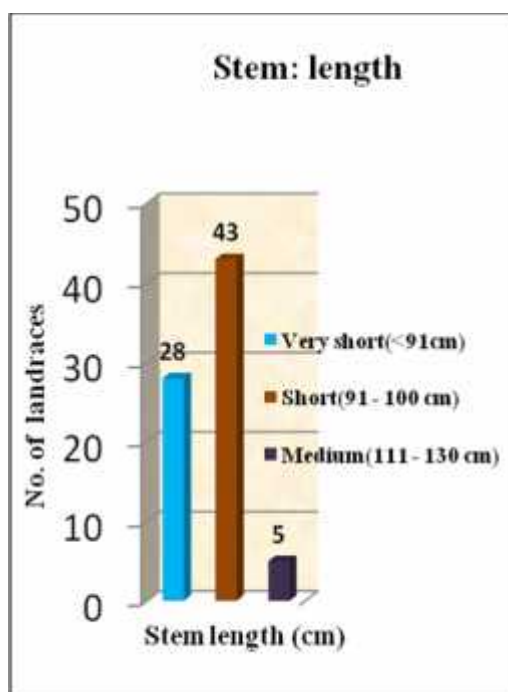


Figure 4.2 Frequency distribution of 76 landraces of rice for
a) Stem: length
b) Stem: thickness
c) Panicle: length of main axis
d) Decorticated grain: width

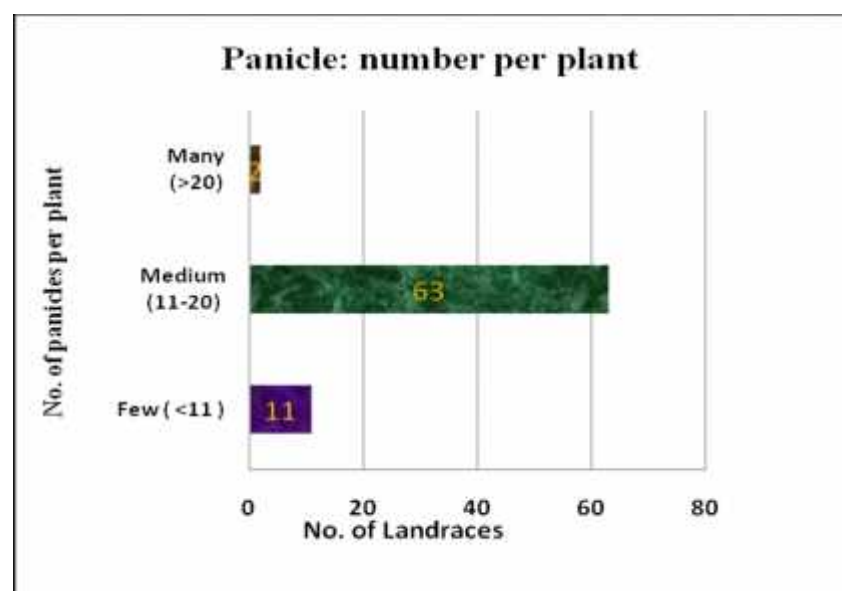
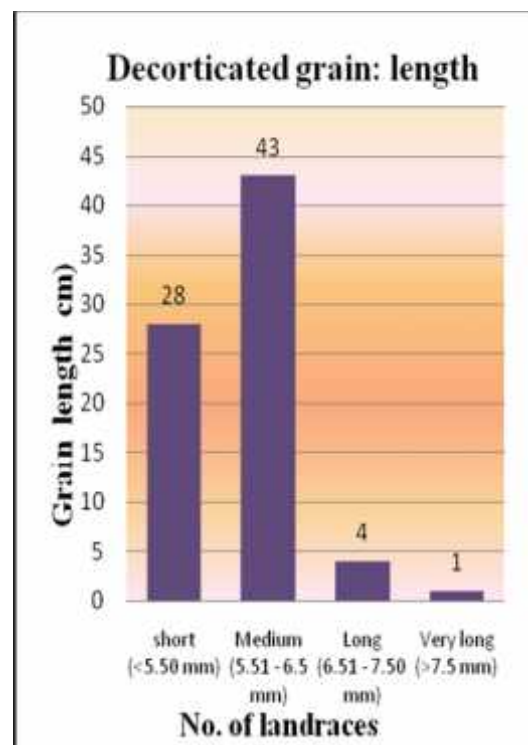
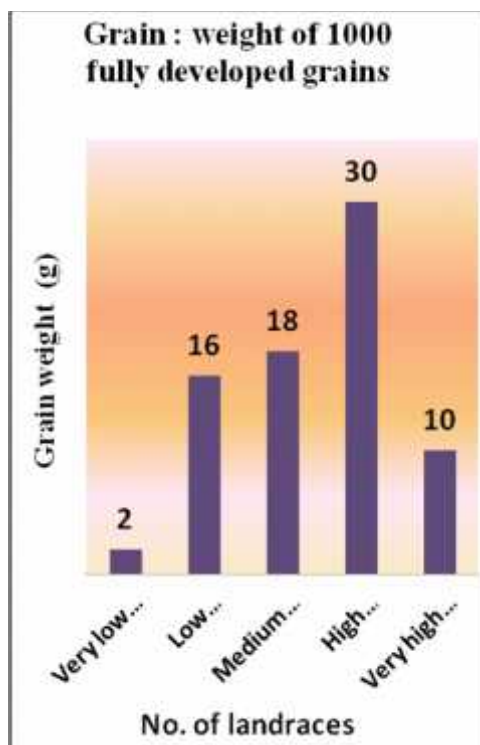


Figure 4.2 Cont... Frequency distribution of 76 landraces of rice for
a) Grain: 1000 grain weight
b) Decorticated grain: length
c) Panicle: number per plant

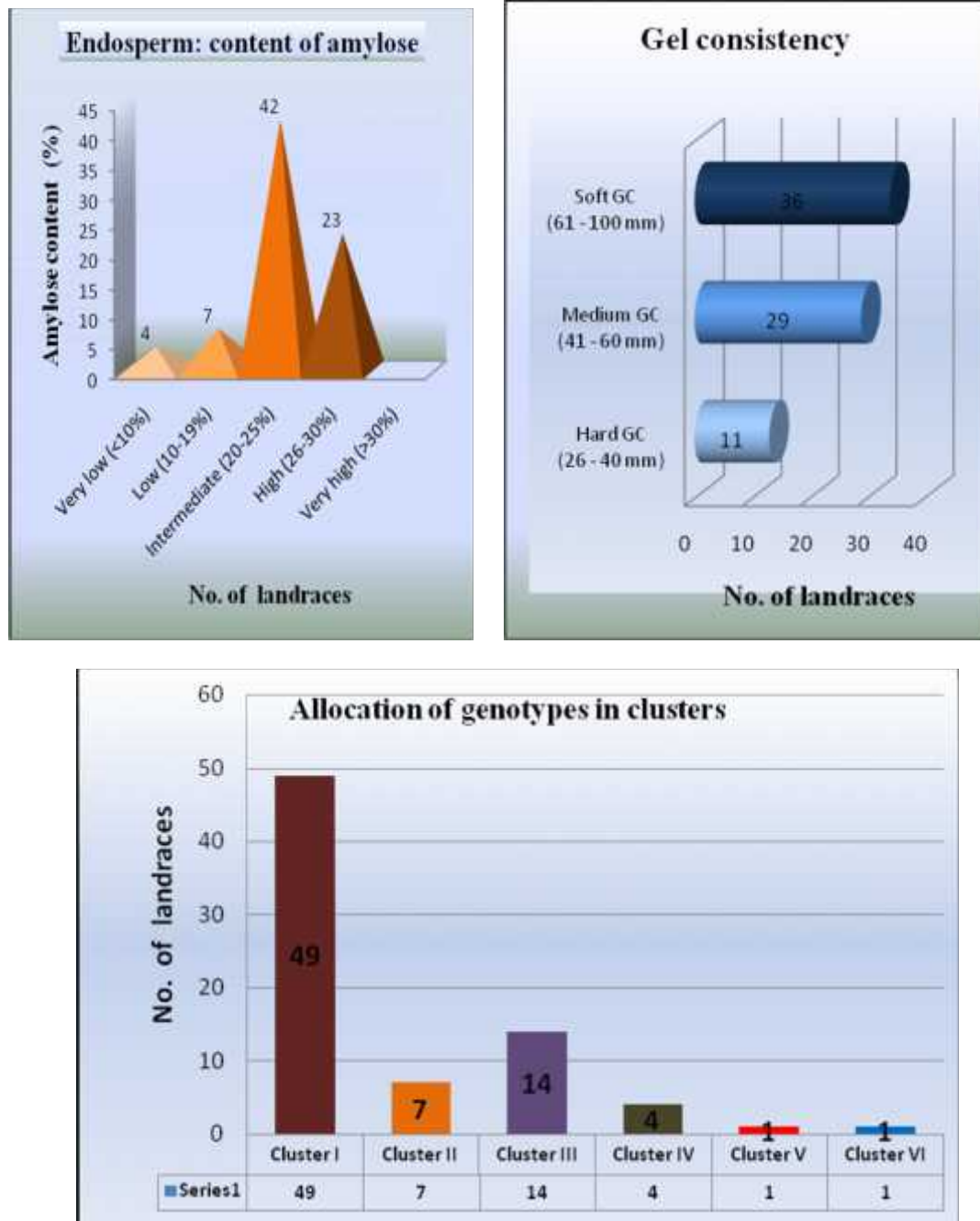


Figure 4.3 Frequency distribution of 76 landraces of rice

- Amylose content**
- Gel consistency**
- Allocation of genotypes to different clusters.**

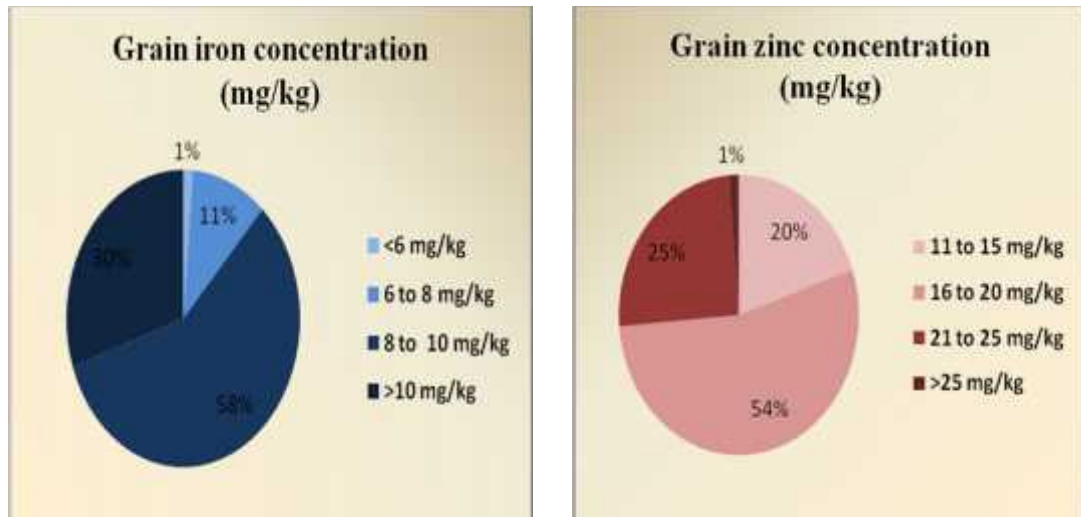


Figure 4.3 cont.. Frequency distribution of 76 landraces of rice for
a) Grain iron concentration
b) Grain zinc concentration.

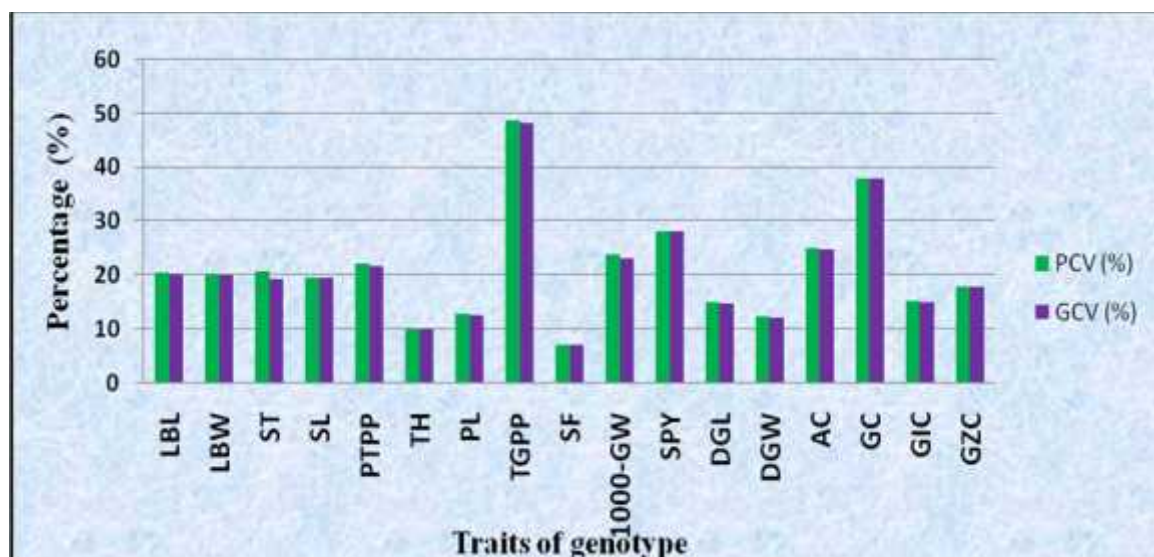


Figure 4.4 Graphical representation of phenotypic and genotypic coefficients of variation for various characters in landraces of rice.

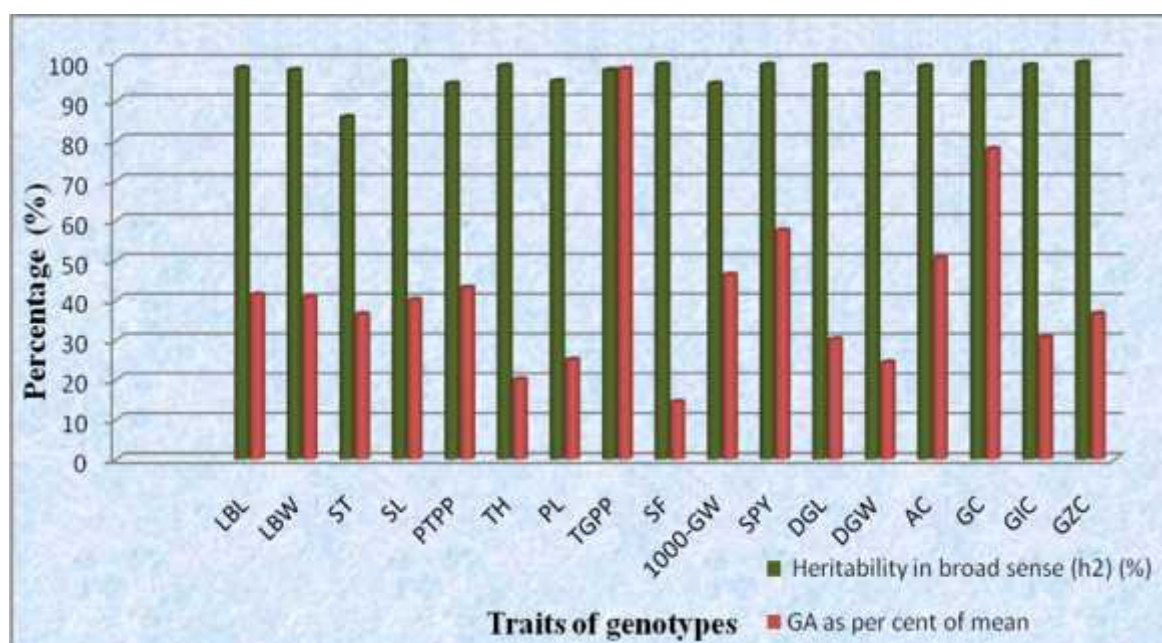


Figure 4.5 Graphical representation of heritability (broad sense) and genetic advance as a per cent of mean for various characters in landraces of rice.

LBL – Leaf blade length; LBW – Leaf blade width; ST – Stem thickness; SL - Stem length; PTPP – Number of productive tillers per plant; TH – Time of heading; PL – Panicle length; TGPP – Total number of grains per panicle; SF - Spikelet fertility; 1000-GW - 1000-grains weight; SPY – Single plant yield; DGL - Decorticated grain length; DGW - Decorticated grain width; AC - Amylose content; GC - Gel consistency; GIC - Grain iron concentration and GZC - Grain zinc concentration

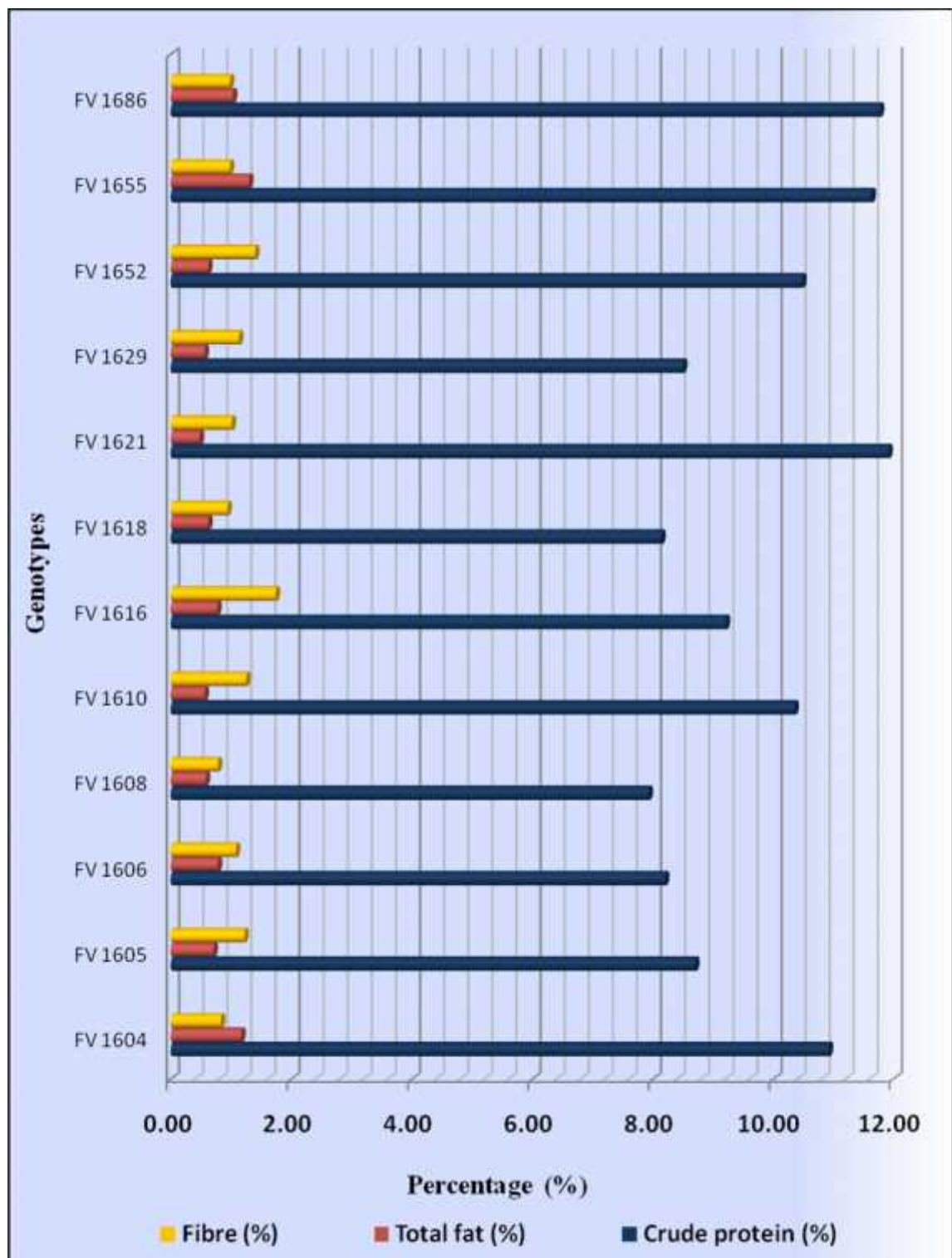
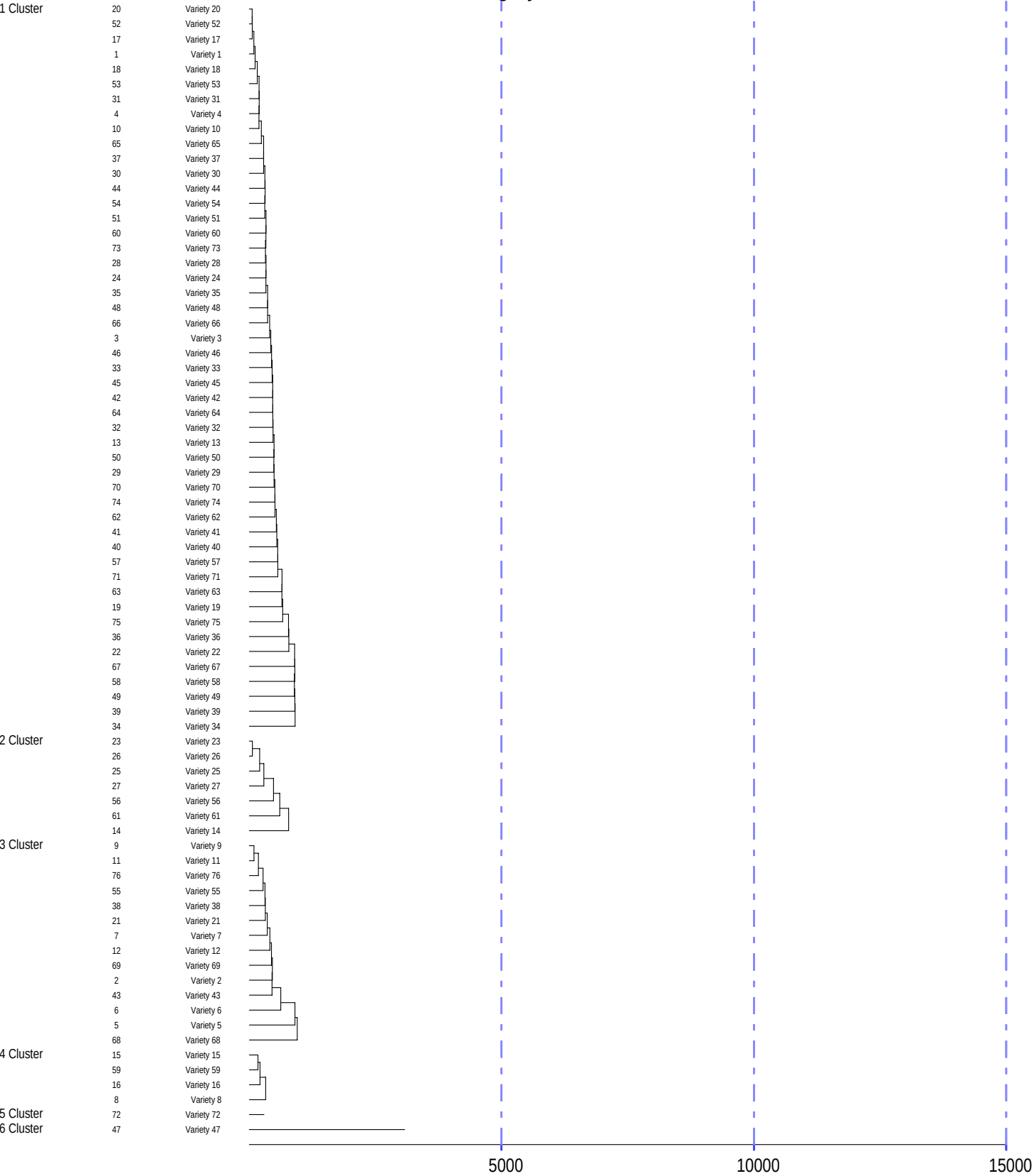
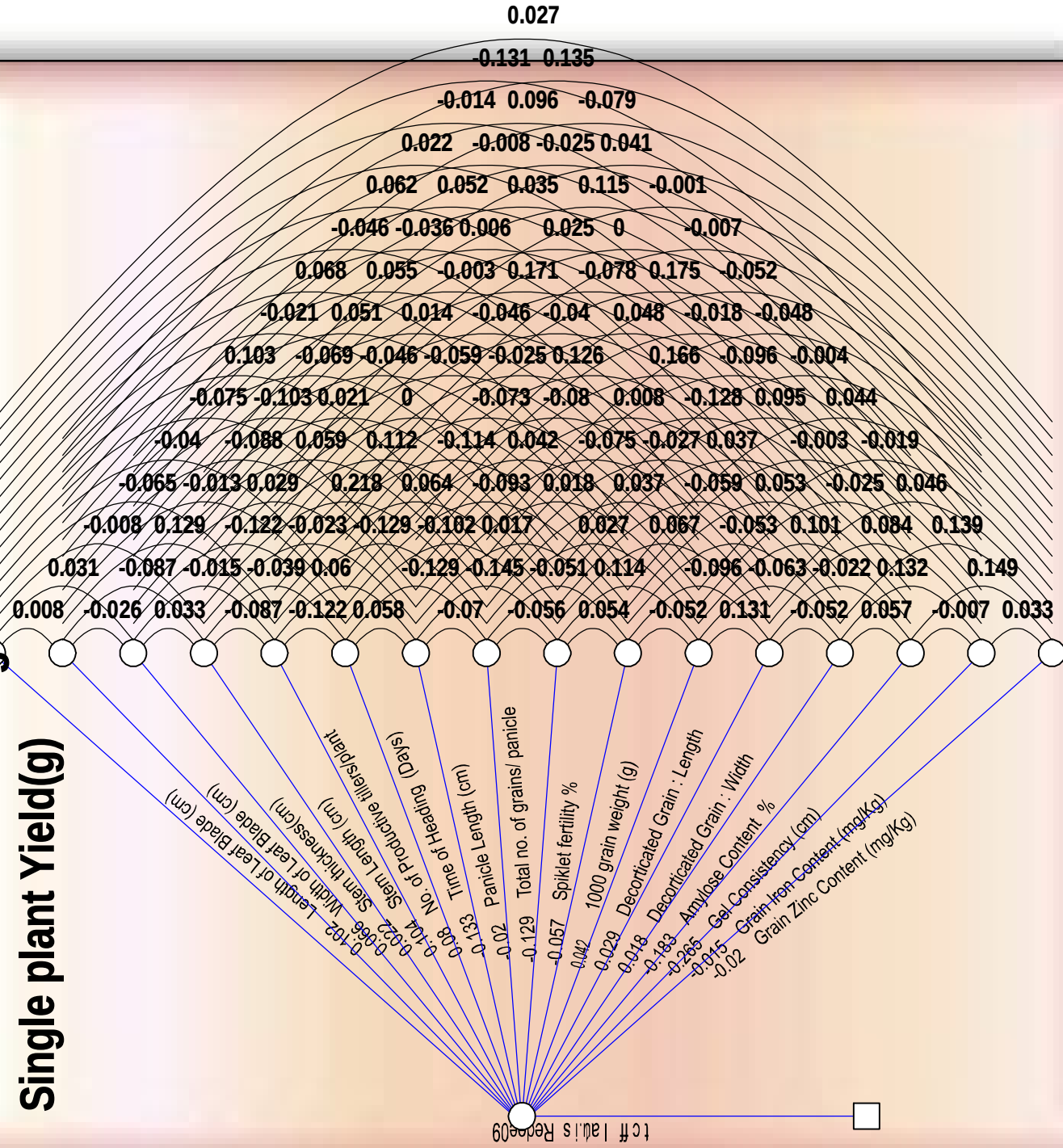


Table 4.9 Proximal composition of 12 landraces of rice from 6 clusters

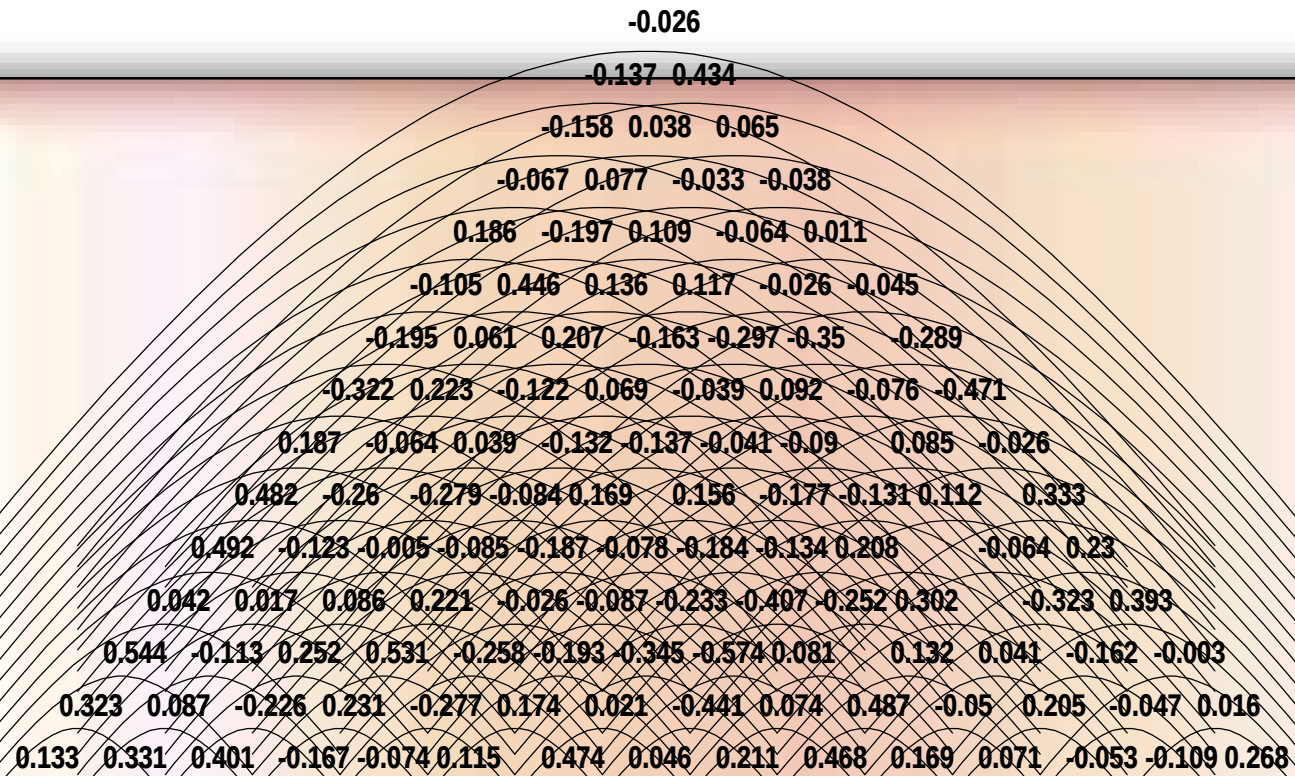
Clustering by Tocher Method



Environmental Path Diagram for Single plant Yield(g)



Genotypical Path Diagram for Single plant Yield(g)



- 0.034 Length of Leaf Blade (cm)
- 0.106 Width of Leaf Blade (cm)
- 0.106 Stem thickness (cm)
- 0.06 Stem Length (cm)
- 0.212 No. of Productive tillers/plant
- 0.033 No. of Heading (Days)
- 0.227 Time of Heading (cm)
- 0.161 Head Length (cm)
- 0.382 Total no. of grains/ panicle
- 0.052 Spiklet fertility %
- 0.174 1000 grain weight (g)
- 0.201 Decorticated Grain : Length
- 0.022 Decorticated Grain : Width
- 0.156 Amylose Content %
- 0.123 Gel Consistency (cm)
- 0.44 Grain Iron Content (mg/Kg)
- 0.107 Grain Zinc Content (mg/Kg)