VARIABILITY, CORRELATION, PATH ANALYSIS AND GENETIC DIVERGENCE IN BUNDED FIELD RICE (*Oryza sativa* L.)

A

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ABSTRACT

VARIABILITY, CORRELATION, PATH ANALYSIS AND GENETIC DIVERGENCE IN BUNDED FIELD RICE (*Oryza sativa* L.)

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ABSTRACT

Variability, correlation, path analysis and genetic divergence were studied in a set of 98 genotypes of bunded field rice (*Oryza sativa* L.) grown in a randomized block design with three replications at the National Agricultural Research Project, Musa Farm. Vyara during *kharif* season of 1998.

Analysis of variance revealed significant genotypic differences for all the nine characters under study. A wide range of variation was apparent for all the characters. The genotypic coefficient of variation was highest for grain yield per m^2, followed by straw yield per m^2, 100-grain weight and number of grains per panicle. Heritability estimates were high for protein content followed by days to 50 % flowering, 100-grain weight and grain yield per m^2. The expected genetic advance as a percentage of mean was high for grain yield per m^2, straw yield per m^2 and 100-grain weight. High heritability coupled with high genetic advance was exhibited by grain yield per m^2 and 100-grain weight. Thus, phenotypic selection would be effective for the genetic improvement in these traits.

Correlation analysis revealed that grain yield per m^2 was significantly and positively correlated with panicle length, 100-grain weight,

straw yield per m^2 and number of grains per panicle at genotypic levels. These yield contributing characters also possessed associations amongst themselves. The traits, plant height and protein content were negatively correlated with grain yield.

Path coefficient analysis indicated the highest positive direct effect of straw yield per m^2 followed by panicle length, 100-grain weight, number of grains per panicle and total productive tillers per meter row length. The character, days to 50 % flowering exhibited high negative direct effect, while protein content showed negative low direct effect.

Based on these findings, it can be suggested that for improving grain yield in bunded field rice, more emphasis should be given to plant height, straw yield per m^2, panicle length, number of grains per panicle and 100-grain weight.

The genetic diversity was assessed using Mahalanobis's D^2 statistic wherein 98 genotypes were grouped in seven clusters. The clustering pattern of the genotypes was independent of their geographical distribution. Based on inter-cluster distance, cluster-IV showed high genetic divergence with cluster-VI and VII and cluster-V with VI and VII. Therefore, it may be concluded that the genotypes belonging to these groups can be utilized in developing diverse variability and improving grain yield in bunded field rice. The characters, grain yield per m^2, straw yield per m^2, 100-grain weight, protein content, number of grains per panicle, days to 50 % flowering and plant height contributed maximum to the divergence.

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CERTIFICATE

This is to certify that the thesis entitled **"Variability, correlation, path analysis and genetic divergence in bunded field rice (*Oryza sativa* L.)."** submitted by **Shri A. I. Patel** in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Plant Breeding and Genetics** of the Gujarat Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari

Date : March 30, 1999

(D. U. Patel)

Major Advisor

DECLARATION

This is to declare that the whole of the research work reported in this thesis in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Plant Breeding and Genetics** by the undersigned is the result of investigation done by me under the direct guidance and supervision of **Dr. D. U. Patel**, Associate Research Scientist (Plant Breeding), Regional Sugarcane Research Station, Gujarat Agricultural University, Navsari Campus, Navsari and that no part of the work has been submitted for any other degree so far.

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Place : Navsari

Date : March 30, 1999

(A. I. Patel)

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INTRODUCTION

I INTRODUCTION

Among the cereals, rice, wheat and maize are three most important food crops of the world. Rice (*Oryza sativa* L.) is one of the oldest and second most intensively grown cereal crop and ranks third in grain production. Asia is considered to be "rice bowl" of world occupying 90 per cent of world rice area. The total area of the world under rice cultivation is 148.36 million hectares producing 519.86 million tonnes. India has the largest rice growing area (43.6 million ha.) which produces 82.1 million tonnes (Siddiq, 1999), but average production is quite low (2.6 tonnes per hectare) as compared to temperate countries like Japan, Italy, Spain etc. In Gujarat, rice is grown in an area of 0.64 million ha. with the production of 0.95 million tonnes (Anonymous, 1996-97).

Rice is grown under varied cultural systems on the flat-low-land, irrigated and/ or rainfed conditions according to the source of water supply and soil topography.

Bunded field means a field with a low ridge of soil built along the field contours. Bunded rice refers to rice grown on flat fields that are bunded, that were prepared and seeded under dry conditions and depend totally on rainfall for moisture. Bunded field rice is grown either by drilling, dibbling or broadcasting without irrigation. Bunded field play an important role in the area which are scare of water. Bunded field improve the water conserving capacity of the field. Bunded field rice is grown in Vyara, Mangrol, Mandvi, Songadh, Dodiyapada, Uchhal etc., tehsils of Surat and Bharuch districts of South Gujarat.

In the recent years, a number of varieties of rice suitable for varying agroclimatic conditions as well as farming situations have been released for general cultivation in different rice growing states of the country. Most of these varieties are pure lines, being the outcome of hybridization programme followed by selection. Selection is one of the basic methods of crop improvement in rice. The efficiency of selection, largely depends upon the existence of genetic variability in the base population. Efforts are strengthened in India to develop hybrids in rice and three hybrids have been recommended for commercial growing.

A programme of breeding for high yield requires information on the nature and magnitude of genetic variation. Therefore, the first step would be its assessment in the base population under study. Since most of the plant characters which are of economic importance are quantitatively inherited, they are highly influenced by environmental conditions. It is difficult to judge whether observed variability is heritable or environmental. This suggests the imperative need of partitioning the phenotypic variability into its heritable and non-heritable components.

The estimates of variability, heritability and genetic advance for the yield components and their correlations with yield have been considered to be of great importance. The genetic variability could be determined with the help of certain genetical parameters such as genetic coefficient of variation (GCV), heritability estimates (h^2) and genetic advance (GA). GCV indicates the relative degree of genetic variability existing for different characters in a population of genotypes. The heritability expresses the relative amount of heritable portion of the variation. However, the heritability estimates along with genetic gain is more useful in selecting the best population individual.

The parameter like correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Path analysis unravels whether the association of these characters with yield is due to their indirect effect via some other trait or traits.

Among the available methods of multivariate analysis, Mahalanobis D^2 - analysis appeares to be most suitable for divergence study because it permits precise comparison among all possible pairs of populations in any given group before affecting actual crosses. The present investigation, therefore was undertaken with following objectives :

1. To ascertain the extent of variability in rice genotypes and to partition it into heritable and non-heritable components.

2. To study the association between grain yield and its components by estimating genotypic and phenotypic correlation coefficients.

3. To estimate the direct and indirect effects of grain yield components by partitioning the total component through path coefficient analysis.

4. To know the extent of genetic distance among different genotypes within a group (cluster) and to provide a basis for selection of parents for hybridization.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The literature pertaining to rice (*Oryza sativa* L.) has been reviewed in the following sub-headings :

2.1 Genetic variability, heritability and genetic advance

2.2 Correlation

2.3 Path coefficient analysis

2.4 Genetic Divergence

2.1 Genetic variability, heritability and genetic advance

The progress of any breeding programme depends on the information regarding genetic variability present in a population. This together with information on heritability and genetic advance would be rewarding in designing an effective breeding programme for improvement of any crop. Therefore, assessment of the genetic variability in the base population is the first step in any breeding programme. The genetic variability is determined with the help of certain genetic parameters such as genetic coefficient of variation, phenotypic coefficient of variation, heritability estimates and partitioned in to heritable and non-heritable components. Heritablity refers to the degree to which variability of a quantitative character may be transmitted to the progeny and is an index of transmissibility. The knowledge of heritability helps the plant breeder in pre-assessing the results of selection for a particular character. Heritability in broad-sense is the ratio of genotypic variance to the phenotypic variance. On the other hand, heritability in narrow sense, is a fraction of the total variance that is due to additive effects of genes. Its estimate is quite important for measure of the character. If it is high, the phenotypic value provides a fairly close genotypic value and thus breeder can base his selection on the phenotypic performance. However, mention may be made that for predicting the effect of selection, heritability estimates along with genetic advance are more useful than the heritability estimates alone (Johnson *et al.*, 1955).

Panwar and Gupta (1969) observed that high heritability was associated with high genetic advance and coefficient of genetic variation for spikelet number, and leaf area in rice. Heritability was also high for other characters, except grain yield, but the expected genetic advance and coefficient for genetic variation were low for these characters. For grain yield, heritability as well as other parameters had low values. Number of panicles and grain number seemed to be more suitable traits (reliable criteria) for selection and further improvement.

Sen *et al.*, (1969) observed that the maximum and minimum genetic differences were found for tiller number and plant height, respectively. Heading duration and weight of 100 gains were less affected by environmental factors and possess high heritability value. The low heritability value, as found for grain yield, showed the complex inheritance.

Swamy Rao *et al.*, (1970) observed that plant height, panicle length, number of grains per panicle and number of days to 50 per cent flowering had high heritability values in eight rice varieties. The height and number of grains per panicle showed high genetic gains.

Jogi and Hassan Baba (1971) reported that the genetic variation was high for number of ear-bearing tillers, 100-grain weight and plant height. Heritability estimates were high for grains per panicle and panicle length.

While studying eight characters in ten varieties Majmudar *et al.* (1971) observed wide range of genetic variation for grain yield, number of grains per panicle, panicle per plant, 100 grain weight, plant height and number of effective tillers. They also observed high heritability coupled with high genetic advance for number of grains per panicle, plant height and number of effective tillers.

Shukla *et al.*, (1972) observed wide range of phenotypic variation for all the eight plant characters in 179 rice varieties. High coefficient of variation was observed for the number of effective tillers per plant, 100 grain weight, grain weight per panicle, grain yield per plant and spikelets per panicle. Relatively moderate heritability values ranging from 73.64 to 78.63 per cent were found for the number of effective tillers per plant, panicle length, spikelets per panicle and grain yield per plant. However, heritability values ranging from 81.30 to 97.10 per cent were observed for number of days to heading, plant height, grain weight per panicle and 100 grain weight. Chaudhary *et al.*, (1973) studied genetic variability and correlation in 23 rice varieties and found high genotypic coefficient of variation for panicle weight, panicle number and yield per plant. They also reported high heritability and high genetic advance for panicle weight, single plant yield, number of panicle and grains per panicle.

Sivasubramaniam and Madhvamenon (1973) reported that genetic coefficient of variation was higher in case of number of grains per panicle, number of tillers, panicle weight and grain yield. Heritability estimated in broad sense were high for grain yield, number of grains per panicle and panicle weight. High value of heritability and genetic advance were obtained which indicated predominance of additive gene effects.

Tripathi *et al.*, (1973) observed high heritability values for yield and its contributing characters. The weight per panicle and high genetic advance coupled with high heritability estimates. It indicated that there was scope for improvement in these characters through selection.

Goud *et al.*, (1974) studied genotypic and phenotypic values for certain characters in paddy and observed that the heritability values for number of the grains per panicle, plant height and length of the panicle were higher indicating that higher genetic gains could be obtained by selecting for these characters.

Talwar *et al.*, (1974) recorded significant differences for all the eleven characters studied in 33 rice varieties. They found high estimates of heritability (broad-sense) and genetic advance for days to flowering, grains per panicle, plant height, straw, grain and kernel weight, grain and kernel volume, and grain yield.

Prasad and Chadra (1977) observed high genetic coefficient of variation and moderate to high heritability (broad-sense) for plant height, area of second leaf, number of grains per panicle and grain weight per panicle, and high genetic advance for grain yield per plant.

While studying heritability and genetic advance for thirteen traits in $21F_1$s and $21F_2$s derived from seven parents, Maurya (1978) advocated that improvement in grain yield could be best affected by selection for high grain number per panicle, high test weight and long grains as their heritability estimates were high.

Chaudhary *et al.* (1980) studied heritability and correlation in 7 x 7 diallel crosses of rice varieties and observed high heritability and genetic advance for number of spikelets per panicle and 100 grain weight. They further reported that improvement in grain yield could be affected by exercising selection in F_2 for high number of spikelets per panicle and 100-grain weight.

Sinha and Bhattacharya (1980) studied genetic variability in Sundarband rice varieties under saline conditions and found that the genetic coefficient of variation ranged from 8.54 for panicle length to 28.19 for yield per plant. Broad sense heritability was nearly 90 per cent for plant height, panicle length and high for most of the other characters. Genetic advance expressed as a percentage of mean was the highest for yield per plant followed by spikelets sterility.

Bhattacharya and Mishra (1981) studied different quantitative characters of rice grown in sodic and non-sodic soils and found that plant height, ear bearing tillers, panicle weight and grains per panicle showed higher genetic coefficient of variation, higher heritability with genetic gain as percentage of mean under stress sodicity. In normal soil, plant height, panicle weight, grains per panicle and grain yield per plant had a higher genetic coefficient of variability, high heritability value and high genetic advance.

Ghosh *et al.* (1981) reported wide phenotypic variability for plant height, days to flowering number of ear bearing tillers, 1000-grains weight and length and width of leaf in Meghalaya rice varieties. They observed high values of genetic advance and heritability (broad sense) for number of ear bearing tillers per plant and plant height indicating possibility of improvement through selection.

Mahajan *et al.* (1981) reported that the variation in late duration cultures of rice could be explained by ear bearing tillers or grain number per panicle and 100 grain weight among the six variables viz., ear bearing tillers, panicle length, grain number per panicle, sterility, 100-grain weight and yield.

Paramasivan (1981) reported that heritability ranged from 16.20 per cent (number of productive tiller) to 94.60 per cent (length of panicle). Number of spikelets showed very high value of heritability (93.26%) along with high genetic advance (51.38%). The high value of heritability and genetic advance for number of grains per panicle was attributed to high degree of additive effect.

Ghorai and Pande (1982) reported that additive and dominance effects were important in the inheritance of yield and three related characters. Heritability was high for yield, number of ear bearing tillers per plant, number of spikelets per panicle and 1000-grain weight. Selection for ear bearing tillers per plant, spikelets per panicle and test weight was effective in improving yield in the advanced generations.

Kaul and Kumar (1982) studied genetic variability in 21 varieties of rice and reported considerable variation for all the traits under study. Plant height showed maximum variation followed by tiller number, grain yield and grain fineness. They also reported that plant height exhibited high genotypic coefficient of variation along with high heritability and high expected genetic advance.

Sedlovskii *et al.*, (1982) reported that the coefficient of heritability for some of the yield related characters varied according to environment. Selection for plant height, panicle length and number of elongated internodes could be performed under any environmental condition. On the other hand selection for spikelet number and weight of grains from the main panicle was best performed under low stand densities and selection for total and fertile tiller number and for grain weight per plant could only be successfully performed under low stand densities.

Singh and Sharma (1982) found high heritability value for days to 50 per cent flowering, plant height, 100-grain weight and high genetic advance for plant height and number of grains per panicle.

Lal *et al*, (1983) studied eighty semi-dwarf cultures of rice derived from cross combination of seven rice cultivars. A wide range of variation was recorded for most of the characters. Heritability in broad sense was very high for all the characters studied. Flag leaf angle exhibited maximum variation with highest genetic advance as the percent of mean. The culture having minimum flag leaf angle recorded maximum grain yield.

Chauhan and Tandon (1984) studied 30 hill rice varieties in two environments viz., Rainfed upland direct seeded and irrigated transplanted. They found that plant height, number of ear bearing tillers and grain yield had high heritability and high genotypic variation under both the environments for the characters under study.

Huang (1984) studied nine varieties of rice and observed highest heritability (broad sense) for 1000 grain weight followed by number of ears per unit area, number of spikelets per panicle and fertility.

Roi and Smetanin (1984) recorded high genotypic variation, heritability and genetic advance for harvest index among all the F_1 hybrid studied.

Maurya *et al*., (1986) evaluated 48 lowland rice cultivars for assessing variability, heritability and genetic advance. A wide range of phenotypic variation was found for characters like grains per panicle, plant height, leaf length, days to flowering and leaf angle. High heritability coupled with high length, kernel length-breath ratio, plant height, grains per panicle, test weight and panicle length.

Moeljopawiro (1986) reported moderate heritability (narrow sense) for plant height, panicle length, grain length, grain width and 100 grain weight in F_1 and F_2 populations of diallel crosses in rice.

Singh *et al.*, (1986) studied variability, heritability and genetic advance in 98 upland rice cultivars. They reported that all the characters except sheath length showed a wide range of phenotypic variation. They also found that phenotypic coefficient of variability was higher than genotypic coefficient of variation. Heritability was highest for days to 50 per cent flowering followed by plant height and seedling height.

Sardana and Sasikumar (1987) reported wide variation in days to 50 per cent flowering, plant height, effective tillers per plant, panicle length, number of filled grains per panicle, 1000-grain weight and grain yield per plant in 62 cold tolerant strains of rice.

Lu (1988) reported that grain number per panicle had the greatest direct effect on grain weight per plant, followed by 1000 grain weight and effective panicle number per plant. He further concluded that the efficiency of indirect selection for grain weight per plant according to correlative heritability was lower than that of direct selection under the same selection rate and the selection for grain number per panicle was effective in high-yielding breeding programmes.

Sundaram *et al.*, (1988) studied genetic variability and correlation coefficient in early rice varieties and reported higher estimates of phenotypic and genotypic variance for grains per panicle, plant height and dry matters, whereas, lowest for productive tillers. They also reported moderate to high heritability coupled with high genetic gains for straw yield, chaffs per panicle, grains per panicle, dry matter and productive tillers indicating presence of additive gene effects for these characters.

Dewarkar *et al*, (1989) collected information on genotypic and phenotypic variation, heritability expected genetic advance and correlations of 10 yield characters in 30 lines growing during 1984. They concluded that selection should be based on plant height, 1000 grain weight and grainsper panicle.

Moeljopawiro (1989) studied nine rice lines which were grown at 2 locations (high and low altitudes) in West Java over 4 growing seasons (from 1979-1981). Heritability values for 1000 grain weight suggested that the trait can be selected in any of the environment studied. Correlation coefficients indicated that grains per panicle was yield determining component. Selection for tiller number, in either direction was expected to be accompanied by a negative response in grains per panicle and 1000 grain weight.

Pathak and Patel (1989) studied genetic variability and character associated in upland rice and reported wide range of phenotypic variability for grain yield, fodder yield, days to flowering, days to maturity, plant height, panicle length, grains per panicle, and 1000 grains weight. They also reported high heritability with high genetic advance for grains per panicle, plant height and 1000 grain weight, while moderate heritability with high genetic advance for grain yield and fodder yield.

Sardana *et al.*, (1989) reported that panicle/ m^2, panicle length days to 50 per cent flowering days to maturity and plant height were the most important characters contributing to yield.

Heritability and genetic advance were studied by Vishwakarma *et al*, (1989) in 82 populations of rice. They reported that estimates of broad sense heritability were high for grains per panicle, moderate for grain yield and low for number of tillers. Genetic advance was high for grains per panicle and medium to low for grain yield, test weight and number of tillers.

Sahu *et al.* (1990) studied variability, heritability and genetic advance in two rice hybrids and observed that heritability was moderately high only for days to heading and grain yield/ plant in AC 517 x Cross 1, while heritabilities of other characters in both the crosses were low.

Singh *et al.*, (1990) measured 16 yield components in 56 genotypes sown in sodic soil and reported that heritability of all traits was high except for grin yield per plant. Grain sterility, spikelets per panicle, filled grains per panicle, biological yield per plant, flag leaf area and harvest index showed high values for genetic advance.

Bai *et al.*, (1992) assessed five yield components in the F_2 of three crosses during wet season 1990. They observed high values for phenotypic and genotypic coefficients of variability for panicles per hill, grains per panicle and single plant yield. Grain weight had a low broad-sense heritability value and low genetic advance, indicating non-additive gene action. Very high values of heritability and genetic advance for single plant were obtained.

Anand Kumar (1992) studied fifteen F_1's and eight parents involving upland rice cultivars for genetic variability and found that plant height, tiller number and boot leaf breath had high heritability and genetic advance.

Chauhan *et al*, (1992) reported a wide range of variability for grain length, shape, water uptake and head rice recovery. They also observed higher magnitude of phenotypic coefficients of variation than genotypic coefficients of variation. The heritability estimates were higher for grain length, alkali digestion value, length - breadth ratio of grain and grain breadth along with high genetic advance.

Genetic variability of 11 plant characters was studied in 16 rice genotypes by Yadav (1992). He observed heritability estimates for plant height, yield per plant, sterility, harvest index, days to 50 per cent flowering and days to maturity, Grain yield per plant was positively correlated with days to 50 per cent flowering, days to maturity, panicles per plant and seeds per plant.

Chauhan *et al.* (1993) studied genetic variation and character association in rainfed upland rice and reported that straw yield per plant exhibited highest genetic variation followed by harvest index. They further reported that straw yield per plant, harvest index, 1000-grain weight, days to 50 per cent flowering, panicle length and per cent filled spikelets possessed high heritability coupled with high expected genetic advance in 21 advance breeding lines in rice.

Patel *et al.*, (1993) studied genetic variability and heritability in thirty-seven promising cultures of upland rice. They reported that the characters grains yield/ m^2, straw yield/ m^2, number of filled grains per panicle and panicles/ m^2 showed high GCV, while high heritability was observed for all the characters studied. Straw yield/ m^2 expressed maximum genetic gain followed by grain yield/ m^2, number of filled grains per panicle and number of panicles/ m^2. They suggested that these characters could be of great importance for selecting better genotypes in the rice improvement programme.

Sarawgi and Soni (1994) observed that sterility showed the highest level of variability but this was probably due to variation in temperature. Heritability estimates were highest for plant height, grain length, 100-seed weight, spikelets density, days to 50 per cent flowering, panicle length and fertile spikelets per panicle.

Wali and Mahadevappa (1995) showed that heritability estimates were high for plant height, maturity, regeneration percentage and number of plants regenerated, but low for grain yield and ratooning ability. High heritability coupled with genetic advance were observed for plant height and regeneration percentage.

Sawant and Patil (1995) observed that high co-efficient of variation were observed for grains per panicle, grain yield per plant and plant height. High values of heritability coupled with high expected genetic advance were observed for the characters, grains per panicle, plant height, grain yield per plant and 1000 grain weight.

Singh *et al.*, (1996) observed that hybrid-derived populations had higher heritability and genetic advance estimates than irradiated populations. The pattern of heritability estimates and genetic advance were similar in the pure line and hybrid derived populations.

Reddy and De (1996) studied thirty-six genotypes with water depths of up to 61 and 65 cm respectively. They observed that grain yield per hill, grains per panicle and panicle weight had the highest estimates of genotypic and phenotypic variability. High heritability estimates were observed for grain length followed by 1000-grain weight, grain breath, plant height, panicle weight, grain yield and grains per panicle.

Manonmani *et al.* (1996) studied genetic variability, heritability and genetic advance in F_1's of 200 cross combinations of 9-short duration rice genotypes. The traits, days to flowering, height, 100-grain weight, number of grains per primary ear and grain yield had high values for heritability and genetic advance.

Marekar and Siddiqui (1997) studied genetic variability, heritability and correlation coefficients in 73 rice varieties grown during Kharif 1989-90. Genotypic and phenotypic coefficient of variations were high for grains length and length : breath (L/B) ratio. High estimates of heritability together with genetic advance were also observed for these traits.

2.2 Correlation between yield and its components

Most of the quantitative character of economic importance show correlated responses. As yield is dependent on several component characters, the knowledge of character association would be useful to plant breeder for formulating effective breeding programme.

Correlation study provides a measure of association amongst characters. These may be appreciated when highly heritable traits are positively and closely associated among themselves and with grain yield. Thus, breeding procedures based on improvement of one or more sub-traits would lead to tangible improvement in yield than straight selection in yield.

The concept of correlation was given by Galton (1889) which was further elaborated by Fisher (1918). It is an index of the proportion of the causes common on genesis of two variables to total (Bowley, 1920) and not the causes themselves. Fryxeel (1956) reported that selection based on component characters was 250 per cent as efficient as one based on yield alone. The correlation studies give amount of association between any pair of characters. The degree of association between yield and component characters might vary with environment or material under study or both. Hence, it is essential to measure the correlations at phenotypic and genotypic level.

Important findings of several workers who have established correlation between different traits on rice are as under.

Reddy and Goud (1970) reported that yield was positively correlated with 1000-grain weight but negatively with number of unproductive tillers, whereas, plant height was significantly and positively correlated with panicle length.

In a correlation study Chaudhary *et al*, (1973) reported that yield was significantly and positively correlated with panicle weight and 1000-grain weight. They also found positive correlation between 1000-grain weight and panicle length, number of grains per panicle and panicle length, while significant negative correlation were found between panicle number with panicle weight, number of grains per panicle and 1000-grain weight.

While studying 45 dwarf lines from 30 different crosses of rice, Mishra *et al.* (1973) found significant positive correlation between grain yield and grain number per panicle, but number of ear bearing tillers was negatively correlated with number of panicle and 100-grain weight.

Saini and Gagneeja (1975) reported that grain yield was significantly associated with days to heading, panicle length and spikelets per panicle in 40 semi-dwarf rice cultures. While days to heading had significant positive correlation with plant height and 1000-grain weight, number of earbearing tillers was negatively associated with all the characters including yield.

Vinagurai and Murty (1977) observed that yield displayed significant positive relationship with grains per panicle and total dry weight.

While studying correlation coefficient in 18 semi-dwarf rice strains, Yadav and Singh (1979) found that grain yield per plant had significant positive correlation with days to flowering, number of grains per panicle, plant height and 1000-grain weight. They advocated that indirect selections for 1000-grian weight followed by plant height and number of grains per panicle may further increase the yield level.

Singh *et al.* (1980) observed that yield was significantly and positively correlated with flag leaf length, width, tiller number fertile tiller number, panicle length, grain number per panicle and days to maturity.

Parmasivan (1980) studied correlation coefficient in 15 tall and dwarf indica rice varieties and noted that panicle length, plant height and chaff number per panicle were correlated with yield. Grain number and number of panicles per clum were correlated to grain yield only in few varieties, 100-grain weight was not correlated with yield.

Singh *et al.* (1982) showed that genotypic correlations with yield were significant positive for flag leaf length and width, tiller number, fertile tiller number, panicle length, grain number per panicle and days to maturity.

Amirthadevarathinam (1983) reported that grain yield was positively and significantly associated with productive tillers, while it was negatively associated with duration and plant height.

Correlation coefficient in F_2 indica hybrid progenies were studied by Yang (1986). He observed that gain yield per plant was closely correlated with height and grain set percentage.

While testing rice cultivars at varied spacing and fertility levels, Hedge (1987) found that grain yield was positively correlated with number of grains per panicle, productive tillers and plant height.

Patel (1989) noted significant positive correlation between grain yield and harvest index, whereas, 100-grain weight had highly significant negative correlation with days to 50 % flowering.

Pathak and Patel (1989) reported that grain yield was significantly and positively correlated with plant height, panicle length and 1000-grain weight, while fodder yield showed positive correlation with plant height, panicle length, grains per panicles and 100-grain weight.

Sampath (1989) reported that yield was significantly and positively correlated with 100-grain weight, panicle length and number of grains per panicle in parents. But in hybrids, yield was positively correlated with the number of primary and secondary branches per panicle, number of days to panicle emergence and tiller number.

Reddy and Ramachandrah (1990) in a F_2's study observed highly significant positive correlation between grain yield and eight yield components. viz., plant height, panicle length, flag leaf area, number of effective tillers per plant, number of fertile grains per panicle, number of primary branches per panicle, number of secondary branches per panicle and 1000-grain weight.

While studying correlation coefficient in twenty two rice cultivars, Dewande *et al.*, (1991) observed positive correlation between yield and panicle weight.

Bai *et al.*, (1992) studied fifty eight medium duration rice cultivars and reported that flag leaf area and panicle exertion were positively correlated with yield at only genotypic level. They also found that genotypic correlations were greater than phenotypic ones.

Yadav (1992) evaluated 16 genotypes of rice during kharif 1989 and observed that grain yield per plant was positively correlated with days to 50 per cent flowering, days to maturity, panicles per plant and seeds per plant.

Chauhan *et al.* (1993) observed positive and significant association of grain yield per plant with per cent filled spikelets, harvest index and biological yield in 21 advance breeding lines of rice. They also reported that spikelets fertility, 1000-grainweight, biological yield and harvest index were important factors influencing the yield and deserve consideration in the breeding programme for upland rice.

Chaubey and Richharia (1993) reported that grain yield per plant showed significant positive correlation with plant height, panicle length, spikelets per panicle, panicle weight and test weight.

Wilfred *et al.*, (1993) observed that plant height, panicles per plant, grains per panicle and dry matter production had significant positive correlation with grain yield.

Abd-el-samie and Hassan (1994) revealed that highly positive significant phenotypic relationships were observed between grain yield per hill and number of panicle per hill and panicle length, grain yield per hill also showed positive and significant genotypic correlations with all studied characters except 100-grain weight.

Yolanda and Das (1995) studied that grain yield was significantly and positively correlated with panicle length, spikelets per panicle, grains per panicle, 100-grain weight and harvest index.

Sawant and Jadhav (1995) observed that the genotypic correlation coefficient for all characters were higher than the corresponding phenotypic correlation coefficients. Ear bearing tillers per plant, plant height, number of grains per panicle and 100-grain weight were positively correlated with grain yield.

Padmavathi *et al.*, (1996) observed that number of tillers per plant, number of panicles per plant, panicle length and 1000-grain weight were positively associated with grain yield.

Sarawgi *et al.*, (1997) observed that grain yield of rice had significant positive correlations with number of fertile spikelets per panicle, 100-grain weight, grain width and harvest index. Harvest index registered positive significant correlation with number of effective tillers per plant, number of fertile spikelets per panicle, 100-grain weight, grain length and grain width.

Verma *et al.*, (1997) observed that grain yield had highly significant r_p and r_g with panicle bearing tillers and grains per panicle. Grain yield had highly significant r_p and r_g with plant height, panicle length in 3 sets only where test weight was high.

2.3 Path coefficient analysis

Yield is a complex character composed of a number of simple characters each contributing directly or indirectly through other characters.

Thus, selection based on simple correlation without taking into consideration interaction between the characters may often mislead the plant breeder. A detailed examination of specific forces acting to produce given correlation and the relative importance of each causal factor will aid in designing appropriate breeding procedure. Path coefficient analysis suggested by Sewall Wright (1921) has been often used in partitioning of genotypic correlation coefficient into direct and indirect effects, thereby providing the relative importance of each of causal factors.

Kumar and Saini (1973) studied path coefficient analysis of yield and its components in rice and revealed that tiller number, spikelets number and days to maturity had appreciable direct effect on yield.

Lenka and Mishra (1973) studied path coefficient in four varieties of rice and found that the number of panicles and grains per panicle had the maximum direct contribution to yield.

Saini and Gagneeja (1975) found that spikelets per panicle was the most important yield component followed by ear bearing tillers per plant, 1000-grain weight, panicle length and days to heading.

Brar and Saini (1976) studied F_2 populations of two dwarf varieties transplanted under normal agronomical condition. Correlations were compiled among seven agronomic characters. Path analysis showed that ear bearing tillers, plant height, sterility and 100-grains weight were important traits in segregating populations.

Banerjee and Sinha (1977) reported that number of ear bearing tillers had largest positive and direct effect on grain yield, followed by number of grains per panicle, length-breadth ratio, plant height and 100-grain weight. While secondary character expressed indirect effects on grain yield through these traits.

While studying path analysis in improved dwarf and tall rice varieties, Rao *et al.*, (1978) found that number of tillers and grain weight per panicle had the highest positive direct effect on yield. Whereas, other characters influenced yield through number of fertile tillers or grain weight per panicle.

Yadav and Singh (1979) found maximum correlated response and relative selection efficiency on grain yield through indirect selection for 1000-grain weight, plant height and number of grains per panicle. The 1000-grain weight had highest positive direct effect on grain yield followed by days to flowering and grains per panicle.

Rao *et al.*, (1980) reported that ear bearing tillers and grain number per panicle had direct positive effect on yield. The indirect effect of grain number per panicle through ear bearing tillers was negative, resulting in a reduction of total correlation of these two characters with grain yield. The indirect effect of panicle length was negative through ear bearing tillers and positive through grain number per panicle.

Amirthadevarathium (1983) made path analysis studies in 26 medium and 36 long duration genotype of rice and reported that plant height and grain breadth had negative direct effect on grain yield in medium and long duration group. Internodes per culm, leaf length, days to 50 per cent heading showed high negative effects on grain yield.

Experiment conducted on different rice genotypes under varied spacing and fertility levels, Hedge (1987) observed that number of grain per panicle and productive tiller had highest direct effect on yield.

Reaban and Katuli (1988) found that per cent filled grains per panicle and plant height had positive direct effects on grain yield, while panicle length had strong and negative independent effect. Plant population and number of panicles per plant had moderate direct effects of grain yield.

Katoch (1989) revealed that harvest index and effective tillers per plant had positive direct effects on grain yield, while grains per panicle, effective tillers per plant, 1000-grain weight and panicle length contributed indirectly towards grain yield.

While studying the path analysis in 116 upland rice varieties, Patel (1989) observed positive direct effect of harvest index, straw yield per plant, days to maturity, number of productive tillers and 100-grain weight. While days to 50 per cent flowering and grains per panicle had negative direct effect on grain yield.

Pathak and Patel (1989) revealed that 1000-grain weight and panicle length had greater direct effect on yield. While highest direct contribution to grain yield per plant was found through secondary branches per panicle by Reddy and Ramachandraiah (1990).

Direct and indirect effects of four yield components with grain yield were measured by Ibrahim *et al.*, (1990) under rainfed low land conditions. They observed that number of productive tillers had high direct effect on grain yield, while panicle length and flowering duration had moderate direct effect, but plant height had slightly negative effect.

Chaubey and Richharia (1993) found that panicle weight was the greater contributor to the grain yield.

While studying path analysis in hybrid rice, Mandel and Rangaswami (1993) observed maximum direct positive effect of panicle length on grain yield while negative direct effect of plant height and panicles per plant on grain yield.

Marwat *et al.*, (1994) found that productive tillers, panicle length and 1000-grain weight had the highest direct effect on grain yield per plant in path analysis. Whereas, other important characters influencing grain yield were flag leaf area, grains per panicle.

Sundaram and Palanisamy (1994) reported that grains per panicle had the highest positive direct effect on yield and highest positive indirect effect via productive tillers, panicle weight and grain weight.

Yadav *et al.*, (1995) revealed that number of panicle-bearing tillers had the greatest direct effect on yield, followed by 1000-seed weight.

Rajeswari and Nadarajan (1995) reported that plant height, days to 50 % flowering, panicle length and grains per panicle had direct effects on yield. But the characters panicle exertion, productive tillers for plant and 100-grain weight showed negative effects on yield.

Gopalkrishnan and Ganapathy (1996) showed that dry matter production was the principal character responsible for grain yield per plant followed by grains per panicle, panicle length and 100-grain weight.

2.4 Genetic divergence

Genetic divergence is a basic criterion to the continued improvement to the crop plant, whether through natural selection or directed selections in plant breeding. Several methods have been developed for measuring genetic divergence between populations using multivariate analysis such as, coefficient of racial likeness (Pearson, 1926) multiple regression (Hotelling, 1936), discriminant function (Fisher, 1936) and D^2

statistic (Mahalanobis, 1936). Out of these methods D^2 statistic is a powerful tool in quantifying degree of divergence.

Singh *et al.*, ((1979) studied genetic divergence in 35 induced dwarf varieties of rice. Those were grouped into ten clusters irrespective of area. The study showed that plant height followed by area of second leaf, length of first internode and test grain weight contributed maximum to genetic divergence.

Singh (1981) observed grain yield as major contributing character to genetic divergence (77.8%) followed by days to maturity and days to heading, while test weight contributed least (0.5%) to D^2 value.

While studying the genetic divergence for yield and eleven yield related traits. Kanwal *et al.*, (1983) observed that panicle weight, number of days to maturity, plant height and grain size contributed most towards divergence. Strains were grouped into nine clusters and was not correlated with geographical diversity.

Ratho (1984) studied genetic divergence in 39 scented varieties of rice using D^2 statistic analysis. Varieties were grouped into five clusters. Clustering pattern was not related to geographical distribution. He observed that Kernel length contributed maximum towards genetic divergence (30.2%) followed by volume expansion ratio (29.4%) and alkali-value (20.8%).

Kotaiah et. al. (1986) observed that days to fifty per cent flowering, grain breadth, plant height and per cent grain protein contributed most to total divergence. They also concluded that D^2 statistic is more precise and refined method for studying genetic divergence. While metroglyph analysis is more suited to preliminary work prior to D^2 analysis.

De and Rao (1987) studied genetic divergence using D^2 statistic. They grouped varieties into ten clusters. Geographical distribution and genetic divergence were not associated. Per cent sterility, number of fertile tillers per hill, grain yield and grain length contributed most to divergence.

Pande and Ghorai (1987) studied genetic divergence measured by D^2 statistic analysis. They found that clustering differed significantly between characters and was greatly influenced by environment. Genetic variance were high for grains per panicle and culm length.

De *et al.*, (1988) studied D^2 analysis of 67 genotypes and grouped them into 13 clusters. They concluded that 100-grain weight and grains per panicle had greater contribution to D^2 values.

Singh *et al.*, (1988) studied 50 low land rice varieties and grouped them into ten clusters using D^2 analysis. Genetic diversity was not related to geographical diversity. They observed that plant height, sheath length, spikelet number, grain length and breadth, test weight and panicle length were mainly responsible for divergence.

While studying the genetic divergence in different rice varieties obtained from IRRI, India, Korea, Sri Lanka and Vietnam, Bai and Tran (1989) concluded that plant height and days to 50 per cent flowering contributed most of genetic divergence.

Sarathe and Perraju (1990) studied genetic diversity and heterosis in 65 rice varieties and grouped into 18 clusters. They concluded that genetic diversity was not related with heterosis for grain yield, panicle number, panicle length and 100-grain weight. Parents with high to moderate diversity estimates may be utilised in order to increase high heterotic manifestation.

Sinha *et al.*, (1991) studied genetic divergence in 30 traditional upland rice. Varieties were grouped into six clusters. Number of secondary branches per panicle, yield per plant and number of fertile grains per panicle had contributed more to genetic divergence.

Roy and Panwar (1993) reported that panicle per plant, spikelets per panicle, number of grains per panicle, grain yield per plant were mainly responsible for genetic divergence.

Vivekanandan and Subramanian (1993) reported that plant height and grain yield contributed most to genetic divergence. They also found that geographical diversity was not related with genetic diversity.

Mishra *et al.*, (1994) studied genetic divergence in 37 strains of rice. They grouped them into five clusters and concluded that number of fertile grains per panicle, number of sterile grains per panicle and plant height had contributed most to D^2 values.

Singh *et al.*, (1996) studied genetic divergence in 40 genotypes of rice. They grouped them into six clusters. They observed that grain yield contributed the most, (40.6%) of total divergence followed by plant height (16.5 %). The genotypes belonging to cluster II and V having greater cluster distance and recommended for inclusion in a hybridization programme.

Sawant *et al.*, (1996) studied genetic divergence in 75 genotypes of rice. They grouped them into ten clusters. Clustering pattern was not related to geographical distribution. The average inter-cluster distance was higher between clusters IX and X (56.62), suggesting that these groups of genotypes were highly divergent from each other.

Sarawgi and Shrivastava (1996) showed that Roti, Early Raskadam and Roti X IR54 might be useful for crop improvement under irrigated condition and early Raskadam for improvement under rainfed conditions.

Kumari and Rangasamy (1997) studied D^2 analysis for 62 early rice genotypes. There was no relationship between geographical distribution and genetic diversity. They observed that grain yield per plant, panicle exeration and plant height were mainly responsible for divergence.

MATERIALS AND METHODS

III MATERIALS AND METHODS

3.1 Location and climatic conditions

The present investigation was carried out at the National Agricultural Research Project, Musa Farm, Vyara during *kharif* season. Soil of experimental plot is heavy black with pH 7.5 to 8.0. Geographically, Vyara is situated at the Western part of India and on 28°-10′ N latitude and 73°-02′ E longitude. The meteorological data for the cropping season is given in Appendix I.

3.2 Experimental materials

The present study consisted of 98 entries comprised of different strains or cultures collected/ received from various sources and maintained as germplasm at Vyara Station for bunded field rice. The details of experimental material used in the present investigation are given in Table 3.2.1.

Table 3.2.1 Details of the rice genotypes used in the present study

Sr. no.	Genotype	Source
1.	GR-3	G.A.U., Nawagam
2.	GR-4	"
3	GR-5	N.A.R.P., Vyara
4	GR-6	G.A.U., Navsari
5	IR-28(C)	I.R.R.I.
6	IR-50	"
7	IR-66	"
8	Ratna	I.C.A.R., New Delhi
9	Pusa-33	"
10	Kada-176-12	G.A.U., Nawagam
11	SK-20	"
12	Halki-jaya	N.A.R.P., Vyara

Table 3.2.1 (Contd....)

Sr. no.	Genotype	Source
13	VRA-55	N.A.R.P., Vyara
14	IRTP-10800	I.R.R.I.
15	Tichun	N.A.R.P., Vyara
16	Zinisathi	"
17	Sathi-34-36	G.A.U., Nawagam
18	IET-13837	AICRP(R), Hyderabad
19	IET-14349	"
20	IRAT-341	I.R.R.I.
21	DDR-43	N.A.R.P., Derol
22	DDR-52	"
23	DDR-54	"
24	Rewa-3-45	I.R.R.I.
25	IR-82-5-199	"
26	Rewa-16-88-1	"
27	Aus-96	AICRP(R), Hyderabad
28	IR-53236	I.R.R.I.
29	IR-53167	"
30	IR-47-701-6-8-1	"
31	IR-47-6-86-6-7-1	"
32	Futia (WR-1)	G.A.U., Waghai
33	Amistad-82	-
34	Juna-61	-
35	TGR-75	-
36	KMP-34	I.R.R.I.
37	CNA-3290	"
38	CNA-4143	"
39	IR-10147-113-5-1-1-5	"
40	ITA-337	"
41	TOX-1012-12-18	I.I.T.A.
42	IET-13830	AICRP(R), Hyderabad

Table 3.2.1 (Contd....)

Sr. no.	Genotype	Source
43	IET-13831	AICRP(R), Hyderabad
44	IET-13832	"
45	IET-14345	"
46	IET-14347	N.A.R.P. Navsari
47	Indrani	N.A.R.P., Vyara
48	IET-14350	AICRP(R), Hyderabad
49	IET-14353	"
50	IET-14364	"
51	Damam-basmati	N.A.R.P., Vyara
52	IET-14848	AICRP(R), Hyderabad
53	BIR	-
54	IR-55537-34	I.R.R.I.
55	IRAT-349	I.R.A.T.
56	63-83	-
57	BG-1639	Sri Lanka
58	CNA-6870	Brazil
59	IR-57313-106-2-3	I.R.R.I.
60	IR-60819-34-2-1	"
61	IR-62127-55-1-2-2-3	"
62	IR-62141-114-3-2-2-2	"
63	QING LIU AI No.1	China
64	RP-1873-715-3-2	India
65	RP-1888-4259-1529-126	"
66	RP-1899-1481-76-1	"
67	RP-2095-5-8-31	"
68	RP-2161-51-4-1	"
69	RP-2235-48-54-6	"
70	RP-2633-30-4-10	"
71	RP-2633-30-4-7	"
72	TOX-3344-TOC-3-4	I.I.T.A.

Table 3.2.1 (Contd....)

Sr. no.	Genotype	Source
73	ZHEN-GUI-AI 1	China
74	132	Vietnam
75	IR-72	I.R.R.I.
76	Kalam	N.A.R.P., Vyara
77	Bhadarvi dangar	"
78	Bawali	N.A.R.P. Navsari
79	Lal chhalwali	"
80	Hara	"
81	Rati bawali	"
82	Dudhani	"
83	Futia	"
84	Dodihal	"
85	Ponijayal	"
86	IR-8	I.R.R.I.
87	Nagpur-22	N.A.R.P., Vyara
88	Ek dandi	"
89	Bharihar	"
90	Kali dangar	"
91	Chirni	"
92	Ratwal	"
93	Deshi kalam	"
94	Dhanhad	"
95	Challi	"
96	Truvana	"
97	Challi-3	"
98	Tulsya-(WR-6)	G.A.U., Waghai

3.3 Experimental design

The experiment was laid out in a randomized block design with three replications. Each plot consisted of 6 rows of 3 meter length spaced at

20 cm between lines. All the recommended agronomic practices and plant protection measures were followed timely for successful raising of the crop. The crop was sown on June 25, 1998.

3.4 Characters studied

For recording observations, five competitive plants were randomly selected in each plot in all the three replications for recording observations for plant height, panicle length and number of grains per panicle while other characters were recorded on meter/ square meter/ plot basis;

3.4.1 Grain yield per m^2 (gm)

From the one m^2 plot all panicles of the plantswere threshed and cleaned paddy weighed to record grain yield of plants in grams.

3.4.2 Days to 50 per cent flowering

When 50 per cent of plant spikelets in a plot flowered, the data were recorded. Number of days were worked out from the date of sowing to flowering.

3.4.3 Total productive tillers per meter row length

The total number of productive tillers which contributed for yield from one meter row length were counted.

3.4.4 Plant height (cm)

Plant height was measured from soil level to tip of panicle in centimeter at harvesting stage.

3.4.5 Straw yield per m^2 (gm)

Weight of sun dried straw of one m^2 plot was recorded in grams.

3.4.6 Panicle length (cm)

The length of main panicle was measured in centimeters from the base to the tip of panicle at the time of harvesting.

3.4.7 Number of grains per panicle

The grains of main panicle were counted for each selected plant as a number of grains and recorded.

3.4.8 100-grain weight (gm)

The seeds of all panicles per plant were mixed up thoroughly and 100-grains were taken randomly and weighed in grams.

3.4.9 Protein content (%)

The nitrogen content was estimated from each sample by micro Kjeldhal method and percentage of protein was calculated using factor 5.95.

The following abbreviations are used for various terms in this dissertation

1.	Genotypic variance	σ^2g
2.	Phenotypic variance	σ^2p
3.	Error variance	σ^2e
4.	Standard error of mean	S.Em.
5.	Critical difference	C.D.
6.	Coefficient of variation	C.V.
7.	Co-variance	Cov. σ^2
8.	Genotypic correlation coefficient	rg
9.	Phenotypic correlation coefficient	rp

10.	Number of replications	r
11.	Genotype	g
12.	Grams	gm
13.	Centimeters	cm
14.	Meters	m

3.5 Statistical procedure

For all the characters under study, the mean values of five randomly selected plants were used for statistical analysis. The data recorded for different characters were subjected to analysis of variance. Different components of variance viz., phenotypic, genotypic and environmental variances were estimated. Different parameters of genetic variability were computed by standard statistical procedures. The phenotypic and genotypic correlations were also estimated. The genotypic correlations were subjected to path coefficient analysis. In genetic divergence, the D^2 values and grouping and clustering of genotypes were also done with the help of computer.

3.5.1 Analysis of variance

The data recorded for all the characters were subjected to analysis of variance with the formula suggested by Panse and Sukhatme (1978). The following linear model for the randomized block design was used.

$$Y_{ij} = \mu + a_i + b_i + e_{ij}$$

Where,

Y_{ij} = Yield of j^{th} genotype in i^{th} replication,

μ = General mean,

a_i = Effect of i^{th} replication,

b_j = Effect of j^{th} genotype

e_{ij} = Uncontrolled variation associated with i^{th} replication and j^{th} genotype.

Analysis of variance had the following form :

Source of variation	**D.F.**	**Mean square**	**Expected mean square**
Replications	(r-1)	M_1	$\sigma^2e + g\sigma^2r$
Genotypes	(g-1)	M_2	$\sigma^2e + r\sigma^2g$
Error	(r-1).(g-1)	M_3	σ^2e

Where,

r = Number of replications

g = Number of genotypes

σ^2e, σ^2r, σ^2g = Variances due to error, replications and genotypes, respectively

M_1, M_2, M_3 = Mean squares for replication, genotypes and error, respectively

The standard error for differences between treatment mean was calculated from ANOVA table :

$$S.Em. = \frac{M_3^{0.5}}{r}$$

Where,

S.Em = Standard error of mean

M_3 = Error mean sum of square

r = Number of replications

The critical difference to compare the mean values of various genotypes was calculated by using the following formula :

$$C.D. = \frac{2M_3^{0.5}}{r}$$

Where,

C.D = Critical difference

M_3 = Error mean sum of square

r = Number of replications

The coefficient of variation (C.V. %) was calculated by using the following formula :

$$C.V.\ \% = \frac{M_3^{0.5}}{X} \times 100$$

Where,

C.V. % = Coefficient of variation

M_3 = Error mean sum of square

X = Population mean

3.5.2 Variability parameters

(i) Mean

It is computed by dividing the sum of all observations in a sample by their number.

Thus,

$$X = \frac{\Sigma Xij}{n}$$

Where,

X = Population mean

Xij = Any observation in i^{th} replication and j^{th} genotype

n = Number of observations

(ii) Range

It is difference between the lowest and the highest value for each character.

The genotypic, phenotypic and environmental components were estimated as explained by Johnson *et al.* (1955).

(iii) Genotypic variance ($\sigma^2 g$)

The variance contributed by the genetic causes.

$$\sigma^2 g = \frac{M_2 - M_3}{r}$$

Where,

$\sigma^2 g$ = Genotypic variances

M_3, M_2 = Mean squares for error and genotypes, respectively

r = Number of replication

(iv) Environmental variance

Defined as error mean square due to environmental variances

$\sigma^2 e = M_3$

Where,

$\sigma^2 e$ = Environmental variances

M_3 = Error mean sum of square

(v) Phenotypic variance

It is the sum of the variances contributed by genetical cuses and environmental factors, and is calculated as under,

$$\sigma^2p = \sigma^2e + \sigma^2g$$

Where,

σ^2p, σ^2e, σ^2g = Variances due to phenotype, error and genotype, respectively

(vi) Coefficient of variation

The coefficient of phenotypic and genotypic variations was calculated by the formula suggested by Burton (1982).

(a) Phenotypic coefficient of variation (PCV) :

$$PCV = \frac{\sigma p}{X} \times 100$$

(b) Genotypic coefficient of variation (GCV) :

$$GCV = \frac{\sigma g}{X} \times 100$$

Where,

σp, σg = Standard deviation of phenotype and genotype

X = Mean value of the character

(vii) Heritability (broad-sense) H(b)

It is the proportion of phenotypic variability that is due to genetic reasons.

In broad-sense, it was calculated by using the formula proposed by Allard (1960) :

$$H(b) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

H(b) = Heritability (broad-sense)

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

(viii) Expected genetic advance (GA)

Expected genetic advance represents the shift in a population towards superior side under some selection pressure after single generation of selection.

It could be calculated by using the methodology suggested by Allard (1960) at 5 per cent selection intensity using the constant 'K' as 2.06.

$$G.A. = H(b) \times K \times \sigma p$$

Where,

GA = Genetic advance

H(b) = Heritability (broad-sense)

K = Selection intensity at 5 per cent =2.06

σp = Phenotypic standard deviation

(ix) Genetic advance expressed as per cent of mean (Genetic gain)

The expected genetic advance as expressed in per cent of mean was calculated by the method suggested by Johnson *et al.* (1955).

$$\text{Genetic gain} = \frac{G.A.}{X} \times 100$$

Where,

GA = Expected genetic advance

X = Mean of the character under study

3.5.3 Correlation coefficient

For this purpose,analysis of covariance for all possible pairs of nine characters were carried out using the procedure of Panse and Sukhatme (1978). The analysis of covariance had the following form.

Analysis of covariance

Source	D.F.	Mean square of products	Expectation of mean square of products
Replications	(r-1)	MSP_1	$Cov_e\, xy + gCov_r\, xy$
Genotypes	(g-1)	MSP_2	$Cov_e\, xy + rCov_g\, xy$
Error	(r-1).(g-1)	MSP_3	$Cov_e\, xy$

Where,

r = Number of replications

g = Number of genotypes

$Cov_e\, xy$, $Cov_r\, xy$, $Cov_g xy$ = Environmental, replication and genotypes component of covariance, respectively.

MSP_1, MSP_2, MSP_3 = Mean square products for replication, genotypes and error, respectively

The components of covariance were estimated by equating the observed mean sum of products with their expectations as shown below :

$$Cov_g\ xy = \frac{(MSP_2 - MSP_3)}{r}$$

$$Cov_e\ xy = MSP_3$$

$$Cov_p\ xy = Cov_g\ xy + Cov_e\ xy$$

Where,

Cov_g xy, Cov_e xy, Cov_p xy are the genotypic, environmental and phenotypic components of covariance, respectively.

The genotypic (r_g) and phenotypic (r_p) correlation coefficient were calculated as under by adopting the procedure explained by Miller *et al.* (1968).

(a) Genotypic correlation coefficient

$$r_g\ xy = \frac{Cov_g\ xy}{\sigma_g x \times \sigma_g y}$$

(b) Phenotypic correlation coefficient

$$r_p\ xy = \frac{Cov_p\ xy}{\sigma_p x \times \sigma_p y}$$

Where,

r_g xy and r_p xy are genotypic and phenotypic correlation coefficient for a pair of trait x and y, respectively.

Cov_g xy and Cov_p xy are genotypic and phenotypic covariance for a pair of characters viz., x and y, respectively.

The phenotypic correlation was tested using the method suggested by Fisher and Yates (1963).

3.5.4 Path coefficient analysis

The cause and effect, inter-relationship between two variables can not be known from simple correlation coefficient. Therefore, path analysis suggested by Wright (1921) and Dewey and Lu (1959) was adopted in order to partition the genotypic correlation between variables with grain yield into direct and indirect effects of those variables on yield. Genotypic correlation coefficient of nine variables with yield were used to estimate the path coefficients for the direct effect of various independent characters on dependent character grain yield.

The path coefficients were obtained by solving a set of simultaneous equations as below :

$$r_{ny} = P_{ny} + r_{n2} \cdot P_{2y} + r_{n3} \cdot P_{3y} + r_{n4} \cdot P_{4y} + \ldots\ldots + r_{nx} \cdot P_{xy}$$

Where,

r_{ny} = represents correlation coefficient between one component characters and grain yield

P_{ny} = represents the path coefficient between one trait and grain yield

r_{n2}, r_{n3}, ... r_{nx} = represents correlation coefficient between that character and other yield component in turn.

The following genotypic correlation matrix was formed :

$$\underset{\text{Matrix-A}}{\begin{bmatrix} r_1y \\ r_2y \\ r_3y \\ \vdots \\ \vdots \\ r_ny \end{bmatrix}} = \underset{\text{Matrix-B}}{\begin{bmatrix} r_{11} & r_{12} & r_{13} \ldots\ldots & r_{1n} \\ r_{21} & r_{22} & r_{23} \ldots\ldots & r_{2n} \\ r_{31} & r_{32} & r_{33} \ldots\ldots & r_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} \ldots\ldots & r_{nn} \end{bmatrix}} \times \underset{\text{Matrix-C}}{\begin{bmatrix} p_1y \\ p_2y \\ p_3y \\ \vdots \\ \vdots \\ p_ny \end{bmatrix}}$$

or A = B x C

Where,

$r_{12} = r_{21}$ and so on

r_{1y} = correlation between first component character and grain yield.

The technique given by Goulden (1962) was followed for inversion of the 'B' matrix using partitioning method of matrix inversion. Path coefficient (P_{ij}) were obtained as follows :

$$P_{ij} = (B^{-1}) \times (A)$$

Where,

(B^{-1}) is the inverse of mutual correlation matrix of character

The indirect effect for a particular character through other characters were obtained by multiplication of direct path and particular correlation coefficient between those two characters, respectively.

Indirect effect = $r_{ij} \times P_{ij}$

Where,

$i = 1, 2, 3, \ldots\ldots, n$

$j = 1, 2, 3, \ldots\ldots, n$

$P_{ij} = P_{1y} \times P_{2y} \times P_{3y} \times \ldots\ldots \times P_{ny}$

The residual factor which represents the variation in field unaccounted for this association was calculated from the following formula.

$$R = |\, 1 - (P_n r_n) \,|^{0.5}$$

3.5.5 D^2 - statistic

3.5.5.1 Wilk's criterion (1932)

After testing the difference in regard to individual character through 'Anova' a simultaneous test of significant difference with regard to the pooled effect of nine characters was carried out using Wilk's criterion (Wilk's, 1932 and Rao, 1952).

$$\text{Wilk's criterion} = \frac{|E|}{|E + V|}$$

$$\text{W.C.} = \frac{\text{Determination of error sum of product matrix}}{\text{Determination of (error + genotype) sum of squares and sum of product matrix}}$$

3.5.5.2 Multivariate analysis of genetic divergence using Mahalanobis's D^2 -technique

Mahalanobis's D^2 statistic technique was used for estimating the genetic divergence among 98 genotypes. The data was subjected to multivariate analysis (Rao, 1952).

The original mean values (X's) were transformed to normalised variables (X's). then the correlated normalised variables (X_1's) were converted to uncorrelated (Y_1's) as follows :

$$Y_1 = X_1$$

$$Y_2 = X_2 - (d_{2.1}XY_1)$$

$$Y_3 = X_3 - (d_{3.2}XY_2) - (d_{3.1}XY_1)$$

$$Y_p = X_p - (d_{p-1}XY_{p-1}) - \ldots\ldots - (d_{p1}XY_1)$$

Where,

Xi = Normalised variables

$$aij = \frac{bij}{V(Yi)}$$

3.5.5.3 Determination of group constellation or clusters

There is no particular rule for forming clusters. The general criteria of grouping by Tocher method that only two groups belonging to the same cluster should show a smaller D^2 value than those belonging to different clusters was followed in the study (Rao, 1952). In this method, the two population having smallest distance from each other were considered first to which a third population was added having smallest average D^2 value but higher than the previous two. Similarly, the next population was added and the process continued till the average D^2 value increased considerably with the next addition. Generally, this level should be approximately near to the maximum D^2 value shown by a population to the nearest population.

The average intra-cluster distance was obtained by using the formula :

$$\text{Average intra-cluster distance} = \frac{\Sigma\, Di^2}{n}$$

Where,

$\Sigma\, Di^2$ = Sum of the distance between all possible combinations of the population included in the cluster and

n = Number of populations in a cluster.

EXPERIMENTAL RESULTS

IV EXPEIMENTAL RESULTS

The results obtained in the present investigation on variability, correlation, path coefficient and genetic divergence in bunded field rice (*Oryza sativa* L.) are presented under the following headings :

4.1 Analysis of variance

4.2 Variability

4.3 Heritability and genetic advance

4.4 Correlation coefficient

4.5 Path coefficient analysis

4.6 Genetic divergence

4.1 Analysis of variance

The analysis of variance indicating the mean sum of squares for all the nine characters studied, are summarised in Table 4.1. The genotypic differences were highly significant for all the nine characters indicating considerable amount of genetic variability among the genotypes tested in the present study.

The mean values of different genotypes in respect of nine characters studied are presented in Appendix-II.

4.2 Variability

The range, mean, phenotypic, genotypic and environmental variances, phenotypic and genotypic coefficient of variation, heritability and expected genetic advance as percentage of mean for nine characters are presented in Table 4.2.

Table 4.1 : Analysis of variance showing mean square for nine characters in bunded field rice

Source	d.f.	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
Replication	2	736.534	0.071	4.085	211.646	29.847	2.044	23.621	0.027	0.047
Genotypes	97	9098.703**	443.596**	335.933**	356.708**	26179.768**	13.809**	641.525**	0.743**	3.990**
Error	194	205.988	20.05	311.593	53.733	5973.661	5.057	233.655	0.012	0.013
S.Em. ±		11.719	3.656	14.412	5.985	63.107	1.836	12.481	0.090	0.093
C.V. %		10.551	6.580	28.545	12.055	26.816	10.991	25.191	4.869	1.832

** significant at-p = 0.01

Table 4.2 : General mean, phenotypic range, variance components, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), H^2(b), genetic advance (% of mean) of 98 bunded field rice genotypes

Source character	General mean	Range (phenotypic)	Genotypic variance	Phenotypic variance	Environmental variance	GCV (%)	PCV (%)	H^2(b) %	G.A. as % of mean
Grain yield per m^2 (gm)	136.024	34.333-301.667	2964.238	3170.226	205.988	40.026	41.393	93.50	79.73
Days to 50 % flowering	68.041	45.000-101.667	145.700	152.196	6.495	17.740	18.131	95.73	35.75
Total productive tillers per meter row length	61.840	45.667-93.000	34.160	267.612	233.452	9.451	26.454	12.76	6.95
Plant height (cm)	60.807	39.467-98.933	100.992	154.724	53.733	16.527	20.456	65.27	27.50
Straw yield per m^2 (gm)	288.214	65.000-613.333	6886.074	12407.621	5521.547	28.792	38.649	55.50	44.18
Panicle length (cm)	20.461	14.200-25.400	2.918	7.975	5.057	8.348	13.802	36.59	10.40
Number of grains per panicle	60.680	29.533-99.533	155.426	330.673	175.247	20.545	29.968	47.00	29.01
100-grain weight (gm)	2.259	1.250-4.273	0.244	0.256	0.012	21.847	22.384	95.27	43.93
Protein content (%)	6.222	2.213-7.867	1.328	1.335	0.008	18.516	18.571	99.41	38.03

4.2.1 Grain yield per m^2 (gm)

The genotypic variation for grain yield per m^2 was found to be highly significant. The maximum grain yield per m^2 was recorded by the genotype IR-47-6-86-6-7-1 (301.67 gm) followed by IR-47-701-6-8-1 (279.33 gm) and Rewa-16-88-1 (254.00 gm). On the other hand, minimum grain yield per m^2 was recorded for Damam basmati (34.33 gm) followed by RP-2095-5-8-31 (48.67 gm) and Bhadarvi dangar (55.00 gm). The overall mean grain yield per m^2 was 136.024 gm. The genotypic, phenotypic and environmental variances were 2964.238, 3170.226 and 205.988, respectively. The estimates of genotypic and phenotypic coefficients of variation were high (GCV = 40.026 and PCV = 41.393 %).

4.2.2 Days to 50 % flowering

The minimum days to 50 % flowering was recorded for genotypes Bhadarvi dangar and Hara (45.00 days) followed by VRA-55 (46.33 days) and Tichun and Dodihal (50.00 days). Whereas, maximum days to 50 per cent flowering was recorded for GR-6 (101.67 days), followed by Damam basmati (100.67 days) and Tulsya-(WR-6)(100.33 days) with an overall average flowering days of 68.041. The genotypic, phenotypic and environmental variances were 145.700, 152.196 and 6.495, respectively. The estimates of genotypic and phenotypic coefficients of variation were moderately high (GCV = 17.740 % and PCV = 18.131 %).

4.2.3 Total productive tillers per meter row length

The variation recorded among the genotypes for total productive tillers per meter row length was highly significant. Maximum number of total productive tillers per meter row length was recorded for Damam basmati (93.00) followed by Zinisathi (86.67) and RP-2235-48-54-6

(84.33). On the other hand minimum number of total productive tillers per meter row length was recorded for Futia (WR-1) and IET-14350 (45.67) followed by IR-53236 (46.00) and IR-53537-34 (46.67). The genotypic, phenotypic and environmental variances were 34.160, 267.612 and 233.451, respectively. The estimates of genotypic and phenotypic coefficients of variation were moderate (GCV = 9.451 % and PCV = 26.454 %).

4.2.4 Plant height (cm)

The variation observed among the genotypes for this character was moderate. The dwarfest genotype was Tichun (39.67 cm), followed by Ekdandi (43.07 cm) and IR-50 (44.60 cm). On the other hand, the tallest genotype was Tulsya-(WR-6) (98.93 cm), followed by IRAT-349 (88.93 cm), and Damam basmati (88.60 cm) with mean plant height of 60.807 cm. The genotypic, phenotypic and environmental variances were 100.992, 154.724 and 53.733, respectively. The estimates of genotypic and phenotypic coefficients of variation were found to be moderately high (GCV = 16.527 % and PCV = 20.456 %).

4.2.5 Straw yield per m^2 (gm)

The variation among genotypes for straw yield per m^2 was found to be highly significant. The maximum straw yield per m^2 was recorded in Damam basmati (613.33 gm), followed by Tulsya-(WR-6) (593.33 gm) and Indrani (470.00 gm). Whereas, minimum straw yield per m^2 was recorded for Bhadarvi dangar (65.00 gm), followed by Hara (76.67 gm) and VRA-55 (80.00 gm). The overall mean straw yield per m^2 was 288.214 gm. The genotypic, phenotypic and environmental variances were 6886.074, 12407.621 and 5521.547, respectively. The estimates of genotypic and phenotypic coefficients of variation were high (GCV = 28.792 % and PCV = 38.649 %).

4.2.6 Panicle length (cm)

The varietal differences for panicle length was found to be highly significant. The maximum panicle length was recorded for genotype IRAT-349 (25.40 cm), followed by ITA-337 and TOX-1012-12-18 (25.20 cm) and IR-47-6-86-6-7-1 (24.67 cm). On the other hand, minimum panicle length was recorded for genotype Hara (14.20 cm), followed by Nagpur-22 (16.27 cm) and Ponijayal (17.13 cm), respectively. The overall mean panicle length was 20.461 cm. The genotypic, phenotypic and environmental variances were 2.918, 7.975 and 5.057, respectively. The estimates of genotypic and phenotypic coefficients of variation were small (GCV = 8.348 % and PCV = 13.802 %).

4.2.7 Number of grains per panicle

The number of grains per panicle ranged from 29.533 to 99.533 with an average of 60.680. The highest number of grains per panicle was observed in genotype Tulsya-(WR-6) (99.53), followed by RP-2633-30-4-10 (95.93) and Zinisathi (93.80). The lowest number of grains per panicle was observed in genotype Dodihal (29.53), followed by CNA-3290 (32.53) and Bharihar (33.87). The genotypic, phenotypic and environmental variances were 155.426, 330.673 and 175.247, respectively. The estimates of genotypic and phenotypic coefficients of variation were moderate (GCV = 20.545 % and PCV = 29.968 %).

4.2.8 100-grain weight (gm)

The range exhibited for 100-grain weight was from 1.250 to 4.273 gm with mean weight 2.259 gm. The maximum 100-grain weight was recorded for genotype IR-47-6-86-6-7-1 (4.27 gm), followed by IRAT-341 (4.09 gm) and IR-53236 (3.64 gm). The minimum grain weight was recorded for genotype Deshi kalam (1.25 gm), followed by GR-4 (1.46 gm) and Ekdandi (1.52 gm). The genotypic, phenotypic and environmental variances were 0.244, 0.256 and 0.012, respectively. The estimates of genotypic and phenotypic coefficients of variation were moderate (GCV = 21.847 % and PCV = 22.384 %).

4.2.9 Protein content (%)

Protein content ranged from 2.213 to 7.867 per cent with mean value of 6.222 per cent. The genotypic, phenotypic and environmental variances were 1.328, 1.335 and 0.008, respectively. The estimates of genotypic and phenotypic coefficients of variation were moderate (GCV = 18.516 % and PCV = 18.571 %).

4.3 Heritability and expected genetic advance in per cent of mean

The estimates of heritability in broad sense [$H^2(b)$] for all the characters under study are presented in Table 4.2. High estimates of heritability was recorded by protein content (99.41 %) followed by days to 50 % flowering (95.73 %), 100-grain weight (95.27 %) and grain yield per m^2 (93.50 %). Moderate estimates of heritability were recorded by plant height (65.27 %), followed by straw yield per m^2 (55.50 %), number of grains per panicle (47.00 %) and panicle length (36.59 %). Lower estimates of heritability was recorded in total productive tillers per meter row length (12.76 %).

The estimates of expected genetic advance in respect of different characters at selection intensity of 5 per cent were calculated. Since these values are not comparable, they were expressed as expected genetic advance in percentage of mean and are presented in Table 4.2. It ranged from 79.73 (grain yield per m^2) to 6.95 (total productive tillers per meter row length) per cent. The very high genetic advance expressed as percentage of mean was obtained for straw yield per m^2 (44.18 %), protein content (38.03 %), days to 50 % flowering (35.75 %), while the remaining characters had shown moderate to low genetic advance as expressed as percentage of mean.

4.4 Correlation coefficient

The correlation coefficients between grain yield and its components and among the component characters were estimated at phenotypic and genotypic levels. The phenotypic (rp) and genotypic (rg) correlation coefficients of nine different characters are presented in Table 4.3.

The results of correlation between different pairs of nine characters are described as below.

4.4.1 Grain yield per m^2 (gm)

Grain yield per m^2 showed highly significant positive correlations at both genotypic and phenotypic levels with panicle length (rg = 0.405 and rp = 0.234) and 100-grain weight (rg = 0.306 and rp = 0.281). It was also significantly and positively correlated with straw yield per m^2 (rg = 0.181 and rp = 0.113) and number of grains per panicle (rg = 0.178 and rp = 0.102) at genotypic level only. Days to 50 per cent flowering (rg = 0.100 and rp = 0.090) and total productive tillers per meter row length (rg = 0.082 and rp = 0.078) also showed positive correlation, while plant height (rg = - 0.018 and rp = 0.004) and protein content (rg = - 0.004 and rp = - 0.005) were

Table 4.3 : Estimates of genotypic (rg) and phenotypic (rp) correlation coefficient among nine characters in bunded field rice

Characters		Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
Grain yield per m^2 (gm)	rg	0.100	0.082	- 0.018	0.181**	0.405**	0.178**	0.306**	- 0.004
	rp	0.090	0.078	0.004	0.113	0.234**	0.102	0.281**	- 0.005
Days to 50 % flowering	rg		0.428**	0.150**	0.862**	0.658**	0.512**	- 0.231**	0.273**
	rp		0.189**	0.100	0.610**	0.360**	0.364**	- 0.222**	0.266**
Total productive tillers	rg			0.171**	0.456**	0.358**	0.291**	- 0.306**	0.285**
per meter row length	rp			0.088	0.127*	0.017	0.129*	- 0.120*	0.092
Plant height (cm)	rg				0.351**	0.201**	0.361**	0.198**	- 0.252**
	rp				0.248**	0.258**	0.328**	0.158**	- 0.199**
Straw yield per m^2 (gm)	rg					0.578**	0.481**	- 0.122*	0.180**
	rp					0.263**	0.258**	- 0.096	0.127*
Panicle length (cm)	rg						0.622**	0.212**	0.137**
	rp						0.417**	0.123*	0.084
Number of grains per	rg							- 0.146**	0.072
panicle	rp							- 0.102	0.053
100-grain weight (gm)	rg								- 0.230**
	rp								- 0.226**

** - significant at $p = 0.01$

* - significant at $p = 0.05$

negatively correlated with grain yield per m^2 at genotypic level but did not reach the level of significance.

4.4.2 Days to 50 % flowering

Days to 50 % flowering showed positive and highly significant correlation with total productive tillers per meter row length (rg = 0.428 and rp = 0.189), straw yield per m^2 (rg = 0.862 and rp = 0.610), panicle length (rg = 0.658 and rp = 0.360), number of grains per panicle (rg = 0.512 and rp = 0.364) and protein content (rg = 0.273 and rp = 0.266) at both genotypic and phenotypic levels. It was also significantly and positively correlated with plant height (rg = 0.150 and rp = 0.100) at genotypic level, but it was significantly and negatively correlated with 100-grain weight (rg = - 0.231 and rp = - 0.222).

4.4.3 Total productive tillers per meter row length

Total productive tillers per meter row length showed positive and highly significant correlation with plant height (rg = 0.171), straw yield per m^2 (rg = 0.456), panicle length (rg = 0.358), number of grains per panicle (rg = 0.291) and protein content (rg = 0.285) at genotypic level. It also showed positive correlation with straw yield per m^2 (rp = 0.127), number of grains per panicle (rp = 0.129). Plant height, panicle length and protein content were also positively correlated with the character at phenotypic level but it did not reach the level of significance. But there were negative and highly significant correlation coefficient was estimated with 100-grain weight (rg = - 0.306 and rp = - 0.120) at genotypic level and negative correlation at phenotypic level.

4.4.4 Plant height (cm)

Plant height showed positive and highly significant correlation with straw yield per m^2 (rg = 0.351 and rp = 0.248), panicle length (rg = 0.201 and rp = 0.258), number of grains per panicle (rg = 0.361 and rp = 0.328), 100-grain weight (rg = 0.198 and rp = 0.158), while negative and highly significant correlation with protein content (rg = - 0.252 and rp = - 0.199) at both the levels.

4.4.5 Straw yield per m^2 (gm)

Straw yield per m^2 exhibited positive and significant correlation with panicle length (rg = 0.578 and rp = 0.263), number of grains per panicle (rg = 0.481 and rp = 0.258) and protein content (rg = 0.180 and rp = 0.127) at both the levels, but it showed significant negative genotypic correlation with 100-grain weight (rg = - 0.122).

4.4.6 Panicle length (cm)

Panicle length showed positive and highly significant correlation with number of grains per panicle (rg = 0.622 and rp = 0.417) at both levels. The panicle length showed positive and highly significant correlation with protein content (rg = 0.137) and 100-grain weight (rg = 0.212). It also exhibited significant positive phenotypic correlation with 100-grain weight (rp = 0.123), and positive but non-significant correlation with protein content (rp = 0.084) at phenotypic level.

4.4.7 Number of grains per panicle

Number of grains per panicle showed negative and highly significant correlation with 100-grain weight (rg = - 0.146 and rp = - 0.102) at genotypic level. While protein content showed positive correlation but did not reach to the level of significance.

4.4.8 100-grain weight (gm)

100-grain weight showed negative and highly significant correlation with protein content (rg = - 0.230 and rp = - 0.226), at both genotypic and phenotypic levels.

4.5 Path coefficient analysis

Grain yield per m^2 was considered as the resultant variable, while, the remaining eight yield contributing characters as the causal variables. The genotypic correlation coefficient were worked out between grain yield per m^2 and each of the eight causal variables and among themselves to study the direct and indirect effects on grain yield per m^2. The data on the direct and indirect effects of these variables on grain yield per m^2 are presented in Table 4.4.

4.5.1 Days to 50 % flowering

The genetic correlation between days to 50 per cent flowering and grain yield per m^2 was positive and non-significant (0.100). Its direct effect on grain yield was negative (- 0.600). The indirect effect of this trait via number of grains per panicle (0.037) and total productive tillers per meter row length (0.015) was positive and moderate and though the straw yield per m^2 (0.436) and panicle length (0.306) was positive and high. The negative indirect effect via 100-grain weight (- 0.046), plant height (- 0.042) was moderate and through protein content (- 0.010) was low.

4.5.2 Total productive tillers per meter row length

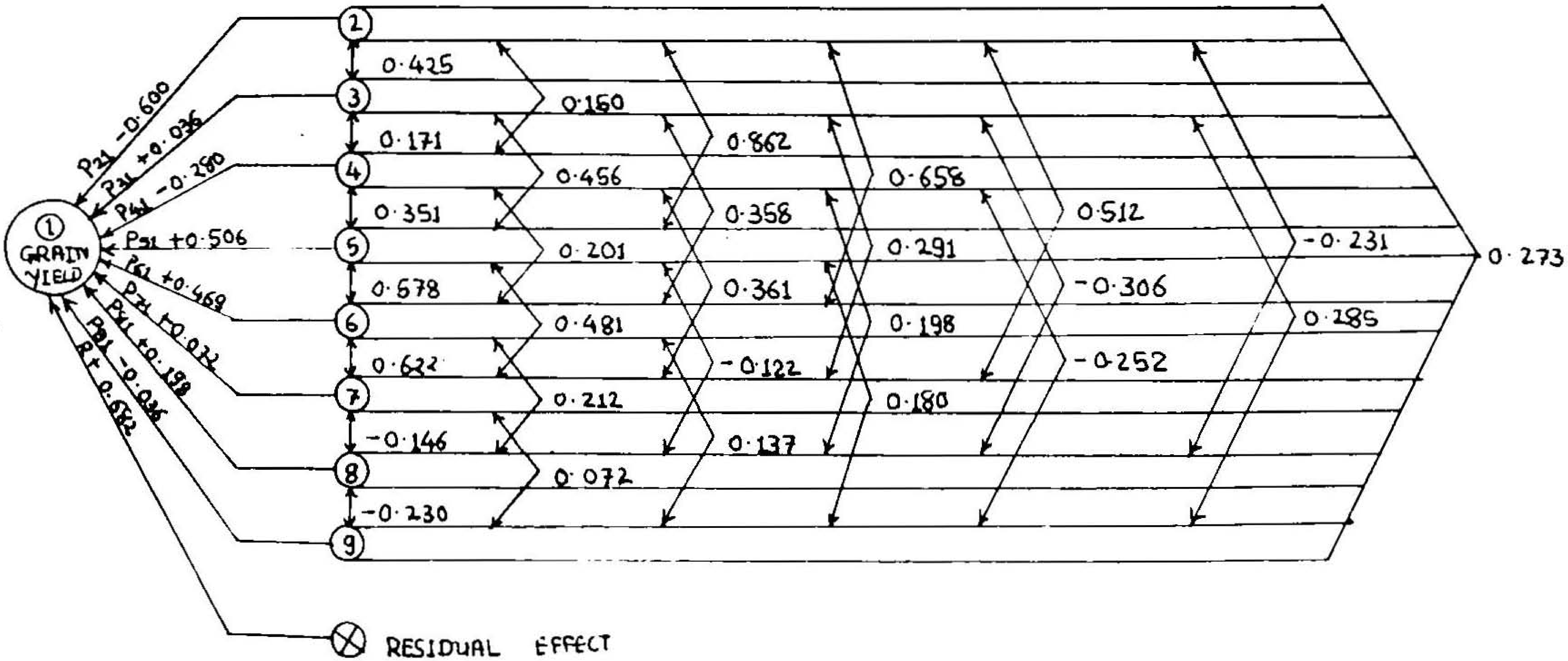
The genetic correlation between total productive tillers per meter row length and grain yield per m^2 was positive and non-significant

Table 4.4 : Direct and indirect effects of different characters on grain yield in bunded field rice

Characters	Direct effect on grain yield	Indirect effect on grain yield								Genotypic correlation with grain yield
		Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)	
Days to 50 % flowering	-0.600	-	0.015	-0.042	0.436	0.309	0.037	-0.046	-0.010	0.100
Total productive tillers per meter row length	0.036	-0.255	-	-0.048	0.231	0.168	0.021	-0.061	-0.010	0.082
Plant height (cm)	-0.280	-0.900	0.006	-	0.178	0.094	0.026	0.039	0.009	-0.018
Straw yield per m^2 (gm)	0.506	-0.517	0.017	-0.099	-	0.271	0.035	-0.024	-0.007	0.181**
Panicle length (cm)	0.469	-0.395	0.013	-0.056	0.292	-	0.045	0.042	-0.005	0.405**
Number of grains per panicle	0.072	-0.307	0.011	-0.101	0.243	0.291	-	-0.029	-0.003	0.178**
100-grain weight (gm)	0.198	0.139	-0.011	-0.055	-0.062	0.100	-0.011	-	0.008	0.306**
Protein content (%)	-0.036	-0.164	0.010	0.071	0.091	0.064	0.005	-0.046	-	-0.004

Residual effect = 0.682

**** - Significant at p = 0.01**



Diagramatic representation of factors influencing grain yield in bunded field rice. Double arrowed lines indicate correlation coefficients and single arrowed lines indicate direct effects.

Where,

1. Grain yield per m^2 2. Days to 50 % flowering 3. Total productive tillers per meter row length 4. Plant height
5. Straw yield per m^2 6. Panicle length 7. Number of grains per panicle 8. 100-grain weight 9. Protein content (%)

Fig. 1 : Genotypic path in bunded field rice

(0.082). The direct effects of this trait on grain yield were positive (0.036). The indirect effect via days to 50 per cent flowering was negative and high (- 0.255), while the indirect effect via 100-grain weight (- 0.061) and plant height (- 0.048), was moderate whereas through protein content (- 0.010) was low. The positive indirect effect via straw yield per m^2 (0.231) was high, via panicle length (0.168) was moderate and via number of grains per panicle (0.021) was low.

4.5.3 Plant height (cm)

The genotypic correlation between plant height and grain yield per m^2 (- 0.018) was negative. The direct effect of plant height (- 0.280) was high in magnitude. The indirect effect of plant height on grain yield per m^2 via days to 50 per cent flowering (- 0.900) was negative and high in magnitude. The indirect effect of this trait on grain yield per m^2 via straw yield per m^2 (0.178) was high, while through panicle length (0.094), number of grains per panicle (0.026) and 100-grain weight (0.039) was moderate and via total productive tillers per meter row length (0.006), protein content (0.009) was positive and negligible in magnitude.

4.5.4 Straw yield per m^2 (gm)

The genotypic correlation between straw yield per m^2 and grain yield per m^2 was positive and highly significant (0.181). The direct effect of straw yield per m^2 was positive and high (0.506). Among the indirect effects, this trait had high positive effect via panicle length (0.271), moderate positive effect via number of grains per panicle (0.035), total productive tillers per meter row length (0.017). The negative indirect effect via days to 50 per cent flowering (- 0.517) was negative and high, plant height (- 0.099), and 100-grain weight (- 0.024) was moderate and via protein content (- 0.007) was negative and negligible in magnitude.

4.5.5 Panicle length (cm)

The genotypic correlation between panicle length and grain yield per m^2 (0.405) was highly significant and positive. The direct effect of panicle length on grain yield (0.469) was positive and high in magnitude. The indirect effects of panicle length on grain yield via straw yield per m^2 (0.292), number of grains per panicle (0.045), 100-grain weight (0.042) and total productive tillers per meter row length (0.013) were positive and high to moderate in magnitude. The negative indirect effect via days to 50 per cent flowering (- 0.395) was high, plant height (- 0.056) was moderate and via protein content (- 0.005) was low.

4.5.6 Number of grains per panicle

The genotypic correlation between number of grains per panicle and grain yield was positive and significant (0.178). The direct effect of number of grains per panicle on grain yield per m^2 was positive and low (0.072). Among the indirect effects, this trait had high positive effect via panicle length (0.291), straw yield per m^2 (0.243) and positive but low effect via total productive tillers per meter row length (0.011). The negative indirect effect via days to 50 per cent flowering (- 0.307), plant height (- 0.101) were high, via 100-grain weight (- 0.029) was moderate and via protein content (- 0.003) was low.

4.5.7 100-grain weight (gm)

The genotypic correlation of 100-grain weight and grain yield per m^2 was positive and highly significant (0.306) and its direct effect on grain yield was also positive and high (0.198). Its indirect effects via days to

50 per cent flowering (0.139), panicle length (0.100) were positive and moderate, while via protein content (0.008) it was positive and low. The negative indirect effect via straw yield per m^2 (- 0.062), plant height (- 0.055), total productive tillers per meter row length and number of grains per panicle (- 0.011) were moderate to low.

4.5.8 Protein content (%)

The genotypic correlation of protein content with grain yield per m^2 was negative and low (- 0.004) and its direct effect on grain yield was also negative (- 0.036). The indirect effects of protein content via straw yield per m^2 (0.091), plant height (0.071), panicle length (0.064) were positive and moderate while, via total productive tillers per meter row length (0.010) and number of grains per panicle (0.029) were positive and low. The negative indirect effects via days to 50 per cent flowering (- 0.164) and 100-grain weight (- 0.046) were high to moderate.

4.6 Genetic divergence

Multivariate test, using Wilk's criterion, was carried out to test the differences among the 98 genotypes of bunded field rice.

Based upon the observations of nine characters, the Mahalanobis's D^2 statistic was computed for all possible pairs of 98 genotypes in order to assess the genetic diversity present among the genotypes under study.

4.6.1 Composition of clusters

Clustering of the 98 genotypes was carried out following Tocher method (Rao, 1952). In all, seven clusters were formed and their composition is given in Table 4.5. Cluster-I was found to be the largest with

Table 4.5 : The distribution of 98 rice genotypes to different clusters on the basis of D^2 statistic

Clusters	No. of genotypes	Genotypes
I	71	IR-62141-114-3-2-2-2, RP-2233-30-4-10, IR-10147-113-5-1-1-5, ZHEN-GUI-AI 1, Pusa-33, IET-14345, QING LIG AI No. 1, IR-72, CNA 6870, TOX-3344-TOC-3-4, IET-13830, RP-2235-48-54-6, IR-62127-55-1-2-2-3, IET-14848, IR-57313-106-2-3, Futia, IET-14349, RP-1873-715-3-2, IET-13832, IET-13837, IET-14347, DDR-43, IET-13831, RP-1899-1481-76-1, IET-14353, IET-14350, DDR-54, DDR-52, Sathi-34-36, GR-5, GR-4, Kada-176-12, RP-1888-4259-1529-126, IET-14364, RP-2161-15-4-1, Zinisathi, Dodhial, TGR-75, GR-3, IR-60819-34-2-1, CNA-3290, CNA-4143, Dhundhani, Ponijayal, Juna-61, Ratwal, Chirni, Truvana, AMISTAD-82, KMP-34, Rewa-16-88-1, Tichun, IRTP-10800, Bharihar, BG-1639, Challi, IR-28(C), VRA-55, Challi-3, Rati bawali, IR-50, Bhadarvi dangar, Ek dandi, Futia(WR-I), GR-6, ITA-337, IR-55537, IR-47-761-6-8-1, RP-2095-5-8-31, 132, RP-2633-30-4-7,
II	20	IR-53163, Kali dangar, J.R.-82-5-199, Lal chhalwali, IR-8, Bawali, Dhanhad, Rewa-3-45, Halki jaya, Ratna, Kalam, IR-66, Aus-96, TOX-1012-12-18, IRAT-349, Deshi kalam, IR-53236, 63-83, Hara, Indrani
III	1	Tulsya-(WR-6)
IV	3	S.K.-20, BIR, Nagpur-22
V	1	Damam basmati
VI	1	IRAT-341
VII	1	IR-47-6-86-6-7-1

71 genotypes followed by cluster-II and IV with genotypes 20 and 3, respectively.

4.6.2 Intra and inter-cluster distance

Intra and inter-cluster distance (D) between all possible pairs of seven clusters were computed and presented in Table 4.6.

A study of the data revealed that the inter-cluster distance (D) ranged from 14.249 to 64.157. The maximum inter-cluster distance (D = 64.157) was observed between cluster-IV and V followed by those between cluster-III and IV (D = 50.499). The minimum inter-cluster distance (D = 14.249) was observed between cluster-VI and VII followed by the cluster-III and V (D = 15.406).

Intra-cluster distance (D) ranged from 12.459 to 15.097. At intra-cluster level cluster-I had the highest value (D = 15.097) which was followed by the cluster-II (D = 14.273). The minimum intra-cluster distance (D = 12.459) was observed in cluster-IV which included 3 genotypes.

4.6.3 Cluster means of various characters

Cluster means of all the nine characters are presented in Table 4.7. The maximum coefficient of variation was noted under grain yield per m^2 (C.V. % = 59.55), it was followed by straw yield per m^2 (C.V. % = 40.33), 100-grain weight (C.V. % = 40.31), protein content (C.V. % = 27.01), number of grains per panicle (C.V. % = 25.58). The lowest coefficient of variation was observed in panicle length (C.V. % = 10.72).

Cluster-VII had maximum mean value for grain yield per m^2 (301.67 gm), panicle length (24.67 cm) and 100-grain weight (4.27 gm). Cluster-VI had second highest mean value for 100-grain weight (4.09 gm) with second highest grain yield per m^2 (157.00 gm) and it had minimum

Table 4.6 : Intra and inter-cluster (D) values for 98 genotypes of bunded field rice

Clusters	I	II	III	IV	V	VI	VII
I	15.097	25.696	20.889	50.238	24.755	24.050	28.778
II		14.273	28.037	30.094	39.682	21.007	27.901
III			0.000	50.499	15.406	32.224	35.200
IV				12.459	64.157	41.063	47.093
V					0.000	40.279	42.833
VI						0.000	14.249
VII							0.000

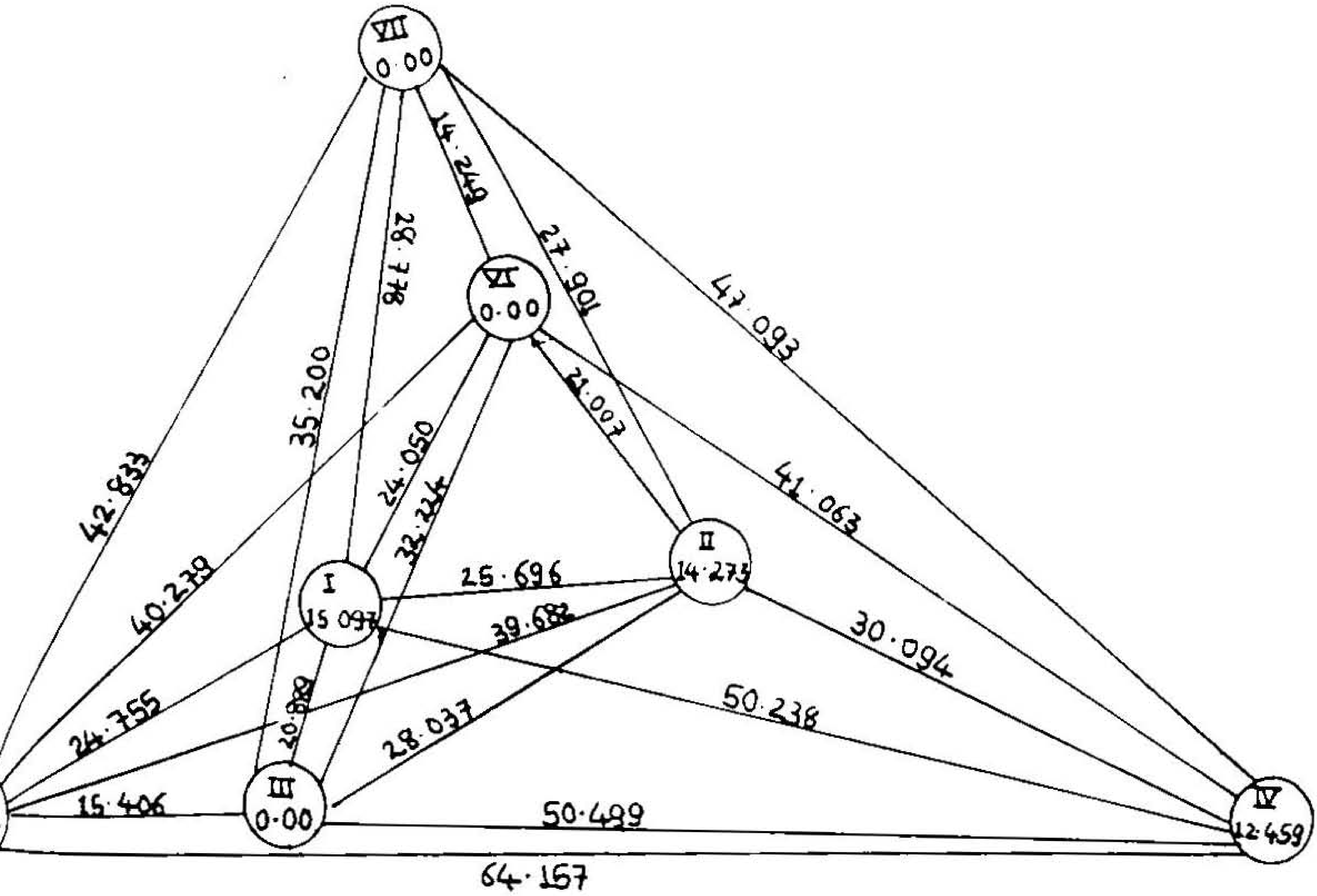


Fig. 2 : Mutual relationship among the D^2 clusters

Table 4.7 : Cluster means for nine characters in 98 genotypes of bunded field rice

Cluster	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
I	136.76	68.29	61.98	58.25	281.53	20.49	61.25	2.20	6.74
II	136.00	65.50	61.20	65.71	279.00	20.55	58.30	2.38	4.91
III	57.33	100.33	60.67	98.93	593.33	20.47	99.53	1.60	6.59
IV	116.78	58.67	53.44	62.44	285.56	17.84	56.27	2.23	2.60
V	34.33	100.68	93.00	88.60	613.33	22.53	56.27	1.44	7.78
VI	157.00	61.33	70.00	57.13	193.33	18.07	44.20	4.09	5.51
VII	301.67	71.00	51.68	77.33	420.00	24.67	63.40	4.27	5.60
Mean	134.27	75.11	64.57	72.63	380.87	20.66	62.75	2.60	5.68
S.Em.±	30.224	6.236	4.868	5.656	58.064	0.837	6.066	0.396	0.579
C.V.%	59.55	21.97	19.95	20.60	40.33	10.72	25.58	40.31	27.01

mean value for plant height (57.13 cm). Cluster-V had the highest protein content (7.78 %) and lowest mean value for 100-grain weight (1.44 gm). Cluster-V had maximum mean value for straw yield per m^2 (613.33 gm), total productive tillers per meter row length (93.00) and days to 50 per cent flowering (100.68), while lowest mean value for grain yield per m^2 (34.33 gm). Cluster-III had maximum mean value for plant height (98.93 cm) and number of grains per panicle (99.53).

4.6.4 Contribution of different characters to diversity

The utility of D^2 analysis is enhanced by its applicability to estimate the relative contribution of the various plant characters to genetic divergence. The present study revealed that protein content followed by days to 50 % flowering contributed more to genetic divergence (Table 4.8).

Table 4.8 : Contribution of different characters to diversity in bunded field rice

Sr. no.	Characters	Contribution %
1	Grain yield per m^2 (gm)	8.29
2	Days to 50 % flowering	14.96
3	Total productive tillers per meter row length	0.13
4	Plant height (cm)	0.78
5	Straw yield per m^2 (gm)	0.04
6	Panicle length (cm)	0.08
7	Number of grains per panicle	0.13
8	100-grain weight (gm)	11.00
9	Protein content (%)	64.59

DISCUSSION

V DISCUSSION

Evaluation of the germplasm is the pre-requisite to collect the basic information before initiating any breeding programme for the improvement of the crop. Success of the crop improvement programme is largely dependent on the extent of genetic variability present in the population. Environment has a great influence on many quantitative characters, in which the variability partitioned into heritable and non-heritable components like genetic coefficient of variation, heritability, genetic advance etc. are most important to the plant breeder for selection of the breeding method in crop improvement programme.

A knowledge of the inter-relationship of quantitative traits of economic importance with seed yield and among themselves is important for the improvement in a complex character like yield through selection. The correction studies are helpful to some extent to the breeder, but they do not take into consideration the cause and effect relationship which restricts the practical utility of correlations in selection programme.

The technique of path coefficient analysis devised by Wright (1921) and utilized for the first time in plants by Dewey and Lu (1959) in crested wheat grass is efficient in disintegrating the total correlation between two variables into direct and indirect effects. This technique could be used to understand the cause of association between two variables and provides basis for selection of superior genotypes from the diverse breeding populations.

Mahalanobis's D^2 statistic is being used as an efficient tool in quantitative estimation of genetic diversity and selection of parents for hybridization programme.

5.1 Variability

The present study showed a wide range of phenotypic variability and highly significant varietal differences for all the characters indicating considerable amount of variability. This suggests that there is an ample scope to identify high yielding, early and dwarf genotypes to improve different characters simultaneously, provided the material is subjected to judicious selection pressure.

All the nine characters had a wide range of variability (Table 4.1). Similar results were reported for grain yield/ m^2 (Majmudar *et al.*, 1971; Mahajan *et al.*, 1981; Kaul and Kumar, 1982; Sardana and Sasikumar, 1987; Pathak and Patel, 1989), plant height (Jogi and Hassan Baba, 1971; Majumdar *et al.*, 1971, Ghosh *et al.*, 1981; Sardana and Sasikumar, 1987; Pathak and Patel, 1989), days to 50 per cent flowering (Ghosh *et al.*, 1981; Maurya *et al.*, 1986; Sardana and Sasikumar, 1987; Pathak and Patel, 1989), panicle length (Mahajan *et al.*, 1981; Sardana and Sasikumar, 1987; Pathak and Patel 1989), number of grains per panicle (Majumdar *et al.*, 1971; Maurya *et al.*, 1986; Sardana and Sasikumar, 1987) and 100 grain weight (Jogi and Hassan Baba, 1971, Majumdar *et al.*, 1971)

It will be of great interest to consider the per se performance of different genotypes in respect of different quantitative characters of economic importance particularly earliness, grain size and grain yield. The varieties Bhadarvi dangar and Hara, VRA - 55 and Tichan and Dodihal were early in flowering. The boldest seed size was recorded by IR-47-6-86-6-7-1 followed by IRAT-341 and IR-53236. The highest yielding variety was IR-47-6-86-6-7-1 which was at par with Rewa-16-88-1.

The phenotypic range of variation is not the precise criterion of judging the amount of genetic variation present in population The genetic parameters like variance components, genotypic coefficients of variation, heritability and genetic advance are important to study the extent of genetic variability more precisely. Since breeding potential of experimental material depends on the amount of genetic variability which is a pre-requisite for response to selection, the phenotypic variance was partitioned into its genotype and environment components to know the genetic variability present in each character.

The genotypic variance followed the trend of phenotypic variance and was greater than environmental variance for all the characters. This implied that phenotypic variability might be considered as a reliable measure of genotypic variability. In the present study, the phenotypic and genotypic variance were greater than the environmental variances for all the characters under study (Table 4.2). This indicated that selections for these characters would be effective.

With a view to compare different quantitative characters in respect of phenotypic and genotypic variability, phenotypic coefficients of variation and genotypic coefficient of variation were calculated. The genotypic coefficient of variation measures the range of variability present in a character and helps to compare the variability present in different characters. The highest amount of genotypic coefficient of variation was exhibited by grain yield per m^2 followed by straw yield per m^2, number of grains per panicle and total productive tillers per meter row length. Moderate extent of genotypic coefficient of variation was exhibited by 100-grain weight, plant height, protein content and days to 50 per cent flowering, while character such as panicle length possessed lowest magnitude of genotypic coefficient of variation.

High genetic coefficient of variation for grain yield per m^2 was reported by Chaudhary *et al.*, (1973), Sivasubramanian and Madhvamemon (1973), Patel *et al.*, (1993), Sawant and Patil (1995), for number of grains per panicle by Sivasubramaniam and Madhvamemon (1973), Prasad and Chadra (1977), Bhattacharya and Mishra (1981), Patel *et al.*, (1993), Sawant and Patil (1995), and for straw yield per m^2 by Patel *et al.*, (1993).

Genetic coefficient of variation measures the amount of variation in character, but it is not possible to assess the amount of heritable variation based on this estimate. Burton (1952) suggested that genotypic coefficient of variation along with heritability estimates would provide better estimates of the amount of genetic gain expected through phenotypic selection.

5.2 Heritability and genetic advance

The heritability estimates were quite high for the characters, grain yield per m^2, days to 50 per cent flowering, 100-grain weight and protein content and indicated that these characters were least influenced by environmental factors. Moderate heritability estimates were observed for the characters plant height, straw yield per m^2, panicle length and number of grains per panicle. The higher estimates of heritability obtained in the study may be due to the fact that the experiment was conducted only at a single location and for one year. Thus, the genotypic variance estimated from a single test contained interaction to genetic variance in addition to genetic variance resulting in the upward bias in the estimates of broad sense heritability.

High estimates of heritability in rice were also reported for grain yield per m^2 (Sivasubramaniam and Madhvamemon, 1973, Talwar *et al.*, 1974; Bhattacharya and Mishra, 1981; Sawant and Patil, 1995; Reddy and De, 1996), days to 50 per cent flowering (Swamy Rao *et al.*, 1970; Singh and Sharma, 1982; Singh *et al.*, 1986; Chauhan *et al.*, 1993), 100-grain weight (Sen *et al.*, 1969; Shukla *et al.*, 1972; Chaudhary *et al.*, 1980; Singh and Sharma, 1982; Manonmani *et al.*, 1996).

While moderate estimates of heritability in rice were also reported for Panicle length (Shukla *et al.*, 1972; Singh *et al.*, 1986) straw yield per m^2 (Sundaram *et al.*, 1988; Pathak and Patel, 1989), and for plant height (Singh *et al.*, 1986).

The high heritability estimates have been helpful to the plant breeders as these enable the plant breeders to base the selection programme on phenotypic performance. Johnson *et al.*, (1955) in their studies with F_4 and F_5 generations of a cross in soyabean suggested that heritability estimates in conjunctions with genetic advance were more reliable in prediction the resultant effect from selecting the best individuals. Ramanjum and Tirumalachar (1967) also discussed the limitations of estimating heritability in broad sense as it included both additive as well as epistatic gene effects and suggested that it would be reliable only if accompanied by high genetic advance.

The expected genetic advance expressed in percentage of mean was high for characters viz., grain yield per m^2, straw yield per m^2 and 100-grain weight. It was moderate for days to 50 per cent flowering, plant height, number of grains per panicle and protein content, while it was of lower magnitude for total productive tillers per meter row length and panicle length.

The same results were also obtained on high genetic advance for grain yield per m^2 (Chaudhary *et al.*, 1973; Talwar *et al.*, 1974; Prasad and Chadra, 1977; Sinha and Bhattacharya, 1980; Bhattacharya and Mishra, 1981; Patel *et al.*, 1993; Sawant and Patil, 1995), straw yield (Talwar *et al.*, 1974; Chauhan *et al.*, 1993; Patel *et al.*, 1993) and 100-grain weight (Chaudhary *et al.*, 1980; Manonmani *et al.*, 1996).

Grain yield per m^2, days to 50 per cent flowering, 100-grain weight and protein content showed high heritability along with higher to moderate genotypic coefficient of variation and genetic advance indicating that most likely the heritability was due to additive gene effects and the genotypes under study were highly diverse and of great genetic potential with regard to these characters. Further improvement in these characters would be achieved by phenotypic selection. An advantage of this nature also deserved careful and sustained exploitation of genetic improvement in rice.

5.3 Correlation coefficient

Prior to any breeding programme for the improvement in crops, it is imperative to obtain information regarding the inter-relationship of different plant characters with yield and among themselves since it facilitates a quick assessment of high yielding genotypes in selection programmes. The real or true association could be known only through genotypic correlation which eliminates the environmental influence.

The correlations of grain yield with other eight characters and among the characters themselves were estimated at genotypic and phenotypic levels. In general, the values of genotypic correlations were higher than their phenotypic correlation which is in agreement with the findings of Bia *et al.*, (1992) and Sawant and Jadhav (1995). This indicated that there was a high degree of inter-relationship between two variables at genotypic level. In few cases, however, the phenotypic correlations were slightly higher than their genotypic counterparts which implied that the non-genetic causes inflated the values of genotypic correlation because of the influence of environmental factors.

In the present investigation grain yield per m^2 had highly significant positive association with panicle length and 100-grain weight at both genotypic and phenotypic level indicating that these traits contributed directly towards grain yield and were important components in Rice. Reddy and Goud (1970), Chaudhari *et al.*, (1975), Saini and Gagneeja (1975), Yadav and Singh (1979) Singh *et al.*, (1980), Singh *et al.*, (1982), Pathak and Patel (1989), Sampath (1989), Reddy and Ramachandrah (1990), Chaubey and Richharia (1993), Add-el-Samie and Hassan (1994), Yolanda and Das (1995), and Sarawgi *et al.*, (1997), also stressed importance of these traits as selection indices for yield improvement in rice.

Number of grains per panicle had high significant and positive correlation with grain yield at genotypic level, while positive but non-significant correlation at phenotypic level. Hedge (1987), Sampath (1989), Wilfred *et al.*, (1993), Yolanda and Das (1995), Sawant and Jadhav (1995), Verma *et al.*, (1997), also obtained similar results in their studies.

Straw yield per m^2 had high significant positive correlation with grain yield at genotypic level, while positive correlation at phenotypic level. Wiltred *et al.*, (1993), also arrived at similar findings in their studies.

Plant height was negatively associated with grain yield at genotypic level and positively at phenotypic level. Amirthadevarathinam (1983) also reported similar results in their studies.

Total productive tillers per meter row length was found to have positive correlation with grain yield. Similar results was obtained by Hedge (1987). Grain yield per m^2 was found to have positive correlation with days to 50 per cent flowering. Similar results were obtained by Yadav (1992). Protein content had very low and negative correlation with grain yield per m^2 which was negligible.

In the present investigation, days to 50 per cent flowering had highly significant and positive correlation with total productive tillers per meter row length, straw yield per m^2, number of grains per panicle and protein content at both the levels, while, plant height had highly significant and positive correlation with days to 50 per cent flowering at genotypic level and positive correlation at phenotypic level. It is very interesting to note that days to 50 per cent flowering had highly significant negative correlation with 100-grain weight which presumed that early flowering resulted in availability of more time for growth and development of grain resulted into heavier grain. Such results were observed by Patel (1989). Among the other yield components, plant height had highly significant positive correlation with straw yield, panicle length, number of grains per panicle and 100-grain weight, while negative association with protein content. This indicated that plant height was an important indicator for increasing straw yield, panicle length, number of grains per panicle and 100-grain weight. Similar results were observed by Pathak and Patel (1989). Significant positive correlation between plant height with panicle length was observed by Reddy and Goud (1970), Saini and Gegnera (1975), Singh (1980) and Chaubey and Richharia (1993). Amirthadevrathinam (1983) recorded positive association between plant height and no of filled grains per panicle which supports the present findings.

Thus, results revealed that no of grains per panicle, panicle length, plant height, straw yield and days to 50 per cent flowering were important traits which contributed towards higher yield. So, more emphasis should be given to these components during selection for higher yield. Amirthadevrathinam (1983) also advocated that due care should be taken at the time of selection for number of grains per panicle, panicle length, medium height and earliness for rice cultures.

Interrelationships among yield components further suggested that selection for yield components would help in increasing the yield level.

5.4 Path coefficient analysis

In the selection programme, when less number of variables are considered, correlation study alone can serve the purpose. However, when variables are increased the situation becomes complex. For overcoming this complexity path analysis (Wright, 1921 and Dewey and Lu, 1959) method is adapted to partition the correlation into direct and indirect effects, so that relative merits of each trait is established and their number is reduced in selection programme.

In order to obtain a clear idea of the inter relationship of various component characters with yield, direct and indirect effects were calculated using path coefficient analysis at genotypic level.

In the present study highest positive direct effect on grain yield was recorded by straw yield per m^2 followed by panicle length, 100-grain weight, number of grains per panicle and total productive tillers per meter row length. Similar results were reported by Patel (1989) for straw yield. For panicle length by Saini and Gagneeja (1975), Rao *et al.*, (1980), Hedge (1987) Gopalkrishnan and Ganpathy (1996), for 100-grain weight by Saini and Gagneeja (1975), Brar and Saine (1976), Banerjee and Sinha (1977), Yadav and Singh (1979), Patel (1989), Pathak and Patel (1989), for number of grains per panicle by Rao *et al.*, (1980), Hedge (1987) and for total productive tiller per meter row length by Katoch (1989). Negative direct effect on grain yield was found with days to 50 per cent flowering, plant height and protein content. Similar results were reported by Rao *et al.*, (1986), Patel (1989) for days to 50 per cent flowering and for plant height by Ibrahim *et al.*, (1990) and Manuel and Rangaswami (1993).

Days to 50 per cent flowering, plant height and protein content had negative direct effects on grain yield but their indirect effects via straw yield, panicle length and number of grains per panicle were positive resulting into significant and positive correlation with grain yield except for protein content. Direct effect of days to 50% flowering was negative but positive correlation with grain yield was observed by Patel (1993).

It is interesting to note that a highly significant correlation of grains per panicle with grain yield came from its own positive direct effect, whereas, its indirect effect through other traits were negligible. Rao *et al.*, (1980) and Lenka and Mishra (1973) reported similar results.

5.5 Genetic divergence

Plant breeders are always interested to assess the genetic diversity among the germplasm, varieties or advance breeding material available with them so as to utilize them in direct breeding programme because (i) genetically diverse parents are likely to produce high heterotic effects (Griffing and Lindston, 1954) and (ii) the distantly related parents within the same species when utilized in cross breeding programme are likely to produce wider spectrum of variability.

To a plant breeder, single character is not of so much importance as the combined merit of a number of desirable traits become more important when he is concerned with a complex trait like yield. So, for improving yield, selection of parents based on a number of characters having quantitative divergence is required which can be fulfilled by D^2 statistic developed by Mahalanobis (1936).

In the present study, D^2 statistic estimated on 98 genotypes for nine characters showed that generalized distance (D) between two populations varied from 14.249 to 64.157 which was an indicator of the diversity present on the material evaluated.

5.5.1 Clustering pattern

The clustering pattern showed that varieties from different sources were clubbed into one group and also varieties of same source forming different clusters indicated no relationship between geographical diversity and genetic divergence. Rathod (1984), Pande and Ghorai (1987) and Vivekanandan and Subramanian (1993) also reported that there was no parallelism between genetic diversity and geographical distribution. Murthy and Arunachalam (1966) stated that genetic drift and selection in different environment could cause greater diversity than geographical distance. Further, there was a free exchange of seed material among different regions consequently character constellations that might be associated with particular region in nature, lose their individuality under human interference. In rice, Kumari and Rangaswamy (1997) had suggested that geographical diversity may not be necessarily be related to genetic diversity.

Cluster - I contained as many as 71 genotypes. Out of 7 clusters four had only one genotype. The maximum inter-cluster distance was observed between cluster IV and V (D = 64.157) followed by cluster III and IV (D = 50.499) and cluster I and IV (D = 50.238). Hence, crosses between the genotypes involving these clusters might give more variability in the segregating generations.

5.5.2 Clusters means

In the present study cluster VII had the highest mean values for grain yield per m^2, panicle length, 100-grain weight, cluster V for days to 50 per cent flowering, total productive titlers per meter row length, straw yield per m^2 and protein content, whereas, cluster III was superior for plant height and number of grains per panicle. Therefore, inter crossing of such genotypes involved in these clusters will be useful for variability in the respective traits.

The clustering pattern could be utilized in crossing the parents and deciding the cross combinations which may generate highest variability for various traits. The superior genotypes for breeding programme can also be selected on the basis of cluster means and to increase yield by inter crossing the genotypes of cluster VII for grain yield per m^2, panicle length and 100-grain weight, cluster V for days to 50 per cent flowering, total productive tillers per meter row length, straw yield per m^2 and protein content while cluster III for plant height and number of grains per panicle. Whereas, for inducing earliness genotypes of cluster IV will be desirable.

SUMMARY AND CONCLUSIONS

VI SUMMARY AND CONCLUSIONS

The investigation reported here on bunded field rice (*Oryza sativa* L.) was carried out in a randomized block design with three replications at National Agricultural Research Project, Musa Farm, Vyara during kharif season of 1998. A set of 98 genotypes was utilised to study the variability parameters, correlation, path coefficient and genetic divergence taking one qualitative and eight quantitative characters including seed yield.

- The analysis of variance for all the characters with all the 98 genotypes showed differences among the genotypes studied, indicating sufficient amount of variability present in the material.

- The genotypic and phenotypic variances were higher for grain yield per m^2 and straw yield per m^2.

- The highest genetic coefficient of variation was observed for grain yield per m^2 followed by straw yield per m^2, 100-grain weight and number of grains per panicle, thereby indicating considerable amount of variability in the material for these characters.

- High heritability was found for protein content followed by days to 50 per cent flowering, 100-grain weight and grain yield per m^2, indicating that these characters were less influenced by environment and direct selection for these components would be effective for further improvement in yield level.

- High genetic advance as per cent of mean was recorded for grain yield per m^2, straw yield per m^2 and 100-grain weight. It indicated operation of additive gene action for these traits. Moderate to high heritability coupled with high/ considerable expected genetic advance for these traits, indicated that more emphasis should be given to these characters at the time of selection for further improvement in yield.

- Grain yield per m^2 exhibited highly significant and positive correlation with panicle length and 100-grain weight at both genotypic and phenotypic levels, while, highly significant and positive correlation with straw yield per m^2 and number of grains per panicle at genotypic level only. Correlation between days to 50 per cent flowering and total productive tillers per meter row length, straw yield per m^2, panicle length, number of grains per panicle, protein content were also highly significant and positive. Correlation between plant height and straw yield per m^2, panicle length, 100-grain weight were also highly significant and positive. Correlation between straw yield per m^2 and panicle length, number of grains per panicle, panicle length with number of grains per panicle were highly significant and positive.

- Considering the above relationships of an ideal plant type in bunded field rice can be considered having more productive tillers per meter row length, panicle length and number of grains per panicle.

- Path coefficient analysis revealed the highest positive direct effect of straw yield per m^2 followed by panicle length, 100-grain weight, number of grains per panicle and total productive tillers per meter row length on grain yield per m^2. Days to 50 per cent flowering exhibited high negative direct effect, while plant height showed moderate negative direct effect and protein content showed negative but low direct effect. Indirect effect through total productive tillers per meter row length and protein content were very low and negligible. Indirect effect of plant height, straw yield per m^2, panicle length and number of grains per panicle were high and positive. Indirect effect of above characters via, days to 50 per cent flowering, total productive tillers per meter row length, plant height, 100-grain weight and protein content were negative or positive and high to low.

- Based on these findings it could be concluded that in breeding programme aiming to improve grain yield in bunded field rice, more weightage should be given mainly to plant height, straw yield per m^2, panicle length, number of grains per panicle and 100-grain weight.

- D^2 analysis indicated wider genetic variability among the 98 genotypes which were grouped in seven clusters, cluster-IV showed much genetic divergence with cluster-VI and VII similarly cluster-V with VI and VII.

- The characters grain yield per m^2, straw yield per m^2, 100-grain weight, protein content, number of grains per panicle, days to 50 per cent flowering and plant height showed considerably high genetic divergence.

- Cluster-VII was superior for the character grain yield per m^2, panicle length and 100-grain weight, cluster-V for days to 50 per cent flowering, total productive tillers per meter row length and straw yield per m^2 whereas, cluster-III was superior for plant height and number of filled grains per panicle.

- As the characters viz., panicle length, 100-grain weight, straw yield per m^2 and number of grains per panicle possessed significant positive correlation with grain yield along with high direct effects, these characters should be given due emphasis for the improvement in grain yield.

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*** Original not seen.**

APPENDIX

Appendix - I Meteorological observations during crop period in the year 1998 at Musa Farm, Vyara

Month	Temperature (°C)		Relative humidity	Rainfall
	Maximum	Minimum	(%)	(mm)
June	30.6	27.1	98.6	681.7
July	28.9	25.0	95.8	567.8
August	29.9	24.1	94.8	413.2
September	28.8	24.3	91.7	393.2
October	33.6	21.5	85.0	15.2

Appendix-II : Mean performance of eighty six genotypes of green gram for various characters

Sr no	Genotypes	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
1	GR-3	126.00	82.00	74.00	56.67	273.33	21.13	80.93	1.84	6.50
2	GR-4	172.00	76.67	76.33	59.53	393.33	19.47	73.93	1.46	6.82
3	GR-5	165.00	60.33	74.33	63.20	183.33	18.80	51.53	2.55	6.65
4	GR-6	77.00	101.67	64.33	57.27	413.33	20.40	58.53	1.94	6.69
5	IR-28(C)	142.67	68.33	70.67	48.87	280.00	20.13	52.47	2.29	5.65
6	IR-50	103.33	67.33	77.67	44.60	240.00	20.80	52.00	1.85	5.60
7	IR-66	223.33	69.67	64.00	51.53	280.00	20.47	63.93	2.16	5.29
8	Ratna	96.33	72.33	67.67	56.20	286.67	22.93	56.47	1.98	4.38
9	Pusa-33	176.33	76.67	77.33	63.20	273.33	17.40	55.53	2.24	6.76
10	Kada-176-12	119.67	56.00	73.33	55.93	193.33	18.27	42.73	2.70	7.08
11	SK-20	132.67	63.00	65.00	63.27	253.33	18.33	54.93	1.92	2.21
12	Halki-jaya	111.67	76.67	70.33	60.93	286.67	24.87	72.87	2.03	4.80
13	VRA-55	110.00	46.33	51.33	66.60	80.00	19.67	54.53	2.77	6.15
14	IRTP-10800	99.33	51.33	61.33	48.47	170.00	18.33	55.80	2.35	6.07
15	Tichun	72.00	50.00	55.67	39.47	116.67	17.47	46.80	2.29	6.31
16	Zinisathi	98.67	57.00	86.67	84.20	293.33	20.00	93.80	2.03	7.00
17	Sathi-34-36	115.00	59.33	65.67	71.27	280.00	20.40	52.93	2.77	6.99
18	IET-13837	126.00	62.67	70.67	47.27	213.33	21.20	51.00	2.17	7.24
19	IET-14349	127.33	67.33	68.33	53.00	223.33	19.13	53.87	2.21	7.15
20	IRAT-341	157.00	61.33	70.00	57.13	193.33	18.07	44.20	4.09	5.51
21	DDR-43	133.00	64.00	62.67	62.13	263.33	21.47	63.20	2.53	6.87
22	DDR-52	105.33	64.00	72.00	53.93	220.00	19.93	56.13	1.85	6.85
23	DDR-54	105.33	65.00	54.33	65.67	230.00	23.60	63.60	2.35	6.72
24	Rewa-3-45	171.33	60.33	72.67	51.47	360.00	20.07	65.87	2.04	4.71
25	IR-82-5-199	126.67	64.00	61.00	56.73	116.67	21.67	50.53	2.62	5.20
26	Rewa-16-88-1	254.00	65.00	72.67	71.87	273.33	20.07	56.67	2.55	6.11

Appendix-II : (Contd.....)

Sr no	Genotypes	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
27	Aus-96	212.00	64.00	59.33	71.07	313.33	21.27	55.00	2.79	5.33
28	IR-53236	68.00	57.00	46.00	70.73	263.33	18.93	54.20	3.64	4.73
29	IR-53167	71.00	57.00	62.33	70.07	316.67	17.40	36.53	2.71	4.99
30	IR-47-701-6-8-1	279.33	74.33	54.00	65.67	306.67	22.60	63.00	2.60	5.84
31	IR-47-6-86-6-7-1	301.67	71.00	51.67	77.33	420.00	24.67	63.40	4.27	5.60
32	Futia (WR-1)	66.33	75.67	45.67	61.60	103.33	20.13	64.67	1.74	5.75
33	Amistad-82	188.33	75.67	72.33	55.33	400.00	23.27	59.53	2.19	5.95
34	Juna-61	126.00	81.00	72.33	56.33	280.00	23.73	72.20	2.14	6.14
35	TGR-75	153.33	73.00	73.33	58.93	276.67	21.13	50.80	1.96	6.32
36	KMP-34	76.00	73.00	63.00	45.87	260.00	19.80	55.00	2.04	5.97
37	CNA-3290	85.67	58.00	49.67	56.53	233.33	17.47	32.53	1.88	7.74
38	CNA-4143	83.67	79.00	56.00	68.93	413.33	22.60	70.30	2.08	7.82
39	IR-10147-113-5-1-1-5	192.00	75.67	72.33	71.60	276.67	22.60	68.20	2.28	7.05
40	ITA-337	143.00	72.00	65.67	79.07	313.33	25.20	84.00	2.71	5.48
41	TOX-1012-12-18	124.33	76.67	48.33	67.87	243.33	25.20	87.47	3.06	4.47
42	IET-13830	248.67	71.00	63.33	55.60	276.67	20.13	57.73	2.06	7.43
43	IET-13831	113.33	61.67	59.33	51.93	336.67	19.47	42.27	2.53	7.02
44	IET-13832	112.00	70.00	53.67	55.40	216.67	19.87	47.47	2.26	7.01
45	IET-14345	196.00	68.67	55.67	58.20	366.67	23.93	67.07	1.92	7.09
46	IET-14347	130.33	66.00	59.00	50.20	246.67	19.40	48.80	2.09	6.86
47	Indrani	225.67	87.00	58.33	62.20	470.00	20.33	50.27	1.92	4.00
48	IET-14350	122.67	56.00	45.67	51.07	300.00	19.67	45.40	2.16	6.98
49	IET-14353	92.67	63.00	48.67	45.07	273.33	19.47	47.13	2.04	7.11
50	IET-14364	78.00	59.00	67.00	45.33	290.00	16.53	46.87	1.85	7.13
51	Damam-basmati	34.33	100.67	93.00	88.60	613.33	22.53	56.27	1.44	7.78

Appendix-II : (Contd.....)

Sr no	Genotypes	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
52	IET-14848	160.00	66.33	67.67	50.07	233.33	19.20	43.73	2.04	7.49
53	BIR	113.33	57.00	47.00	62.00	336.67	18.93	54.40	2.80	2.24
54	IR-55537-34	131.67	66.00	46.67	62.40	300.00	20.67	60.73	2.86	5.44
55	IRAT-349	105.00	72.00	70.33	88.93	406.67	25.40	77.07	3.21	4.35
56	63-83	182.33	74.33	65.33	71.13	343.33	22.47	57.33	3.60	5.07
57	BG-1639	214.00	80.33	73.67	55.87	340.00	20.27	79.53	3.25	6.69
58	CNA-6870	161.67	77.00	61.00	53.47	220.00	22.80	70.00	2.15	7.49
59	IR-57313-106-2-3	113.00	72.00	77.67	50.53	303.33	21.07	65.47	2.17	7.35
60	IR-60819-34-2-1	89.33	88.33	80.00	54.80	460.00	21.67	64.53	1.91	7.29
61	IR-62127-55-1-2-2-3	142.67	75.33	66.00	53.53	346.67	24.27	85.73	1.71	7.45
62	IR-62141-114-3-2-2-2	206.00	84.00	52.33	55.93	396.67	21.00	84.13	2.05	6.92
63	QING LIU AI No.1	188.67	72.33	57.00	52.00	320.00	19.47	63.33	2.15	7.45
64	RP-1873-715-3-2	103.67	72.00	50.33	53.53	333.33	19.73	61.20	2.08	7.02
65	RP-1888-4259-1529-126	120.00	57.00	52.33	54.14	290.00	19.33	48.87	2.60	7.55
66	RP-1899-1481-76-1	112.33	64.00	68.00	47.53	246.67	20.40	74.93	2.32	6.88
67	RP-2095-5-8-31	48.67	93.33	47.33	58.73	413.33	21.20	53.67	1.91	7.49
68	RP-2161-51-4-1	126.00	82.33	81.00	52.93	406.67	21.93	72.13	1.98	7.62
69	RP-2235-48-54-6	246.33	72.00	84.33	55.47	380.00	22.80	76.53	2.12	7.42
70	RP-2633-30-4-10	207.33	83.33	58.33	52.07	353.33	21.73	95.93	2.08	7.01
71	RP-2633-30-4-7	140.00	93.33	52.67	59.20	433.33	23.67	92.07	2.02	7.75
72	TOX-3344-TOC-3-4	225.67	65.00	56.33	58.27	290.00	20.47	54.27	2.15	7.32
73	ZHEN-GUI-AI 1	203.33	83.67	51.67	56.87	330.00	24.47	75.80	2.55	7.20
74	132	109.67	87.00	53.00	55.33	440.00	20.53	67.20	2.04	7.87
75	IR-72	152.33	74.33	53.67	58.13	300.00	21.20	47.00	2.14	7.39
76	Kalam	242.67	61.67	58.67	70.67	300.00	21.13	53.77	2.05	4.73

Appendix-II : (Contd.....)

Sr no	Genotypes	Grain yield per m^2 (gm)	Days to 50 % flowering	Total productive tillers per meter row length	Plant height (cm)	Straw yield per m^2 (gm)	Panicle length (cm)	Number of grains per panicle	100-grain weight (gm)	Protein content (%)
77	Bhadarvi dangar	55.00	45.00	48.67	63.10	65.00	18.53	56.40	1.93	6.19
78	Bawali	66.67	56.00	56.00	66.27	206.67	19.20	69.60	1.86	5.18
79	Lal chhalwali	150.00	57.00	53.67	59.40	646.67	19.93	43.93	2.07	5.27
80	Hara	56.67	45.00	70.67	56.40	76.67	14.20	40.00	1.74	5.49
81	Rati bawali	76.00	57.00	64.00	85.27	263.33	19.33	69.00	2.04	5.86
82	Dudhani	153.33	61.67	73.33	78.33	300.00	20.07	67.20	2.33	6.26
83	Futia	144.33	71.00	58.00	69.33	290.00	18.40	46.33	2.04	7.01
84	Dodihal	120.67	50.00	52.00	61.67	146.67	21.07	29.53	2.57	6.93
85	Ponijayal	125.00	57.00	61.67	58.13	280.00	17.13	46.00	2.39	6.17
86	IR-8	132.67	72.00	60.33	73.53	320.00	19.93	53.47	2.18	5.02
87	Nagpur-22	104.33	56.00	48.33	62.07	266.67	16.27	59.47	1.97	3.36
88	Ek dandi	103.33	66.33	47.67	43.07	276.67	18.67	63.53	1.52	5.67
89	Bharihar	94.33	58.33	52.00	50.93	263.33	18.33	33.87	2.11	5.89
90	Kali dangar	65.67	60.33	49.33	55.60	213.33	18.07	36.07	2.37	5.08
91	Chirni	66.67	60.33	49.33	66.67	233.33	17.67	82.67	2.15	6.26
92	Ratwal	138.67	54.67	53.67	72.67	280.00	21.93	75.80	2.18	6.17
93	Deshi kalam	113.33	78.00	78.00	82.67	286.67	18.40	81.67	1.25	5.01
94	Dhanhad	174.67	49.00	49.66	63.80	193.33	19.20	56.33	2.22	5.16
95	Challi	132.33	51.00	52.00	66.53	226.67	19.33	83.00	2.35	5.94
96	Truvana	154.33	60.33	60.33	67.47	213.33	22.47	71.73	2.10	6.02
97	Challi-3	228.00	53.33	57.00	55.00	230.00	19.00	54.80	2.61	5.85
98	Tulsya-(WR-6)	57.33	100.33	60.67	98.93	593.33	20.47	99.53	1.60	6.59
	Mean	136.024	68.041	61.840	60.807	288.214	20.461	60.680	2.259	6.223
	S.Em. ±	11.719	3.656	14.412	5.985	63.107	1.836	12.481	0.090	0.093
	C.V. %	10.551	6.580	28.545	12.055	26.816	10.991	25.191	4.869	1.832

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference services in a library or documentation centre.

Place : Navsari

Date : March 30 1999

APatel

(A. I. Patel)