GENETIC VARIABILITY, CHARACTER ASSOCIATION, PATH ANALYSIS AND GENETIC DIVERGENCE IN LOWLAND BREEDING LINES OF RICE

(*Oryza sativa* L.)

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(**PLANT BREEDING AND GENETICS**)

BY

Lingaraj Nayak

Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
Orissa University of Agriculture and Technology
BHUBANESWAR

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THESIS ADVISOR Dr. A. ROY

DEDICATED TO
THE IMMORTAL SOUL OF
MY FATHER

Dr. Ashutosh Roy,
Reader,
Department of Plant Breeding and
Genetics, College of Agriculture,
Orissa University of Agriculture and
Technology, Bhubaneswar-751003.

Bhubaneswar
Dated, the 11 th March, 1991

CERTIFICATE -I

This is to certify that the thesis entitled " GENETIC VARIABILITY, CHARACTER ASSOCIATION, PATH ANALYSIS AND GENETIC DIVERGENCE IN LOWLAND BREEDING LINES OF RICE (*Oryza sativa* L.)" submitted by Lingaraj Nayak in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in Plant Breeding and Genetics is a faithful record of *bona fide* research work carried out under my guidance and supervision.

This research work is original and no part of this has been submitted to any other University or published in any form.

11/03/91

(Ashutosh Roy)

CERTIFICATE - II

This is to certify that the thesis entitled " GENETIC VARIABILITY, CHARACTER ASSOCIATION, PATH ANALYSIS AND GENETIC DIVERGENCE IN LOWLAND BREEDING LINES OF RICE (*Oryza sativa* L.)" submitted by Lingaraj Nayak to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements of the degree of Master of Science in Agriculture in the subject of Plant Breeding and Genetics has been approved by the Students Advisory Committee, after an oral examination on the same collaboration with the external examiner.

Advisory Committee:

Chairman: Dr. Ashutosh Roy

Member : 1.Dr. D. Satpathy

2.Dr. K. P. Das

External Examiner.

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Lingaraj Nayak

Bhubaneswar
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(LINGARAJ NAYAK)

CONTENTS

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LIST OF TABLE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

INTRODUCTION

Rice is the staple food for two third of global population and continues to be the major cereal crop of the world from time immemorial. In Asia where 90 percent of world's rice is grown and consumed, nearly 2.8 billion people derive 25 to 30 percent of colories from rice. India has the largest area under rice and produces about 100 million tonnes of paddy from over 42 million hectares. The current average yield of milled rice in India is about 1.7 t/ha in contrast to nearly 5 t/ha in Korea, Japan, Australia and USA and 4 t/ha in China.

In contrast to national average of 1.7 t/ha, Orissa yield remains at 1.3 t/ha despite release of several high yielding rice varieties in the state. In order to bridge the gap, additional quantities of rice need be produced from less land, research should focus attention in the improvement of the productivity and stability of rice production on an ecologically sustainable basis. As has been assessed that without increase in Kharif rice yield, the high yields of summer rice can not alone raise the average.

In Kharif about 40 ~~million~~ Lakh hectares of land come under rice cultivation in Orissa. The land form fall into three distinctly different ecological classes. Rainfed uplands constitute 15%, medium lands 35% and rainfed lowlands 50% of the total rice growing area. It is needless to emphasise that the plant type concept of high yielding modern varieties does not hold good for the rainfed lowland ecosystem. Therefore, farmers still continue with indegenous and improved tall indica varieties and are able to produce low stable yields of around 1.5 t/ha.

Rainfed lowlands in Orissa are characterized by prolonged stagnation of rain water throughout the major growth period of the rice crop. Ill or no drainage conditions coupled with an anaerobic microenvironment makes it difficult to emancipate higher production by improved agro-techniques like maintenance of uniform population and fertilizer management.

Therefore, a possible short term answer remains with the development of suitable plant type. Yield is a product of interaction between genetic efficiency of the plant and management efficiency of the farmer. For promoting sustainable rice production in lowlands, there is a need to integrate in the measurement of productivity as a factor of sustainability.

In recent years, release of Savitri has gained popularity among lowland farmers for its high production potential despite few unacceptable draw backs. Attempts have been made by the scientists of the Orissa Univeristy of Agriculture and Technology to develop suitable varieties for the rainfed lowlands. From among the elite breeding lines, 39 were picked up for the present investigation along with Savitri as a high yielding check variety with the following objectives.

* To assess the relative yield performance of the breeding lines,
* To findout the range of variation contained in the elites for future improvement,
* To estimate the manner of character association among the yield attributing characters.
* To findout the cause and effect relationship of characters with *per se* yield

and* to assess the genetic divergence of the breeding lines for planning future strategies by recombination or heterosis breeding.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Genetic variability

Research publications on qualitative and quantitative variations in rice germplasm and segregating populations of selected crosses are found to be extensive. However, critical review by Ramiah *et al*.(1953), Ghosh, *et al*.(1956) and subsequently by Chandraratna (1964) are worth mentioning. The present review incorporates most of the works during the last two decades on rice.

Sivasubramaniam *et al*.(1968) observed significant genetic difference among rice varieties for yield components .

Shukla *et al*. (1972) in their study on eight characters in 179 varieties of rice, reported wide range of phenotypic variation for all characters. High GCV was observed for the number of effective tillers per plant, 100-grain weight, grain weight per panicle and spikelet number per panicle. They concluded that characters with moderate heritability and with high to moderate genetic advance as was in 100-grain weight, number of effective tillers, spikelets per panicle, grain weight per panicle and grain yield per plant were useful in selection.

Sivasubramaniam and Madhavamenon (1973) reported high GCV for number of grains per panicle, number of tillers, panicle weight and grain yield. High genetic advance was reported for number of grains per panicle, grain yield and panicle weight while high heritability was observed for all the characters.

Sinha et al.(1980) observed the range of genotypic coefficient of variation from 8.54 for panicle length to 28.19 for plot yield in a study of 40 rice varieties. As high as 90 % heritability (broad sense) was observed for plant height, panicle length and number of days to 50 % flowering. The genetic advance was highest for yield per plant followed by spikelet sterility.

In a study of 22 genotypes including traditional talls, semi-dwarfs and mutants in normal and sodic soils Bhattacharya et al.(1981) found that plant height, number of ear bearing tillers, panicle weight and number of grains per panicle showed high genotypic coefficient of variation, high heritability and high genetic advance in sodic soils while plant height, panicle weight, number of grains per panicle and grain yield per plant showed high GCV, high heritability and genetic advance in normal soils.

Ghosh _et al_.(1981) conducted an experiment taking 34 indigenous rice varieties of Meghalaya. He observed significant difference in respect of characters like plant height, days to flowering, number of fertile tillers per plant, leaf length and width, and 1000 grain weight. Heritability estimates ranged from 19.05 % for panicle length to 87.22 % for days to flowering. Expected genetic advance was highest for plant height and number of fertile tillers per plant.

Kaul and Kumar (1982) observed considerable variability for all the traits under study. The genetic coefficient of variation was minimum for grain and panicle length but maximum for shoot height, tiller number and grain fineness whereas grain breadth and yield possessed an intermediate value. Heritability estimates were high for shoot height, panicle length, grain length and breadth and L/B ratio but low for grain yield and tiller number. Shoot height showed high genetic advance whereas tiller number and grain fineness showed moderate genetic advance.

In an experiment with 162 accessions including breeding lines, local varieties and some introductions Amirthadevarathinam (1983) observed high PCV and GCV in 11 agronomic characters. Natural selection appeared to act against heavy tillering habit. High coefficient of variation, heritability and expected genetic gain in grain yield, total tillers per m^2, productive tillers per m^2 and days to flowering was also reported by him.

Ravindranath et al.(1983) studied nine characters and observed highest range of variation for grains per panicle while it was lowest for 100-grain weight. A substantial range of genetic variability was manifested in case of number of grains per panicle and grain yield per plant. High heritability and high genetic advance were observed in all the nine characters except grain yield per plant which exhibited high heritability associated with low genetic advance.

Chauhan and Tondon (1984) conducted experiments under two different cultural environments taking 30 hill rice varieties and reported high heritability and genotypic coefficient of variation for plant height, number of tillers and grain yield under both the environments.

In a study in nine varieties Haung (1984) reported high heritability (98%) for 1000-grain weight and medium heritability of 70% for number of ears per unit area, 68% for number of spikelets per panicle and 55% for grain fertility.

Subramaniam and Rathinam (1984) reported that grain and straw yield in rice were under the influence of dominance action though showed moderate heritability. Additive gene action govern plant height, number of grains per panicle, 100-grain weight, harvest index mainly due to high heritability estimates and dominance gene action control tiller number due to low heritability while additive and dominance gene actions influence panicle length exhibiting high heritability estimates.

In a field experiment with six genotypes Alias (1985) found 26 to 50% broad sense heritability for plot yield and 60 to 99% heritability for grain number per panicle and 1000-grain weight.

Maurya et al.(1986) reported wide range of phenotypic variation for grains per panicle, plant height, days to flowering and leaf angle. The phenotypic coefficient of variability ranged from 5.7% for days to flowering to 45.09% for leaf angle. Grain length, grain length-breadth ratio, plant height, grains per panicle, 1000 grain weight and panicle length showed higher heritability and genetic advance.

Maurya *et al.*(1986) again reported wide range of phenotypic variation for yield per plant and in 11 related traits. The PCV was reported to be higher than GCV and ranged from 7.51% for days to 50% flowering to 32.92% for tillers per plant. Heritability was highest for days to 50% flowering (95.1%) followed by plant height (94.3%) and seedling height (93%).

By conducting an experiment with 53 ecotypically diverse genotypes Shamsuddin (1986) found considerable genetic variation for 100-grain weight, grain number per panicle, grain yield per plant, rachilla number per plant and panicle length. Heritability estimates of all the traits were high and ranged from 86.94% to 98.04% . In 100-grain weight, grain number per panicle and grain yield per plant, genetic and coefficient of variation showed high association.

De and Surya Rao (1987) in an experiment with 30 low land rice strains grown under semi deepwater condition reported high GCV, high heritability and high genetic advance for low spikelet sterility, high ear bearing tillers per hill and grain yield per m^2.

Hilton Lahai (1987) reported that most of the 150 indigenous local cultivars examined, showed good panicle exertion and low spikelet sterility, a few nonshattering forms were identified. Variation for panicle length and exertion was low, but variation for 100-grain weight was wide . Most of the cultivars having average values of 25-29 g, five cultivars had very small grains and six had very large.

Zeng and Wang (1988) reported the broad sense heritability estimates of > 85% for characters like days to heading (X_2), grain density on panicle (X_6), total floret number per panicle (X_4), flag leaf length (X_9), panicle length (X_4), all filled grain number per panicle (X_5) . The relative expected genetic advance values ($\Delta G'$) of X_6, X_4 and X_5 at 5% and 1% . Selection intensities were 43.77 and 57.37, 39.81 and 52.17, 35.73 and 46.83 % respectively. When direct selection was made for grain yield $\Delta G'$ was estimated at 12.04 and 15.78% for the trait at 2 selection intensities.

Paramsivan and Sreerangaswamy (1988) studied plant height, panicle length, grains per panicle, grain weight and yield in F_2 populations of six different crosses and found that genetic advance was greatly influenced by heritability in all characters except the plant height.

Sardana, Sashikumar and Modak (1989) estimated the genetic parameters for six yield attributes in 60 fixed cultures of rice and revealed high estimates of heritability with low genetic advance for five of the characters. The low genetic advance is attributed to low genotypic variability for different characters.

In a study on low land rice germplasm grown under semi-deep condition over two seasons Roy (1990) reported that grain yield and grain number per panicle exhibited moderate degree of genetic variability (GCV = 14.6% and 14.3%) respectively, while 1000-grain weight showed high genetic variability (GCV=29.4%). The genetic variability was relatively low in panicle number (less than 10%).

Character association in rice

A report by Chandramohan (1964) reveals high significant correlation of ear bearing tiller with yield in rice variety TKM-6 both at the phenotypic and genotypic levels.

Sree Rangaswamy and Murugesan (1973) found high correlation between plant height and leaf length, plant height and tiller number and leaf length with panicle length.

In an experiment on 23 varieties of different groups of cultivated rice Chaudhury *et al*.(1973) found significant character association between panicle length and grain number, 1000-grain weight and per plant yield. Significant negative correlations were obtained between panicle number and panicle weight, while significant and positive correlation was obtained between panicle weight and 1000-grain weight.

Osamu (1973) reported lower degree of association between number of panicle and other characters in his study of growth analysis experiment on dwarf rice and commented that the number of panicle to be a character independent of other characters.

In a study of interrelationship between yield and its components Rao et al.(1976) observed positive significant association for yield with number of fertile tillers per plant and grain weight per panicle in all the varieties.

Mudryi (1977) in his study with 55 rice varieties reported that duration of growth showed positive correlation with panicle length, plant height, number of spikelets on main panicle, percentage of empty grains and percentage of filled grains.

Khaleque (1978) reported correlation between short statured and earliness in heading time indicating higher grain yield.

In a study of 15 varieties and 7 traits Nakayama _et al_.(1978) reported positive correlation of grains per plant with number of productive tillers in most of the varieties.

Satapathy and Nanda (1978) in a study of inter-relationship between yield and some associated characters of rice in rainfed upland condition, reported that grain yield is correlated with 1000-grain weight. But no correlation was found between grain yield and productive tillers.

From a study of 39 diverse genotypes Singh _et al_. (1978) reported that grain yield was positively correlated with days to 50% flowering, days to maturity, plant height, panicles per plant, grain number per panicle and 1000-grain weight but negatively correlated with panicle length.

Bhattacharya (1980) in a study involving 20 salt tolerant indica rice varieties found yield per plant showing high positive correlation with fertile tillers, moderate correlation with grains per panicle and weak association with height and panicle length .

Rangel _et al_.(1980) reported marginal difference between the genotypic and phenotypic correlations with regard to plant height, maturity, grain yield and six other yield related traits. However, high correlation (r=0.80) between yield and number of filled grains, moderate degree of association between yield and number of spikelets per panicle and low positive correlation in case of yield with panicle length and days to maturity was observed. But a negative correlation was found between yield and number of tillers per hill.

Singh *et al.*(1980) found that the number of ear bearing tillers was only significantly associated with yield while plant height had a positive and significant correlation with number of grains per panicle and negative correlation with number of ear bearing tillers.

Shankar (1980) reported significant genotypic correlation of grain yield with plant height, number of productive tillers, number of grains per panicle and straw weight. He also observed significant phenotypic correlation of grain yield with spikelet weight, number of grains per panicle and straw weight.

Venkateswarulu *et al.*(1981) reported negative correlation of 1000-grain weight with number of grains per panicle, number of grains per unit area and grain yield in a study of late duration varieties of varying 1000-grain weight.

Singh et al.(1981) in an experiment on rice reported that yield was greater influenced by plant height/deep water and days to maturity.

In a study of 162 accessions consisting of breeding lines and varieties Amirthadevarathinam (1983) reported positive correlation of yield with total tiller number and productive tiller number and negative correlation with plant height and days to maturity.

In a study of 30 hill rice varieties Chauhan and Tondon (1984) reported positive and significant correlation of grain yield with that of plant height, number of grains per panicle and 100-grain weight under upland environment, while under irrigated environment the number of ear bearing tillers showed positive and significant association.

A positive correlation of fertility with yield was reported by Haung (1984) He also concluded that fertility had the highest direct contribution for path coefficient.

Paramasivan (1984) reported positive and highly significant correlation between ear bearing tillers and yield in tall and dwarf indica rice crosses.

In a field experiment with six genotypes Alias (1985) reported that main tiller performance and single plant performance for grain number per panicle and 1000-grain weight were positively and significantly correlated.

Shamsuddin (1985) reported positive and significant genotypic correlation of grain yield per plant with 100 grain weight, rachilla number per plant and panicle length.

Alvarez and Ismail (1986) studied phenotypic and genotypic correlations among the chief components of yield in 9 varieties and reported positive correlation of yield with number of panicles per m^2 (r=0.59), number of tillers per panicle (r=0.79) and 1000-grain weight (r=0.52) .

From a study of 98 cultivars Chauhan et al.(1986) gave a general conclusion that genotypic correlation was higher than the phenotypic correlation, which indicates that the phenotypic correlation reduced slightly due to environmental effect. However, it was found that at both levels, there was a positive and significant correlation of yield per plant with days to flowering, leaf angle, leaf length, plant height, panicle length, leaf sheath length, tillers per plant and grains per panicle.

Morales (1986) reported high positive correlation of yield with grains per panicle and 1000-grain weight. Thus he concluded that these were important criteria for increasing the yield.

Daskalov et al.(1987) studied 3 varieties over 3 years at 3 sowing dates and reported that flag leaf area was correlated with grain weight per panicle, grain number per panicle (r=0.33 to 0.34). So, it was thought that flag leaf area would be a useful indirect character in selection for yield.

De and Surya Rao (1987) recorded that sterility per cent, ear bearing tillers per hill and grain yield per m^2 had high genetic coefficient of variation, high heritability and high genetic advance. Grain yield per m^2 showed significant positive genotypic correlation with ear bearing tillers per hill and negative genotypic correlation with sterility percentage. He advocated use of these characters as selection criteria for yield improvement under low land situation.

De and Rao (1988) studied 30 rice varieties under semi-deepwater logged situation and reported significant positive and negative genotypic correlation of grain yield per m^2 with ear bearing tillers per hill and sterility percentage respectively.

Gomathinayagam *et al*.(1988) studied 7 biometrical traits and reported that grain yield was correlated with duration (r=0.29) and plant height (0.32).

Panwar, Bansal and Naidu (1989) studied the character association in 50 advanced breeding lines from diverse crosses along with 10 check varieties using 11 characters. They found that grain yield was significant and positively correlated with plant height, panicle number, grain number and spikelet number.

Roy (1990) reported in his study on low land rice germplasm grown under semi-deep conditions over two seasons that the grain yield per plant showed highly significant genotypic correlation with each of the six component traits like panicle length, panicle number, panicle weight, grain number per panicle, 1000-grain weight and spikelet sterility.

Path analysis

In their study on assessment of yield components of rice, Sivasubramanian and Madhavamenon (1973) reported that plant height, panicle weight and days to flowering were the three important characters making major contribution to yield as direct effect .

Sree Rangaswamy and Murugesan (1973) reported high direct effects of leaf length, productive tillers and plant height on yield in six strains of diploid rice.

In a study of 162 accession breeding lines, Amirthadevarathinam (1983) reported that total tillers and days to flowering has a positive direct effect of the contribution of grain yield .

Haung (1984) in a study of rice varieties reported that fertility had the highest direct effect for the path coefficient. He concluded that fertility was important for improving the grain yield.

In a study of path coefficient analysis Hong (1985) indicated that sink capacity was the major factor, limiting yield. He also reported that increasing the floret number per unit area, was important for yield.

Awasthi and Borthakur (1986) in their experiment involving 12 varieties reported that panicle length, 1000-grain weight, fertile grains per panicle had a direct positive effect on the grain yield per plant.

Alvarez and Ismail (1986) reported highest direct effect of filled grains per panicle on yield in their study in intermediate cultivation cycle.

In their study of reciprocal crosses involving an induced mutant of TKM-6 with 5 and 7 varieties Kumar and RangaSwami(1986) reported that both leaf length and breadth followed by number of tillers had high direct positive effect on grain yield.

De and Roy (1986) in a study of rice varieties under semi-deep situation revealed that ear bearing tillers per m^2 had direct effect on yield followed by number of grains per panicle and other characters were found to have direct positive effect on yield.

Reuben and Kisanga (1989) conducted an experiment taking 12 upland advanced breeding lines of rice, to study the path coefficient analysis of phenotypic correlation and concluded that grain yield is greater influenced by panicles per m^2, proportion of sound matured grains per panicle, panicle weight and panicle length in that order.

In a study on partitioning of correlation coefficients into direct and indirect effects, taking

60 fixed cultures of rice Sardana et al.(1989) found that panicles per m^2 panicle length, days to 50% flowering, days to maturity and plant height were the most important attributes of yield.

Ibrahim et al.(1990) studied the direct and indirect association of four yield components with grain yield measured in drought tolerant lines MDVI, Browngora, BR 319-1, OS_4, E_{45}, C_{22}, OS_6, IR 12979-24-2-8, UPLR 5, UPLR 7, Azuuna, N_{22}, Kalakeri and the local control variety PKM_1 and reported that productive tillers had high direct effects on grain yield while panicle length and flowering duration had moderate direct effects. The effect of plant height was slightly negative.

Genetic divergence

A number of workers like Ram and Panwar, (1970); Vairavan et al.(1973); Maurya and Singh (1977); Singh et al.(1979); Kanwal et al.(1983); Kotaiah et al.(1986) De and Surya Rao (1987) used Mahalanobis's D^2 statistic effectively in assessing genetic divergence in rice.

Ram and Panwar (1970) in their study with japonica rices, reported that the D^2-statistic was effective in discriminating the two races; races of early, medium and late maturing duration; varieties of

China, Japan and Taiwan; and rices of hills from those of plains among Indian varieties. They further concluded that there was a fair degree of correspondence between genetic diversity and geographical origin.

With a view to study the nature of genetic divergence among 190 rice varieties from North-East India along with three indica and one japonica varieties as standards Vairavan et al.(1973) used D^2-statistic and canonical analysis on the characters. They concluded that there was no good correspondence between the two methods in grouping of the varieties or in relating genetic divergence to geographical distribution. However, both the techniques distinctly discriminated japonicas from indicas; all the same there were groups of intigrades between the two races.

No correspondence between genetic divergence through D^2-statistic and geographical origin was observed by Singh et al.(1979), Kanwal et al.(1983); Singh (1983); and Singh et al.(1987); while Nagesh (1976) reported some degree of relationship between geographical distribution and genetic diversity. Rao et al.(1981) reported that clustering pattern of the 120 rice varieties included in their study generally followed the geographical distribution of the entries.

Mahajan <u>et al</u>.(1981) assessed genetic divergence among 60 derivations of 14 rice crosses involving 28 parents and found them grouped into 18 different clusters. Most of the derivatives constelling together were found to be of the same parentage.

Table 1, summarises findings on characters contributing greatly towards genetic divergence in rice. The order of importance of characters contributing to divergence varied greatly depending upon the number of varieties or genotypes and number of characters analysed. However, in majority of cases, plant height and days to flowering contributed most towards genetic divergence.

Kotaiah <u>et al</u>.(1987) analysed results of 36 long duration genotypes of rice for grouping by D^2 statistic and meteroglyph analysis and found that the genotypic constellations were 10 by D^2 and 8 by meteroglyph. Days to 50% flowering and 100-grain weight were the main contributors to total divergence. The comparative study of these methods indicated that meteroglyph was suitable for preliminary grouping before taking up the D^2 analysis.

Table 1. Characters contributing to genetic divergence in rice

Characters in order of contribution to divergence	No.of genotypes tested	No.of characters studied	Prepared by
Days to maturity, plant height and tiller number	18	4	Ram and Panwar (1970)
Plant height, leaf area, 100 grain weight and amylose content	194	10	Vairavan *et al*.(1973)
Flowering time, 100 grain weight and height	26	6	Das and Borthakur(1973)
Days to maturity, plant height and tiller number	43	12	Maurya and Singh (1977)
Plant height, area of the 2nd leaf, length of the first internode and 100 grain weight	34	12	Singh *et al*.(1979)
Panicle density, seed volume, L/B ratio of grain, 100 grain weight and tiller number	54	15	Palanichamy and Siddiq(1979)
Grain yield, days to maturity and days to heading (77.8%)	35	6	Singh (1981)
Plant height, panicle sterility and grains per panicle	32	6	Singh (1983)
Panicle weight (52.9 %), days to maturity, plant height and grain size	100	12	Kanwal *et al*.(1983)
Days to 50% flowering (34.76 %), grain breadth, plant height, grain protein % and grain length	26	13	Kotaiah *et al*.(1986)
Days to 50 % flowering (75.39 %), 100 grain weight and plant height.	90	11	Bastia (1986)
Grain length, grain weight, plant height and grain number	12	12	Mahapatra (1988)
Days to 50 % flowering and panicle exertion	15	15	Roy (1990)

De and Rao (1987) in a study of genetic divergence under low land situation reported the absence of relationship between geographical distribution and genetic divergence. The sterility percentage, ear bearing tillers/hill, yield/m^2, length and breadth of grains were the major potents of variables to influence the genetic divergence.

Singh *et al*.(1987) classified fifty low land rice cultivars into 10 clusters using D^2 analysis of 15 characters related to yield. Cluster I (23 cultivars), II (8) and III (7) were the largest and together accounted for more than two-thirds of the total population.

Sun and Xu (1988) reported that the contribution of first 4 principal components. The total diversity of the population was 84.8% in an analysis of 10 quantitative characters of 49 rice cultivars. Using cluster analysis the cultivars were grouped into 9 clusters with genetic distances (D^2) of 364.26 between the farthest pair and 22.9 between the nearest pair of clusters.

No research publications on the clustering pattern of rice genotypes over environments are available. However, works on crops like wheat (Somayajulu *et al*.1970; Jatsara and Paroda, 1978); pearl millet (Upadhyay and Murty,1970) and chick pea (Jain *et al.* 1981) indicated that the number of clusters and their constitution varied greatly from one environment to the other.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

With the objective of assessing relative performance, character association, character contribution and genetic divergence of late maturity breeding lines an experiment was laid out in transplanted low land condition.

Experimental Material

The experimental material consisted of 40 elite breeding lines of different cross combinations. The details of the parentage and origin of the test entries are presented in Table 2. The experiment was conducted at the Rice Research Station, Bhubaneswar during kharif 1990. The field lay out was in randomised complete block design with three replications. Nursery sowing and transplanting were done on 27.6.90 and 25.7.90 respectively. The plot size was seven, 40 single plant hill rows with spacing of 15 x 20 cm. The prescheduled fertilizer management practices were followed in the experiment with the fertilizer dose of 80:40:40 N:P:K .

Characters studied

Observations on 10 metric characters like days to 50% flowering, plant height, panicle length, panicle number, number of grains per panicle, spikelet fertility,

Table 2. Designation, parentage and origin of breeding lines

Sl No.	Designation	Parentage	Origin
1.	OR 612-11	Jagannath/OR 1102	O.U.A.T.
2.	OR 666-ST-2	OR 1102/FR 13A	-do-
3.	OR 856-ST-62	(CR 1009/FR 43B)//IR 19661-131-1-3-1-3	-do-
4.	OR 856-ST-63	(CR 1009/FR 43B)//IR 19661-131-1-3-1-3	-do-
5.	OR 856-ST-66	(CR 1009/FR 43B)//IR 19661-131-1-3-1-3	-do-
6.	OR 869-ST-12	IR 38329/IR 19661-131-1-3-1-3	-do-
7.	OR 869-9 -25	IR 38329/IR 19661-131-1-3-1-3	-do-
8.	OR 877-ST- 2	(IR 42/CR 1009)// IR 42	-do-
9.	OR 885-ST-22	(IR 42/CR 1009)// IR 38338	-do-
10.	OR 885-3-136	(IR 42/CR 1009)// IR 38338	-do-
11.	OR 885-3-138	(IR 42/CR 1009)// IR 38338	-do-
12.	OR 885-5-138	(IR 42/CR 1009)// IR 38338	-do-
13.	OR 888-5-31	(IR 9764-45-2-2/ IET 3257	-do-
14.	OR 888-13-39	IR 9764-45-2-2/ IET 3257	-do-
15.	OR 889-ST-45	IR 13426-19-2/ CR 1002	-do-
16.	OR 890-3-158	IR 13426-19-2/ IET 3257	-do-
17.	OR 890-4-159	IR 13426-19-2/ IET 3257	-do-
18.	OR 898-ST-12	IR 42/IR 19672	-do-
19.	OR 900-2-161	IR 42/BKN 6986-147-2	-do-
20.	OR 901-ST-1	IR 42/IR 17494-32-2-2-1-3-3	-do-
21.	OR 902-4-165	IR 42/CR 1009	-do-
22.	OR 909-7-92	IR 42/CR 1009	-do-
23.	OR 909-10-97	IR 42/CR 1009	-do-
24.	OR 909-12-99	IR 42/CR 1009	-do-
25.	OR 909-22-109	IR 42/CR 1009	-do-
26.	OR 909-29-116	IR 42/CR 1009	-do-
27.	OR 912-1	IR 17494/Jagannath	-do-
28.	OR 912-3	IR 17494/Jagannath	-do-
29.	OR 912-7-185	IR 17494/Jagannath	-do-
30.	OR 912-10-190	IR 17494/Jagannath	-do-
31.	OR 912-15-195	IR 17494/Jagannath	-do-
32.	OR 912-21-201	IR 17494/Jagannath	-do-
33.	OR 912-38-218	IR 17494/Jagannath	-do-
34.	OR 1092-ST-8	RD 19/CR 1009	-do-
35.	OR 1092-ST-10	RD 19/CR 1009	-do-
36.	OR 1092-ST-12	RD 19/CR 1009	-do-
37.	OR 645-18	Rajeswari/Jajati	-do-
38.	Savitri	Pankaj/Jagannath	C.R.R.I.
39.	OR 621-6	Pankaj/Mahsuri	O.U.A.T.
40.	OR 909-4-89	IR 42/CR 1009	-do-

100 grain weight, grain length/breadth ratio, grain yield per plant and plot yield were recorded on five competitive plants except for plot yield which was recorded on whole plot bases (8.4 m^2).

Days to 50% flowering (DF) was recorded when about 50% of the tillers in the experimental plot exhibited full emergence of the panicle.

Plant height (pH) was measured as the length from the base of the clump to the tip of the tallest panicle bearing tiller to the nearest centimetre and was recorded 25 days after flowering.

Panicle length (PL) was measured in centimetre from the ciliate base to the tip of the topmost spikelet in the panicle of the tallest tiller.

Panicle number (PN) was recorded as the number of panicles per clump.

Number of grains per panicle (GN) was recorded as the average number of fertile grains counted from the panicles of the main culms of the five sample plants.

Spikelet fertility (SF) was recorded as the percentage of fertile grains to total grains per panicle. This is calculated from the average number of fertile grains and the average number of total grains of five sample plants.

100 grain weight (GW) was recorded from the weight of 100 well filled grains at 14% grain moisture content.

Grain length/Breadth ratio (L/B) was recorded as the ratio of the length and breadth of the grains (average of 20 grains) as measured by a dial thickness gauge.

Grain yield per plant or per plant yield(GY) was recorded as the average grain yield of the five sample hills in gram.

Plot yield (PY) was tabulated to q/ha from the total yield of the experimental plot.

Statistical analysis

The data recorded were subjected to statistical analysis, based on sample means of the various characters under observation.

Analysis of variance

The analysis of variance was carried out separately for each trait following the procedures of randomised block design analysis (Panse and Sukhatme, 1954). Analysis of variance was done on the basis of the following model:

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

where, Y_{ij} = Phenotypic observation in the i^{th} genotype j^{th} replication.

m = General mean

g_i = Effect of the i^{th} genotype

r_j = Effect of the j^{th} replication

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

Table 3. Form of the analysis of variance and expected mean square in individual experiments

Source	df	MS	Expected mean sum of square
Replication	(r-1)	M_R	$\sigma_e^2 + g\,\sigma_r^2$
Genotype	(g-1)	M_G	$\sigma_e^2 + r\,\sigma_g^2$
Error	(r-1)(g-1)	M_E	σ_e^2

Mean, range, standard error and critical difference

Mean values of each character was worked out by dividing the totals by corresponding number of observations while the lowest and highest values for each character were taken as the range.

$$\text{Standard error of mean} = \sqrt{\frac{2EMS}{r}}$$

$$\text{Critical difference} = \sqrt{\frac{2EMS}{r}} \times \text{t value at error degrees of freedom at 5\% and 1\% levels of significance}$$

where,

r = Number of replications

EMS = Error mean sum of square

Coefficients of variation

From the structure of the analysis of variance

$$\text{Error variance} = \sigma_e^2 = M_E$$

$$\text{Genotypic variance} = \sigma_g^2 = \frac{M_G - M_E}{r}$$

$$\text{Phenotypic variance} = \sigma_p^2 = \frac{M_G}{r} = \sigma_g^2 + \frac{\sigma_e^2}{r}$$

The genotypic coefficients of variation (GCV) and the phenotypic coefficients of variation (PCV) were calculated by the formulae given by Burton (1952).

$$GCV = \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \times 100$$

$$PCV = \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \times 100$$

Heritability (Broad sense)

Heritability (h^2) estimate was worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953).

$$h^2 \text{ (broad sense)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Expected genetic advance

Genetic advance was estimated as per the formula suggested by Johnson, Rabinson and Comstock (1955).

$$GA = k.h^2.\ \sigma_p$$

where,

k = Selection differential in standard units which is 2.06 for 5% selection intensity.

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

$$\text{GA expressed as percentage of mean} = \frac{GA}{Mean} \times 100$$

Analysis covariance

The analysis of covariance between all possible pairs of characters was done on plot mean value following the procedures of Randomised Block Design Analysis (Panse and Sukhatme, 1954).

Table 4. Form of covariance and expected mean sum of products in individual experiments

Source	df	MP	Expected mean sum of products
Replication	(r-1)	$M_{R(xy)}$	$\sigma_{e(xy)} + g\ \sigma_{r(xy)}$
Genotype	(g-1)	$M_{G(xy)}$	$\sigma_{e(xy)} + r\ \sigma_{g(xy)}$
Error	(r-1)(g-1)	$M_{E(xy)}$	$\sigma_{e(xy)}$

$M_{R(xy)}$, $M_{G(xy)}$ and $M_{E(xy)}$ stand for mean sum of products between pairs of characters due to replication, genotypes and error respectively. From the structure of the analysis of covariance the following estimates were computed.

$$\text{Error covariance} = \sigma_{e(xy)} = M_{E(xy)}$$

$$\text{Genotypic covariance} = \sigma_{g(xy)} = \frac{M_{G(xy)} - M_{E(xy)}}{r}$$

$$\text{Phenotypic covariance} = \sigma_{p(xy)} = \frac{M_{G(xy)}}{r} = \sigma_{g(xy)} + \frac{\sigma_{e(xy)}}{r}$$

<u>Estimation of correlation coefficients</u>

Simple correlation coefficients were computed at genotypic and phenotypic levels between pairs of characters adopting the following formula:

$$\text{Genotypic correlation } (r_g) = \frac{\sigma_{g(xy)}}{\sigma_{g(x)} \times \sigma_{g(y)}}$$

$$\text{Phenotypic correlation} (r_p) = \frac{\sigma_{p(xy)}}{\sigma_{p(x)} \times \sigma_{p(y)}}$$

where,

$\sigma_{g(xy)}$ = Genotypic covariance between the two traits x and y

$\sigma_{p(xy)}$ = Phenotypic covariance between the two traits x and y

$\sigma_{g(x)}$ and $\sigma_{g(y)}$ stand for genotypic standard deviations for x and y respectively.

$\sigma_{p(x)}$ and $\sigma_{p(y)}$ stand for phenotypic standard deviation for x and y respectively.

To test the significance of correlation coefficients at phenotypic level, the estimated values were compared with the table value (Fisher and Yates, 1967) at (n-2) degrees of freedom at the 5 per cent and 1 per cent levels of significance.

Path coefficient analysis

The path coefficient analysis is a type of cause and effect relationship among the various correlated characters. Path coefficients were standardised partial regression coefficients which individually provide a measure of direct effect of the causal factors on the effect variable. These permit partitioning of the correlations between causal factor and the effect of variables into components of direct a nd indirect effects and thus give a better picture of the associations of the casual factors with the effect variable.

In the present investigation, grain yield per plot was taken as the 'effect' with other characters like days to 50% flowering, panicle length, panicle

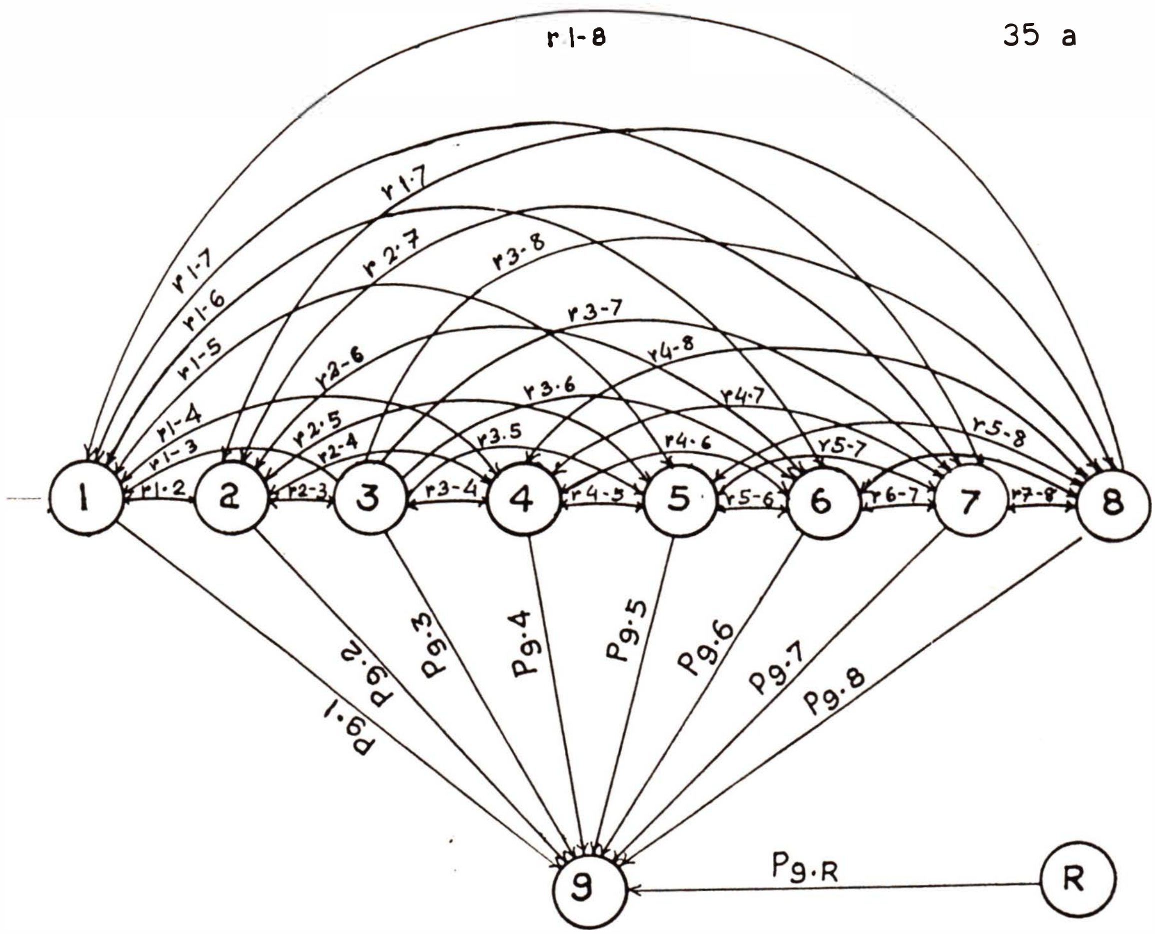

Fig.1. PATH DIAGRAM OF FACTORS INFLUENCING YIELD IN RICE

(1) DAYS TO 50% FLOWERING
(2) PLANT HEIGHT
(3) PANICLE NUMBER
(4) PANICLE LENGTH
(5) GRAIN NUMBER
(6) PANICLE FERTILITY
(7) 100 GRAIN WEIGHT
(8) GRAIN L/B RATIO
(9) SINGLE PLANT YIELD
R - RESIDUAL EFFECT

number, total number of grains, 100 grain weight, and grain yield per plant related to yield as the casual factors. The path coefficients were obtained by solving the following simultaneous equations which given the basic relationship between correlations and path coefficients in a system of correlated causes (Wright, 1971; Dewey and Lu, 1959).

$$r_{19} = P_{19} + r_{12}P_{29} + r_{13}P_{39} + \cdots\cdots\cdots + r_{18}P_{89}$$

$$r_{29} = r_{21}P_{19} + P_{29} + r_{23}P_{39} + \cdots\cdots\cdots + r_{28}P_{89}$$

$$r_{39} = r_{31}P_{19} + r_{32}P_{29} + P_{39} + \cdots\cdots\cdots + r_{38}P_{89}$$

. . . .

. . . .

$$r_{89} = r_{81}P_{19} + r_{82}P_{29} + r_{83}P_{39} + \cdots\cdots\cdots + P_{89}$$

where, r_{ij} is the coefficient of correlation between i^{th} and j^{th} characters and P_{qi} is the path coefficient (direct effect of i^{th} character on yield (character-9).

The solutions for path coefficients, direct and indirect effects of the casual factors were estimated as the values of the individual terms of the above equations in R.H.S.

The coefficient of determination (R^2) and the residual effect ($P_{9.R}$) were calculated as follows:

$$1 = P_{9.R}^{2} + \Sigma P_{iy} r_{iy}$$

$$R^{2} = \Sigma P_{iy} r_{iy}$$

$$= P_{19} r_{19} + P_{29} r_{29} + P_{39} r_{39} + \cdots\cdots\cdots + P_{89} r_{89}$$

Hence, $P_{9.R} = \sqrt{1 - R^{2}}$

The path analysis at the phenotypic level with the same cause and effect relationship was computed using the phenotypic correlations as stated earlier.

Genetic divergence

After testing for difference between varieties for each of the 9 characters except plot yield a simultaneous test of significance of difference in mean values of the 9 correlated variables for the forty breeding lines was carried out using Wilk's Lambda(Λ) criterion (Wilks, 1932) and V-statistic (Rao, 1952).

Genetic divergence was computed by using Mahalanobis' generalized distance, D^2-statistic, as described by Rao (1952). The original measurements were transformed to standardised uncorrelated variables by pivotal condensation (Rao, 1952). The divergence between any two varieties was obtain as the sum of squares of the differences in the values of the corresponding transformed values (Y_{ij}).

$D^2_{ij} = \sum_{i=1}^{k} (Y_{i1} - Y_{j1})$ gives the D^2 between i^{th} and j^{th} varieties for K characters. The all possible 780 pairs of D^2 were calculated from the forty breeding lines. Following Tocher's method as described by Rao (1952), the genotypes were grouped into clusters. Inter- and intra-cluster distances were determined and their relationship was diagramatically represented. Canonical analysis was done according to Anderson (1958). The divergence of forty genotypes of rice was represented in a two dimensional graph using the first two canonical vectors (Z_1 and Z_2) as co-ordinates.

CHAPTER IV

RESULTS

EXPERIMENTAL RESULTS

Assessment of relative performance, variability, character association, path analysis and genetic divergence among 40 low land breeding lines including the check variety Savitri were the objectives of the experiment. The results obtained are presented in the following paragraphs.

ANALYSIS OF VARIANCE

The analysis of variance is presented in Table 5. It was observed that the breeding lines differed significantly in respect of all the ten characters. The magnitude of significance were high for number of grains per panicle, days to 50% flowering and plant height in that order and might be due to sensitive nature of the characters in low land environment.

The mean, range, genotypic coefficient of variation (GCV), phenotypic co-efficient of variation (PCV),cœfficient of variation (CV),broad sense heritability and genetic gain per generation as percentage of mean are presented in Table 6. The mean performance of genotypes clearly spelt out the abundant scope for selection befitting low land ecosystem. Wider range in grain number per panicle (85.7 to 175.2), per

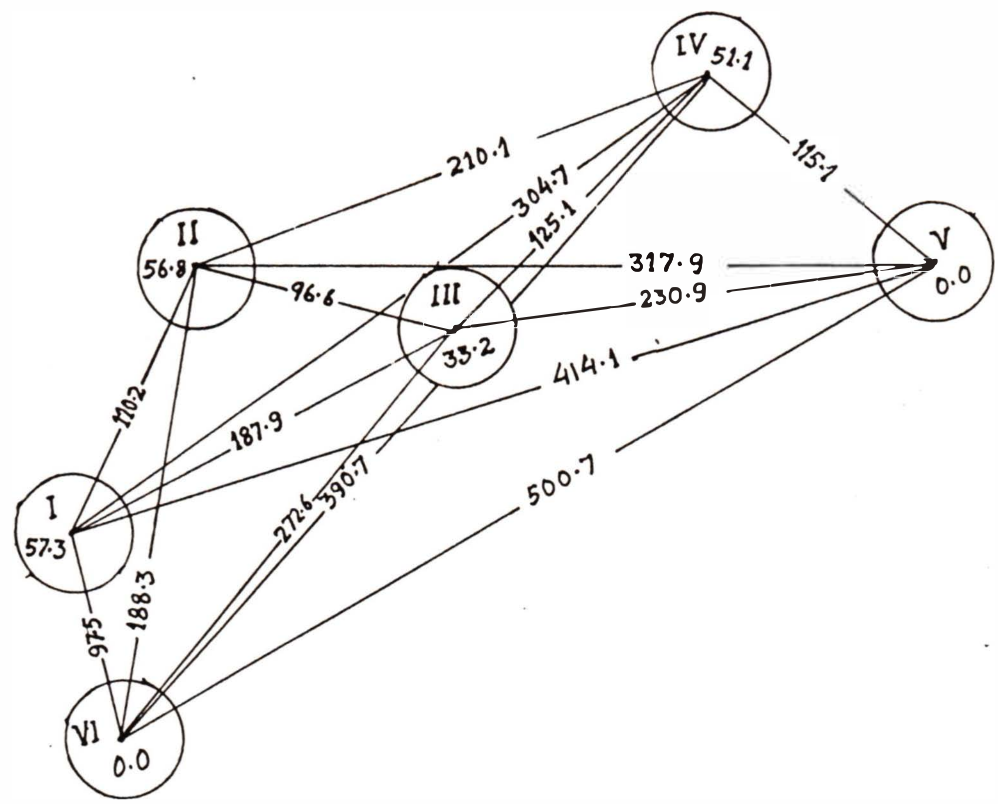

Fig.2. Relative dispersion of genotypes under divergent clusters showing average genetic distance between and within them.

Table 5. Analysis of variance for 10 characters in forty lowland breeding lines

Characters	Mean sum of squares		
	Replications (2)	Genotypes (39)	Error (78)
Days to 50% flowering	0.625	240.676**	0.556
Plant height	1.313	162.590**	1.314
Panicle number	49.552	7.956**	3.708
Panicle length	22.430	9.111**	1.554
Grain number	1952.313	1263.679**	370.027
Panicle fertility	5.938	21.458**	0.929
100 grain weight	0.001	0.203**	0.001
Grain L/B ratio	0.001	0.357**	0.000
Per plant yield	58.758	13.871**	5.647
Plot yield	4.254	1.296**	0.488

** Significant at 1% level of probability.

Figures in the parentheses indicate degrees of freedom of respective sources of variation.

Table 6. Mean, range, genotypic and phenotypic coefficients of variation, coefficient of variation, heritability and genetic advance of 10 characters in forty low land rice breeding lines

Characters	Mean	Range	GCV	PCV	CV	h^2	GA
Days to 50% flowering	123.41	108.3 to 145.0	7.25	7.27	0.60	99.31	18.36
Plant height	109.40	96.1 to 127.1	6.70	6.78	1.04	97.61	14.92
Panicle number	9.98	7.1 to 15.3	11.93	22.69	19.30	27.63	1.29
Panicle length	24.88	22.4 to 28.4	6.55	8.11	5.00	61.84	2.57
Grain number	119.60	85.7 to 175.2	14.43	21.61	16.08	44.60	23.74
Panicle fertility	88.36	80.2 to 94.0	2.96	3.15	1.09	88.04	5.06
100 grain weight	2.30	1.8 to 2.9	11.26	11.36	1.52	98.21	0.53
Grain L/B ratio	3.04	2.4 to 4.0	11.33	11.35	0.52	99.79	0.71
Per plant yield	11.98	8.9 to 18.0	13.82	20.17	19.82	32.68	1.95
Plot yield	2.74	1.3 to 4.2	18.92	31.73	25.47	35.58	0.64

plant yield (8.9 to 18.0 g) and plot yield (1.3 to 4.2 q/ha) superimposed an high level of panicle fertility (>85 per cent) further strengthens the possibility of isolating superior lines for lowlands.

COEFFICIENTS OF VARIATION

A good degree of correspondence was observed between GCV and PCV in respect of all characters except for panicle number, grains per panicle, per plant yield and plot yield. This might be due to extreme sensitive nature of the characters to lowland conditions. Further, it was observed that the magnitude of GCV was as low as 2.96 in panicle fertility. However, on the basis of C.V. estimates, the characters can be grouped into three distinct classes.

* Characters like days to 50% flowering, plant height, panicle length, panicle fertility, 100 grain weight, L/B of grains can be regarded to low variable characters (CV less than 10%).
* Characters like panicle number, grains per panicle, and per plant yield might be considered as moderately variable characters (CV less than 20 per cent).
* Plot yield showing more than 20 per cent C.V. value can be considered as highly variable a character under study.

HERITABILITY

The heritability estimates (broad sense) ranged from 27.63 per cent in panicle number to 99.79 per cent in length breadth ratio of grains. Characters exhibiting more than 80 per cent heritability estimates were L/B ratio of grains (99.79%), days to 50 per cent flowering (99.31 per cent), 100 grain weight (98.21%), plant height (97.61%) and panicle fertility (88.04%). Moderately heritable characters were panicle length (61.84%) and grains per panicle (44.60%) while characters showing low heritability estimates were panicle number (27.63%), per plant yield (32.68%) and plot yield (35.58%). However, the general trend of heritability estimates intrigues chance for selecting superior genotypes favouring lowland adaptation.

GENETIC ADVANCE

The estimates of genetic gain ranged from minimum of 0.53 per cent in 100 grain weight to 23.74 per cent in grain number per panicle. Added to this, days to 50 per cent flowering and plant height exhibited 18.36 and 14.92 per cent genetic gain respectively indicating possibility of further improvement in these characters for lowland handicapped situations.

MEAN PERFORMANCE

The mean performance of the breeding lines are presented in Table 7. Five best breeding lines on the desirable limits for various characters are presented in Table 8.

Plot yield

The yield range of the breeding lines varied from 1.29 q/ha to 4.17 q/ha as expected of the handicapped lowland environment. The highest yield (4.17 q/ha) was obtained in OR 912-10-190 as against the check variety Savitri yielding 3.85 q/ha. The lowest yielder was OR 901-ST-1(1.29 q/ha) which has been screened as a submergence tolerant breeding line. The highest yield of OR 912-10-190 might be due to highest per plant yield (18.00 g) and moderately high 100 grain weight (2.70 g).

Per plant yield

The yield per plant of the breeding lines ranged from 8.87 g in OR 856-ST-62 to 18.00 g in OR 912-10-190. The mean per plant yield was as low as 11.98 g slightly higher than that of the lowest yielding line. It is apparent that the per plant yield might be the major

Table 7. Mean performance of breeding lines under low land condition

Varieties	DF	PH	PN	PL	GN	PF	GW	L/B	GY	PY
1. OR 612-11	125	106.47	8.27	22.50	139.47	87.74	2.32	2.65	9.53	2.62
2. OR 666-ST-2	127	106.30	10.47	25.07	119.80	88.90	2.38	2.64	12.47	2.86
3. OR 856-ST-62	130	113.13	8.60	24.93	131.80	88.77	2.17	2.48	8.87	1.61
4. OR 856-ST-63	139	125.47	8.97	25.80	141.67	90.10	1.79	2.89	10.07	2.62
5. OR 856-ST-66	145	127.13	8.40	23.43	122.07	89.20	2.18	2.77	9.73	2.14
6. OR 869-ST-12	121	112.77	10.70	27.40	129.73	89.32	2.37	3.03	12.40	3.25
7. OR 869-9-25	139	114.30	9.47	27.90	123.60	88.53	2.39	3.25	13.87	3.59
8. OR 877-ST-2	115	107.40	9.07	25.20	98.47	89.90	2.55	3.36	10.60	2.54
9. OR 885-ST-22	121	118.33	9.80	23.83	98.47	89.40	2.34	3.30	10.60	2.44
10. OR 885-3-136	115	116.77	10.97	27.90	130.47	89.83	2.23	4.01	12.47	2.96
11. OR 885-3-138	115	102.57	8.60	26.00	91.20	87.17	2.31	3.81	9.80	2.30
12. OR 885-5-138	114	105.83	9.43	24.47	106.20	89.80	2.12	2.89	9.93	2.32
13. OR 888-5-31	119	110.23	7.70	28.33	122.33	89.71	2.34	2.83	9.13	2.04
14. OR 888-13-39	139	121.27	9.33	28.43	120.27	89.54	2.38	2.99	10.87	2.70
15. OR 889-ST-45	120	103.77	13.80	23.50	117.53	89.25	2.57	3.15	16.07	3.65
16. OR 890-3-158	116	107.47	9.13	24.80	105.87	87.42	2.48	4.03	12.07	3.07
17. OR 890-4-159	121	111.93	9.97	27.10	128.33	90.65	2.57	3.62	11.80	2.94
18. OR 898-ST-12	115	109.30	8.70	26.53	160.47	90.32	2.25	2.98	10.27	2.14
19. OR 900-2-161	119	106.57	11.83	25.13	108.27	88.60	2.32	2.81	13.73	3.41
20. OR 901-ST-1	109	106.43	7.13	25.50	106.13	91.67	2.55	3.62	8.87	1.29
21. OR 902-4-165	121	107.80	10.13	25.80	122.27	89.49	2.04	3.16	12.20	2.94
22. OR 909-7-92	122	103.47	9.37	23.07	98.07	89.23	2.27	2.77	11.40	2.86
23. OR 909-10-97	129	97.10	9.67	23.27	98.73	85.70	1.93	2.95	11.60	2.86
24. OR 909-12-99	119	105.57	9.40	25.83	117.00	88.35	2.23	2.44	11.47	1.98
25. OR 909-12-109	131	121.67	8.87	26.27	131.67	91.00	2.14	3.25	10.47	2.24
26. OR 909-29-116	119	110.20	10.30	26.40	119.27	90.25	2.16	3.02	13.40	3.45
27. OR 912-1	115	105.97	9.30	25.03	111.53	88.51	2.73	2.73	11.60	2.04
28. OR 912-3	114	112.57	9.63	25.57	121.33	93.39	1.97	3.13	10.93	2.02
29. OR 912-7-185	121	109.57	9.67	23.27	90.27	85.80	2.67	3.26	11.60	2.42
30. OR 912-10-190	127	106.77	15.30	24.87	108.47	83.60	2.70	3.32	18.00	4.17
31. OR 912-15-195	121	99.07	12.00	22.93	88.80	84.42	2.68	2.95	14.83	3.47
32. OR 912-21-201	125	101.87	10.37	24.60	96.87	86.43	2.65	3.17	13.53	2.78
33. OR 912-38-218	121	103.77	10.43	22.40	85.73	80.17	2.90	3.23	13.53	2.82
34. OR 1092-ST-8	140	120.53	10.13	22.53	125.67	85.37	2.19	3.22	12.93	3.25
35. OR 1092-ST-10	126	119.20	11.87	22.90	128.33	82.56	2.07	3.10	14.20	3.17
36. OR 1092-ST-12	138	107.13	9.23	22.53	113.00	87.90	2.22	2.71	11.13	2.46
37. OR 645-18	108	106.13	8.37	22.57	159.93	94.04	1.82	2.93	10.60	2.04
38. Savitri	135	96.10	12.63	23.57	135.80	88.40	2.25	2.49	16.07	3.85
39. OR 621-6	121	107.67	12.50	24.03	175.20	86.80	2.16	2.80	15.87	4.05
40. OR 909-4-89	121	100.37	9.57	24.33	153.73	87.30	1.97	2.90	10.87	2.68
Mean	123	109.40	9.97	24.88	119.59	88.60	2.30	3.02	11.98	2.73
S.D.	8.96	7.36	1.63	1.74	20.52	2.97	0.27	0.34	2.15	0.66

contributing character to the plot yield.

Days to 50% flowering

The number of days to 50 per cent flowering ranged from 108 days in OR 645-18 to 145 days in one of the submergence tolerant lines OR 856-ST-66. The mean flowering duration was 123 days. It was observed that 14 out of 40 breeding lines were found to flower earlier than 120 days which is considered as an undesirable expression for the lowland environment. However, the highest yielding line OR 912-10-190 flowered in 127 days while the latest flowering line mentioned earlier yielded only 2.14 q/ha. It seems that longer duration is not a guiding factor for high yield.

Plant height

The plant height ranged from 96.10 cm in Savitri to 127.13 cm in OR 856-ST-66. The mean plant height of the breeding lines was tabulated to be 109.40 cm. For sustenance of lowland stress environment, an intermediate height is desirable which has recorded in 22 out of 40 test entries (more than 100 cm but less than 110 cm). The top yielding line OR 912-10-190 grew 107 cm.

Pancile number per plant

The panicle number per plant ranged from 7.13 in OR 901-ST-1 to 15.3 in OR 912-10-190, the highest yielding line. Despite the fact the tillering ability in lowland varieties is inhibited for obvious reasons of high water stagnation. There were 15 out of 40 lines produced more than 10 panciles per plant as against overall mean of 9.97 and seems to be an indication of better morphogenetic manifestation.

Pancil length

The pancile length ranged from 22.40 in OR 912-38-218 to 28.43 cm in OR 888-13-39. The mean length of panicle was tabulated to be 24.88 cm. It is interesting to note that 22 out of 40 lines crossed the overall mean limit and the highest yielding line OR 912-10-190 was at per with the overall mean.

Grain number per panicle

The grain number per panicle ranged from 85.73 in OR 912-38-218 to 175.20 in OR 621-6. The mean grain number was around 120. It was observed that 19 lines exceeded the overall mean limit. The highest yielding line was found to produce only

108.47 grains per panicle.

Pancile fertility

Invariably the fertility was found to be higher than 80 per cent in all the test lines. It was lowest (80.17%) in OR 912-38-218 and 94.05% in the earliest maturing line OR 645-18. As is desirable the panicle fertility should not be less than 85 per cent while in the present experiment it was observed 4 lines produced less than 85 per cent fertile grains per panicle and the highest yielding line OR 912-10-190 was among them.

100 grain weight

The 100 grain weight ranged from 1.82 g in the earliest maturing line OR 645-18 to 2.90 g in OR 912-38-218. The mean 100 grain weight was 2.3 g and 20 lines produced less than the overall mean.

L/B ratio of grains

L/B ratio of grains ranged from 2.44 in OR 909-12-99 to 4.03 in OR 890-3-158. The average L/B ratio was 3.02 indicating that the commercial grade of grains in most of the breeding lines was towards long slender types.

Table 8, depicts five best entries in all the ten characters pertaining to desirable expressions. It was observed that the lines OR 912-10-190, OR 621-6 and OR 912-15-195 appeared in four characters while OR 888-5-31, OR 890-4-159, OR 889-ST-45, Savitri in three of the 10 characters, OR 912-7-185, OR 869-9-25, OR 645-18, OR 901-ST-1 appeared in two out of ten characters and rest of the entries found to appear once in one or the other character. However, OR 912-10-190 producing highest grain yield is considered as promising compared to OR 621-6 or OR 912-15-195. Considering per plant and plot yield, selection for OR 912-10-190, OR 621-6, OR 889-ST-45, Savitri and OR 869-9-25 might prove rewarding.

CHARACTER ASSOCIATION

The genotypic and phenotypic correlation coefficients among various characters are presented in Table 9, Out of 90 pairs of estimates for genotypic and phenotypic correlations 15 associations were found to be significant at 1 per cent level of significance and 5 were significant at 5 per cent level. There was close correspondence between the level of significance either at genotypic or at phenotypic levels indicating

Table 8. Five best breeding lines in lowland experiment for 10 characters

Characters	Desirable expression	Overall mean	Five best genotypes
Days to 50% flowering	125 days	123.41	OR 909-7-92, OR 835-ST-22, OR 912-15-195, OR 888-5-31, OR 902-4-165.
Plant height	110 cm	109.40	OR 898-ST-12, OR 912-7-185, OR 909-29-116, OR 885-5-31, OR 890-4-159.
Panicle number	Moderate	9.97	OR 912-10-190, OR 889-ST-45, OR 621-6, OR 912-15-195, Savitri.
Panicle length	Long	24.88	OR 888-13-39, OR 888-5-31, OR 885-3-136, OR 869-9-25, OR 869-ST-12,
Grain number	High	119.59	OR 621-6, OR 645-18, OR 612-11, OR 909-4-89, OR 856-ST-63.
Panicle fertility	High	88.60	OR 645-18, OR 901-ST-1,OR 912-3, OR 909-12-109, OR 890-4-159.
100 grain weight	High	2.30	OR 912-38-218, OR 912-10-190, OR 912-1, OR 912-15-195, OR 912-7-185.
Grain L/B ratio	High	3.02	OR 890-3-158, OR 885-3-138, OR 890-4-159, OR 901-ST-1, OR 877-ST-2.
Per plant yield	High	11.98	OR 912-10-190, OR 889-ST-45, OR 621-6, OR 912-15-195,Savitri.
Plot yield	High	2.73	OR 912-10-190, OR 621-6, Savitri, OR 889-ST-45, OR 869-9-25.

selection on phenotypic basis might prove equally effective as selection on genotypic basis.

It was observed that the plot yield was significantly associated with panicle number per plant both at genotypic and phenotypic levels. Also, plot yield exhibited high degree of association with panicle fertility only at genotypic level while with per plant yield both at genotypic and phenotypic levels.

Per plant yield exhibited high significant association with panicle number both at genotypic and phenotypic level, but with panicle fertility at genotypic level only. However, the per plant yield showed positive association with panicle fertility at the phenotypic level also (5% level).

Days to flowering exhibited high positive correlation with plant height but nonsignificant association with rest of the characters. Plant height exhibited positive association with panicle length at the genotypic level but negative association with per plant yield. Panicle number exhibited high negative association with panicle fertility.

Table 9. Estimates of genotypic (r_g) and phenotypic (r_p) correlation coefficients among characters under low land condition

Characters		PH	PN	PL	GN	PF	GW	L/B	GY	PY
DF	r_g	0.452**	0.128	-0.099	0.102	-0.252	-0.015	-0.280	0.176	0.300
	r_p	0.444**	0.055	-0.081	0.067	-0.240	-0.151	-0.280	0.082	0.165
PH	r_g		-0.303	0.338*	0.295	0.224	-0.030	0.076	-0.366*	-0.252
	r_p		-0.167	0.263	0.191	0.211	-0.296	0.074	-0.203	-0.147
PN	r_g			-0.254	0.026	-0.668**	0.037	-0.070	0.973**	0.999**
	r_p			-0.135	-0.054	-0.272	0.159	-0.037	0.914**	0.740**
PL	r_g				0.125	0.485**	0.001	0.188	-0.257	-0.138
	r_p				0.181	0.375*	0.015	0.148	-0.130	-0.072
GN	r_g					0.435**	-0.063	-0.418**	-0.050	0.087
	r_p					0.286	-0.427**	-0.273	-0.007	0.014
PF	r_g						-0.044	-0.063	0.673**	0.577**
	r_p						-0.048	-0.058	0.334*	0.315*
GW	r_g							0.029	0.046	0.026
	r_p							0.289	0.226	0.141
L/B	r_g								0.014	0.067
	r_p								0.010	0.043
GY	r_g									0.987**
	r_p									0.836**

* and ** significant at 5% and 1% level of probability respectively.

Panicle length exhibited high significant association with panicle fertility at genotypic level and positive association at phenotypic level (at the 5 per cent level of significant only).

Grain number per panicle exhibited high positive association with panicle fertility and high negative association with length/breadth ratio at genotypic level only. High negative association of grain number per panicle with 100 grain weight at phenotypic level was observed.

It may be noted that yield *per se* can apparently be the decissive character for selection of high yielding breeding lines adaptable to lowland conditions.

PATH ANALYSIS

In view of assessing the cause and effect relationship between *per se* yield and other characters, path analysis had been carriedout and the estimates presented in Table 10. The correlation of per plant yield was partitioned into components of direct and indirect effects which reflects on the nature of these associations and relative contribution of these components in determining yield. The phenotypic correlation coefficients were used for the path analysis.

Table 10. Direct (diagonal) and indirect effects of component traits on per plant yield in low land breeding lines at the phenotypic level

Traits	DF	PH	PN	PL	GN	PF	GW	L/B	Correlation with yield
DF	0.499	-0.184	0.058	0.018	0.005	-0.228	-0.009	-0.085	0.082
PH	0.221	-0.415	-0.117	-0.058	-0.015	0.200	0.018	0.022	-0.203
PN	0.027	0.069	1.063	0.030	0.004	-0.258	0.010	-0.011	0.914
PL	-0.040	-0.109	-0.143	-0.223	-0.014	0.356	-0.001	0.045	-0.130
GN	0.033	-0.079	-0.057	-0.040	-0.079	0.272	0.027	-0.083	-0.007
PF	-0.119	-0.087	-0.289	-0.083	-0.022	0.951	0.003	-0.017	0.334
GW	-0.075	0.123	0.169	-0.003	0.033	-0.045	-0.063	0.088	0.026
L/B	-0.139	-0.030	-0.039	-0.033	0.021	-0.055	-0.018	0.304	0.010

DF = Days to 50% flowering, PH= Plant height, PN= Panicle number, PL=Panicle length,

GN = Grain number/panicle, PF= Panicle fertility, GW=100 grain weight, L/B= Grain length/breadth ratio.

The direct effect of panicle number, panicle fertility, days to 50 per cent flowering and grain size (L/B) were observed in that order and were partially nullified through direct effects plant height, panicle length, grain number per panicle and 100 grain weight.

The indirect effect of per plant yield was in positive direction via panicle length, panicle number, panicle fertility, grain weight and L/B ratio while was found to be partially nullified via negative and indirect effects of plant height, panicle length and grain number. The path diagram of factors influencing per plant yield is presented in Fig.1.

GENETIC DIVERGENCE

Simultaneous variation in all the ten characters of 40 varieties were tested for assessing the nature of genetic divergence among them following D^2 analysis and canonical analysis.

D^2 analysis

The D^2 estimates corresponding to 780 possible paired values among forty genotypes were computed.

The D^2 value obtained for a pair of population was taken as the calculated value of x^2 and was tested against the tabulated value of x^2 at 10 degrees of freedom. The tabulated value of x^2 at 5 per cent level of significance for 10 degrees of freedom being 18.31 was lower than the calculated value of D^2 in all the cases, which clearly showed that all the D^2 values were significant. Thus, it would be worthwhile to classify the population into different genetic groups on the basis of the characters chosen.

The D^2 values ranged from 35.422 between the breeding lines OR 612-11 and OR 666-ST-2 to 250698.766 between OR 890-3-158 and 909-12-99. The genetic closeness between the breeding lines OR 612-11 and OR 666-ST-2 was apparently due to their matching plant height, fertility percentage, 100 grain weight and grain L/B ratio. On the other hand the maximum distance between OR 890-3-158 and OR 909-12-99 could be attributed to greater difference in characters like grain L/B ratio and number of grains per panicle Table 7.

Table 11, depicts average D^2 values of 10 characters for 39 paired wise combinations involving each of the 40 breeding lines alongwith percentage to total D^2 estimates. The high average D^2 values were observed for characters like yield per plant, grain L/B ratio and plot yield.

Table 11. Average D^2 values and percentage to total D^2 of the ten characters in forty lowland breeding lines

Characters	Average D^2 values	Percentage to total D^2
Days to 50% flowering	288.58	4.32
Plant height	102.76	1.54
Panicle number	14.72	0.002
Panicle length	6.21	0.0009
Grain number	3.05	0.0004
Panicle fertility	14.43	0.002
100 grain weight	156.02	2.33
Grain L/B ratio	812.02	12.15
Per plant yield	4538.54	67.88
Plot yield	749.03	11.02
Total	6685.36	

Clusering pattern

Following Tocher's method the 40 genotypes were grouped into six clusters and the average intra and inter-cluster distances were presented in Table 12. The scattered diagram indicating dispersion of genotypes under divergent clusters is presented in Fig. 2.

Cluster I consisted of 11 varieties and the constellation of these genotypes in one cluster was mostly due to their matching panicle number, fertility percentage, 100 grain weight and grain L/B ratio.

Cluster II constituted of 16 varieties and these genotypes showed more or less similar fertility percentage and grain L/B ratio.

Cluster III consisted of 8 genotypes and they exhibited similar grain L/B ratio only.

Cluster IV constituted of 3 genotypes apparently due to their matching fertility percentage and 100 grain weight.

Both cluster V and VI were monogenotypic clusters with OR 890-3-158 and OR 909-12-99 respectively. OR 890-3-158 discrimited itself from others by its highest grain L/B ratio. On the other hand OR 909-12-99 occupied a separate cluster apparently due to its lowest

Table 12. Average intra-(diagonal) and inter-cluster distance (D^2) among forty breeding lines

Cluster	I	II	III	IV	V	VI	Varieties in cluster
I	3279.2 (57.3)	12150.8 (110.2)	35298.5 (187.9)	92824.5 (304.7)	171414.9 (414.1)	9517.5 (97.5)	1, 2,3,5,13,19,22,27,36,38,39
II		3225.8 (56.8)	9339.9 (96.6)	44160.2 (210.1)	101109.8 (317.9)	35457.0 (188.3)	4, 6,10,12,14,15,18,21,23,26, 28,31,32,35,37,40
III			1104 .1 (33.2)	15635.8 (125.1)	53309.9 (230.9)	74302.7 (272.6)	7, 8, 9, 25, 29, 30, 33, 34
IV				2613.0 (51.1)	13243.3 (115.1)	152629.7 (390.7)	11, 17, 20
V						250699.0 (500.7)	16
VI							24.

Figures in the parentheses indicate the D^2 values.

Variety numbers given above are as listed in Table 2.

grain L/B ratio. Besides other characters, the L/B ratio of grains was apparently in decissive character for clustering pattern.

Intra-and inter-cluster distance

From the average intra-and inter-cluster distances presented in Table 12, it is evident that among the four multi-variety clusters, cluster III had the minimum intra-cluster distance (D^2 = 1104.1) and cluster I had the maximum intra-cluster distance (D^2 = 3279.2). The average inter-cluster distance revealed that the most divergent clusters were V and VI (D^2 = 250699.0) followed by I and V (D^2 = 171414.9) and IV and VI (D^2 = 152629.7). The least divergent clusters were II and III (D^2 = 9339.9).

Characteristic features of the clusters

Table 13 shows cluster means of ten characters. It is evident from this Table that cluster I consisting of 11 genotypes was characterised by highest grain number, longest flowering duration and shortest panicle types.

Cluster II with 16 genotypes was charactersied by its second highest grain number per plant yield and lowest 100-grain weight.

Table 13. Cluster means of ten characters in forty lowland breeding lines

Characters	Clusters					
	I	II	III	IV	V	VI
Days to 50% flowering	126.83	121.65	126.80	114.60	116.33	118.67
Plant height	108.15	109.30	112.75	106.93	107.46	105.57
Panicle number	9.82	10.18	,10.30	8.53	9.13	9.40
Panicle length	24.29	25.12	24.50	26.20	24.80	25.83
Grain number	125.23	124.68	107.76	108.53	105.87	117.00
Panicle fertility	88.50	88.81	86.68	89.76	87.42	88.34
100 grain weight	2.25	2.13	2.37	2.43	2.48	2.23
Grain L/B ratio	2.64	2.95	3.22	3.66	4.03	2.44
Per plant yield	11.73	12.10	12.67	9.80	12.06	11.47
Plot yield	2.68	2.73	2.88	2.13	3.07	1.98

The chief characteristic feature of cluster III was highest per plant yield, tallest plant height, highest panicle number and lowest panicle fertility.

Cluster IV excelled the other clusters by its highest panicle length and highest panicle fertility. Moreever, it exhibited lowest expression for characters like days to 50% flowering, panicle number and yield per plant.

Cluster V, a monogenotypic cluster was characterised by highest 100 grain weight, grain L/B ratio and lowest grain number per panicle.

Cluster VI was characterised by shortest plant height, lowest L/B ratio and lowest plot yield.

Canonical analysis

The canonical analysis was carried out in the present investigation and the contribution of the two canoncial roots were 97.5 and 2.1 percent respectively, together accounting for 99.6 percent of the total variability. The graphic presentation of the populations along the two axes Z_1 and Z_2 was shown in Fig.3. The groupings obtained through D^2 analysis were super imposed on the groupings by canonical analysis. The scattered points in Z_1-Z_2 graph were in good agreement with clustering by D^2 values following Tocher's method.

Table 14. Canonical vactors (Z_1 and Z_2) of characters in D^2 analysis

Characters	Z_1	Z_2
Days to 50% flowering	- 0.0380	- 0.0278
Plant height	0.0044	0.0008
Panicle number	- 0.0042	- 0.0050
Panicle length	0.0002	- 0.0007
Grain number	- 0.0043	- 0.0036
Panicle fertility	- 0.0051	- 0.0057
100 grain weight	0.0200	0.0221
Grain L/B ratio	0.8782	0.9704
Per plant yield	0.4425	0.2055
Plot yield	0.1787	0.1215

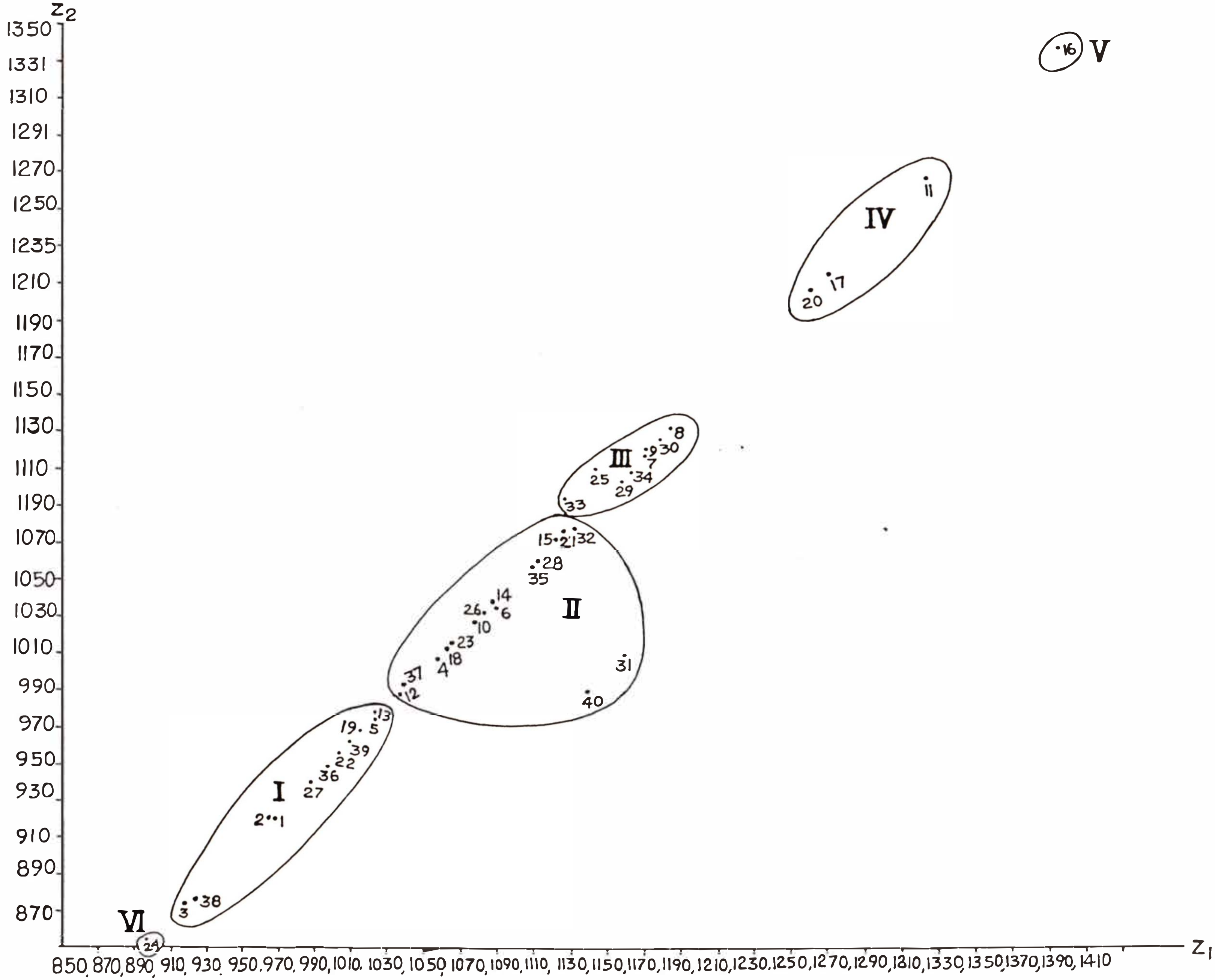

Fig.3. GROUP CONSTELLATIONS IN THE $Z_1 - Z_2$ GRAPH

Contribution of characters to genetic divergence

The relative importance of the characters contributing towards the divergence is reflected in the coefficients of the first two canonical vectors given in Table 14. Considering the Z_1 values, it was observed that the important characters responsible for genetic divergence in the major axis of differentiation were grain L/B ratio (2.878), yield per plant (0.442) and plot yields (0.179). This was in confirmity with the results obtained by D^2 analysis (Table 11). But the only difference is that yield per plant was the character contributing maximum towards genetic divergence in D^2 analysis, where as grain L/B ratio in canonical analysis.

CHAPTER V

DISCUSSION

DISCUSSION

Wide variation in morphogenetic characters is the key to success for selection of desirable plants aimed at producing higher yields. Rice is unique among all crop plants in that, natural selection brought enormous evolutionary diversity in every conceiveable character. Lowlands are a special ecological nitche coupled by handicapped environment like prolonged water stagnation and enaerobic microenvironment. Traditionally parental selection in any breeding programme is based on *per se* performance and is considered as a good index. The environment of selection, the quality of the environment in particular and the effectiveness of selection in lowland environment is being discussed in the context of the present investigation.

The plant type concept has been realised after Taichung (N) 1 and the form of the plant has been associated with function instead of physiologically efficient plant componets, involving the form. It is essential for the breeder to identify the plant type that is suited to specific agroclimatic complexes like lowlands (Balkrishna Rao *et al.*,1971).

In the present study the breeding lines developed through recombination breeding for lowland ecosystem indicate wide range of variation in respect of yield and characters influencing yield (Table 5,6 and 7).

Besides yield two other ancilliary characters like flowering duration and height deserve consideration for designing an appropriate plant type for lowlands. It is implicitly desirable to have flowering duration of 120 days and plant height of arround 110 cms for sustaining water-logged lowland stress. In the present study the flowering duration ranged from 108 days to 145 days and plant height from 96.10 cm to 127.13 cm showing ample possibility of selecting lines with desirable characters. Mention may be made of OR 912-10-190 which has shown better manifestation of yield through higher tillering ability, high panicle fertility and high *per se* yield and appreciable grain size (L/B ratio 3.92). Similar results have been reported by Shuka *et al*., (1972), Subramanian and Madhavmenon (1973) Sinha *et al.* (1990), Kaul and Kumor (1982), Amritha devarathinam (1983), Maurya *et al*.(1986), De and Surya Rao (1987), Sardane *et al*.(1989) and Roy (1990).

Pattern of variation

The discovery of single dwarf gene in some varieties in Taiwan and its use in developing new high yielding adaptable varieties has resulted in a major break though in tropical rice yields (Athwal, 1968). But limitations exist in developing suitable high yielding varieties for rainfed lowlands. In the present study attempts have been made to identify suitable lowland breeding lines that can produce satisfactory yield under rainfed lowland conditions.

The estimate of the extent of variability available in fixed breeding lines could be of amense value to efficiently identfy superior lines. In the present study genotypic and phenotypic variabilities have been workedout besides association of character and cause and effect relationships among various characters with *per se* yield.

The analysis of variance for each character indicated existance of significant difference among the breeding lines in respect of all characters (Table 5). Wide range of phenotynic variation observed in all the characters as indicated by the estimates of mean, range, GCV, PCV, CV, heritability and genetic advance (Table 6). Larger genotypic variations (more than 10 per cent) were observed in panicle number, grains per panicle, 100 grain weight, grain L/B ratio, per plant yield and plot yield which indicates the predominance of gene effect in expression of the characters. This, however, cannot reveal the true genetic worth of the breeding lines without sufficient reasonings through GCV, heritability and genetic advance estimates (Madhavameaon, 1973).

The characters showing more than 10 per cent GCV are likely to be influenced by the change in enviromental conditions and thus can be considered as indices to selection.

In the present study high estimates of heritability was observed in days to 50 per cent flowering, plant height grain L/B ratio and in 100 grain weight approaching 100 per cent mark. This indicates that criteria for selection might be chosen among these characters on the basis of phenotypic performance. Similar results have been reported by Ghosh et al.(1981) Chauhan and Tondon (1984). But such an estimate alone fails to indicate genetic progress as has been stated by Johanson et al. (1955).

Higher genetic advance (around 20 per cent) was observed in plant height and grains per panicle indicating the predominance of additive effects (Panse, 1957) which can be taken as unit characters for effective selection. High heritability (more than 90 per cent) with low genetic advance (around 1 per cent) was observed in 100 grain weight, Grain L/B ratio which indicates that these two characters are under the control of non-additive gene action. Ghosh *et al*.(1981), Kaul and Kumar (1982) and Gopinath *et al*.(1983) have reported similar results.

Character association

White House *et al*.(1958) stated that yield is an end product of multiplicative interaction between the yield components. So, there cannot be any definite gene system for yield. Genetical studies on association of yield components throw light on the evolutionary trend and direction of divergence in association among a group of characters and enables the breeders to plan for manipulating or accentuating the expression of characters channelizing towards higher yields. In the present study correlation coefficients at genotypic and phenotypic levels were computed (Table 9) for meaningful understanding of character contribution to yield *per se*.

In general, the genotypic correlation coefficients were higher than the phenotypic correlation coefficients. Several workers like Rao *et al*.(1976), Asrawal *et al*.(1978), Singh (1980) Sun(1982), Amrithadevarathinom (1983), Gopinath *et al*.(1984), Chauhan *et al*.(1986) and De and Rao (1987) have reported results of correlation studies in rice, but a total review on character association can not be generalised and thus seems inconclusive.

Plant height bears negative association with per plant yield and plot yield and might be due to the characteristic features of lowland and sybmergence tolerent rice genotypes.

Days to flowering, panicle number, panicle fertility and grain L/B ratio exhibited positive association with per plant yield and plot yield and thus, selection on the basis of these characters would be reliable.

Panicle number bears negative association with panicle length, panicle fertility and grain L/B ratio. Increase in panicle number and decrease in fertile grains per panicle might be due to imbalanced source and sink relationship. Similar association was also observed in case of panicle fertility with 100 grain weight. Chaudhury _et al_.(1973) have reported similar results on his study in 23 varieties of different groups of cultivated rices.

Path analysis of yield components

The relationship of per plant yield whether direct or indirect manifestation was further analysed by the method of path coefficient analysis. At the phenotypic level, the estimates of direct and indirect effects of various characters on per plant yield (Table 10) indicated that panicle number per plant panicle fertility, days to 50% flowering and grain size exerted direct positive effects. This supports the findings of Sree Rangaswamy _et al_.(1973). Contribution of plant height as a direct effect on yield was also observed by Sivasubramaniam and Madhavmenon (1973). The direct effects of other characters some of which were negative and dismal. The indirect effects were generally small with only a few exceptions like L/B ratio via grain weight, panicle length and plant height.

The indirect effects via days to flowering on yield was partially nullified by negative effects of plant height, grain number, panicle fertility and L/B ratio. The negative direct effect of plant height was found to be due to negative indirect effects of panicle number panicle length and grain number.

It was observed that high negative indirect effect of panicle fertility and L/B ratio via panicle number was not accountable. The direct negative effect of panicle length was more due to indirect negative effects of panicle number plant height, days to 50% flowering grain number and 100 grain weight.

Since the phenotypic correlation coefficient between panicle number and per plant yield is found to be almost equal to its direct effect the correlation explains existance of true relationship and direct selection through this trait could be effective (Singh and Kakar, 1977).

Genetic divergence

The multivariate analysis based on Mahalanobis' D^2 statistic is being used as a powerful tool for measuring genetic distance among the test genotypes. Published report of Murty and Arunachalam (1966), Anand and Murty (1968), Ramanujan *et al.* (1974) have emphasized the merit of D^2 statistic and canonical analysis for genetic grouping of germplasm. In the present study, the grouping by two multivariate techniques have shown good agreement. Being a numerical estimate, the multivariate technique has the added advantage over other criteria of permitting precise comparisons among all possible pairs of population in any given group. Since, the estimates are obtained from a study of potential genotypes themselves, the required information is available before deciding parents for future recombination breeding and thus can be used with advantage.

Hybrid deviativatives from divergent parents are found to be promising probably because of complementary interaction of divergent genes in the parents. The present study has revealed that OR 890-3-158 and OR 909-12-99 are the two genetically most divergent genotypes. As is found from the pedigree of these lines, the parantage is different. The parents involved in the cross are from diverse origins. Thus, confirm the findings of Nagesh(1976) and Rao *et al.*(1981). Therefore, as expected hybridization involving these two lines could be result oriented and expected to produce highly heterotic hybrids and wide variation in segregating generations favouring selection of superior progeny and/or transgressive segregants.

It is interesting to note that promising selections from a cross donot necessarily cluster togather but found to group separately. May it be reasonable to say that besides other factors, the selection criteria over generations proves operative in clustering pattern when breeding lines are considered.

It was observed that the characters like grain L/B ratio, yield per plant and plot yield had contributed appreciably to the group constellations of breeding lines. Similar results were reported by Palanichamy and Siddiq (1979), Singh (1981), Kanwal et al.(1983), Kotaiah et al. (1986). Hence selection of parents differing in those traits may be useful for the utilisation of these parents for heterosis breeding programmes in rice.

Breeding implication

It is redundant to say the misfit nature of semidwarf rice varieties in rainfed lowlands. The lowland ecology deserves special consideration for deciding appropriate plant types. As is evidenced from the present study that an intermediate plant height of around 110 cm and maturity duration of around 130 days are good enough to sustain lowland stress.

Since monsoon innundation is a recurrent threat to Kharif lowland rices incorporation of submergence tolerance is an imperative factor in future varieties . But as is seen in the present study, the submergence tolerant lines earmarked as ST in their designations are found to yield low. Hence improvement of these lines through recombination breeding is necessary. The high yielding attributes of OR 912-10-190, Savitri and may be transferred to the back ground of submergence tolerant lines.

Lines which are genetically more distant like OR 890-3-158 and OR 909-12-99 may be utilised for exploitation of heterosis in yield and characters influencing yield. Selection on the basis of good panicle features like more number of grains as opposed to high panicle number, high panicle fertility and higher grain weight through high L/B ratio might pay dividend in lowland breeding programmes.

CHAPTER VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The experiment was carried out with the primary objective of assessing the genetic variability, character association, path analysis and genetic diversity of 39 lowland breeding lines with Savitri as the check variety.

All the 40 genotypes were grown during Kharif, 1990, at the Rice Research Station, Bhubaneswar. The field layout was in Randomised block Design with three replications. The plot size was 8.4 m^2.

The 10 characters studied included days to 50% flowering, plant height, panicle length, panicle number, number of grains per panicle, fertility percentage, grain L/B ratio, per plant yield and the plot yield. Observations were recorded on randomly selected five competitive plants except for plot yield taking into account all the plants in the plot.

The analysis of variance showed highly significant difference among the genotypes for all the 10 characters.

Number of grains per panicle exhibited highest genetic variability (14.43%) while panicle fertility showed the lowest genetic variability of 2.96% (Table 6).

The broad sense heritability estimates showed highest and lowest heritability estimates for grain L/B ratio(99.79%) and panicle number (27.63%) respectively. This indicates that the low panicle number in lowland breeding lines is a major constraint in achieving higher yield.

The genetic gain per generation was highest for number of grains per panicle (23.74%) and lowest for 100 grain weight (0.53%) as recorded in Table 6.

The per plant yield and plot yield were associated with panicles per plant and panicle fertility both at genotypic and phenotypic level, while these were negatively associated with plant height and panicle length.

A significant positive correlation was observed between days to 50% flowering and plant height both at genotypic and phenotypic level. Days to 50% flowering showed negative correlation with panicle length, panicle fertility, 100 grain weight and L/B ratio.

Panicle number exhibited high negative correlation with panicle fertility while panicle length showed high significant association with panicle fertility at genotypic level. Grain number per panicle exhibited high positive association with panicle fertility at genotypic level but was negatively correlated with grain L/B ratio. High negative association between number of grains per panicle and 100 grain weight was observed at phenotypic level only.

The direct effect of panicle number, panicle fertility, days to 50% flowering and grain L/B ratio was partially nullified by panicle length, plant height and 100 grain weight. The indirect positive effect of per plant yield with panicle length, number of panicles per plant, panicle fertility, grain L/B ratio was partially nullified by the negative indirect effects of plant height, panicle length and number of grains/panicle.

By D^2 statistic and Tocher's method, the 40 breeding lines were grouped into six clusters. The cluster II was the largest cluster containing 16 breeding lines while cluster V and VI were monogenotypic clusters. The variety OR 890-3-158 occupied the monogenotypic cluster V for its highest grain L/B ratio where as OR 909-12-99 occupied cluster VI due to its lowest grain L/B ratio. Cluster I and III had the maximum and minimum intra-cluster distance respectively. Cluster V and VI were the most divergent clusters where as cluster II and III were the least divergent clusters.

Yield per plant was the character contributing maximum towards genetic divergence in D^2 analysis but grain L/B ratio contributed most in canonical analysis.

The divergent breeding lines OR 890-3-158 and OR 909-12-99 could be taken for hybridization for better manifestation of characters contributing to higher productivity.

Thus it may be concluded that

* The materials used in the present investigation lay ample oppertunity for further selection and isolation of high yielding lines. Mention may be made of OR 912-10-190.

* *Per se* performance is the best index for selection of high yielding lines.

* Characters like panicle number per clump and 100 grain weight are important in selecting superior lines.

* Panicle number, grains per panicle, 100 grain weight and grain size were found to be under predominance of gene effects, hence selection on the basis of these characters might prove effective.

* Late flowering is no guidance to selection of high yielding lines but overall mean flowering duration might be a good index.

* Panicle number per plant and panicle fertility are good indeces for selection of high yielding lines.

* Panicle number and panicle fertility exert high direct effect on <u>per se</u> yield.

* Origin of parents involved in the cross and selection criteria over generations are believed to be the major reasons of group constellations of the breeding lines.

* OR 890-3-158 and OR 909-12-99 are found to be the most divergent genotypes and can be effectively used in the future recombination breeding programmes of lowland.

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