GENETIC ANALYSIS OF HIGH YIELDING RICE VARIETIES OF DIVERSE ORIGIN

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**GENETIC ANALYSIS OF HIGH YIELDING RICE VARIETIES OF DIVERSE ORIGIN**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled **"GENETIC ANALYSIS OF HIGH YIELDING RICE VARIETIES OF DIVERSE ORIGIN"** is a record of research work done independently by Ms. **Vanaja, T.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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VANAJA, T.

Dedicated to
my
Husband and Son

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Rice is cultivated in about 42 mha in India under diverse agro-ecosystems, broadly classified into rainfed and irrigated. The average rice production in the country is around 1.9 tonnes ha^{-1}. Breeding for higher yield is of prime importance in rice, since it is the staple food of the people of India.

Since the release of semi-dwarf high yielding rice variety IR8 by the IRRI, rice yield potential has remained more or less constant (Singh, 1998). This plateau is evident in the yield records from several long term experiments, in which the most recent elite rice genotypes have been substituted, for earlier varieties. Despite this apparent yield barrier, the quest for higher yield potential continues. By the year 2000, global paddy production should go up to 560 million tonnes in order to meet the requirements of the population (Swaminathan, 1989).

As mentioned above, rice grain yield reached a plateau in the last few years. The narrow genetic base of the varieties used in breeding programmes seems to be the most important reasons for the yield plateau. It is hypothesized that the broadening of the genetic base of the breeding stocks will open new avenues in the improvement of yield and other traits of economic importance. So diversification of the maternal origin of future rice varieties, is imperative in breeding programmes. Hence the present investigation was directed towards the exploitation of indigenous and exotic varieties, which are of genetically diverse origin with wide wide adaptability and geographical distribution.

Yield attributing characters of different geographic origin recombine in different fashion in different genotypes leading to its high grain yield. The morphological architecture of the presently used high yielding varieties is not conducive in utilizing the available resources to maximise yield. Recombination of these yield attributes using plants of diverse origin is vital to make a break through in increasing the genetic yield potential of the present day high yielding rice varieties.

Any successful hybridization programme, for varietal improvement depends mainly on the selection of parents having wide genetic variability. Crosses between genetically diverse genotypes are likely to produce high heterotic expression in the F_1s and wide spectrum of variability in the segregating generations. Since yield is a complex character, the practice of unilateral selection often results in retrograde or less optimum progress in isolating superior genotypes. Therefore, the understanding of the inter-relationship of characters and their direct and indirect contributions towards yield plays a vital role in the development of appropriate selection criteria for the improvement of yield. Formulation of a selection index, based on the important yield components for isolating superior genotypes will go a long way in achieving this objectives.

In order to formulate efficient breeding programmes for improvement of yield, it is essential to characterise the nature and mode of gene action that determines the yield and its components. The success of any plant breeding programme depends to a greater extent the understanding of the genetic architecture of the population handled by the breeder. Basic information on the inheritance of various economic characters will help in choosing the appropriate method of breeding for effecting further improvement towards increasing the yield potential of the crop.

Heterosis breeding has immense scope in breeding programmes for increasing productivity of rice. Wild abortive (WA) cytoplasm, which was evolved in China, is the major source of male sterile cytoplasm so far identified. Constant use of this (WA) cytoplasm, has led to genetic vulnerability of hybrids to pests and diseases. Besides, break down of this male sterility system very often occurs in tropical climate. Hence identification of alternative source of cytoplasmic male sterility system, will be a turning point for a successful hybrid rice programme in the tropical countries.

Further, in rice, ideotype breeding is believed to offer great opportunities to enhance the yield potential (Khush, 1984).

Rice being the staple food of the population in South India, quality traits are of crucial importance for its general acceptance. Therefore, quality traits should be given due recognition during selection. Red rice, with intermediate amylose content which is non-sticky is preferred in South India, especially in Kerala.

Therefore, the present investigation was taken up with the following major objectives.

1. To assess the genetic variability in the genotypes of different eco-geographical origin.
2. To determine the genetic parameters like heritability, genetic advance and genetic gain of different quantitative and qualitative characters.
3. To determine the genotypic and phenotypic correlation between yield and yield components.
4. To find out the direct contribution and indirect effect of different yield component characters on yield.
5. Formulation of a suitable selection model.
6. Grouping the genotypes based on genetic distance.
7. To assess the general combining ability of selected parents for hybridization, specific combining ability and reciprocal combining ability of the crosses for yield, different yield attributes and important cooking quality parameters.
8. Identification of genotypes having cytoplasmic effect on yield and different yield contributing characters.
9. To determine the components of variances and nature of gene action.
10. To determine the heterotic effects for different characters.
11. To estimate the effect of inbreeding depression on yield and important yield contributing characters.

12. Identification of alternative source of cytoplasmic male sterile system suitable to tropical climate.
13. To estimate various genetic parameters using six parameter model.
14. To study the inheritance of rice kernel colour.
15. To isolate promising segregants from the F_2 and back cross generations for developing new ideotypes having high yield and qualities suited to Keralites and adaptable to various ecogeographical conditions of Kerala.

Review of Literature

2. REVIEW OF LITERATURE

An overview of works concluded in rice, in the aspects of genetic variability, genotypic and phenotypic coefficient of variation, heritability, expected genetic advance, correlation and path analysis, selection index, genetic divergence, combining ability analysis, heterosis, generation mean analysis and other related studies, is presented here under.

2.1 Genetic variability

Wide range of genetic variation in yield plant^{-1} was observed by Govindaswami *et al.* (1973), Shamsuddin (1986), Singh *et al.* (1986), Sardana and Sasikumar (1987), Chaubey and Richharia (1990) and Gomathinayagam *et al.* (1990). Singh *et al.* (1984) reported high genetic variability for the characters namely grains panicle^{-1}, panicles m^{-2}, days to maturity, number of spikelets panicle^{-1}, sterility percentage, 1000 grain weight, panicle length and plant height.

A wide variation in 1000 grain weight was observed by Govindaswami *et al.* (1973), Shamsuddin (1986), Sardana and Sasikumar (1987), Chauhan *et al.* (1989) and Chaubey and Richharia (1990). Chauhan *et al.* (1989) reported a wide range of variation in characters namely, grains panicle^{-1}, secondary branches panicle^{-1}, panicle length.

Substantial genetic variability for plant height was observed by Govindaswami *et al.* (1973), Singh *et al.* (1984), Singh *et al.* (1986), Sardana and Sasikumar (1987) and Chaubey and Richharia (1990). Shamsuddin (1986), Singh *et al.* (1986), Sardana and Sasikumar (1987) and Chaubey and Richharia (1990), indicated considerable genetic variation for the trait panicle length.

Wide range of variation in number of grains panicle^{-1} was reported by Shamsuddin (1986), Singh *et al.* (1986) and Sardana and Sasikumar (1987). Chaubey and Richharia (1990) reported high range of genetic variation for harvest index. A wide variation in flowering duration and leaf angle was reported by Singh *et al.* (1986). Variability in flowering duration was also reported by Govindaswami *et al.* (1973), Lal *et al.* (1983) and Sardana and Sasikumar (1987).

2.2 Genotypic and phenotypic coefficient of variation, heritability and expected genetic advance

Bhattacharyya (1978), Shamsuddin (1986), Remina *et al.* (1992) and Ganesan *et al.* (1995) revealed high estimates of genotypic and phenotypic coefficients of variation and heritability in broad sense and genetic advance for grain yield plant^{-1} in rice. High estimate of heritability and expected genetic advance for grain yield plant^{-1} was reported by Amirthadevarathinam (1983a), Singh *et al.* (1984), De and Rao (1988), Gomathinayagam *et al.* (1990), Bai *et al.* (1992) and Ramalingam *et al.* (1994). High heritability for yield was observed by Chaubey and Richharia (1990) and Patil *et al.* (1993). When Singh *et al.* (1986) observed low heritability for grain yield plant^{-1}, Anandakumar (1992) recorded moderate heritability for this character.

Bhattacharyya (1978), Shamsuddin (1986), Remina *et al.* (1992) and Ganesan *et al.* (1995) reported that the character, number of grains panicle^{-1} had high estimates of genotypic coefficient of variation, heritability and expected genetic advance. High expected genetic advance as percentage of mean associated with high heritability estimates were observed for the character number of grains panicle^{-1} by Singh *et al.* (1984), Pathak and Patel (1989), Lokaprakash *et al.* (1992) and Ramalingam *et al.* (1994). High heritability estimate for number of grains panicle^{-1} was also observed by Kihupi and Doto (1989) and Patil *et al.* (1993).

High estimates of genotypic coefficient of variation, heritability in broad sense and genetic advance were noticed for spikelet sterility percentage by Remina *et al.* (1992). Singh *et al.* (1984) and De and Rao (1988) reported high estimates of heritability in broad sense along with high estimates of expected genetic advance for sterility percentage.

Shamsuddin (1986) reported high value for heritability estimates and high genetic advance associated with high genotypic coefficient of variation for the character 1000 grain weight. Chaudhury *et al.* (1980), Reddy *et al.* (1988), Pathak and Patel (1989), Lokaprakash *et al.* (1992), Roy and Kar (1992) and Chauhan *et al.* (1993) indicated high heritability coupled with high expected genetic advance for 1000 grain weight. High heritability in broad sense for this character was also reported by Kihupi and Doto (1989), Chaubey and Richharia (1990) and Roy and Kar (1992). But, Katoch *et al.* (1993) and Chakraborty and Hazarika (1994) observed high heritability in broad sense coupled with low expected genetic advance for the character, 1000 grain weight.

Singh *et al.* (1986), Kihupi and Doto (1989), Chaubey and Richharia (1990), Anandakumar (1992) and Roy and Kar (1992) reported high heritability estimate for the character plant height. High heritability in the broad sense coupled with high expected genetic advance for plant height were reported by Singh *et al.* (1984), Pathak and Patel (1989), Chaubey and Richharia (1990), Bai *et al.* (1992) and Roy and Kar (1992). Reddy *et al.* (1988) observed high genotypic coefficient of variation along with high estimates of heritability and genetic advance for the character plant height. High heritability in broad sense coupled with low expected genetic advance were observed for this character by Sardana *et al.* (1989), Chauhan *et al.* (1993), Katoch *et al.* (1993) and Chakraborty and Hazarika (1994).

High expected genetic advance coupled with high heritability estimates were recorded for days to 50 per cent flowering by Amirthadevarathinam (1983a) and Chauhan *et al.* (1993). High heritability in the broad sense for days to 50 per cent flowering and days to harvest was also reported by Singh *et al.* (1986), Kihupi and Doto (1989).

Roy and Kar (1992) and Patil *et al.* (1993), Sardana *et al.* (1989), Roy and Kar (1992), Katoch *et al.* (1993) and Chakraborty and Hazarika (1994) observed high heritability in the broad sense but low expected genetic advance for the character days to 50 per cent flowering. Sardana *et al.* (1989) also reported high heritability and low expected genetic advance for number of days to harvest.

High heritability and high genetic advance were recorded for the character number of spikelets panicle^{-1} by several scientists namely Chaudhury *et al.* (1980), Chaubey and Richharia (1990) and Chakraborty and Hazarika (1994).

High heritability in the broad sense coupled with high expected genetic advance for the character, panicle length was observed by Chauhan *et al.* (1993). High heritability estimate for this character was also reported by Singh *et al.* (1986) and Chaubey and Richharia (1990). At the same time Sardana *et al.* (1989), Katoch *et al.* (1993) and Chakraborty and Hazarika (1994) observed high heritability in the broad sense but low expected genetic advance for this character panicle length.

Chauhan *et al.* (1993) reported high heritability estimates and high expected genetic advance for harvest index. High heritability for harvest index was also reported by Roy and Kar (1992).

High heritability estimates in the broad sense coupled with high expected genetic advance were observed for the characters, primary and secondary branches panicle^{-1} by Ramalingam *et al.* (1994); for panicle bearing tillers plant^{-1} by De and Rao (1988) and Gomathinayagam *et al.* (1990). High heritability estimates in the broad sense for the characters namely number of panicles m^{-2}, number of panicle bearing tillers plant^{-1} and length of flag leaf was reported by Chaubey and Richharia (1990) and Anandakumar (1992), Patil *et al.* (1993), Sardana *et al.* (1989) recorded high heritability associated with low expected genetic advance for the character, number of panicles m^{-2}.

Sardana and Sasikumar (1987) indicated moderate estimate of heritability, moderate genotypic coefficient of variation and moderate expected genetic advance for the characters namely plant height, panicle length and number of grains panicle^{-1}. Reddy *et al.* (1988) recorded moderate value for heritability estimate, genotypic coefficient of variation and expected genetic advance with respect to the character number of grain panicle^{-1}.

2.3 Character association and path coefficient analysis

The success of any breeding programme depends on the presence of sufficient genetic variability to permit effective selection. It is imperative to assess the relative magnitude of components of variability nature and extent of association among yield and its attributes, and relative importance of direct and indirect influences of each of the component traits towards grain yield so as to improve plant type as a whole rather than individual character.

The relationship between grain yield and yield attributes were investigated with 20 salt tolerant and four high yielding semi-dwarf rice varieties grown under non-stress (normal) soil condition of Central Saline Rice Research Station, Canning Town (India) by Bhattacharyya during 1980. Grain yield plant^{-1} showed high positive correlation at all levels with ear bearing tillers, moderate with grains panicle^{-1} and feable with plant height and panicle length. Plant height showed high and positive association with panicle length, grains panicle^{-1} at all the three levels; low and positive association with spikelets panicle^{-1} and 1000 grain weight. With ear bearing tillers it was negative appreciably at the genotypic level. Ear bearing tillers showed negative genotypic and phenotypic association with all characters excepting grain yield plant^{-1} . Panicle length exhibited positive and high genotypic and phenotypic correlations with grains panicle^{-1} , spikelets panicle^{-1} and 1000 grain weight. Grains panicle^{-1} showed high correlation with spikelets panicle^{-1} and was fairly positively associated with grain yield plant^{-1} at all levels. Spikelets panicle^{-1} was found to be positively associated with spikelet sterility which was high at the genetic level and low at the phenotypic and environmental levels. Spikelet sterility was negatively associated and was feable with 1000 grain weight while it was considerably high with grain yield plant^{-1} . Similar results of significant correlation of different characters with yield at both genotypic and phenotypic levels were reported by Murty and Murty (1981) for LAI at flowering and number of spikelets m^{-2}; Ghorai and Pande (1982) for effective tillers plant^{-1}; Kaushik and Patel (1982) for number of spikelets panicle^{-1}; Shamsuddin (1986) for 1000 grain weight, panicle length and rachilla number; Xiang *et al.* (1986) for harvest index and 1000 grain weight; Paramasivan (1987), Paramasivan and Rangaswamy (1988a), Bai *et al.* (1992), Manuel and Rangaswamy (1993) and Dssawant (1995) for plant height, number of productive tillers plant^{-1} and number of grains panicle^{-1}.

Singh (1980), in non-segregating and segregating populations among crosses of rice found that the grain yield was positively correlated with panicle bearing tillers, grain weight and fertile grains panicle^{-1} in F_1 and F_2. Conversity panicle length in F_1 and F_2 and grains panicle^{-1} in F_1 showed strong negative correlations with grain yield. There was a substantial positive association of plant height and sterile grains panicle^{-1} with yield in each generation. Among yield components, grain weight showed positive and significant correlation with fertile grains panicle^{-1} (F_1 and F_2) and grains panicle^{-1} (F_2). Grains panicle^{-1} with panicle length (F_1 and F_2) and plant height (F_1) also exhibited positive high correlations. Path coefficient analysis revealed that panicle bearing tillers, grain weight and fertile grains per panicle in F_1 and F_2 and grains panicle^{-1} in F_2 had high positive direct effects on grain yield.

In a study with twenty tall indica and four high yielding semi-dwarf rice varieties grown under saline soil conditions of Central Saline Rice Research Station, West Bengal, Bhattacharyya (1981) reported that grain yield per plant showed positive correlation of different magnitudes at all levels with ear bearing tillers, grains per panicle and spikelets per panicle. He also reported that plant height showed positive and high correlation with panicle length and it was negative and low with spikelets per panicle at all levels. Panicle length was moderately associated negatively under all levels with grains per panicle. However, this character was of moderate strength and associated positively with spikelet sterility at the genotypic level. The association of grains per panicle with spikelets per panicle was positive and moderately high at the genotypic level and appreciably high at other levels. Grains per panicle was inversely correlated with spikelet sterility at all levels. Spikelet sterility was negatively correlated with grain yield per plant. The trait 1,000 grain weight was found to have feeble positive association with grain yield per plant.

The phenotypic and genotypic correlation coefficients among water uptake, volume expansion and kernel elongation when cooked at 77°C as well as alkai value and amylose content in F_2 population of six crosses of rice were computed by Tomar and Nanda during 1981. Water uptake was positively correlated with volume expansion, kernel elongation, alkali value and amylose content. Volume expansion and kernel elongation also showed similar positive association with other traits. However, association of above traits with amylose content was much less than with alkali value. The alkali value was found much more important than the amylose content in the determination of water uptake and kernel elongation.

Amirthadevarathinam (1983a) reported that grain yield was positively correlated with total tillers and productive tillers, and negatively correlated with plant height and days to ripening. Path analysis showed that total tillers and days to flowering made a positive direct contribution to grain yield.

In a correlation study conducted by Chauhan and Nanda (1983), amylose content in general showed positive and significant correlation with plant height. The association between amylose content and effective tillers per plant was negative but non-significant. Panicle length had positive and significant association with amylose content. Grains per panicle, 1000 grain weight and grain yield per plant exhibited positive but non-significant association with amylose content. This study revealed that amylose content and grain yield can be recombined as desired since both these traits appeared to be independent with positive association.

The relationships of five yield components with grain yield were analysed in 26 combinations of characters. Eight combinations of 3-5 characters, including in each case harvest index and biological yield controlled 98 per cent of the variation in grain yield. Path analysis indicated that biological yield contributed most to grain yield, followed by harvest index (Liao and Liu, 1983).

Cooking quality and acceptability of some high yielding varieties were studied by Madan and Bhat during 1984 and found that there was a positive correlation coefficient between amylose content and volume of cooked rice. Similarly a significant positive correlation coefficient between amylose content, water absorption and kernel elongation ratio of rice was obtained.

Correlation study in 22 upland varieties conducted by Singh *et al.* (1984) revealed that panicle number m^{-2} and number of grains per panicle had significant positive association with grain yield while spikelet sterility had significant negative association with grain yield. Plant height had significant positive association with panicle length and days to maturity. The association of grains per panicle with spikelet sterility percentage and 100 grain weight was negative. On the other hand spikelet sterility itself had positive association with days to maturity and 100 grain weight. Path analysis revealed that panicles m^{-2} exerted a direct positive influence on grain yield followed by number of grains $panicle^{-1}$, panicle length and 100 grain weight.

In a study conducted by Jun (1985) it was found that genotypic correlations of grain length was positively correlated with grain weight and the length/width ratio, grain width was negatively correlated with the length/width ratio and positively correlated with thickness, and grain thickness was positively correlated with grain weight. Grain weight and length/width ratio had the greatest direct effects on grain length at one site but the length/width ratio and grain width had the greatest direct effects at the other.

In a field experiment on upland direct seeded rice, Sharma and Choubey (1985) opined that grain yield $plant^{-1}$ was positively correlated with the number of productive tillers, panicles and spikelets $plant^{-1}$, plant height and test weight. Among the above characters, productive tillers, panicles and spikelets $plant^{-1}$ were strongly correlated. Similarly positive correlation of yield with different characters was also reported by Shamsuddin (1986), Pathak and Patel (1989), Chaubey and Richharia (1990), Paramasivan (1991) and Rosamma *et al.* (1992) for the characters, panicle length, number of grains $panicle^{-1}$, 1000 grain weight, plant height, number of total tillers $plant^{-1}$ and crop duration.

Takita (1986) opined that longer grain type was better than wider grain type for getting large sink size. It was found that wider grain was associated with thick culm and fewer panicle number. In addition, wider grain was associated with poor grain filling character such as higher white belly rice ratio and lower value of the ratio in hulled grain weight/unhulled grain weight. On the other hand, longer grain was not associated with any disadvantageous characters Hence, it was suggested that to breed for large grain types in japonica rices, it is better to go for longer grains.

Grain yield showed a significant positive correlation with (in descending order of magnitude) number of effective tillers, 1000 grain weight, number of grains $panicle^{-1}$ and panicle length and selection for these characters is suggested for yield improvement. Days to flowering showed a negative correlation with all six other characters (Dhanraj *et al.*, 1987).

Hussain *et al.* (1987), reported that, most of the cooking quality traits had positive correlation among themselves. Amylose content showed significant positive association with test weight and water uptake. Physical characters, such as grain length, showed positive and significant association with L/B ratio and test weight and significant negative correlation with grain breadth. L/B ratio showed positive significant correlation with test weight, and hulling percentage showed positive association with milling percentage and it was observed that hulling and milling recovery were not influenced by amylose content.

Jangale *et al.*(1987) conducted investigation in rice to partition direct and indirect effect of each attribute on yield to clarify the importance of each yield attributing character and its relative influence on yield. The F_4 generations of two crosses were considered for the studies. In one cross, the number of ear bearing tillers per plant was the most effective character in increasing the grain yield plant^{-1}. However, in other cross panicle weight and flag length were the most important characters followed by panicle weight and panicle length.

Analysis of data on yield plant^{-1} and 10 related traits from 74 diverse genotypes indicated that number of ear-bearing tillers makes the largest direct positive contribution to yield, followed by grain number panicle^{-1}. Grain length breadth^{-1} ratio and 100 grain weight also directly influenced yield, but not via the two major yield components, indicating that breeding for semi dwarf stature would not jeopardize improvement of these components (Sinha and Banerjee, 1987).

In an experiment with thirty rice strains under semi-deep low land situation De and Rao (1988) reported that grain yield m^{-2} showed significant positive and negative genotypic correlations with EBT hill^{-1} and sterility percentage respectively. Therefore selection based on these three characters would be effective for improving the grain yield under such type of low land situation. EBT hill^{-1} showed significant negative correlation with sterility percentage. Length of grain indicated significant negative correlation with breadth of grain and positive correlation with 100 grain weight.

Correlation and path coefficient analysis under taken by Gomathinayagam (1988) reported that duration and plant height were correlated significantly for the grain yield in upland rice varieties. There was significant but negative correlation between grain yield and total tillers. Among the characters studied viz., duration, plant height, total tillers, productive tillers, length of panicle, grains per panicle and thousand grain weight, duration was negatively correlated with all characters except plant height. Plant height was correlated with total tillers and length of panicle and grains per panicle. Total tillers have shown significant correlation with productive tillers, length of panicle and grains per panicle where as productive tillers have significant correlation to length of panicle and grains per panicle. A significant correlation was obtained between grains per panicle and 1000 grain weight. Path analysis revealed maximum contribution of plant height to yield. The other direct contributing factors were duration and grains per panicle. It was found that the indirect effect of duration via. all other characters except plant height was negative. Plant height contributed directly to the yield and indirectly via. all other characters except 1000 grain weight.

Lu *et al.* (1988) reported that the grain yield hill^{-1} was positively correlated with biomass, harvest index, grains panicle^{-1}, filled grains panicle^{-1}, fertility, and plant height and negatively with panicles hill^{-1}. Path analysis showed that the direct effect of yield related characters on grain yield was positive except for filled grains panicle^{-1} and the indirect effect was negative except for filled grains panicle^{-1}. Similar results of positive significant correlation of yield with harvest index, number of grains

Prasad *et al.* (1988) reported positive and significant association of grain yield plant^{-1} with total spikelets panicle^{-1}, followed by fertile grains panicle^{-1} and 100 grain weight and negative significant association with sterility. Fertile grains panicle^{-1} had high and positive correlations with total spikelets panicle^{-1} and negative correlation with sterility. Plant height and flag-leaf length showed positive and significant correlations with days to flowering and panicle length respectively. All the yield components accounted for more than 90 per cent of the variation in grain yield. The grain yield was found to be influenced mainly by the direct effects of fertile grains panicle^{-1} followed by panicle number and 100 grain weight. Though total spikelets panicle^{-1} had negative direct effect, the indirect effects via. fertile grains panicle^{-1} were high and positive. Attributes like days to flowering, plant height, panicle length and sterility, had low or negative direct and indirect effects and their contribution to yield was negligible.

Correlation and path analysis conducted by Deosarkar *et al.* (1989) for different quality characters in 30 breeding lines of upland rice revealed that amylose content was non-significant and negatively correlated with grain yield plant^{-1}. Similarly L/B ratio was significantly correlated with days to maturity and days to 50 per cent flowering.

Fifty newly developed lines from diverse crosses and ten varieties were studied by Panwar *et al.* (1989) for correlation and path coefficient analysis for grain yield using 11 characters. Grain yield was significantly and positively correlated with plant height, panicle length, panicle number, grain number and spikelet number. Hundred grain weight was neither associated with grain yield nor with grain number. The lack of association of grain weight with grain number offers scope to improve both characters by selection. Positive and significant correlation of plant height with panicle length and panicle number indicated that tall plants might be expected to produce longer and more number of panicles. The characters, panicle length, spikelet number and grain number were associated among themselves. The spikelet number was the main component character affecting yield directly. Plant height and panicle number also had pronounced positive direct effect. On the other hand, the direct effect of grain number was high and negative. High and positive indirect effects were contributed by panicle length and grain number via. spikelet number.

Path coefficient analysis of phenotypic correlations using twelve advanced breeding lines of upland rice conducted by Reuben and Kisanga (1989) revealed that panicles m^{-2}, proportion of sound matured grains $panicle^{-1}$, panicle weight and panicle length were important in influencing grain yield directly in that order. These components were also positively associated among themselves and with grain yield.

In an experiment with 60 fixed cultures of rice, Sardana *et al.* (1989) revealed that days to 50 per cent flowering had maximum positive direct effect on grain yield.

However the correlation value of this character with grain yield reduced to great extent due to negative indirect effect of other traits. Similarly, number of panicles m^{-2} had large positive direct effect on grain yield as well as high association with yield, but its indirect effect on other characters were not significant. Direct effect of tillers $plant^{-1}$ on yield was of low magnitude as well as association with grain yield. Although panicle length had significant association with yield, its direct effect on yield was negligible, though it contributed considerably towards yield via. days to 50 per cent flowering and days to mature. Plant height and days to mature had negligible direct effects as well as negative or insignificant correlation with grain yield but these characters have contributed to yield via. days to 50 per cent flowering.

In the correlation study conducted by Kaw and Cruz (1990), he observed significant negative correlation between amylose content and alkali spreading value.

In a study conducted by Palaniswamy and Kumarankutty (1990), it is revealed that panicle length was correlated negatively with flowering duration. Regression analysis indicated panicle length to be dependant on flowering duration.

In a field experiment to test the relative yield performance of certain genotypes, Malik *et al.* (1990) reported that while 1000 grain weight has positive association with grain yield, the number of grains per panicle and plant height were associated negatively with ultimate grain yield. The very high association value of 1000 grain weight was nullified by negative value of its indirect effect via. grains per panicle. Although the correlation between grains per panicle and grain yield/ha was found to be negative and significant, yet this component had high positive value in its direct effect. Most of the positive effect was nullified by negative indirect effect via. 1000 grain weight.

Rao (1990) studied direct and indirect influences of seven auxiliary characters on yield in certain lines. In certain lines direct and indirect positive influence of ear bearing tillers, panicle length, grain weight and fertile grains on yield were of high magnitude. Direct and indirect negative influence of height on yield was considerable. Path analysis for a line showed selection for less number of sterile grains with low sterility percentage, is the most single important selection criterion to improve productivity of the semidwarf line. In another line, plant height had large negative direct influence as well as indirect negative effects through other characters on yield. However, negative effects of height was compensated by the positive effect of ear bearing tillers, panicle length and fertile grains. This line represents ideal plant height (119 cm) for growing in waterlogged areas and further improvement in productivity is possible by slightly increasing the tiller ability from 4.1 to 5.1.

Krishnayya *et al.* (1991) suggested that under intermediate water depth situation, for the improvement of rice grain yield greater emphasis should be given to selection on number of grains per panicle and plant height as these characters possessed high direct effects on grain yield. Sterility percentage had high negative direct effect on grain yield. Panicle number m^{-2} and 1000 grain weight showed indirect effect on yield via. plant height.

Correlation study in rice by Murty *et al.* (1991) revealed that leaf area at early crop growth stage and harvest index showed positive association with grain yield, while the leaf area at flowering showed no association with grain yield.

Wada (1991) reported that yields and yield components for a range of sites in Hokkaido in both favourable and unfavourable years showed that there was a low correlation between yield and grain number and high correlation between yield and harvest index, but very little correlation between harvest index and grain number.

The character association study in upland rice cultures indicated only tiller number, panicle length and boot leaf breadth had positive significant association. The negative association between plant height with panicle length and boot leaf breadth with yield as revealed by partitioning analysis clearly made to have only plant height and tiller number as a basis for selection criteria in yield improvement of upland rice cultures (Anandakumar, 1992).

Path coefficient analysis in parental lines indicated that the highest direct and indirect contributions were made by straw yield plant^{-1} and number of grains panicle^{-1} to the make up of final grain yield. Plant height, panicle length and number of effective tillers exerted their influence on yield indirectly through straw yield alone. Correlations between 1000 grain weight and straw yield plant^{-1} was positive and high. These two traits also exerted high direct effects on grain yield plant^{-1} (Reddy and Nerkar, 1992).

Arumugachamy *et al.* (1993) reported that in rice, the plant crop traits like plant height, panicle length and grain number per panicle revealed positive and significant correlation with ratoon yield and these traits can be taken as a criterion to predict ratoon yields. Grain yield also showed significant positive correlation with productive tiller number, days to 50 per cent flowering and not with 100 grain weight. Productive tiller number per plant showed non significant negative association with days to 50 per cent flowering in plant crop. Selection based on grain number per panicle and days to 50 per cent flowering would be effective since they showed high direct and indirect effects on ratoon yields.

In a study of twenty six indica rice genotypes tall and semi dwarf stature Katoch *et al.* (1993) reported that grain yield had significant positive association with harvest index and grains panicle^{-1} in both the sets of genotypes at the phenotypic level. In addition, grain yield showed significant association with effective tillers plant^{-1} in tall statued plants. Path analysis at genotypic level revealed harvest index to be the major attribute contributing towards grain yield in both the sets of genotypes. Grains panicle^{-1}, effective tillers and long panicles contributed indirectly via harvest index in both the sets.

Chakraborty and Hazarika (1994) reported that the grain yield exhibited significant and positive correlation with plant height, panicle length, panicles plant^{-1} and kernel breadth at genotypic level. The trend of association was similar at both genotypic and phenotypic levels. So direct selection for these five yield components could improve grain yield in rice. Kernel length/breadth showed significant negative correlation with grain yield at genotypic and phenotypic levels.

Chauhan *et al.* (1994) reported that total milling out turn was positively and significantly correlated with hulling recovery. Hulling recovery was positively correlated with kernel breadth. Thus, bold grains might be having high hulling recovery. However it is an undesirable association as the bold grains tend to break during milling which results in poor head rice yields. Hulling and milling recovery were not influenced by 100 grain weight, L/B ratio, alkali digestion value and amylose content. Kernel length had significant and positive association with L/B ratio, where as kernel breadth showed negative and significant relationship with L/B ratio. The 1000 grain weight exhibited positive and significant association with alkali digestion value and kernel breadth indicating that bold grains have high grain weight but low gelatinization temperature. Alkali digestion value had no significant relationship with amylose content.

The study conducted by Nadarajan and Kumaravelu(1994), to know the relationship between different yield component traits in rice under drought stress and to suggest selection strategy for improving grain yield revealed that single plant yield had significant positive association with plant height, ear length, grains per ear and 100 grain weight. These four yield components had high intercorrelation among themselves. Ear length had high and positive direct effect on grain yield. Other three yield components had high positive indirect effect through ear length.

Mehetre *et al.* (1994) reported that grain yield m^{-2} was positively and significantly correlated with straw yield m^{-2} and filled grains $panicle^{-1}$, while it was negatively and significantly correlated with days to 50 per cent flowering and maturity. Plant height was significantly and positively correlated with straw yield m^{-2}, panicle length and filled grains $panicle^{-1}$, while it was significantly and negatively correlated with productive tillers m^{-2}. Panicle length was significantly and positively correlated with straw yield m^{-2} and filled grains $panicle^{-1}$. Filled grains $panicle^{-1}$ was significantly and positively correlated with straw yield m^{-2} and grain yield m^{-2}.

Analysis of correlations in gora (Group I) and medium/lowland (Group II) rices by Chauhan *et al.* (1995) revealed a consistent trend of associations for hulling, milling, kernel size and shape in both the groups. Alkali value and amylose content exhibited differential pattern of association with grain size, shape and milling characteristics. The cooking quality attributes showed highly variable associations with physico-chemical properties of the rice grain. Amylose content showed negative correlation with water uptake in all groups. Cooked kernel length, was highly correlated with kernel elongation. It appeared that characters like grain size, shape, hulling, milling and head rice recovery could be improved by similar selection criteria. However, it seems difficult to simultaneously improve alkali value, amylose content, water uptake, kernel elongation and grain dimensions due to the complex nature of associations among these traits.

Grain yield was positively and significantly correlated with panicle length, grains per panicle and 100 grain weight. Path analysis studies indicated that productive tillers per plant and grains per panicle had low direct effects on grain yield. For the other traits the effect was negative. Although panicle length and 100 grain weight had a positive and significant correlation with grain yield, they did not exhibit direct effect on grain yield. These characters had an indirect effect on grain yield (Ramalingam *et al.,* 1995).

Chauhan (1996) reported that the improvement in grain yield plant^{-1} could be achieved by exercising selection simultaneously for spikelet number, percentage of filled spikelets, panicle weight, biological yield and harvest index, owing to their positive and significant relationship with grain yield. It was suggested that increase in plant height and growth duration would tend to increase straw yield and panicle length as days to 50 per cent flowering and plant height were positively and significantly correlated with these characters.

In an investigation with F_2 and F_3 generations of three inter varietal crosses involving four semidwarf rice varieties, Ganesan *et al.* (1997) reported that the correlation of number of productive tillers and harvest index with single plant yield was highly significant and positive. Harvest index showed profound positive direct effect on single plant yield.

Nath and Talukdar (1997) opined that grain yield plant^{-1} was positively and significantly correlated with number of grains panicle^{-1} and 100 grain weight at genetic level.

Rather *et al.* (1997) reported that 50 per cent flowering, leaf length, grain/straw ratio and 100 grain weight are important characters that influence the yield directly. Besides the direct contribution of leaf length, most of the yield components contribute through it. The negative direct effect of spikelet sterility indicates its deleterious effect on yield.

Sharma and Dubey (1997) observed that grain yield panicle^{-1} had significant positive association with number of grains panicle^{-1}, number of primary and secondary branches panicle^{-1} and panicle length. Path analysis at genotypic level revealed the number of grains panicle^{-1} to be the major contributing character towards the grain yield panicle^{-1} followed by number of primary branches panicle^{-1} and panicle length. In addition, number of secondary branches panicle^{-1} contributed indirectly via number of grains and primary branches panicle^{-1}. For improving the grain yield panicle^{-1} emphasis should be given for longer panicles coupled with more number of grains and primary and secondary branches panicle^{-1}.

Verma and Mani (1997) observed that at phenotypic level, panicle length exhibited high positive association with number of grains panicle^{-1} and grain yield plant^{-1}. Path coefficient analysis showed that in the randomly selected genotypes number of tillers $plant^{-1}$, number of grains $panicle^{-1}$ and 1000 grain weight had high direct effect on grain yield $plant^{-1}$, while in the genotypes selected on the basis of grain yield alone, number of tillers $plant^{-1}$ had maximum direct effect on grain yield.

2.4 Selection indices

Grain weight $plant^{-1}$ (y), effective panicles $plant^{-1}$ (x_1), filled grains $panicle^{-1}$ (x_2), panicle length (x_3) and 1000 grain weight (x_4), were studied in ten genotypes of Keng (Japonica) rice in field trial conducted in 1987 by Bao (1989). Path analysis showed that the number of filled grains $panicle^{-1}$ had the greatest direct effect on grain weight $plant^{-1}$ followed by that of 1000 grain weight and effective panicle $plant^{-1}$. The indirect effect of panicle length to grain weight $plant^{-1}$ via. filled grains $panicle^{-1}$ was also important. Out of 8 selection indices established, the selection index for yield expressed by the relation $y = 0.3895\ y + 0.0971\ x_1 + 0.1412\ x_2 + 0.2890\ x_3 + 0.05584\ x_4$ would produce the highest expected genetic gain (3.37) and relative efficiency (159%). The selection index for rod-like panicles was 10.2, intermediate panicles 11.3 and bow like panicle 12.0. It is concluded that selection for filled grains $panicle^{-1}$, grain weight $plant^{-1}$, panicle length and bow like panicle could be effective for improving yield.

Genetic correlations among yield and yield components (panicle number, panicle weight, panicle length, primary branches and plant height) for southern long grain rice were estimated by Gravois and Mcnew (1993) and used in developing selection methodologies in rice breeding programmes. In 1989, two 4x4 crossing factorials were completed, and the $32F_1$ hybrids and 16 parents were evaluated in 1990 at two locations. Additive genetic and broad sense genetic correlations were estimated. At both the additive and broad sense genetic levels, yield was positively correlated with panicle weight. Yield was negatively correlated with panicle number; but the effect was diminished at the broad sense genetic level. Panicle weight was negatively correlated with panicle number. Path analysis, however, revealed positive direct effects for both panicle number and panicle weight on rice yield at both the additive genetic and broad sense genetic levels, with panicle weight exhibiting larger direct effects on yield than panicle number. Selection indices were developed from the additive genetic and phenotypic variances and covariances. The selection indices indicated that selecting for increased yield via. selection for either panicle weight or panicle number alone would be ineffective. A selection index that included selection for both increased panicle weight and panicle number to increased yield was estimated to be 91 per cent as effective as selecting for yield directly.

A study conducted by Mishra *et al.* (1993) revealed that 100 - grain weight can be successfully utilized to identify higher yielding genotypes during early generation selection in rainfed rice. Simultaneous selection for grains panicle^{-1}, 100 - grain weight and grain yield plant^{-1} can lead to identification of high yielding genotypes in F_2 generation.

2.5 Genetic divergence in rice

Genetic improvement mainly depends upon the amount of genetic variability present in the population. Divergence analysis is used to identify diverse genotypes for hybridization and to generate crosses that give transgressive segregants in later generations. An over view of works conducted in rice on this aspect and other related studies are presented here under.

Murty and Arunachalam (1966) reported that genotypes belong to same geographic region cluster in different groups may be due to reasons such as heterogeneity, genetic architecture of the populations, past history of the selection, developmental factors and degree of general combining ability.

Singh and Bains (1968) opined that varieties involved under similar selection pressure will cluster together irrespective of their geographic origin.

Angadi (1976) reported that varieties in a cluster found with high order of divergence among themselves would be the best breeding materials for achieving maximum genetic advance with regard to yield. Selection within a cluster might also be exercised based on the highest mean performance of the varieties for desirable traits such as number of grains $panicle^{-1}$ and productive tillers having profound influence on yield in rice.

Verma and Mehta (1970) reported that genotypes from different geographical regions cluster together may be due to free exchange of breeding materials from one place to other.

Chatterjee *et al.* (1978) used Mahalanobis D^2 statistics to assess the nature of genetic divergence in relation to low temperature tolerance and high-yielding capabilities in a collection of 25 rice strains. The 25 strains were grouped into 12 clusters on the basis of nine agronomic characters. The clustering pattern revealed that yield and yield attributes exercised profound effect on genetic diversity irrespective of the origin of the variety. Both geographical diversity as well as directional selection pressure for specific agro-ecological condition have resulted in genetic divergence among the genotypes. From the results of inter-cluster distances the fact that geographical diversity also accounts for genetic divergence cannot be ruled out.

Singh *et al.* (1980b) pointed out that interaction of some similar genotypes at different places may result in clustering of genotypes from different geographic regions together.

Singh (1983) grouped 32 varieties from India, Philippines, China and Bangladesh into nine clusters using multivariate analysis of genetic divergence for grain yield/plant and five yield related characters. Geographic distribution was not related to genetic diversity. Varieties from the same ecogeographic region were found in different clusters. Similarly Singh (1981) grouped 35 indigenous varieties into nine clusters.

Raut *et al.* (1985) suggested that genetic drift and human selection could cause greater diversity than the geographic distance. Therefore genetic diversity must form the sound basis for selection of parents for hybridization.

Kotatah *et al.* (1986) grouped 26 diverse mid-duration genotypes of rice into five clusters. Genotypes derived from the same parent were included in one cluster, although there were instances of some of them distributed in different clusters. The clustering pattern indicated no relation between geographic and genetic diversities.

Genetic divergence, as measured by Mahalanobis D^2 technique, was studied for yield and its component traits in 30 strains of rice (*Oryza sativa* L.) under low land situation (De and Rao, 1987). The strains were grouped into ten clusters showing no relationship between geographical distribution and genetic divergence.

Forty-eight improved varieties of cultivated rice from different ecogeographical areas were put to D^2 analysis by Pande and Ghorai (1987). Grouping of genotypes in the same cluster confirmed that there is no parallelism in between genetic diversity and geographical distribution. The difference between the characters were highly significant and the pattern of clustering was greatly influenced by environment.

Mahajan *et al.* (1987) studied the genetic diversity by D^2 technique for 11 characters related to yield in 60 cultures of rice developed from 14 crosses involving 23 parents. The 60 cultures were grouped into 18 clusters. Mostly the cultures in a cluster came from the same cross. The geographical diversity was associated with genetic diversity to some extent. Seven cultures were identified with genetic diversity, high yield potential and multiple resistance to be utilized as parents in future rice breeding programme.

Genetic divergence was assessed in 50 cultivars of low land rice by Singh *et al.* (1987), using D^2 statistics for 15 traits related to yield. All the cultivars were grouped into 10 clusters. Clustsers I, II and III were larger and consisted of more than two thirds of the total population. The genetic diversity was not related to geographical diversity.

De *et al.* (1988) grouped seventy five strains comprising indica, Japonica, Ponlai and Javanica rice were grouped into 13 clusters using D^2 statistic. The association of ARC strains with Javanica in the same group has great significance. Sixty seven ARC strains revealed high order of genetic diversity, indicating the importance of the north eastern region of India as a rich source of diverse rice germplasm and in tracing the centre of origin of cultivated rice. The possibility of existence of intergrades between various subspecies in this region can not be ignored. Genetic drift and selection pressure were inferred to have played a great role in bringing about genetic divergence among the strains. The ARC strains also generated noteworthy variability among themselves with regard to intra and intercluster distances.

Anandakumar and Subramanian (1989) evaluated 23 drought resistant cultures for their genetic diversity, using Mahalanobis D^2 analysis. The genotypes were grouped into six clusters. The clustering pattern failed to indicate any relationship between geographic divergence and genetic variability. The wide genetic variability of genotypes of the same origin might be due to varied phenological conditions. Similar results of absence of parallelism between geographical distribution and genetic diversity was reported by Biswal (1990), Rangel *et al.* (1991) and De *et al.* (1992).

Selvakumar, *et al.* (1989) reported substantial genetic diversity among the 40 cold tolerant rice genotypes for components of fitness between and within the geographic regions existed. The clustering pattern indicated that geographic diversity was not a reliable criterion of genetic diversity in cold tolerant rice. The genotypes related by their origin of region or by pedigree tended to group in the same cluster in general and there were also instances where the genotypes from the same centre of origin or pedigree were distributed in different clusters.

Genetic distance, as measured by the D^2 statistic was estimated by Bansal *et al.* (1990) for 50 breeding lines and cultivars of diverse parentage using data from 11 quantitative traits. 12 clusters were formed. Clustering patter was influenced by the pedigree of the breeding lines.

Kumar and Subramanian (1992) evaluated 23 cultures to find out genetic divergence and observed that geographical diversity need not necessarily be related to genetic divergence. The desirable diverse plants need not be selected for hybridization from distance geographical regions but locally adapted diverse plants may serve as better parents for upland rice improvement.

Mall and Maurya (1992) has undertaken an investigation to examine the extent of genetic diversity as measured by D^2 statistics present in a set of 50 breeding lines derived from two crosses Jalmagna x Sona and Madhukar x Sona using uniform multiple selection criteria, and ten cultivars including parents and standard varieties. The genetic diversity was revealed among the breeding lines. The two crosses with a common parent showed distinct variability inspite of uniform selection pressure exerted.

Roy and Panwar (1993) opined that the genetic diversity was not related to geographic diversity. Yield plant^{-1}, panicles plant^{-1}, spikelets panicle^{-1} and grains panicle^{-1} were mainly responsible for genetic divergence. The assessment of genetic diversity is likely to be more fruitful in elite materials.

The nature and magnitude of genetic divergence was assessed in 28 genotypes of rainfed rice using Mahalanobis D^2 statistics by Vivekanandan and Subramanian (1993). The population was grouped into 5 clusters. The geographical diversity has not been found related to genetic diversity. Such unparallelism between geographic and genetic diversity might be due to forces other than geographic distance such as ancestral relationship genetic drift, free exchange of breeding materials from one place to another and varied nature of selection in different regions.

Genetic divergence studies using D^2 analysis showed that the genotypes fall into seven distinct clusters. When planning hybridization programs to achieve early flowering and maturity, varieties from cluster VII may be used, for dwarfness, clusters I and V I; for panicle length, cluster V I; for filled grains per panicle, cluster V I; for productive tillers $plant^{-1}$, cluster IV; and for straw yield $plant^{-1}$, cluster VII (Mehetre *et al.*, 1994).

2.6 Combining ability analysis

Combining ability analysis was made in rice through line x tester analysis by Amirthadevarathinam (1983b) for major yield and yield components. Considerable degree of genetic variability was observed in the parents. The combining ability variances were significant and indicated the importance of both additive and non-additive gene action in the expression of yield characters. Best general combiners and best cross combinations with respect to different characters were identified. The crosses chithariyan/kannagi and chithariyan/IR-5 showed very high heterosis for three important yield components namely, productive tillers, grains per panicle and plant yield. Both chithariyan and kannagi possessed high *gca* coupled with superior *sca* effects and in view of this, the above two crosses would be preferred for further breeding. Anandakumar and Rangasamy (1984) reported importance of both additive and non-additive gene actions for the characters, plant height, panicle length, productive tillers $plant^{-1}$ and yield $plant^{-1}$ with preponderance of non-additive gene action for the characters, plant height, panicle length and yield $plant^{-1}$.

In a line x tester analysis using 16 lines and three testers for three traits viz. grain size, volume weight and hulling per cent in rice, Sonrexa (1984) reported that additive gene effects, partial dominance, high heritability and high genetic advance were noticed for grain size. Simple breeding procedures like selection based on progeny testing is suggested for the improvement of this trait, whereas for other two traits non-additive gene effects, low heritability and low genetic advance were observed. Partial dominance for volume weight and over dominance for hulling per cent was also observed. For these traits biparental mating and recurrent selection may be useful.

A diallel technique was employed in which ten varieties of rice were crossed among themselves in all possible combinations. A total of 90 hybrids and ten parents were studied. The analysis for combining indicated the presence of both additive and non-additive gene actions for all the characters with predominance of additive gene actions for all the characters. Parents having significant *gca* effects were identified. No specific cross combination was found desirable for all the characters as indicated by their *sca* effect but some combinations were found generally good for grain yield, short stature and quality of grain (Subramanian and Rathinam, 1984a).

F_1 and parental material of a diallel cross of 5 lines were analysed according to Griffing's model 1, method 11 by Singh (1984). Variances indicated approximately equal importance of additive and non-additive gene action in most of the characters studied. Regular selection interspersed with crossing between selected genotypes is recommended as a suitable breeding strategy. Lines showing superior general combining ability for a range of characters of breeding interest are identified as well as cross combinations which exhibited significant specific combining ability for some of these characters.

Twelve early varieties - nine semidwarfs plus three traditional talls - and all their possible F_1's without reciprocals were analyzed for combining ability in 30 different characters. Both general combining ability and specific combining ability were highly significant in almost all the characters. Genes with additive action were predominant in the inheritance of 21 traits, including such important ones as days to flowering, number of spikelets, and grains panicle^{-1}. On the other hand spikelet fertility and harvest index showed a predominance of genes with non-additive effects. Characters like biological yield and grain yield showed more or less equal importance for both types of gene action (Mohapatra and Mohanty, 1986).

Panwar *et al.* (1985) revealed that the variances for general and specific combining ability were highly significant for all the yield and related characters. Good general combiners for yield and other important traits were identified and recommended for intermating or biparental mating in the early generation. Similarly crosses having high *sca* effects for yield and important traits were identified. In some cross combinations of high *sca* effects, either both parents or one of the parents exhibited high general combining effect, which indicate that these combinations might throw out desirable transgressive segregates. They may hence be used for inter-se crossing to accelerate genetic recombinations and help breaking linkage blocks. Preponderance of non-additive gene action was seen for grains panicle^{-1}, grain yield, days to heading and panicle length in the F_1. Panicles plant^{-1} and spikelets panicle^{-1} showed complete dominance in the F_1's, indicating control by an equal proportion of additive and non-additive genes. Partial dominance was observed for plant height and 1000 grain weight in the F_1.

The diallel analysis with eight varieties of rice revealed very poor manifestation of heterosis for kernel length, breadth and length : breadth ratio. The gene action appeared to be additive for kernel length but both additive and non-additive gene actions were found important for kernel - breadth and length : breadth ratio. In general, a close association between *per se* performance and *gca* effects of parents was observed (Singh and Singh, 1985). Similar result was also reported by Singh *et al.* (1993).

In order to diversify sources of CMS in rice, research is in progress in China, at IRRI, and elsewhere to identify additional CMS sources. At IRRI a highly sterile BC_4F_1 progeny from the cross ARC13829-26/IR10179-2-3-1 was obtained suggesting that ARC13829-26 does possess sterility inducing cytoplasm (Virmani *et al.*, 1985).

A line x tester analysis of data from eight dwarf cultivars used as females and two tall cultivars testers revealed significant general and specific combining ability effects for the four traits measured. Non-additive gene action (dominance or epistasis) conditioned plant height, panicle length and yield $plant^{-1}$. Three crosses were superior on the basis of *per se* performance and *sca* effects (Anandakumar and Rangasamy, 1986).

Analysis of data on grain yield per plant and five related traits from a 5 x 5 half-diallel cross involving two foreign and three Indian varieties revealed that the foreign varieties had higher *gca* effects than the Indian varieties. F_1 hybrids from crosses between the foreign and Indian varieties had higher positive *sca* effects than crosses between the foreign or crosses between the Indian varieties for most yield components. The best crosses for yield and most of its components were identified (Ghosh and Hossain, 1986).

Four crosses involving eight varieties differing in amylose content and gelatinization temperature were studied in the F_1 and F_3 by Heda and Reddy (1986). Amylose content appeared to be controlled by two genes, with high content dominant over low. The segregation patterns for GT differed among the crosses. In crosses between varieties with low and intermediate GT or between varieties each with intermediate GT, the distribution curve was bimodal as for amylose content, where as in crosses where both parents had high GT, the character appeared to be controlled polygenically.

In a 9 x 9 diallel cross, Kuo and Liu (1986) observed that additive effects were more important than dominance effects for grain length, width and length/width ratio and 1000 grain weight. General and specific combining ability effects were significant for all four characters, although the former were more important than the latter. Narrow-sense heritability estimates were high in all cases. Maternal effects were detected for all four characters. Dominance was partial or incomplete. Similar results for alkali spreading value, amylose content and grain yield were reported by Sarathe *et al.* (1986).

Twelve early varieties were crossed in a diallel fashion without reciprocals and scored for 30 characters by Mohapatra and Mohanty (1986). The gca and *sca* effects were highly significant for almost all characters. Additive effects appeared to predominate for 21 traits, including days to flowering, and number of spikelets and grains panicle^{-1}. Similar results for days to 50 per cent flowering and days to maturity were revealed by Agrawal and Sharma (1987). Spikelet fertility and harvest index showed predominantly *sca* effects. Heterosis over the mid-parental value for grain yield varied widely and was closely associated with heterosis for biological yield and to a lesser extent harvest index. The four parents with high *gca* also showed high variety heterosis. Specific combining ability was significant in some heterotic hybrids. Heterotic hybrids appeared more frequently in crosses between high and low *gca* parents than a high x high or low x low crosses, indicating the importance of interaction effects in producing heterosis.

In a set of diallele crosses (excluding reciprocals) involving eight rice cultivars, Sarathe and Singh (1986) reported significant differences for general combining ability and specific combining ability indicating the importance of both additive and non-additive interactions for all the traits. The proportion and ratio of genetic components σ^2g and σ^2s indicate that non-additive gene action was more important as compared to additive gene action in controlling the yield per plant, biological yield, grains per panicle, panicle sterility, harvest index, days to flower and 1000 grain weight. The additive portion for panicles per plant and panicle length was higher as compared to other traits. Similar results for yield and harvest index were also reported by Manuel and Prasad (1992) in a line x tester analysis.

Tripathy and Misra (1986) studied the nature of gene action for plant height in some diverse dwarf and semi-dwarf varieties in a 7 x 7 diallel cross and reported presence of genetical variation among the parents due to additive genetic effect. The effect of dominance was not significant although there was an indication of significant effect of unidirectional dominance and asymmetrical distribution of both positive and negative alleles averaged over all the loci in parents. The direction of dominance was towards tallness. Presence of additive and overdominance effect of gene loci without any epistasis and genotype x environment interaction effect is indicated. Such a situation is expected since the semi-dwarfs used in this study are known to have one major gene with some inhibitors and a number of modifiers. Since the minimum number of gene pairs was 1.0, few generations of simple recurrent selections would be required to give homozygous selections for this trait.

Genetic analysis of grain yield and yield attributes in rice by Kalaimani and Sundaram (1987a), with 7 x 7 diallel revealed that although bot additive and dominance components are significant for all the characters studied, additive genetic component was predominant for plant height and grain yield and non-additive genetic component for days to flowering, productive tillers per plant and number of grains per panicle. Overdominance was observed for days to flowering, productive tillers per plant and number of grains per panicle, dominance for grain yield and partial dominance for plant height and 100 grain weight.

Analysis of data on 27 yield related and morphological characters from the parents and F_1 of a diallel cross among 5 diverse cultivars by Murai *et al.* (1987) revealed that mean squares due to additive gene action predominated over those due to dominance for culm length, upper internode elongation index, number of panicles plant^{-1} and number of spikelet panicle^{-1}. Dominance effects predominated for 100 grain weight and grain length. The results indicated that panicle weight as a percentage of plant weight was controlled by additive gene action, but panicle weight per plant was not.

In a 5 x 5 diallel cross (excluding reciprocals) of rice Sardana and Borthakur (1987) reported that genetic variability, general combining ability (*gca*) and specific combining ability (*sca*) were significant for grain yield per plant, days to flowering, plant height, effective tillers per plant, panicle length, flag leaf length, flag leaf width, filled grains per panicle and 100 grain weight. Both additive and non-additive gene effects were important for all these traits. Best general combiners and best cross combinations for different characters were identified. A preponderance of non-additive gene effect over additive effect was observed for grain yield per plant, flag leaf length and filled grains per panicle, where as it was the reverse for 100 grain weight, panicle length, flag leaf width and days to flowering. Suitable breeding methods are suggested depending on the gene effects.

Genetics of harvest index and its components was studied following line x tester approach by Sharma *et al.* (1987). Thirty cross combinations (3 x 10) along with parental strains were studied for 16 characters. Analysis of variance indicated the existence of significant variation among F1 and parents for all 16 characters. Combining ability analysis showed both additive and non-additive types of gene action playing significant role in controlling the expression of all characters under study. The exception was economical yield for which only non-additive gene action was found to be significant. The comparative roles were worked out on the basis of their expected mean squares. For days to flowering, plant height, second leaf length, number of ear bearing tillers plant^{-1}, grain length and width, additive type of gene action was important, whereas for the remaining characters viz., harvest index, economical yield, and biological yield, non-additive type of gene action seems to be playing significant role. Similar results of importance of both additive and non-additive gene actions for the characters, days to flowering, plant height, panicle length, number of grains panicle^{-1}, number of spikelets panicle^{-1} sterility percentage, 1000 grain weight and yield with preponderance of additive gene action for plant height, days to flowering and preponderance of non-additive gene action for the remaining characters were reported by Manuel and Palanisamy (1989). Sharma *et al.* (1996) reported preponderance of non-additive gene action for the characters, plant height and yield plant^{-1} and reponderance of additive gene action for panicle length and number of panicle bearing tillers plant^{-1}.

Eleven varieties with a high amylose content were crossed with low content by Tomar (1987). Data from the F_1-F_3 suggested that in nine of the 11, high amylose content was controlled by a single dominant gene, in the remaining two, it was controlled by a single recessive gene.

Analysis of combining ability of seven diverse varieties of rice indicated the predominance of additive gene effects for the trait, days to flower initiation and 100 grain weight. Good general combiner for earliness, lateness and grain weight were identified. It was found that the crosses showing high specific combining ability with negative effects were derived from crosses involving early x late parents, where as those with positive effects were from early x early or late x late combinations (Tripathy and Misra, 1987).

Diallel analysis of five parents and their ten F_1.s revealed highly significant *gca* and *sca* effects for most of the yield attributing characters viz., plant height, effective tillers plant^{-1}, panicle length, primary branches panicle^{-1}, number of grains panicle^{-1}, grain weight and yield plant^{-1}. For most of the characters, variance due to dominance was always superior to additive variance except for effective tiller number for which both the components were of equal magnitude and for number of grains panicle^{-1}, additive variance was superior. A predominant control of dominant factor was noted in respect of characters like plant height and primary branches panicle^{-1} as reflected by high degree of dominance, with very low heritability and genetic advance. Expression of number of grains panicle^{-1} was controlled by additive components and consequently resulted in higher magnitudes of heritability and genetic advance. Parents having high *gca* effects were the best parents for all the characters, except effective tillers plant^{-1} and panicle length. It was further noticed that genotype with best *gca* was not necessarily the best specific combiner for the characters except panicle length and primary branches panicle^{-1}. It was also noted that the maximum *sca* effects were obtained from high x low general combiners (Ghosh and Hossain, 1988).

The combining ability for yield and yield attributes was studied using 7 x 7 diallel by Kalaimani and Sundaram (1988). The results revealed the existence of *gca* variance in greater magnitude than *sca* variance for all characters studied, viz., days to flowering, plant height, productive tillers per plant, number of grains per panicle, 100 grain weight and grain yield per plant, indicating the scope for improvement by exploiting the available additive components. A positive association was noticed between parental performance *per se* and *gca*' effects except days to flowering. The *gca* effects of parents and *sca* effects of their combinations revealed that only with reference to days to flowering and plant height, the direction of *sca* effect of combinations was the same as that of *gca* effects of the parents involved, indicating additive x additive type of interaction. Although the additive gene action was predominant for other characters, the direction and magnitude of the *sca* effect with respect to their combinations was not following any set pattern indicating that these characters have greater magnitude of dominance and epistatic effect in addition to additive gene action, and it is clear that these characters are governed by genes, some having additive effect and others having epistatic effect. Hence caution has to be taken on the reliance of *sca* alone in choosing the parents for improvement of any character.

Kaushik and Sharma (1988) studied gene action and combining ability for yield and its component characters in rice in seven parent F_1 diallel (excluding reciprocals). Gene action as estimated through Hayman and Griffing approaches revealed the predominance of additive gene action for plant height, panicle length and spikelets panicle^{-1}, predominance of non additive generation for 1000 grain weight and presence of only non-additive gene action for sterility and yield plant^{-1}. Griffing approach revealed the presence of both additive and non-additive components for days to flower and number of tillers. Hayman approach revealed the presence of only non-additive gene action for number of tillers. The results revealed the presence of epistatic interaction for days to flower, number of tillers, sterility and yield plant^{-1} and the interaction was of probably complementary nature for all but yield plant^{-1}. For plant height, panicle length and spikelets panicle^{-1}, the proportion of dominant genes in the parents was higher. Good general combiners for yield and its component characters were identified.

Assessment of seven quality characters by Kuo *et al.* (1988) in a complete 5 x 5 diallel cross indicated the importance of additive and dominance effects for all characters although additive effects were greater for all except gel consistency. Maternal effects were observed for alkali spreading score, amylose content, gel consistency, grain width and grain thickness. Estimates of dominance indicated partial or incomplete dominance for all characters, except for gel consistency which exhibited complete dominance. The number of dominant genes exceeded the number of recessive genes for alkali spreading score, protein content and amylose content while the reverse was true for gel consistency and grain dimensions.

In a study of combining ability and maternal effects for agronomic and grain characters in rice seven diverse rice parents selected on the basis of grain characters viz., grain length (L), grain thickness (B), L/B ratio, grain density and 1000 grain weight, were crossed in all possible combinations to estimate general combining ability effects, specific combining ability effects, genetic components of variance and reciprocal cross effects . Mean squares due to *gca*, *sca* and *rca* were significant for days to 50 per cent flowering, plant height, number of panicles per plant, panicle length, grain per panicle, grain length, grain thickness, 100 grain weight and grain yield. Mean square for *sca* effects were non-significant for grain density. Non-additive genetic variance was predominant for all traits except grain density where additive gene effects were more important. Partitioning of *rca* indicated significant variance due to maternal effects only for plant height and grain density. Basmati 370 was the main parent contributing to maternal effects for these characters and the cytoplasmic factors of this parent may be exploited through hybridization for the improvement of these characters. The predominance of non-additive genetic variance for agronomic characters suggests the improvement of these traits through hybridization (Dhaliwal and Sharma, 1990).

Inheritance of amylose content was studied in six crosses and their reciprocals in the F_1, F_2 and F_3 generations by Huang and Li (1990). Amylose content was determined using a technique requiring only a single grain of rice. The results indicated that a single major gene in association with modifier genes governed inheritance of amylose content. High and medium amylose content was completely dominant over low amylose content. Gene dosage effects existed in several crosses.

In an inheritance study conducted by Kaw and Cruz (1990) for amylose content and gelatinization temperature, in 102 F_1 hybrid seed generations, obtained by crossing each of six indica type elite IRRI lines as testers to indica and japonica lines, most hybrids (76.5%) from crosses between high x high, intermediate x high and low x high amylose parents were intermediate in amylose content. A wide range of variation for gelatinisation temperature was observed in indica testers and a narrow range in japonica lines. Additive and non-additive gene effects in the control of these two physiochemical characters were found, the variances for *sca* being much larger than the component for *gca*.

Peng and Virmani (1990a) studied combining ability for grain yield, dry matter, harvest index, plant height and days to flower, using line x tester analysis involving seven maintainers and eleven restorer lines. General combining ability and specific combining ability variances were significant for yield, dry matter, days to flowering and plant height. For harvest index, only *sca* variance was significant implying that the first four traits are controlled by both additive and dominant gene action. The harvest index however is primarily controlled only by dominant gene action. Significant *gca* effects for the five traits were observed in the parents and good general combiners for each of the characters could be identified. High *gca* effect for yield of a specific line was found associated with high *gca* effect for dry matter production or harvest index (HI). Parental lines possessing significantly high *gca* effects for both dry matter and HI were not available among those included in the study. High *gca* effects for yield mostly was associated with high *gca* effect for plant height and days to flower, though in some cases the high *gca* effect was related with low *gca* effect for plant height and days to flower.

The cytoplasmic influence on yield and yield components in rice was studied utilizing CO41 as common parent and IR50, ADT36, Paiyur I and CO43 as the other parents by Thyagarajan and Sivasubramanian (1990). Significant reciprocal differences for mean performance and heterosis were observed in the F_1 for earliness, plant height, tiller number, grain number and grain yield per plant. CO41 as maternal parent induced earliness with all the pollinators tested, and tallness, high tillering and enhanced grain yield per plant in combination with IR 50, ADT 36 and Paiyur I. Significant reciprocal differences in heterosis and heterobeltiosis were observed for all the characters studied. High positive heterosis for plant height, productive tillers and grain yield per plant was recorded when IR50 and ADT36 were used as pollinators with CO41 as ovule parent. The days to flowering and grain number varied widely when Paiyur I formed the maternal parent. Plasmon influence on tillering was also observed. This investigation aimed to bring out the need for selection of specific maternal source in breeding programmes.

Twelve rice hybrids involving four CMS lines and three testers were analysed for their combining ability for quantitative traits by Banumathy and Prasad (1991). The *sca* variance was higher than the *gca* variance for plant height, number of filled grains, percentage of spikelet sterility and grain yield per plant indicating the prevalence of non-additive gene action in the expression of these traits. Additive gene action was found to be important for number of productive tillers and length of panicle. Among the parents good general combiners for grain yield, plant height and number of filled grains were identified.

Lokaprakash *et al.* (1991) revealed importance of both additive and non-additive gene actions for the characters plant height, panicle length, productive tillers plant^{-1}, number of spikelets panicle^{-1}, 1000 grain weight harvest index and grain yield with preponderance of non-additive gene action for all the characters except for plant height. Similar results were also reported by Ganesan *et al.* (1997) in a line x tester analysis.

A 10 x 10 diallel cross conducted by Ram *et al.* (1991) for yield and yield components in rice revealed that both additive and non-additive gene actions were important. The influence of non-additive was more than the additive genetic variance for all the characters. The degree of dominance revealed overdominance for panicle length, number of effective tillers, grain yield and sterile spikelets; complete dominance for days to panicle emergence, number of grains per panicle and partial dominance for the rest of the characters. The proportion of positive and negative alleles was equal at most of loci for all the characters except grain yield. The dominant genes were more than the recessive in the parents for all the characters except plant height. Heritability in narrow sense was highest in plant height and lowest in grain yield.

Singh and Singh (1991) conducted combining ability analysis in 8 x 8 parental diallel (excluding reciprocals) progenies for harvest index and other related characters.

Plant height was observed to be controlled mainly by additive genetic variance, panicle length, panicle weight and milled rice (%) was found mainly controlled by non-additive genetic variances, while both additive and non-additive genetic variances were important for harvest index. Mean performances of lines was related with their *gca* effects in most of the cases. Hybrid breeding along with reciprocal recurrent selection were suggested to be more appropriate to capitalise both additive and non-additive gene effects for harvest index and other related characters in rice.

In a diallel cross involving 7 rice varieties of different duration groups, Mohanty *et al.* (1995) reported that the additive nature of gene action was predominant for heading duration, number of primary branches panicle^{-1}, number of secondary branches panicle^{-1}, 100 grain weight, grain length and grain breadth. The high heritability in narrow sense was also established for all the characters.

Paramasivam *et al.* (1995) evaluated six popular high-yielding rice genotypes and their 15 F_1 hybrids obtained through diallel mating (without reciprocals) for combining ability of 10 grain quality traits and reported that the variances due to general combining ability and specific combining ability were significant except for kernel length. This indicated that the genotypes differed widely for the traits studied. Higher *gca* variance than *sca* variance for all the traits (except kernel length after cooking and linear elongation ratio) indicated the predominance of additive gene action. Best parents possessing desirable *gca* effects for several characters were identified and recommended for recombination breeding.

The study of 9 x 9 diallel analysis in F_2 generation (excluding reciprocals) in rice for various yield components revealed significant differences for general and specific combining abilities for all the characters. The magnitude of *gca* variance was relatively higher than *sca* variance and thus predominance of additive gene action was observed for all the characters except for biological yield per plant and number of effective tillers $plant^{-1}$. On the basis of *gca* effects, the parents PP 72, Jaya and Sita were good general combiners for yield and most of its components. The crosses involving the above parents were more promising and therefore these parents should be exploited in hybridization programme. Based on *sca* effects, the cross PP 72 x Mahsuri, Jaya x Sita, and PP 72 x Sita are suggested for isolation of high yielding lines through pedigree method while crosses Jaya x Govind, Jaya x T_3, Sita x Prasad, Jaya x Prasad and Sita X Govind can be exploited for hybrid breeding (Verma *et al.*, 1995).

Combining ability studied in F_1 and F_2 populations of a 9 x 9 diallel set in rice (*Oryza sativa* L.) by Katre and Jambhale (1996) indicated Mahsuri and Kasturi as good general combiners for yield and other important traits under both transplanted and direct seeded conditions. Fine grained variety Mahsuri was found to be the best general combiner for all the characters except 1000 grain weight and length of grain with late maturity under transplanted and direct seeded condition. Thus, Mahsuri was suggested for developing fine grain varieties with late to mid-late maturity suitable for both the conditions. The best specific combinations involved the parents with high x high high x low and low x low *gca* effects. Ramalingam *et al.* (1997) also observed the similar results in a line x tester analysis. Promising combinations were identified based on the *per se* performance and *sca* effects for yield and yield components.

Using combining ability studies through line x tester analysis in rice for grain traits, Vivekanandan and Giridharan (1997) revealed additive gene action for 100 grain weight, grain length, breadth and thickness. Based on the *per se* performance and *gca* effects, best parents were identified for grain traits besides grain yield. Similarly best parents for recombination breeding and heterosis breeding were identified.

Combining ability and heterosis were estimated for ten characters in a line x tester analysis with three lines, five testers and their 15 hybrids by Padmavathi *et al.* (1997). GCA and SCA variances were significant for days to 50 per cent flowering, number of tillers $plant^{-1}$, number of panicles $plant^{-1}$ and 1000 grain weight. Parents showing significant *gca* effects for more than one desirable traits indicating their utility in heterosis breeding programme were identified. Similarly crosses with high *sca* effects for each character and those recorded significant heterosis for yield and its contributing characters were identified. It was observed that crosses involving one high and the other low, medium or high general combining parents would produce heterotic hybrids.

Combining ability for eight quantitative characters in saline rice cultivars was studied through line x tester analysis by Rogbell and Subbaraman (1997) involving five saline susceptible lines and seven saline tolerant testers. The combining ability analysis revealed that variance due to line x testers was significant for all the eight characters viz., days to 50 per cent flowering, plant height, number of productive tillers plant^{-1}, ear length, ear weight, number of filled grains ear^{-1}, 100 grain weight and grain yield plant^{-1}. The estimates of σ^2sca, σ^2gca and their ratio indicated preponderance of non-additive gene action for all the eight characters studied. Among the parents good general combiners for grain yield were identified. Six crosses were identified as best hybrids based on their *per se* performance, high heterosis and high *sca* effects.

2.7 Heterosis

Using the performance of 13 parents and 17 hybrids, Anandakumar and Rangasamy (1986) studied heterobeltiosis and standard heterosis over the superior parent of the 17 hybrids for yield plant^{-1} and six related characters. Heterobeltiosis and standard heterosis for grain yield ranged from -76.1 to 97.6 per cent and from -51.2 to 42.4 per cent, respectively.

Heterosis over the better parent was observed in hulled rice by Jun (1985) in 11 crosses for grain thickness and in 7 crosses for width, and weight, in brown rice, it was seen in nine crosses for grain width and thickness, in five crosses for weight, in four crosses for the length/width ratio and in three crosses for length. General combining ability was greater than specific combining ability, although both were significant.

Mohapatra and Mohanty (1986) conducted combining ability and heterosis study in twelve early varieties - nine semidwarfs plus three traditional talls - and all their possible F_1's without reciprocals and reported that, heterosis over midparent in grain yield varied greatly and was closely associated with heterosis in biological yield and to a lesser extent harvest index. The four parents showing high *gca* also exhibited high variety heterosis, thus indicating the importance of genes with additive action in heterosis. The significance of *sca* in some of the heterotic hybrids showed the importance of non-additive gene action. However, heterotic hybrids appeared more frequently in crosses involving parents with high x low (HL) rather than HH or LL for *gca* thus indicating the importance of genetic diversity in *gca* effects for realizing heterosis.

In a 8 x 8 diallel cross of rice Singh and Singh (1985) reported that the range of heterosis for kernel length was from -14.45 to 8.04 per cent over mid parent and from -35.51 to 3.98 per cent over better parent. None of the crosses showed significantly high and positive heterosis for kernel length. For kernel breadth, desirable heterosis was present to the extent of -14.54 per cent. Three crosses showed significant heterosis over mid parent. Only one cross exhibited significant heterosis over better parent. Parents with higher kernel length showed negative but non-significant heterosis in different cross combinations for kernel lengths and length : breadth ratio. Manifestation of heterosis in general was very low and no definite trend was observed in relation to genetic divergence of the parents for all three characters. The mean of the cross was close to the midparent values in most crosses indicating the absence of dominance or overdominance. Negative estimate for relative heterosis and heterobeltiosis for L/B ratio of grain and alkali spreading value were reported by Sahai *et al.* (1986). similarly Sarathe *et al.* (1986) reported positive heterosis for alkali spreading value, amylose content and grain yield plant^{-1}.

Twenty one crosses involving fourteen parents of rice were evaluated for heterosis and heterobeltiosis in F_1 and for inbreeding depression in F_2 by Ananandakumar and Rangaswamy (1986). The better expression of component characters like plant height, tiller number and panicle length resulted in heterosis vigour for grain yield in twelve crosses. The hybrid vigour in F_1 and inbreeding depression in F_2 were noticed in all the cross combinations for at least one of the characters.

Results from 7 x 7 diallel experiment indicated that magnitude as well as direction of heterosis differed from character to character depending upon the cross combination. Almost all combinations involving IR-8 as one of the parents possessed high mean and significant heterosis for yield but none of these combinations excelled it, indicating non-existence of exploitable heterosis with the parents under study. Similarly for other yield components like productive tillers per plant, number of grains per panicle and 100 grain weight, there was no standard heterosis at exploitable level. These results show that selection of parents is a critical step for successful hybrid rice programme (Kalaimani and Sundaram, 1987b).

Three hybrid combinations showing high yield and three hybrids showing low yield were evaluated by Paramasivan and Rangaswamy (1987) for plant height, number of productive tillers, panicle length, number of grains per panicle, 100 grain weight and grain yield per plant in F_1 and F_2 generations. Heterosis was manifested for plant height, tiller number, panicle length, number of grains per panicle, grain weight and grain yield per plant in two high yielding crosses. The mean expression and the extent of transgression noticed in different F_2.s are attributed to the gene action of modifiers present in parents.

Paramasivan and Rangasamy (1988b) and Lokaprakash *et al.* (1992) reported that heterosis for yield plant^{-1} was due to heterosis for other yield component characters. They also observed that there was a close relationship between the frequency of crosses showing significant *sca*' effects and those showing heterosis over better parent for all traits studied.

Sarawgi and Shrivastava (1988) recorded high mean heterosis for yield per plant, biological yield and tiller number in plants grown under irrigated conditions, and for flag leaf area, biological yield and tiller number per plant in those grown under rainfed conditions. Heterosis was only moderate for tiller number in plants grown under rainfed condition. The remaining characters had either very low or negative hybrid vigour.

Hybrids from crosses involving a cytoplasmic male sterile line (MR 365 A) used as the common female parent and four rice cultivars as males, were screened for nine grain quality characters by Mandal and Saran (1989), in respect of heterobeltiosis and standard heterosis. The magnitude of hulling recovery ranged from -4.09 to 4.81 per cent over the better parent (heterobeltiosis) and -8.23 to 1.02 per cent over the standard check (standard heterosis). Kernel length value over the better parent and the standard check were positive in all the hybrids except MR 365 A x IR 36, where heterobeltiosis was negative. Kernel breadth was found to be negative in all the hybrids except MR 365 A x IR 36 which showed a positive heterobeltiosis. The L/B ratio showed a positive heterobeltiosis in all the hybrids except in the above mentioned cross. Except for MR 365 A x IR 36, alkali spreading value showed a positive result. Water uptake, kernel elongation and volume expansion values were negative in almost all the hybrids, the only exception was heterobeltiosis for water uptake in one cross (3.57%).

Seventy five hybrids and eighteen parental lines were evaluated for heterosis for yield, dry matter, harvest index, days to flowering and plant height in a field experiment conducted by Peng and Virmani (1990b). Mean performance of hybrids was superior to that of the inbreds for all the traits. Thirty one hybrids significantly out yielded their better parents. One hybrid showed significant increase over check by 33.6 per cent significant standard heterosis for other traits was also observed. The best hybrids for yield were identified. Heterosis for yield in these hybrids resulted from high drymatter production and for harvest index.

Genetic diversity and heterosis were studied in 65 rice varieties grouped into 18 clusters, by Sarathe and Perraju (1990), on the basis of diversity estimates and popularity of variety. Genetic diversity was not related with heterosis for grain yield, panicle number, panicle length, number of grains per panicle and 1000 grain weight. High positive heterosis for grain yield was obtained for some crosses suggesting that parents having fairly high to medium diversity estimates may be utilized in hybridization programme inorder to increase the chance of getting high heterotic manifestation.

Kaw and Cruz (1991) reported average heterosis of 2.2 per cent for amylose content and -1.3 per cent for gelatinization temperature, was recorded over the midparent in the Japonica x Indica crosses and -5.2 per cent and 1.1 per cent, respectively, in the indica x indica crosses. 72.9 per cent of the indica x indica and 44.4 per cent Japonica x indica hybrids had significant negative midparent heterosis for amylose content. No hybrid was lower than the lower parent in amylose content.

Patnaik *et al.* (1991) studied the magnitude of heterosis in relation to genetic divergence in the line x tester crosses which involved four cytoplasmic genetic male sterile (CMS) lines and thirty four restorers. The genotypes were grouped into clusters using Mahalanobis D^2 statistics. It was seen that the crosses whose parents had moderate genetic divergence showed better performance than the crosses whose parents had extreme genetic divergence. The results revealed that the frequency of heterotic crosses and specific combining effects were found to be higher in crosses between the parents in intermediate genetic divergent classes than the extreme ones.

Peng *et al.* (1991) studied relationship between heterosis and genetic divergence. The F_1 hybrids showed certain degree of heterosis and heterobeltiosis for yield. The mean heterosis and heterobeltiosis were comparable for hybrids from intermediate divergence class and low divergence class, while hybrids from high divergence class showed lowest mean heterosis and three intra-cluster crosses had highest mean heterosis. Heterotic and non-heterotic hybrids were found among cross derived from parents showing different levels of genetic divergence. This study did not show a relationship between heterosis and genetic divergence which could be used as a guide line for predicting heterosis in hybrid rice breeding programme.

Sahai and Chaudhary (1991) studied twelve rice hybrids for days to heading, plant height and grain yield. Reduction in days to 50 per cent heading was recorded in most of the hybrids without sacrificing the grain yield. This clearly indicated that growth duration did not limit the yield potential of hybrids. It was found that hybrids were shorter than their male parents. Most of the hybrids had more than 20 per cent heterosis over better parent and best commercial varieties. The extent of heterosis in rice is significant enough for commercial production of hybrid rice in tropical countries.

Sarawgi and Shrivastava (1991) observed that parents of F_1 showing high heterosis for grain yield were in the same cluster. This indicated that genetic diversity may not be related to high heterosis.

The nature of combining ability and heterosis in rice was studied in a set of 8 x 8 non-reciprocal diallel cross by Singh *et al.* (1993). Superior combinations for kernel length and breadth exhibiting significant heterosis in desired direction were identified. The heterosis for length/breadth ratio was not found to be accompanied by simultaneous heterosis for kernel length and kernel breadth though quite wide range of heterosis (-23.74% to 19.7% over better parent) for this character was recorded. Based upon heterotic effects in conjunction with specific combining ability estimates, good combinations were identified and offered great promises for their utilization in hybrid breeding programmes.

Heterosis and inbreeding depression for grain size, shape and weight were studied in five intervarietal crosses by Chauhan and Chauhan during 1995. The lack of heterobeltiosis for grain size in this study indicated that there was no dominance/over dominance in the expression of this character. Low level of heterosis and inbreeding depression, in general, was recorded for grain size and shape. Substantial positive heterosis and heterobeltiosis for grain weight in some of the crosses appeared to be due to non-additive gene interactions as indicated by high magnitude of inbreeding depression.

In a heterosis study for kernel characters, Vivekanandan and Giridharan (1995) reported that heterosis for kernel length was low and that for L/B ratio was significant and negative, indicating that none of the hybrids were superior for grain fineness.

In rice heterosis over mid and better parents in 42 crosses was worked out for 12 physiological characters including grain yield by Murthy and Kulkarni (1996) and reported that magnitude of heterosis was more for leaf area at early stage, total biological yield and grain yield, while it was comparatively low for harvest index. Top three heterotic crosses over their respective better parents for each trait were identified.

Heterosis study on seven crosses among 28 rice hybrids derived from four early maturing varieties as lines and seven extra-early varieties as testers revealed that heterosis over the mid and better parent was negative for days to panicle emergence and positive for panicle plant^{-1}, grain yield plant^{-1} and harvest index. The inbreeding depression was negative for days to panicle emergence and plant height whereas, residual heterosis was positive for these traits. In contrast, inbreeding depression was positive and residual heterosis was negative for grain yield plant^{-1} and harvest index (Ganesan *et al.*, 1997).

Mishra and Pande (1998) reported that the higher yielding hybrids did not show significant heterosis for the character, number of panicles plant^{-1} and observed that heterosis for yield was largely attributed to heterosis in number of spikelets panicle^{-1}, panicle length, harvest index and 1000 grain weight. He also reported negative standard heterosis and negative heterobeltiosis for the character harvest index.

2.8 Generation mean analysis

Genetic improvement of a crop depends on the extent of genetic variation present in its characters. In self pollinated crops the generation mean analysis is a simple and useful technique to understand the gene effects for a polygenic character (Hayman, 1958). From this analysis the estimation of epistatic gene effects viz. additive x additive (i) additive x dominance (j) and dominance x dominance (l) can be known. The knowledge of the nature and the magnitude of gene action of grain yield and its component characters would help in the choice of efficient breeding methods. Some works carried out in rice using generation mean analysis are reviewed below.

An experiment was conducted by Maurya (1976) with 49 populations (21 F_1s, 21 F_2s and 7 parents) in randomized block design with three replications. High heritability values in both the generations were observed for days to heading, height, number of grains panicle^{-1} and test weight and low values for sterile grains panicle^{-1}, total and ear-bearing tillers. The value for heritability as well as genetic advance was found low in respect of grain yield. Improvement in grain yield could be affected by exercising selection for high grain number panicle^{-1}, test weight and grain length.

Genetic architecture of yield and yield components in rice was investigated by Khaleque, *et al.* (1978) in nine single crosses made within IRRI varieties and between IRRI and local varieties. Non-additive gene effects were found to be predominant in the inheritance of these characters. Dominant component of genetic variation was in the overdominance range mostly which causes an inflation in the heritability estimates for all the characters at least in one cross. High heritability accompanied by high genetic advance was observed for all the characters except for primary branch number in some of the crosses. Transgressive segregation detected in either direction indicated that selection breeding for high yield may be started in early generation of the crosses 1,5,9 and 7. The number of effective factors (k) estimated ranged from 1 for most of the characters to 19 for primary branch number. Non-allelic interaction was mostly of the additive x additive (i) and dominance x dominance (l) type heterosis in most cases was due to overdominance and/or non-allelic interaction. Still in some cases no heterosis was caused by mutual cancellation of d,h,i and l components. Further, in many cases the epistatic gene effects were the cause of low F_3 values resulting a highly significant inbreeding depression.

In the breeding programme for evolving rice varieties for low land conditions, IR 127 and Pankaj were used as donors for intermediate plant height. Derivatives with intermediate plant height, evolved from Pankaj x ARC 12773 and Taichung Native I x IR 127 were examined.for variation and inter relationships of agronomic characters. Several derivates from both crosses showed intermediate plant height and non-lodging characteristic. Despite low to moderate tillering, many derivatives yielded better than their intermediate statured parents. Evidence suggested that IR 127, like Pankaj, could be a suitable donor for intermediate stature.,in varietal improvement (Srivastava, 1981).

After 15 cultivars of diverse origins had each been crossed with strains T_3, T_{21} and N_{22} the 45 F_1 populations obtained, 45 F_{2s} and 18 parental forms were compared in respect of yield and some yield components in a trial with three replications by Singh *et al.* (1984). In grain yield per plant, heterosis, relative to the better parent, ranged from -37.48 per cent to +133.71 per cent, while in all components the range was less. Diversity of geographical origin and pedigree both appeared to affect heterosis +vely and significantly. Of the five highest yielding F_1 populations, three were also among the five which displayed the highest heterosis for yield and similarly, *per se* performance was associated with high heterosis in the characters 500 grain weight, number of grains panicle^{-1}, tillers plant^{-1} and fertile tillers plant^{-1}. Grain yield was invariably lower in the F_2 than in the F_1, but in some components of yield inbreeding depression showed negative values in certain cross combinations. Biparental mating is therefore recommended as a means of minimizing the depression of grain yield in the F_2.

Ponnuthurai and Virmani (1985) evaluated four F_2 rice hybrids, the corresponding F_1 parents and recommended pure line cv - IR 54. The F_1 hybrids and cv. IR 54 flowered earlier and were more uniform in flowering and plant height than the F_2 hybrids. Flowering occurred within 15 days between 99 and 114 days after sowing in IET 3257 / IR 2797, and within 12 days for the other F_2 hybrids. Yield depression in the F_2 ranged from 14 to 21 per cent and was significant in all hybrids, F_2 yields were comparable with those of IR 54. Highest yield depression in the F_2 occurred in IET 3257 / IR 2797; the same combination also showed highest yield heterosis in the F_1.

Srivastava and Roy (1985) reported three types of genetic systems to be involved with intermediate stature in the study where Pankaj, Asgo and IR 127 indicated polygenic and S_3 showed digenic behaviour with normal (tall) parent. The polygenic genes for plant height in IR 127 and digenic genes of S_3 showed non-allelic interaction with Deo-Geo-Woo-Gen semi dwarfing gene showing over dominance of tallness in F_1 generation and higher percentage of taller segregants in F_2 generation.

Genetic architecture of yield, harvest index and component characters in rice was studied by Sharma *et al.* (1986) using generation mean approach for seven cross combinations. The epistatic effect (i, j and l) varied in different characters and crosses, and were much less than the mean effects (m). For yield the major component of genetic variation was due to dominance and additive x additive gene effects, whereas for harvest index the major contribution was from additive x dominance and dominance x dominance effects. In general additive x dominance (j) was less important in the inheritance of characters. Interaction effects (iandl) were of considerable magnitude indicating that these components may be utilized in developing hybrids. For number of panicles plant^{-1} and grains panicle^{-1}, additive x additive effects were of higher magnitude than additive x dominance and dominance x dominance components.

A study of the F_2 generation of 10 F_1s previously categorized for SCA effects indicated that mean grain yield was not significantly different between SCA categories. RNR 29692 x Rajendra (high SCA in the F_1) gave the highest yield plant^{-1} (25.4g), followed by Prabhat x Rajendra (negative SCA in the F_1; 23.3g). Dhanraj *et al.*, 1987).

The semidwarf varieties W x 817, W x 185, Taebaegbyeo and Manseogbyeo, which are similar in terms of plant morphology and genetic background, were crossed in all possible combinations to give single, double, 3-way and back cross hybrids. Progeny means for all crosses were higher than parental means for fertility ratio, number of panicles per hill, 1000 grain weight, yield and shattering and lower for number of grains per panicle, grain length and grain length/width ratio. The progenies were also earlier in heading and have longer culms and shorter panicles. Parental and progeny means did not differ for grain width. Generation mean analysis of the single crosses indicated additive x additive, additive x dominance and dominance x dominance interactions as well as additive and dominance gene action for most of the traits studied. Epistasis was also observed. Heterosis was also significant for all characters except grain width. Average heterosis was negative for certain traits and positive for others. Additive effects were the most important, followed by heterosis effects, for most characters. Heterosis was more important for yield (Hahn and Chae, 1987).

Studying with F_2 populations of some crosses, Chauhan *et al.* (1990) reported that polygenes governed the expression of plant height, tillers per plant and panicles per plant. However, the F_2 distribution was bimodal with transgressive segregants only towards the tall parent in one cross studied indicating the presence of major gene(s) and modifiers for tallness.

In an investigation to study the contribution of the main stem and different tillers, Kim and Vergara (1991) concluded that in breeding for grain yield, low-tillering cultivars with up to five tillers would be ideal as the first five tillers to develop are the most productive.

In a cross of Begunbuchi and IRAT 102 varieties of rice having extreme variations for number of grains and 1000 grain weight, Chauhan *et al.* (1993) found that additive and additive x additive interaction effects were found important in the inheritance of grains panicle^{-1} and 1000 grain weight. However grain yield was predominantly governed by dominance effects and additive x dominance and dominance x dominance interaction effects. Complementary type epistasis was observed for grains panicle^{-1} and 1000 grain weight, while duplicate type epistasis was prominent for grain yield. The mid parent heterosis was maximum (29.3%) for grain yield plant^{-1}. It is therefore, suggested that for simultaneous improvement of yield and its two important components, viz., grain number panicle^{-1} and 1000 grain weight, a single breeding system capable of exploiting additive and non-additive gene effects should be used. In order to achieve this, the use of recurrent selection is advocated.

A study was undertaken by Nandarajan and Kumaravelu (1994) to know the genetics of grain yield and its components in rice. Using six generations in each of five cross combinations built up with five drought resistant genotypes, information was generated on the genetic architecture for six quantitative traits. The analysis of generation means showed that, in general, the traits productive tillers per ear, grain weight, grain yield were governed by additive, dominance and epistatic gene interactions.

The components of gene effect for yield and five yield traits were studied in four crosses using a popular indigenous cultivar as one parent. The character means over six generations were subjected to scaling test. In the presence of epistasis, six parameter model was used to detect all types of gene effects. The analysis revealed the importance of dominance and epistatic components for yield, tillers plant^{-1}, grains panicle^{-1} and 100 grain weight in all the crosses. Additive and dominance effects were important for plant height and panicle length. Among the digenic interactions additive x additive and dominance x dominance effects contributed more in most of the characters. Additive x dominance gene effects was important for 100 - grain weight in some crosses. In general, most crosses revealed duplicate nonallelic interactions for majority of characters. All the crosses exhibited heterosis in F_1 and inbreeding depression in F_2 generation (Ram, 1994).

Magnitude of four components of variation, viz., D, H, F and E was estimated using six generations namely P_1, P_2, F_1, BC_1 and BC_2 of a Pankaj x Manoharsall, cross of rice for yield and yield traits. Additive genetic variance (D) was high for days to 50 per cent flowering, panicle length, spikelets panicle^{-1} and panicle number. Dominance variance (H) was of high magnitude for plant height and yield plant^{-1}. Positive sign of F component for panicle length and spikelets panicle^{-1} revealed that genes with positive effects were dominant for these two characters, whereas for other four characters genes with negative effects were dominant. The presence of additive and dominance variance for yield and yield traits indicated that biparental mating followed by selection or diallel selective mating system could improve these characters in rice (Chakraborty and Hazarika, 1995).

F_1 heterosis over midparent (mp) and better parent (BP) and F_2 inbreeding depression (ID) were studied by Reddy and Nerkar (1995), in 8 crosses of rice for grain yield plant^{-1} and its four other component traits, ie., plant height, effective tillers plant^{-1}, number of filled grains panicle^{-1} and 1000 grain weight. Highly significant and positive MP and BP heterosis for grain yield was expressed by four hybrids and ID in each case invariably accompanied in F_2. Such high heterosis for yield was due to additive heterotic effect of one or more component traits. In all the cases, heterosis for effective tillering was found to be the major contributor and number of filled grains panicle^{-1} contributed less to grain yield heterosis. High heterosis accompanied by high ID for effective tiilers plant^{-1} and number of filled grains panicle^{-1} indicated the presence of nonadditive gene effects governing the inheritance of these traits. Since growth vigour was not of retentive nature as indicated by high ID in F_2 for grain yield, it should be exploited in F_1 itself.

Analysis of gene effects was performed by Chakraborty and Hazarika (1996) using means of six generations, viz., P_1, P_2, F_1, F_2, BC_1 and BC_2 of a cross, Mahsuri x Manoharsati to determine the nature and magnitude of gene actions governing yield and yield components like plant height, panicle length, spikelets panicle^{-1}, panicle number and 100 grain weight. Both additive and nonadditive gene actions were important in controlling all the characters studied. Epistatic effects of mainly duplicate type were predominant over additive and dominance effects for all the traits. Breeding method such as reciprocal recurrent selection could be useful in the genetic improvement of the characters studied.

Materials and Methods

3. MATERIALS AND METHODS

The present study was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University. Field trials were laid out at the Agricultural Research Station, Mannuthy of the Kerala Agricultural University. The area is located at a latitude of 10°32'N, longitude 76°10'E, elevation 1.5 MSL. The soil is a laterite loam.

The whole investigation was grouped into three experiments.

3.1 Experiment No.1

3.1.1 Materials:

Fifty six high yielding diverse rice genotypes representing various eco-geographical conditions namely, Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Srilanka, constituted the materials for the study. Parentage and origin of the breeding lines are given in Table 1. Out of 56 genotypes, 27 genotypes are indigenous to India, recommended for cultivation. in different ecological conditions of Kerala, by the Kerala Agricultural University.

3.1.2 Methodology

Seeds of 56 genotypes were sown in nursery beds during May 1996. Transplanting, of 18-25 day old seedlings according to their maturity duration, was resorted keeping inter and intra row spacing of 20 cm and 15 cm respectively. Plots consisting of 8 rows of 36 hills each were laid out in a randomised block design with

Table 1 Genotype, parentage and origin of breeding lines included in the study

Accession Number	Genotype	Parentage	Origin
(1)	(2)	(3)	(4)
Exotic high yielding genotypes			
V_1	AS25370	ASDI/BG-90-2	India
V_2	AT85-2	IR36/IR9729-67-3	Sri Lanka
V_3	BR4676-72-2-4	BR161-2B-58/IR50	Bangladesh
V_4	BR4689-17-15	BR161-2B-58/BR319-1-HRII	Bangladesh
V_5	CCI22-23-4-301	IR29/NGOBA	India
V_6	CCI38-11-6-F-314	DR-S2/PUSA-2-21	India
V_7	CR294-548	Not available	India
V_8	HS INCHU-64	HS INCHU YU 235/TAINAN-5	Taiwan (China)
V_9	IR53970-21-2-3-2	IR31906-67-1-1-2-2/IR31802-48-2-2-2//IR41985-111-3-2-2	IRRI
V_{10}	IR544883-152-3-3	IR41985-111-3-2-2/IR31802-48-2-2-2	IRRI
V_{11}	IR54550-181-2-1-2-3	NEW SABARMATHI (BAS)IR24632-34-2	IRRI
V_{12}	IR56453-184-2-1-2	IR41985-111-3-2-2/IR28143-51-3-3-1-3	IRRI
V_{13}	IR59682-132-1-1-2	IR48613-54-3-3-1/IR28235-94-2-3-6-2	IRRI

Contd....

Table 1 contd...

V_{14}	IR60133-184-3-2-2	IR42000-211-1-2-2-3/IR-42015-83-3-2-2-2//IR42068-22-3-3-1-3	IRRI
V_{15}	IR60832-187-2-2-2	IR42015-83-3-2-2-2/IR28239-94-2-3-6-2	IRRI
V_{16}	IR61005-37-2-1-2	IR52256-84-2-3/IR35366-90-3-2-1-2	IRRI
V_{17}	IR62030-18-2-2	IR48525-65-2-1/IR52280-117-1-1-3	IRRI
V_{18}	IR62164-14-2-2-2-3	IR52287-153-1-1-2/IR50404-57-2-2-3	IRRI
V_{19}	KACHSIUNG SEN YU 338	SUKEON-264/NAKING//IR1780-150-3	TAIWAN (CHINA)
V_{20}	MR123	IR13526-42-2-2//2*P SERIBU-2/3*MRI/// KHAO SAAD-108/MR7	MALAYSIA
V_{21}	PK2480-7-31	BASMATI-370/IR17492-18-10-2-2-2	PAKISTAN
V_{22}	PK2557-24-2-1	Not available	PAKISTAN
V_{23}	PK3355-5-1-4	KS282/IR24	PAKISTAN
V_{24}	RAVI (RP1664-1529-42540	M63-83//RP79-5/RIKUTO NORIN-21	INDIA
V_{25}	RP1670-1418-2205-1585	M63-83/CAUVERY	INDIA
V_{26}	S9728-22-1-3-1-1	OBS677/IR14632-165	INDONESIA
V_{27}	S9768-PN-25-1	IR14632-312/IR54	INDONESIA
V_{28}	IR36 (INTL CHECK)	IR1561-228//4*IR24/0 NIVARA///CR94-13	IRRI
V_{29}	IR50 (INTL CHECK)	IR2153-14-1-6-2/IR28//IR36	IRRI

Contd......

Table 1 contd...

Indigenous high yielding varieties of Kerala			
V_{30}	AHALYA	Ptb-10/TN1/TN1	KERALA (INDIA)
V_{31}	ANNAPOORNA	TN-1/Ptb-10	-do-
V_{32}	ARATHI	JAYA/Ptb-33	-do-
V_{33}	ARUNA	JAYA/Ptb-33	-do-
V_{34}	ASHA	IR11/KOCHUVITHU	-do-
V_{35}	ATHIRA	BR51-46-1/Cul.2332-2	-do-
V_{36}	BHADRA	IR8/Ptb-20	-do-
V_{37}	BHAGYA	TADUKKAN/JAYA	-do-
V_{38}	HRASWA	IR8/T140	-do-
V_{39}	JAYA	TN-1/T-141	-do-
V_{40}	JAYATHI	BHAVANI/IR2061	-do-
V_{41}	JYOTHI	Ptb-10/IR8	KERALA (INDIA)
V_{42}	KANCHANA	IR36/PAVIZHAM	-do-
V_{43}	KANAKAM	IR1561/Ptb-33	-do-
V_{44}	KAIRALI	IR36/JYOTHI	-do-
V_{45}	KARTHIKA	TRIVENI/IR1539	-do-
V_{46}	MAKAM	ARC-6650/JAYA	-do-
V_{47}	MAHSURI	TAICHUNG-65/MAYANG EBOS	MALASIA

Contd...

Table 1 contd..

V_{48}	MATTATRIVENI	ANNAPOORNA/Ptb-15	KERALA (INDIA)
V_{49}	ONAM	(KOCHUVITHU/TN-1)/TRIVENI	-do-
V_{50}	PAVISHAM	IR8/KARIVENAL	-do-
V_{51}	RANJINI	MO-5/Improved Sona	-do-
V_{52}	REMYA	JAYA/Ptb-33	-do-
V_{53}	SABARI	IR8/2/ANNAPOORNA	-do-
V_{54}	VYTILLA 2	Pure line selection from Cheruvirippu	-do-
V_{55}	VYTILLA 3	Vytilla 1/T(N)1	-do-
V_{56}	VYTILLA 4	Chettivirippu/IR4630-22-2-17	-do-

three replications. All cultural operations were carried out as per the Package of Practices Recommendations of the Kerala Agricultural University 1993.

Observations on growth and yield parameters were recorded on ten randomly selected plants in each replication for each treatment after leaving the border rows. Observations of 32 characters were taken as per the standard evaluation system suggested by Shouichi *et al.* (1976) and IRRI (1995).

3.1.2.1 Characters

1. Internodal length in cm

Two measurements namely, uppermost and second uppermost internodal lengths were taken. Uppermost internodal length was measured as the distance in centimetres between the 1st node and panicle base. Second uppermost internodal length was measured as the distance in centimetres between the 1st and the 2nd nodes.

2. Orientation of leaf

This had been measured using plant canopy analyzer [LAI 2000 (LI COR, USA)]. Plant canopy analyzer measures mean foliage tilt angle which had been substracted from 90° to get foliage orientation.

3. Length of flag leaf

It is the measurement of length in centimetres between base and tip of the flag leaf.

4. Maximum leaf width of flag leaf

It is the actual measurement of width in centimetres at the widest portion of the flag leaf blade.

5. Number of days to panicle initiation

The panicles were examined *in situ* by tagging specific tillers in specific plants. The apices were teased and opened carefully with fine needle to observe the development of panicle. Observations were recorded from five plants for each variety from the primary tillers from each replication (Roy and Pani, 1994).

6. Number of days to 50 per cent flowering

Number of days from seeding to flowering of 50 per cent of the population was counted.

7. Height of plant at harvest

Height of the plant was measured in centimetres from soil surface to the tip of the tallest panicle (awns excluded).

8. Total number of tillers

Total number of tillers in each plant was counted.

9. Number of panicle bearing tillers

Number of panicle bearing tillers per plant was counted.

10. Leaf area plant^{-1} at maximum tillering stage

Six hills per plot were selected at random making sure that the hills were surrounded by living hills. From each selected hill, the number of tillers were counted. The length and maximum width of each of the leaves on the middle tiller was measured and leaf area was worked out using the length - width method (IRRI, 1995).

$$\text{Leaf area} = K \times \text{length} \times \text{width}$$

where `K' is the "adjustment factor". For all stages of growth except for seedling stage and at the time of harvest, the value of `K' was kept as 0.75.

11. Number of days to harvest

Number of days from seeding to grain ripening (when 85 per cent of grains on the panicle have matured) were counted.

12. Harvest Index (HI)

$$HI = \frac{\text{Economic yield}}{\text{biological yield*}}$$

Economic yield and biological yield from one square metre area were taken.

*Weight of root also was included

13. Ratio of vegetative phase to reproductive phase

Number of days from seeding to panicle initiation was taken as vegetative phase and number of days from panicle initiation to harvest was taken as reproductive phase.

14. Number of panicles m^{-2}

One m^2 area was marked out in each plot and actual counts were made on panicles.

15. Number of spikelets panicle^{-1}

All spikelets including fertile and sterile ones in each panicle were counted.

16. Number of secondary branches panicle^{-1}

Number of side branches from primary branch of each panicle was counted.

17. Number of tertiary branches panicle^{-1}

Total number of side branches from the secondary branches was counted.

18. Length of panicle

Actual measurement of the distance in centimetres from panicle base to tip of the top most spikelet was entered (awns excluded) as length of panicle.

19. Number of grains panicle^{-1}

Grains in each panicle of randomly selected plants were counted and mean was worked out.

20. Spikelet sterility percentage

The fertile spikelets were identified by pressing the spikelets with the fingers at maturity and those spikelets without grains were considered as sterile ones.

$$\text{Sterility percentage} = \frac{\text{Number of sterile spikelets}}{\text{Total number of spikelets}} \times 100$$

21. 1000 grain weight

Weight of 1000 number of grains was taken in grams.

22. Grain length

The mean length of 10 grains in millimetres was taken, from the base of the lower most sterile lemma to the tip.

23. Grain breadth

The distance across the fertile lemma and the palea at the widest point was measured in millimetres for 10 grains and the mean was worked out.

24. L/B ratio of grain (Length width ratio)

It is the ratio of length to breadth of the grain. Grain shape can be easily estimated by this method.

25. Grain yield

The entire plants from each plot were harvested discarding border rows and the yield was expressed in kg ha^{-1}.

26. Awning

Awning was graded as follows:

0 Absent

1 Short and partly awned

5 Short and fully awned

7 long and partly awned

9 long and fully awned

27. **Lemma palea pubescence**

Lemma palea pubescence was graded as follows:

1 Glabrous

2 Hairs on lemma keel

3 Hairs on upper portion

4 Short hairs

5 long hairs (velvety)

28. **Lemma palea colour**

Lemma palea colour was graded as follows

0 straw

1 Gold and gold furrows on straw background

2 Brown spots on straw

3 Brown furrows on straw

4 Brown (tawny)

5 Reddish to light purple

6 Purple spots on straw

7 purple furrows on straw

8 purple

9 Black

10 white

29. **Kernel colour**

Dehulled rice was used to record kernel colour as red or white.

30. Hulling percentage

Seeds collected from replicated trials were cleaned and were dried to 14 per cent moisture content. The sample was parboiled after three months of storage by the double steaming method and dried to 14 per cent moisture. Then the sample were dehulled using laboratory model satake rubber roll huller. Hulling percentage was calculated as follows.

$$\text{Hulling percentage} = \frac{\text{Weight of dehulled grains}}{\text{Weight of paddy}} \times 100$$

31. Milling percentage

The dehulled paddy samples, were milled for 30 seconds in a Mc Gill Miller.

$$\text{Milling percentage} = \frac{\text{Weight of milled paddy}}{\text{Weight of paddy}} \times 100$$

32. Cooking quality

Amylose content and alkali spreading value are the important characters in determining the cooking quality of rice (Ghosh and Govindaswami, 1972). Different cooking qualities like, amylose content, alkali spreading value, water uptake, volume expansion ratio and kernel elongation ratio were studied.

a) Amylose content

100 mg parboiled milled rice was powdered. In this sample, one ml of distilled ethanol was added. 10 ml of IN NaoH was added to this and it was kept over night. The volume was made upto 100 ml. 2.5 ml of the extract was taken and

added 20 ml of distilled water and three drops of phenolphthalein. Then 0.1 N Hcl was added drop by drop until the pink colour just disappeared. To this, 1 ml of iodine reagent was added and made up to 50 ml and the colour developed was read at 590 nm using spectrophotometer. 0.2, 0.4, 0.6, 0.8 and 1 ml of the standard amylose solution was taken and developed the colour as in the case of sample. Using the standard graph the amount of amylose present in the sample was calculated. One ml of iodine was taken and diluted to 50 ml for a blank (Sadasivan and Manickam, 1992).

Rice varieties are grouped on the basis of their amylose contents into waxy (1-2% amylose), low amylose (8-19%), intermediate amylose (20-25%), or high amylose (> 25%) [IRRI, 1972].

b) Alkali spreading value

Six milled rice kernels were placed in 10 ml 1.7% KOH in a shallow container (petriplate). The kernels were so arranged that they did not touch each other. They were allowed to stand for 23 hours at 30°C. The appearance and disintegration of the kernels were rated visually after incubation, based on the following numerical scale (Little *et al.*, 1958).

Description		Score
Kernel not affected	:	1
Kernel swollen	:	2
Kernel swollen; collar incomplete or narrow	:	3

Kernel swollen; collar complete and wide	:	4
Kernel split or segmented; collar complete and wide .	:	5
Kernel dispersed, merging with collar	:	6
Kernel completely dispersed and intermingled	:	7

A rating of 1 to 2 was classified as high final gelatinization temperature, 3, high intermediate; 4 to 5, intermediate (70-74°C); and 6 to 7, low final gelatinization temperature (< 70°C).

c) Water uptake

Ten whole milled rice kernel per sample were used to study water absorption. Weight of the samples was recorded before and after cooking. Excess water was removed from the cooked grain with the help of a blotting paper. The difference in weights divided by the weight of uncooked sample was taken as the amount of water absorbed per unit weight of rice (Sadananda *et al.*, 1987).

d) Volume expansion ratio

The volume of raw rice as well as cooked rice were determined by water displacement using a measuring cylinder (Onate and del Mundo, 1966).

$$\text{Volume expansion ratio} = \frac{\text{Volume of cooked rice}}{\text{Volume of raw rice}}$$

e) **Kernel elongation ratio**

Kernel elongation was determined as described by Azeez and Shafi (1966). Five raw and five cooked kernels were taken at random and their length was measured.

$$\text{Kernel elongation ratio} = \frac{\text{Average length of cooked kernel}}{\text{Average length of raw kernel}}$$

The data were subjected to the following statistical analysis.

3.1.3 Statistical analysis

The data were subjected to the following statistical analysis.

3.1.3.1 Estimation of selection parameters:

3.1.3.1.1 Components of heritable variation

a) Variability

Variability existing in the various characters under observation was estimated as per the procedure suggested by Burton (1952). The estimates of pcv and gcv were classified as, less than 10 per cent = low; 10-20 per cent = moderate and > 20 per cent = high.

b) Heritability

Heritability in broad sense was calculated according to the formula suggested by Hanson *et al.* (1956).

The heritability was categorised as, 60-100 per cent = high;

30-60 per cent = moderate; < 30 per cent = low.

c) Genetic advance:

The expected genetic advance under selection was estimated by the formula suggested by Johanson *et al.* (1955).

d) Genetic gain

Expected genetic gain under selection was calculated by the formula suggested by Johanson *et al.* (1955).

Genetic gain was categorised as more than 20 per cent = high;

10-20 per cent = moderate; < 10 per cent = low.

3.1.3.1.2 Phenotypic and genotypic correlations

Phenotypic and genotypic correlation coefficients between yield and various yield components and among themselves were estimated (Rangaswamy, 1995).

3.1.3.1.3 Direct and indirect effects of yield attributes on yield through path analysis

Path coefficient analysis suggested by Wright (1923) was applied to study the cause and effect relationship of yield and yield attributes.

3.1.3.1.4 Evolving a selection index using discriminant function (Hazel, 1943)

For selecting suitable genotypes from a highly heterogeneous mass population, the selection should always be based on the minimum number of characters. An estimation of discriminant function based on most reliable and effective characters is a valuable tool for rice breeder. Thus discriminant function would ensure a maximum concentration of the desired genes in the plants or in the lines selected.

3.1.3.2 Mahalanobis D^2 analysis

Replication mean for each character of each strain was used for Analysis of Variance. After testing the differences, a simultaneous test of significance of difference with regard to the pooled effects of the 32 characters under study was carried out using Wilks' criterion (Rao, 1952).

Original mean values were then transformed into uncorrelated mean using pivotal condensation of common dispersion matrix. From the uncorrelated variables, the actual values of D^2 between any two varieties based on 32 characters were then calculated. Inorder to determine the population constellation, all the varieties were grouped into a number of clusters on the basis of D^2 values as suggested by Tocher (Rao, 1952).

3.2 Experiment No.2

3.2.1 Materials

Twelve genetically diverse photoinsensitive genotypes (Plates 1A to 1F and 2A to 2G) representing nine clusters identified in experiment No.1, using 56 high yielding ecogeographically diverse rice genotypes form the materials for this experiment. Selection of genotypes from each cluster was done based on multivariate analysis done for yield and yield components. Selected genotypes were having different characters and diverse parentage to impart wider variations and genetic base. Out of the 12 genotypes selected, six were indigenous to Kerala and six belonged to different geographical areas of the world. The parentage, source and desirable characters of selected genotypes are given in Table 2.

Plate 1 Varieties selected for hybridization

A

India, Kerala

B

IRRI

C

IRRI

D

IRRI

E

Taiwan

F

Indonesia

Plate 2 Varieties selected for hybridization

A

India, Kerala

B

India, Kerala

C

India, Kerala

D

India, Kerala

E

India, Kerala

F

Pakistan

G

Selected 12 varieties showing variability in maturity period

Table 2 Pedigree of parents selected for crossing

Parent designation	Genotype	Parentage	Origin	Desirable characters	Cluster No.
P_1	MATTATRIVENI	ANNAPOORNA/ Ptb-15	INDIA (KERALA)	High harvest index, high amylose and red kernel	IX
P_2	BHADRA	IR8/Ptb-20	INDIA (KERALA)	High number of panicles m^{-2}, intermediate amylose and red kernel	III
P_3	HRASWA	IR8/T140	INDIA (KERALA)	Short duration, short stature, high amylose and red kernel	VII
P_4	MAHSURI	TAICHUNG-65/MAYANG EBOS	MALAYSIA	Maximum number of days to 50% flowering, large number of spikelets panicle^{-1}, long apnicle, intermediate amylose and white kernel	VI
P_5	KARTHIKA	TRIVENI/ IR1539	INDIA (KERALA)	Maximum harvest index, high amylose and red kernel	V
P_6	VYTILLA 3	Vytilla 1 x TN 1	INDIA (KERALA)	Maximum panicle length, heavy grains, high amylose and red kernel	II
P_7	KACHSIUNG SEN YV 338	SUKEON-264/NAKING// IR1780-150-3	TAIWAN.	Maximum number of spikelets panicle^{-1}, compact panicle, increased grain size and grain shape, long panicle, low amylose and white kernel	I
P_8	IR36 (International check)	IR1561-228//4 IR24 O NIVARA/// CR-94-13	IRRI	Maximum number of panicles m^{-2}, high mylose and white kernel	IV
P_9	IR62030-18-2-2	IR48525-65-2-1/IR52280-117-1-1-3	IRRI	Maximum number of grains panicle^{-1}, high harvest index, high amylose and white kernel	IV

Contd....

Table 2 contd...

P_{10}	IR60133-184-3-2-2	IR42000-211-1-2-2-3/IR42015-83-3-2-2-2/IR42068-22-3-3-1-3	IRRI	High number of panicles m^{-2}, high amylose and white kernel	I
P_{11}	PK3355-5-1-4	KS-282/ IR24	PAKISTAN	Long panicle, high amylose and white kernel	VIII
P_{12}	S-9768-PN-25-1	IR14632-312/IR54	INDONESIA	High harvest index, large number of grains $panicle^{-1}$, intermediate amylose and white kernel	VIII

3.2.2 Methods

3.2.2.1 Crossing

Seeds of 12 selected parents were raised in nursery beds during October, 1996 at the Agricultural Research Station, Mannuthy. Since there were long duration, medium duration and short duration varieties, sowing was staggered so as to get synchronised flowering. Sowing was again repeated after 10 days inorder to enable crossing for a long period to get enough F_1 seeds. 18-25 day old seedlings, according to duration were transplanted to 14" size earthen pots for making hybridization easier. The cultural practices followed for the experiment crop was as per the Package of Practices Recommendations of the Kerala Agricultural University.

One hundred and thirty two cross combinations (12 x 11) between 12 genotypes in all possible combinations including reciprocals were effected during January 1997 to March 1997. For emasculation and hybridization the `wet-cloth' method was followed (Plate 3). Mature F_1 and parental seeds were harvested, sundried and stored separately. Out of 132 cross combinations carried out one cross combination (IR 60133 - 184-3-2-2 x S9768-PN-25-1) failed to set seeds even after repeated crossing.

3.2.2.2 Raising F_1 generation and parents

F_1 seeds of 131 cross combinations and 12 parental seeds were sown in shallow earthen pots. Ten cross combinations did not germinate and 25 cross combinations did not survive beyond seedling stage, details of which are given below.

3.2.2.2.1 Cross combinations not germinated

(1) IR60133-184-3-2-2 x IR62030-18-2-2

(2) IR62030-18-2-2 x HRASWA

(3) IR36 x IR60133-184-3-2-2

(4) IR36 x IR62030-18-2-2

(5) VYTILLA3 x S9768-PN-25-1

(6) KACHSIUNG SEN YU 338 x S9768-PN-25-1

(7) KACHSIUNG SEN YU 338 x IR62030-18-2-2

(8) KACHSIUNG SEN YU 338 x MAHSURI

(9) BHADRA x IR62030-18-2-2

(10) BHADRA x KARTHIKA

3.2.2.2.2 Combinations which did not survive beyond nursery stage

(1) VYTILLA 3 x BHADRA

(2) VYTILLA 3 x PK3355-5-1-4

(3) PK3355-5-1-4 x MAHSURI

(4) PK3355-5-1-4 x S9768-PN-25-1

(5) HRASWA x IR36

(6) HRASWA x MAHSURI

(7) HRASWA x KARTHIKA

(8) HRASWA x PK3355-5-1-4

(9) IR60133-184-3-2-2 x VYTILLA 3

(10) IR60133-184-3-2-2 x KARTHIKA

(11) MATTATRIVENI x IR60133-184-3-2-2

(12) IR62030-18-2-2 x BHADRA

(13) BHADRA x MAHSURI

(14) BHADRA x MATTATRIVENI

(15) BHADRA x KACHSIUNG SEN YU 338

(16) BHADRA x IR 36

(17) BHADRA x PK3355-5-1-4

(18) S9768-PN-25-1 x PK3355-5-1-4

(19) KARTHIKA x S9768-PN-25-1

(20) KARTHIKA x KACHSIUNG SEN YU-338

(21) IR36 x BHADRA

(22) IR36 x KACHSIUNG SEN YU-338

(23) IR36 x PK3355-5-1-4

(24) KACHSIUNG SEN YU 338 x IR60133-184-3-2-2

(25) S9768-PN-25-1 x IR36

Remaining 96 cross combinations that were available for further study are presented in Table 3.

Twenty day old F_1 seedlings and 18-25 day old parental seedlings were transplanted to the main field. A single seedling was planted per hill. The 108 entries (96 crosses and 12 parents) were grown in a randomised block design with two replications during July 1997. Each genotype was grown in a single row of ten plants with a plant and row spacing of 15 and 20 cm, respectively. Data were collected from all plants (leaving one border plant on each side of each genotype) for the observations mentioned in item 3.2.2.2.3 (Dhaliwal and Sharma, 1990). The

Table 3 Details of F_1 generations raised during July 1997

Sl. No.	Combinations	Designation
1	MATTATRIVENI x BHADRA	C-1
2	MATTATRIVENI x HRASWA	C-2
3	MATTATRIVENI x MAHSURI	C-3
4	MATTATRIVENI x KARTHIKA	C-4
5	MATTATRIVENI x VYTILLA 3	C-5
6	MATTATRIVENI x KACHSIUNG SEN YU 338	C-6
7	MATTATRIVENI x IR36	C-7
8	MATTATRIVENI x IR62030-18-2-2	C-8
9	MATTATRIVENI x PK3355-5-1-4	C-9
10	MATTATRIVENI x S-9768-PN-25-1	C-10
11	BHADRA x HRASWA	C-11
12	BHADRA x VYTILLA 3	C-12
13	BHADRA x IR60133-184-3-2-2	C-13
14	BHADRA x S9768-PN-25-1	C-14
15	HRASWA x MATTATRIVENI	C-15
16	HRASWA x BHADRA	C-16
17	HRASWA x VYTILLA 3	C-17
18	HRASWA x KACHSIUNG SEN YU-338	C-18
19	HRASWA x IR62030-18-2-2	C-19
20	HRASWA x IR60133-184-3-2-2	C-20
21	HRASWA x S9768-PN-25-1	C-21
22	MAHSURI x MATTATRIVENI	C-22
23	MAHSURI x BHADRA	C-23
24	MAHSURI x HRASWA	C-24
25	MAHSURI x KARTHIKA	C-25
26	MAHSURI x VYTILLA 3	C-26

Contd...

Table 3 contd...

27	MAHSURI x KACHSIUNG SEN YU 338	C-27
28	MAHSURI x IR36	C-28
29	MAHSURI x IR62030-18-2-2	C-29
30	MAHSURI x IR60133-184-3-2-2	C-30
31	MAHSURI x PK3355-5-1-4	C-31
32	MAHSURI x S9768-PN-25-1	C-32
33	KARTHIKA x MATTATRIVENI	C-33
34	KARTHIKA x BHADRA	C-34
35	KARTHIKA x HRASWA	C-35
36	KARTHIKA x MAHSURI	C-36
37	KARTHIKA x VYTILLA 3	C-37
38	KARTHIKA x IR36	C-38
39	KARTHIKA x IR62-30-18-2-2	C-39
40	KARTHIKA x IR60133-184-3-2-2	C-40
41	KARTHIKA x PK3355-5-1-4	C-41
42	VYTILLA 3 x MATTATRIVENI	C-42
43	VYTILLA 3 x HRASWA	C-43
44	VYTILLA 3 x MAHSURI	C-44
45	VYTILLA 3 x KARTHIKA	C-45
46	VYTILLA 3 x KACHSIUNG SEN YU 338	C-46
47	VYTILLA 3 x IR36	C-47
48	VYTILLA 3 x IR62030-18-2-2	C-48
49	VYTILLA 3 x IR60133-184-3-2-2	C-49
50	KACHSIUNG SEN YU 338 x MATTATRIVENI	C-50
51	KACHSIUNG SEN YU 338 x BHADRA	C-51
52	KACHSIUNG SEN YU 338 x HRASWA	C-52
53	KACHSIUNG SEN YU 338 x KARTHIKA	C-53
54	KACHSIUNG SEN YU 338 x VYTILLA 3	C-54
55	KACH IUNG N YU 338 x IR36	C-55

Contd...

Table 3 contd...

56	KACHSIUNG SEN YU 338 x PK3355-5-1-4	C-56
57	IR36 x MATTATRIVENI	C-57
58	IR36 x HRASWA	C-58
59	IR36 x MAHSURI	C-59
60	IR36 x KARTHIKA	C-60
61	IR36 x VYTILLA 3	C-61
62	IR36 x S9768-PN-25-1	C-62
63	IR62030-18-2-2 x MATTATRIVENI	C-63
64	IR62030-18-2-2 x MAHSURI	C-64
65	IR62030-18-2-2 x KARTHIKA	C-65
66	IR62030-18-2-2 x VYTILLA 3	C-66
67	IR62030-18-2-2 x KACHSIUNG SEN YU 338	C-67
68	IR62030-18-2-2 x IR36	C-68
69	IR62030-18-2-2 x IR60133-184-3-2-2	C-69
70	IR62030-18-2-2 x PK3355-5-1-4	C-70
71	IR62030-18-2-2 x S9768-PN-25-1	C-71
72	IR60133-184-3-2-2 x MATTATRIVENI	C-72
73	IR60133-184-3-2-2 x BHADRA	C-73
74	IR60133-184-3-2-2 x HRASWA	C-74
75	IR60133-184-3-2-2 x MAHSURI	C-75
76	IR60133-184-3-2-2 x KACHSIVNG SEN YU :	C-76
77	IR60133-184-3-2-2 x IR36	C-77
78	IR60133-184-3-2-2 x PK3355-5-1-4	C-78
79	PK3355-5-1-4 x MATTATRIVENI	C-79
80	PK3355-5-1-4 x BHADRA	C-80
81	PK3355-5-1-4 x HRASWA	C-81
82	PK3355-5-1-4 x KARTHIKA	C-82
83	PK3355-5-1-4 x VYTILLA 3	C-83

Contd...

Table 3 contd...

84	PK3355-5-1-4 x KACHSIUNG SEN YU 338	C-84
85	PK3355-5-1-4 x IR36	C-85
86	PK3355-5-1-4 x IR62030-18-2-2	C-86
87	PK3355-5-1-4 x IR60133-184-3-2-2	C-87
88	S9768-PN-25-1 x MATTATRIVENI	C-88
89	S9768-PN-25-1 x BHADRA	C-89
90	S9768-PN-25-1 x HRASWA	C-90
91	S9768-PN-25-1 x MAHSURI	C-91
92	S9768-PN-25-1 x KARTHIKA	C-92
93	S9768-PN-25-1 x VYTILLA 3	C-93
94	S9768-PN-25-1 x KACHSIUNG SEN YU 338	C-94
95	S9768-PN-25-1 x IR62030-18-2-2	C-95
96	S9768-PN-25-1 x IR60133-184-3-2-2	C-96

procedures followed for making observations was same as in the previous experiment with slight change in amylose estimation. Here amylose content in non-parboiled unmilled rice was estimated.

In F_1 generations, half of the plants were used for back crossing with both parents ($B_1C_1 = F_1 \times P_1$; $B_2C_1 = F_1 \times P_2$). Remaining plants were selfed to produce F_2 seeds. Simultaneously 12 parents were again subjected to diallel crosses to get fresh F_1 seeds. Matured seeds of P_1, P_2, F_1, F_2, B_1C_1 and B_2C_1 were separately harvested, sundried and stored.

Since only 96 viable cross combinations were obtained out of 132 cross combinations attempted, a full 12 x 12 diallel analysis was not possible. Hence the available crosses were split into a 5 x 5 full diallel crosses including reciprocals (Table 4), a 8 x 8 half diallel crosses excluding reciprocals (Table 5) and a 6 x 3 line x tester type crosses (Table 6). The whole 96 crosses were ranked based on selection index. Heterosis for all available crosses over mid parent, better parent and standard parent were worked out.

3.2.2.2.3 Observations taken in F_1 generations

(1) Second uppermost internodal length

(2) Number of days to 50 per cent flowering

(3) Leaf area per plant at maximum tillering stage

(4) Number of days to harvest

(5) Height of plant at harvest

Table 4 Crosses included in 5 x 5 diallel analysis including reciprocals

Sl. No.	Cross combinations	Designation
1	MATTATRIVENI x MAHSURI	C-3
2	MATTATRIVENI x KARTHIKA	C-4
3	MATTATRIVENI x VYTILLA 3	C-5
4	MATTATRIVENI x IR62030-18-2-2	C-8
5	MAHSURI x MATTATRIVENI	C-22
6	MAHSURI x KARTHIKA	C-25
7	MAHSURI x VYTILLA 3	C-26
8	MAHSURI x IR62030-18-2-2	C-29
9	KARTHIKA x MATTATRIVENI	C-33
10	KARTHIKA x MAHSURI	C-36
11	KARTHIKA x VYTILLA 3	C-37
12	KARTHIKA x IR62030-18-2-2	C-39
13	VYTILLA 3 x MATTATRIVENI	C-42
14	VYTILLA 3 x MAHSURI	C-44
15	VYTILLA 3 x KARTHIKA	C-45
16	VYTILLA 3 x IR62030-18-2-2	C-48
17	IR62030-18-2-2 x MATTATRIVENI	C-63
18	IR62030-18-2-2 x MAHSURI	C-64
19	IR62030-18-2-2 x KARTHIKA	C-65
20	IR62030-18-2-2 x VYTILLA 3	C-66

Table 5 Crosses included in 8 x 8 diallel analysis excluding reciprocals

Sl. No.	Cross combinations	Designation
1	MAHSURI x PK3355-5-1-4	C-31
2	MAHSURI x VYTILLA 3	C-26
3	MAHSURI x IR60133-184-3-2-2	C-30
4	MAHSURI x KACHSIUNG SEN YU 338	C-27
5	MAHSURI x IR36	C-28
6	MAHSURI x HRASWA	C-24
7	MAHSURI x MATTATRIVENI	C-22
8	PK3355-5-1-4 x VYTILLA 3	C-83
9	PK3355-5-1-4 x IR60133-184-3-2-2	C-87
10	PK3355-5-1-4 x KACHSIUNG SEN YU 338	C-84
11	PK3355-5-1-4 x IR36	C-85
12	PK3355-5-1-4 x HRASWA	C-81
13	PK3355-5-1-4 x MATTATRIVENI	C-79
14	VYTILLA 3 x IR60133-184-3-2-2	C-49
15	VYTILLA 3 x KACHSIUNG SEN YU 338	C-46
16	VYTILLA 3 x IR36	C-47
17	VYTILLA 3 x HRASWA	C-43
18	VYTILLA 3 x MATTATRIVENI	C-42
19	IR60133-184-3-2-2 x KACHSIUNG SEN YU 338	C-76
20	IR60133-184-3-2-2 x IR-36	C-77
21	IR60133-184-3-2-2 x HRASWA	C-74
22	IR60133-184-3-2-2 x MATTATRIVENI	C-72
23	KACHSIUNG SEN YU 338 x IR36	C-55
24	KACHSIUNG SEN YU 338 x HRASWA	C-52
25	KACHSIUNG SEN YU 338 x MATTATRIVENI	C-50
26	IR36 x HRASWA	C-58
27	IR36 x MATTATRIVENI	C-57
28	HRASWA x MATTATRIVENI	C-15

Table 6 Crosses included in 6 x 3 line x tester analysis

Sl. No.	Cross combinations	Designation
1	S9768-PN-25-1 x MATTATRIVENI	C-88
2	S9768-PN-25-1 x BHADRA	C-89
3	S9768-PN-25-1 x VYTILLA 3	C-93
4	HRASWA x MATTATRIVENI	C-15
5	HRASWA x BHADRA	C-16
6	HRASWA x VYTILLA 3	C-17
7	KARTHIKA x MATTATRIVENI	C-33
8	KARTHIKA x BHADRA	C-34
9	KARTHIKA x VYTILLA 3	C-37
10	KACHSIUNG SEN YU 338 x MATTATRIVENI	C-50
11	KACHSIUNG SEN YU 338 x BHADRA	C-51
12	KACHSIUNG SEN YU 338 x VYTILLA 3	C-54
13	PK3355-5-1-4 x MATTATRIVENI	C-79
14	PK3355-5-1-4 x BHADRA	C-80
15	PK3355-5-1-4 x VYTILLA 3	C-83
16	MAHSURI x MATTATRIVENI	C-22
17	MAHSURI x BHADRA	C-23
18	MAHSURI x VYTILLA 3	C-26

(6) Ratio of vegetative phase to reproductive phase

(7) Number of panicles m^{-2}

(8) Number of spikelets $panicle^{-1}$

(9) Number of tertiary branches $panicle^{-1}$

(10) Length of panicle

(11) Number of grains $panicle^{-1}$

(12) Spikelet sterility percentage

(13) 1000 grain weight

(14) L/B ratio of grain

(15) Yield $plant^{-1}$

(16) Harvest index

(17) Amylose content

(18) Alkali spreading value

(19) Colour of the kernel

3.2.3 Statistical analysis

3.2.3.1 Diallel analysis

Diallel analysis proposed by Jinks and Hayman (1953) provides information on

i) the nature and amount of genetic parameters and

ii) general and specific combining ability of parents and their crosses, respectively.

A 5 x 5 full diallel analysis including reciprocals and a 8 x 8 half diallel analysis excluding reciprocals were carried out. Both Hayman's and Griffing's approach were employed.

Griffing's approach

Out of four methods suggested by Griffing (1956), two methods were utilized: method (1) involving parents (n), n(n-1)/2 F_1s and reciprocal, method (2) involving parents and F_1s only excluding reciprocals. In method 1 general combining ability (*gca*), specific combining ability (*sca*) and reciprocal combining ability effects were estimated for 18 characters observed in F_1 generations. In the method 2 only *gca* and *sca* effects were estimated.

Hayman's approach

Using this approach (Hayman, 1954) the parameters like variation due to additive effect (D), the mean of F_1 over arrays (F), component of variation due to the dominance effect of the genes (H_1, H_2), dominance effect (h^2), mean degree of dominance $(H_1/D)^{1/2}$, proportion of gene with positive and negative effects in the parents (H2/4H_1), proportion of dominant and recessive genes in the parents (KD/KR) and the number of genes which control the character and exhibit dominance (h^2/H_2) were estimated for 18 characters observed in F_1 generations.

3.2.3.2 Line x Tester analysis

Line x tester analysis was performed as per Kempthorne (1957). This design provides information about general and specific combining abilities of parents and at the same time it is helpful in estimating various types of gene effects.

3.2.3.3 Application of selection index

Selection index formulated in experiment No.1 was utilized to find out relative efficiency of the 96 F_1 hybrids.

3.2.3.4 Heterosis

Different types of heterosis namely, relative heterosis (based on midparent value, MP), heterobeltiosis (based on better parent value, BP) and standard heterosis (based on a standard parent value, SP) were estimated for 18 characters recorded in F_1 generation and their significance tested.

3.3 Experiment No.3

3.3.1 Materials

Even though back crosses with both parents were carried out in all the 96 F_1 combinations, sufficient seeds for both B_1C_1, B_2C_1 and F_1 generations were obtained from 10 crosses only (Table 7). In addition to these 10 crosses, sufficient F_2 seeds were obtained from other 12 crosses (Table 7). Thus 10 F_1 generation seeds, 22 F_2 generation seeds, 10 B_1C_1 and 10 BC_2 generation seeds, and their parental seeds constituted the materials for experiment No.3.

3.3.2 Methods

3.3.2.1 Generations of P_1, P_2, F_1, F_2 and back crosses

The crop was grown in a randomised block design with two replications during January 1998 to May 1998 (3rd crop season) at the Agricultural Research Station, Mannuthy. In each replication 10 F_1s, their parents and 20 back

Table 7 Details of generations grown druing January 1998 to May 1998

Sl. No.	Generations	Designation
Parents		
1	BHADRA	P2
2	HRASWA	P3
3	KARTHIKA	P5
4	MATTATRIVENI	P1
5	MAHSURI	P4
6	VYTILLA 3	P6
7	IR36	P8
8	IR60133-184-3-2	P10
9	IR62030-18-2-2	P9
10	KACHSIUNG SEN YU 338	P7
11	PK3355-5-1-4	P11
F_1 Generations		
1	HRASWA x MATTATRIVENI	C-15*
2	HRASWA x VYTILLA 3	C-17*
3	HRASWA x IR60133-184-3-2-2	C-20*
4	MAHSURI x HRASWA	C-24*
5	MAHSURI x VYTILLA 3	c-26*
6	MAHSURI x IR36	C-28*
7	MAHSURI x IR60133-184-3-2-2	C-30*
8	KACHSIUNG SEN YU 338 x VYTILLA 3	C-54*
9	IR36 x MATTATRIVENI	C-57*
10	IR62030-18-2-2 x PK3355-5-1-4	C-70*

Contd.....

Table 7 contd...

Back crosses		
B1		
1	(HRASWA x MATTATRIVENI) x HRASWA	B_1C_{15}*
2	(HRASWA x VYTIlLA 3) x HRASWA	B_1C_{17}*
3	(HRASWA x IR60-133-184-3-2-2) x HRASWA	B_1C_{20}*
4	(MAHSURI x HRASWA) x MAHSURI	B_1C_{24}*
5	(MAHSURI X VYTILLA 3) x MAHSURI	B_1C_{26}*
6	(MAHSURI x IR36) x MAHSURI	B_1C_{28}*
7	(MAHSURI x IR60133-184-3-2-2) x MAHSURI	B_1C_{30}*
8	(KACHSIUNG SEN YU 338 x VYTILLA 3) x KACHSIUNG SEN YU 338	B_1C_{54}*
9	(IR36 x MATTATRIVENI) x IR36	B_1C_{57}*
10	(IR62030-18-2-2 x PK3355-5-1-4) x IR62030-18-2-2	B_1C_{70}*
B2		
1	(HRASWA x MATTATRIVENI) x MATTATRIVENI	B_2C_{15}*
2	(HRASWA x VYTILLA 3) x VYTILLA 3	B_2C_{17}*
3	(HRASWA x IR60133-184-3-2-2) x IR60133-184-3-2-2	B_2C_{20}*
4	(MAHSURI x HRASWA) x HRASWA	B_2C_{24}*
5	(MAHSURI X VYTILLA 3) x VYTILLA 3	B_2C_{26}*
6	(MAHSURI x IR36) x IR36	B_2C_{28}*
7	(MAHSURI x IR60133-184-3-2-2) x IR60133-184-3-2-2	B_2C_{30}*
8	(KACHSIUNG SEN YU 338 x VYTILLA 3) x VYTILLA 3	B_2C_{54}*
9	(IR36 x MATTATRIVENI) x MATTATRIVENI	B_2C_{57}*
10	IR62030-18-2-2 x PK3355-5-1-4	B_2C_{70}*

Contd....

Table 7 contd....

F_2 Generations		
1	HRASWA x MATTATRIVENI	F_2 C-15*
2	HRASWA X VYTILLA 3	F_2 C-17*
3	HRASWA x IR60133-184-3-2-2	F_2 C-20*
4	MAHSURI x HRASWA	F_2 C-24*
5	MAHSURI x VYTILLA 3	F_2 C-26*
6	MAHSURI x IR36	F_2 C-28*
7	MAHSURI X IR60133-184-3-2-2	F_2 C-30*
8	KACHSIUNG SEN YU 338 x VYTILLA 3	F_2 C-54*
9	IR36 x MATTATRIVENI	F_2 C-57*
10	IR62030-18-2-2 x PK3355-5-1-4	F_2 C-70*
11	MATTATRIVENI x KARTHIKA	F_2 C-4
12	MATTATRIVENI x KACHSIUNG SEN YU 338	F_2 C-6
13	MATTATRIVENI x IR62030-18-2-2	F_2 C-8
14	BHADRA x HRASWA	F_2 C-11
15	BHADRA x VYTILLA 3	F_2 C-12
16	KARTHIKA x BHADRA	F_2 C-34
17	KARTHIKA x VYTILLA 3	F_2 C-37
18	VYTILLA 3 X IR36	F_2 C-47
19	VYTILLA 3 x IR60133-184-3-2-2	F_2 C-49
20	KACHSIUNG SEN YU 338 x MATTATRIVENI	F_2 C-50
21	IR62030-18-2-2 x IR60133-184-3-2-2	F_2 C-69
22	PK3355-5-1-4 x KARTHIKA	F_2 C-82

* Crosses taken for generation mean analysis

crosses (10 B_1C_1 and 10 B_2C_1) of 10 selected F_1s were grown in single row. The 10 F_2 s were grown in 5 rows. All the rows were 5 m long, with a spacing of 20 cm x 15 cm, having one seedling hill^{-1} (Plate 13). All the management practices were applied as recommended in the Package of Practices, Kerala Agricultural University. Ten competitive plants were selected from each generation, except in the F_2, in which 25 plants were selected for observations. Data on plant height, days to 50 per cent flowering, days to harvest, second uppermost internodal length, number of panicles plant^{-1}, number of tertiary branches panicle^{-1}, number of spikelets panicle^{-1}, spikelet sterility percentage , number of grains panicle^{-1} 1000 grain weight, yield plant^{-1} harvest index and colour of kernel were recorded.

3.3.2.2 **Evaluation of F_2 generations**

The 12 F_2 generations were grown (in addition to the 10F_2 generations mentioned in item 3.3.2.1) in a randomised block design with two replications during January 1998 to May 1998 at the Agricultural Research Station, Mannuthy. In each replication F_2 plants were grown in 5 rows of 5 m length with 20 x 15 cm spacing having single seedling per hill. The crop received all cultural practices as per the Package of Practice recommendations of the Kerala Agricultural University, for high yielding varieties. From 22 F_2 generations phenotypically outstanding seggregants and early stabilized crosses were selected and observations were recorded on 13 characters mentioned in method 1 of experiment No.3.

3.3.3 Statistical analysis

3.3.3.1 Generation mean analysis

Weighted least square technique of Mather and Jinks (1971) was used for estimating various genetic components like mean effect (m), additive effect (d), dominance effect (h), additive x additive type of gene interaction (i), additive x dominance type of gene interaction (j) and dominance x dominance type of gene interaction (l).

3.3.3.2 Inbreeding depression:

The inbreeding depression was expressed as decrease in the mean values of F_2s over F_1s.

3.3.3.3 Chi-square test of goodness of fit

The goodness of fit of expected genetic ratios were tested by Chi-square method for the character kernel colour.

Results

4. RESULTS

4.1 Experiment No.1

4.1.1 Genetic variability

Success in crop improvement depends on the magnitude of genetic variability and the extent to which the desirable characters are heritable. The estimates of variability in respect of yield and quality, its heritable components in the material with which the breeder is working, are therefore, pre-requisites for any breeding programme. Hence it becomes necessary to split the phenotypic variability into heritable and non-heritable components with the help of certain genetic parameters such as genotypic and phenotypic coefficients of variability, heritability, genetic advance and genetic gain. In the present study the extent of genetic variability with respect to 23 quantitative and 13 qualitative characters, in a set of 56 high yielding diverse genotypes, was estimated.

Mean performances of 56 genotypes for 36 different quantitative and qualitative characters are given in Appendix i. The abstract of analysis of variance of these characters is given in Table 8. The data on range, mean and estimates of genetic parameters for various quantitative and qualitative characters are presented in Table 9.

Results from the analysis of variance, revealed highly significant differences among the 56 genotypes for all quantitative and qualitative characters studied.

Table 8 Analysis of variance for grain yield and associated quantitative and qualitative characters in high yielding rice varieties of diverse origin

Source of variation	Degrees of freedom	Mean sum of squares							
		Number of days to panicle initiation	Number of days to 50% flowering	Leaf area plant^{-1} at maximum tillering stage	Orienta-tion of leaf	Length of flag leaf	Maximum width of flag leaf	Height of plant of the time of harvest	Number of days to harvest
Replication	2	0.470	0.375	1193.955	69.125	3.376	0.025	14.023	0.470
Genotypes	55	37.392**	178.138**	1164.500**	154.905**	53.569**	0.044**	849.932**	232.843**
Error	110	0.585	0.569	315.248	42.289	3.006	0.010	10.755	0.585

Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Uppermost internodal length	Second uppermost internodal length	Total number of tillers plant^{-1}	Number of panicle bearing tillers plant^{-1}	Length of panicle	Number of secondary branches panicle^{-1}	Number of tertiary branches panicle^{-1}	Number of spikelets panicle^{-1}
0.000	201.50	0.234	0.295	0.535	0.023	0.029	0.494	3.767	294.726
0.040**	7750.655**	24.698**	33.25**	0.414**	0.129**	9.109**	5.003**	88.625**	1731.671**
0.000	316.458	1.552	0.752	0.761	0.039	0.895	0.556	8.952	195.194

Contd...

Table 8 contd...

Number of grains panicle^{-1}	Spikelet sterility percentage	1000-grain weight	Harvest Index	Yield ha^{-1}	Grain length	Grain breadth	L/B ratio of grain
373.07	1.792	37.351	0.002	552095.912	0.004	0.003	0.002
1515.30**	29.286**	103.655**	0.024**	3625472.616**	1.346**	0.301**	0.689**
199.91	8.200	8.656	0.006	463176.821	0.014	0.008	0.008

Hulling percentage	Milling percentage	Amylose content	Alkali spreading value	Water uptake	Volume expansion ratio	Kernel elongation ratio
12.04	1.02	2.54	2.899	0.000	0.029	0.000
24.21**	174.03**	39.01**	7.90**	0.028**	0.268**	0.033**
0.22	0.65	1.82	0.58	0.000	0.011	0.001

Table 9 Range, mean and estimates of genetic parameters for grain yield and associated quantitative and qualitative characters in high yield rice varieties of diverse origin

Characters	Range	Mean ± SEM	PCV (%)	GCV (%)	Heritability (Broad sense) (%)	Genetic advance (GA)	Genetic gain (%) (G.G)
Quantitative characters							
Number of days to panicle initiation	52 (Hraswa) 70 (IR59682-132-1-1-2	63.02 ± 0.62	5.69	5.56	95.4	7.05	11.2
Number of days to 50% flowering	75 (Hraswa) 116 (Mahsuri)	97.02 ± 0.62	7.97	7.93	99.0	15.77	16.25
Leaf area plant^{-1} at maximum tillering stage (cm^2)	46.78 (Hraswa) 146.09 (Ahallya)	108.34 ± 14.5	22.58	15.53	47.3	23.84	22.0
Orientation of leaf	0.0 (Ranjini) 58.0 (IR62164-14-2-2-2-3)	20.54 ± 5.3	43.51	29.83	47.0	8.66	42.15
Length of flag leaf (cm)	21.13 (IR60133-184-3-2-2) 41.70 (KACHSIUNG SEN YU 338)	27.71 ± 1.4	16.08	14.81	84.9	7.79	28.1
Maximum width of flag leaf (cm)	1.14 (RP1670-1418-2209-1565) 1.76 (Ahallya)	1.35 ± 0.08	10.8	7.87	53.97	0.16	11.92
Height of plant at the time of harvest (cm)	67.04 (Hraswa) 159.95 (Vytilla 2)	93.62 ± 2.7	18.21	17.87	96.3	33.81	36.12

Contd...

Table 9 contd...

Number of days to harvest	100.0 (Hraswa) 142.33 (Mahsuri and Remya)	125.54 ± 0.62	7.04	7.01	99.3	18.06	14.39
Ratio of vegetative phase to reproductive phase	0.793 (Bhadra) 1.34 (Mattatriveni)	1.02 ± 0	11.34	11.34	100.0	0.23	22.6
Number of panicles m^{-2}	109 (CC1-38-11-6-F-314) 336-667 (IR36)	236.38 ± 14.5	22.36	21.06	88.7	96.56	40.85
Uppermost internodal length (cm)	26.03 (Arathi) 38.58 (Mahsuri)	33.52 ± 1.0	9.08	8.29	83.3	5.22	15.57
Second uppermost internodal length (cm)	13.75 (IR53970-21-2-3-2) 32.00 (Vytilla 2)	19.10 ± 0.71	17.84	17.26	93.5	6.57	34.40
Number of total tillers plant^{-1}	1.30 (CR294-548) 7.50 [(RAVI (RP1664-1529-4254)]	3.81 ± 0.71	42.73	36.07	71.2	2.39	62.73
Number of panicle bearing tillers plant^{-1}	1.00 (PK3355-5-1-4; IR54950-181-2-1-2-3; MR123; RP1670-1418-2205-1585; CC1-38-11-6-F-314; AT-85-2, Mahsuri; Vytilla 2; Vytilla 4 Jyothi,; Jaya;Kairali; Sabari and Vytilla 3)1.9 (Hraswa)	1.21 ± 0.16	21.78	14.99	47.3	0.26	21.49

contd...

Table 9 contd...

Length of panicle (cm)	18.35 (HS INCHU 64) 27.05 (Vytilla 3)	22.88 ± 0.77	8.33	7.23	75.4	2.96	12.94
Number of secondary branches Panicle^{-1}	8.6 (IR36 and Annapooma) 14.2 (Kanakam)	10.5 ± 0.61	13.57	11.57	72.72	2.14	20.33
Number of tertiary branches Panicle^{-1}	7.6 (Vytilla 4) 33.8 (Kanakam)	19.9 ± 2.4	29.90	25.86	74.8	9.18	46.06
Number of spikelets panicle^{-1}	74.7 (Vytilla 4) 180.40 (Kanakam)	124.6 ± 11.4	21.34	18.16	72.4	39.67	31.83
Number of grains panicle^{-1}	71.2 (Vytilla 4) 166.0 (KACHSIUNG SEN YU 338)	115.3 ± 11.5	21.92	18.17	68.68	35.75	31.02
Spikelet sterility percentage	1.78 (Makam) 15.86 (Hraswa)	7.76 ± 2.3	62.34	51.85	69.2	7.29	93.9
1000 grain weight (g)	23.23 (Kairali) 50.14 (Onam)	31.81 ± 2.4	19.96	18.0	78.5	10.27	32.3
Harvest index	0.036 (Mahsuri) 0.454 (Karthika)	0.272 ± 0.06	40.28	28.48	50.0	0.113	41.5
Yield (kg ha^{-1})	523.24 (CC1-38-11-6-F-314) 6319.54 (Mattatriveni)	2795.53 ± 555.7	44.03	36.71	69.5	1764.7	63.13
Qualitative characters							
Grain length (mm)	7.35 (HS INCHU-64) 10.11 (IR60133-184-3-2-2)	9.09 ± 0.1	7.45	7.33	96.94	1.35	14.87

contd...

Table 9 contd...

Grain breadth (mm)	2.56 (BR4676-72-2-4) 3.76 (HS INCHU-64)	3.04±0.07	10.69	10.28	92.14	0.62	20.33
L/B ratio of grain	1.95 (HS INCHU 64) 3.85 (IR60832-187-2-2-2 and IR 60133-184-3-2-2)	3.03±0.07	15.98	15.69	96.4	0.96	31.68
Hulling percentage	67.3 (Jayathi) 79.6 (Bhagya)	74.98±0.38	3.82	3.77	97.36	5.75	7.67
Milling percentage	51.1 (AT 85-2) 76.9 (Aruna)	65.43±0.7	11.68	11.62	98.9	15.57	23.80
Amylose content (%)	19.46 (MR123) 36.80 (AT85-2)	27.13±1.1	13.90	12.98	87.2	6.77	24.95
Alkali spreading value	1.00 (Mattatriveni, MR123, IR36 and S9728-22-1-3-1-1) 7.00 (Hraswa and Karthika)	3.88±0.6	44.76	40.25	80.9	2.89	74.48
Water uptake	0.379 (IR62164-14-2-2-2-3) 0.955 (AT85-2)	0.565±0	17.1	17.1	100.00	0.20	35.16
Volume expansion ratio	1.873 (Asha) 3.17 (AT85.2)	2.44±0.09	12.74	12.0	88.66	0.57	23.27
Kernel elongation ratio	1.11 (CR294-548) 1.603 (HS INCHU-64)	1.27±0.03	8.45	8.03	90.2	0.20	15.75

The genotypes showed a large range of variation for all the characters studied (Table 9).

Quantitative characters namely, number of days to panicle initiation and 50 per cent flowering varied from 52 to 70 days and 75 to 116 days, and its average was 63 and 97 days respectively. Leaf area per plant at maximum tillering stage varied from 46.78 to 146.09 cm^2, average being 108.34 cm^2. The orientation of leaf ranged from zero to 58° with a mean 20.54°. Length and maximum width of flag leaf varied from 21.13 to 41.7 cm and 1.14 to 1.76 cm with mean 27.7 and 1.35 cm respectively. Height of plant at the time of harvest varied from 67.04 to 159.95 cm, average being 93.62 cm. In the case of number of days to harvest the range of variation was from 100 to 142 days with an average of 126 days. Ratio of vegetative phase to reproductive phase varied from 0.793 to 1.34, average being 1.02. With respect to number of panicles m^{-2}, the variability ranged from 109 to 337 with a mean of 236. Uppermost internodal length and second uppermost internodal length varied from 26.03 to 38.58 cm and 13.75 to 32.0 cm with an average of 33.52 cm and 19.1 cm respectively. Total number of tillers $plant^{-1}$ and number of panicle bearing tillers $plant^{-1}$ varied from 1.3 to 7.5 and 1.0 to 1.9 with average of 3.8 and 1.2 respectively. Length of panicle varied from 18.35 to 27.05 cm, and had an average 22.88 cm. Number of secondary branches $panicle^{-1}$ and tertiary branches ranged from 8.6 to 14.2 and 7.6 to 33.8 with average of 10.5 and 19.9 respectively. Number of spikelets $panicle^{-1}$ and grains $panicle^{-1}$ varied from 74.7 to 180.4 and 71.2 to 166, average being 124.6 and 115.3 respectively. Percentage of sterility ranged from 1.78 to 15.86, average being 7.76 per cent. 1000 grain weight varied from 23.23 to 50.14 g, and had an average of 31.8 g. The harvest index, ranged from 0.036 to 0.454, average being 0.272. Yield hectare^{-1} varied from 523.24 to 6319.54 kg, with a mean 2795.53 kg.

In the case of qualitative characters, grain length and grain breadth varied from 7.35 to 10.11 mm and 2.56 to 3.76 mm, with average of 9.09 mm and 3.04 mm respectively. L/B ratio of the grain ranged from 1.95 to 3.85, with a mean 3.03. Hulling percentage and milling percentage varied from 67.3 to 79.6 and 51.1 to 76.9 with average of 74.98 per cent and 65.43 per cent respectively. Among cooking quality characters, amylose content ranged from 19.46 to 36.8 per cent with a mean of 27.13 per cent. Out of 56 genotypes studied 41 were in the range of having more than 25 per cent (high amylose), 13 were in the range of 20-25 per cent (Intermediate amylose) and two genotypes had less than 20 per cent amylose (Low amylose). The alkali spreading value varied from 1.0 to 7.0, with population mean of 3.88. Thirty one cultivars were of intermediate type, the range being 4-6. Twenty three and two varieties were low (1-3) and high (7-9) amylose types respectively. Water uptake per unit weight of uncooked rice varied from 0.379 to 0.955 mg, average being 0.565 mg. Volume expansion per unit volume of uncooked rice also varied from 1.873 to 3.17 ml, with population mean of 2.44 ml. Kernel elongation ratio ranged from 1.11 to 1.603, with an average 1.27.

4.1.1.1 Effect of parboiling and milling on amylose content and alkali spreading value

A general trend of increased amylose content and increased score value for parboiled milled rice compared to non parboiled raw rice was seen (Table 11). There was 28.82 per cent increase in amylose content in parboiled milled rice compared to nonparboiled raw rice. Similarly there was 73.82 per cent increase in alkali spreading score for parboiled milled rice compared to raw rice.

The qualitative characters like awning, lemma palea pubescence, lemma palea colour and kernel colour were also observed. Out of 56 genotypes, 44 genotypes were found to be awnless, eight genotypes were short and partly awned, one genotype was found to be, with long but partly awned and one with long and fully awned. With respect to lemma palea pubescence three genotypes belonged to glabrous type, 48 genotypes were with hairs on upper portion and five genotypes were found to be short haired. The lemma palea colour varied among the genotypes examined. Twenty five genotypes were found to be straw coloured, while 20 genotypes were with gold and gold furrows on straw back ground and six genotypes showed brown spots on straw, three genotypes were having brown furrows on straw and two genotypes were tawny coloured. While 29 out of 56 genotypes were found to be having white coloured kernel, 27 genotypes were found to be red coloured.

Since intermediate amylose content (20-25%) is preferred in India, genotypes having intermediate amylose content should be utilized for quality improvement in rice

Table 10 Amylose content of 27 high yielding varieties of Kerala included in the study

Sl. No.	Varieties	Amylose content (%)	Colour of kernel	
1	Asha	23.1	red	Intermediate amylose types
2	Athira	25.3	red	
3	Bhadra	25.1	red	
4	Jaya	23.8	white	
5	Jayathi	23.5	white	
6	Kairali	22.1	red	
7	Mahsuri	23.6	white	
8	Ranjini	22.7	red	
9	Ahallya	31.1	red	High amylose types
10	Annapoorna	25.7	red	
11	Arathi	25.9	red	
12	Aruna	27.3	red	
13	Bhaghya	29.2	red	
14	Hraswa	29.4	red	
15	Jyothi	25.7	red	
16	Kanakam	29.5	red	
17	Kanchana	29.0	red	
18	Karthika	31.4	red	
19	Makam	29.1	red	
20	Mattatriveni	30.3	red	
21	Onam	28.9	red	
22	Pavizham	29.4	red	
23	Remya	26.5	red	
24	Sabari	26.0	red	
25	Vytilla 2	31.6	red	
26	Vytilla 3	30.3	red	
27	Vytilla 4	30.7	red	

Table 11 Amylose content and alkali spreading value of parboiled milled rice and non-parboiled unmilled rice

Sl. No.	Genotype	Amylose content (%)		Alkali spreading value	
		Non-parboiled unmilled rice	Parboiled milled rice	Non-parboiled unmilled rice	Parboiled milled rice
1	Bhadra	20.1	25.1	2.0	4.3
2	Hraswa	20.7	29.4	2.5	7.0
3	Karthika	23.6	31.4	2.0	7.0
4	Mahsuri	24.3	23.6	1.0	4.3
5	Mattatriveni	25.8	30.4	2.5	1.0
6	Vytilla 3	23.2	30.3	2.5	3.3
7	IR36	23.3	30.5	2.0	1.0
8	IR60133-184-3-2	20.9	26.8	3.0	2.7
9.	IR62030-18-2-2	19.6	29.7	2.0	5.0
10	KACHSIUNG SEN YU 338	12.4	21.1	2.0	3.0
11	PK3355-5-1-4	24.5	31.0	3.0	5.3
12	S9768-PN-25-1	21.0	24.9	3.5	4.7
Mean		21.62	27.85	2.33	4.05
% increase			128.82		173.82

in India. In Kerala since red kernel rice is preferred to white rice, red kernelled rice with intermediate amylose content can be used for quality breeding. Amylose contents of 27 high yielding varieties of Kerala included in the present study are presented in Table 10.

4.1.2 Genotypic and phenotypic coefficient of variations

Among the quantitative characters, high magnitude of PCV and GCV were observed for percentage of spikelet sterility (51.85), grain yield $hectare^{-1}$ (36.71), number of total tillers $plant^{-1}$ (36.07), orientation of leaf (29.83), harvest index (28.48), number of tertiary branches $panicle^{-1}$ (25.86) and number of panicles m^{-2} (21.06). Only alkali spreading value exhibited high PCV and GCV (40.25) among qualitative characters. The level of genotypic variation for quantitative characters like leaf area $plant^{-1}$ at maximum tillering stage, length of flag leaf, height of plant at harvest, ratio of vegetative phase to reproductive phase, second uppermost internodal length, number of panicle bearing tillers $plant^{-1}$, number of secondary branches $panicle^{-1}$, number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$ and 1000 grain weight and qualitative characters namely, L/B ratio, milling percentage, amylose content, water uptake and volume expansion were moderate. Low variability was observed with respect to the characters, number of days to panicle initiation, number of days to 50 per cent flowering, maximum width of flag leaf, number of days to harvest, uppermost internodal length and length of panicle among quantitative characters and grain length, grain breadth, hulling percentage and kernel elongation ratio among qualitative characters.

PCV in general was higher for all quantitative characters except for ratio of vegetative phase to reproductive phase for which PCV and GCV were equal and for number of days to panicle initiation and number of days to harvest PCV and GCV were nearly equal. In the case of all qualitative characters PCV was either equal to GCV or nearly equal, except for amylose content and alkali spreading value.

4.1.3 Heritability

Among quantitative characters the heritability estimate (in broad sense) ranged from 47 per cent (orientation of leaf) to 100 per cent (Ratio of vegetative phase to reproductive phase). Heritability estimate of qualitative characters ranged from 80.9 per cent (alkali spreading value) to 100 per cent (water uptake). Heritability estimates of quantitative characters namely, ratio of vegetative phase to reproductive phase (100%), number of days to harvest (99.3%), number of days to 50 per cent flowering (99%), height of plant at harvest (96.3%), number of days to panicle initiation (95.4%), second uppermost internodal length (93.5%), number of panicles m^{-2} (88.7%) length of flag leaf (84.9%), uppermost internodal length (83.3%), 1000 grain weight (78.5%), length of panicle (75.4%), number of tertiary branches $panicle^{-1}$ (74.8%), number of secondary branches $panicle^{-1}$ (72.72%), number of spikelets $panicle^{-1}$ (72.4%), number of total tillers $plant^{-1}$ (71.2%), yield $hectare^{-1}$ (69.5%), spikelet sterility percentage (69.2%) and number of grains $panicle^{-1}$ (68.68%) were found to be high. Maximum width of flag leaf (53.97%), harvest index (50.0%), number of panicle bearing tillers $plant^{-1}$ (47.3%), leaf area $plant^{-1}$ at maximum tillering stage (47.3%) and orientation of leaf (47.0%) exhibited moderate heritability. All qualitative characters exhibited high heritability estimate.

4.1.4 Genetic advance and genetic gain

Genetic advance (expressed as the percentage of mean) varied from 11.2 per cent for number of days to panicle initiation to 93.9 per cent for spikelet sterility percentage. Among qualitative characters, genetic gain ranged from 14.87 per cent for grain length to 74.48 per cent for alkali spreading value. Among quantitative characters genetic advance (expressed as the percentage of mean) was high for the characters, spikelet sterility percentage (83.9%), yield hectare^{-1} (63.13%) number of total tillers plant^{-1} (62.73%), orientation of leaf (42.15%), number of tertiary branches panicle^{-1} (46.06%), harvest index (41.5%), panicles m^{-2} (40.85%), height of plant at harvest (36.12%), second uppermost internodal length (34.4%), 1000 grain weight (32.3%), number of spikelets panicle^{-1} (31.83%), number of grains panicle^{-1} (31.02%), length of flag leaf (28.1%), ratio of vegetative phase to reproductive phase (22.6%) leaf area plant^{-1} at maximum tillering stage (22.0%) and number of panicle bearing tillers plant^{-1} (21.49%). Among qualitative characters genetic gain was high for the characters, alkali spreading value (74.48%), water uptake per unit weight of uncooked rice (35.16%), L/B ratio of grain (31.68%), amylose content (24.95%), milling percentage (23.80%) and volume expansion ratio (23.27%). Estimates of genetic advance was moderate for the quantitative characters namely number of days to panicle initiation, number of days to 50 per cent flowering, maximum width of flag leaf, number of days to harvest and uppermost internodal length, and for the qualitative characters namely, grain length, grain breadth, and kernel elongation ratio.

The quantitative characters, namely the number of panicles m^{-2} number of tertiary branches $panicle^{-1}$, number of total tillers $plant^{-1}$, yield $hectare^{-1}$ and spikelet sterility percentage exhibited high genotypic coefficient of variation (GCV),. heritability (in broadsense) and expected genetic advance. Height of plant at harvest, second uppermost internodal length, length of flag leaf, ratio of vegetative phase to reproductive phase, 1000 grain weight, number of spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ had high percentage of heritability, high expected genetic advance and moderate GCV. High heritability, moderate estimate for GCV and moderate expected genetic advance were observed for number of secondary branches $panicle^{-1}$. High GCV and high expected genetic advance but moderate heritability were observed for the characters harvest index and orientation of leaf. High expected genetic advance but moderate GCV and moderate heritability were seen for number of panicle bearing tillers $plant^{-1}$ and leaf area $plant^{-1}$ at maximum tillering stage. Number of days to panicle initiation, days to 50 per cent flowering and days to harvest, length of uppermost internode and length of panicle exhibited low estimate of GCV, high estimate of heritability and moderate estimate of expected genetic advance. Low value for GCV and moderate value for heritability and expected genetic advance were recorded with respect to maximum width of flag leaf. Among the qualitative characters alkali spreading value expressed high GCV, heritability and expected genetic advance. L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake per unit weight of uncooked rice showed high heritability and high expected genetic advance and moderate GCV and these traits were fairly stable (PCV and GCV were close together). Low GCV and low expected genetic advance but high heritability were recorded for hulling percentage. Grain length, grain breadth and kernel elongation ratio had high heritability but moderate expected genetic advance and low GCV.

4.1.5 Correlation

The genotypic and phenotypic correlation coefficients between grain yield hectare^{-1} and thirty yield component characters and the genotypic correlation coefficients among the component characters *inter se* are presented in Table 12.

The genotypic correlations with yield were found to be higher than phenotypic correlations for all the characters except for uppermost internodal length, total tillers plant^{-1}, number of spikelets panicle^{-1} number of tertiary branches panicle^{-1} length of panicle, kernel elongation ratio and water uptake. Direction of genotypic and phenotypic correlations was the same except for amylose content.

Grain yield in kg ha^{-1} was found to be positively and significantly correlated both at genotypic and phenotypic levels with harvest index (0.889**, 0.691**), number of panicle m^{-2} (0.499**, 0.428**), ratio of vegetative phase to reproductive phase (0.484**, 0.418**), number of grains panicle^{-1}, (0.398**, 0.320*), number of tertiary branches panicle^{-1} (0.345**, 0.351**) and number of spikelets panicle^{-1} (0.318*, 0.363**). The characters number of days to 50 per cent flowering ($^{-}$0.311**), number of days to harvest ($^{-}$0.301*) and spikelet sterility percentage ($^{-}$0.306*) exhibited negative significant correlation with yield but only at genotypic

Table 12 Genotypic (upper diagonal) and Phenotypic (lower diagonal) correlation coefficients between yield and yield component characters in high yielding rice varieties of diverse origin

	1	2	3	4	5	6	7	6	9	10	11	12	13	14	15
1		0.247	0.442 **	0.276	-0.021	0.306 *	0.107	-0.199	0.483 **	-0.018	0.004	0.003	0.329 *	0.337 **	0.45
2	0.268		0.410 **	0.326 **	0.211	0.891 **	-0.298 *	-0.329 *	0.373 **	0.215	-0.126	-0.367 **	-0.145	-0.136	0.21
3	0.409 **	0.371 **		0.327 *	-0.184	0.363 **	0.315 *	0.013	0.566 **	-0.218	0.175	-0.071	0.167	0.025	0.41
4	0.259	0.240	0.269		-0.211	0.183	0.023	-0.073	0.367 *	-0.236	-0.017	-0.148	-0.003	0.097	-0.03
5	-0.018	0.202	-0.166	-0.168		0.350 **	-0.461 **	-0.633 **	0.083	0.942 **	-0.596 **	-0.456 **	0.186	0.187	0.20
6	0.316 *	0.865 **	0.350 **	0.159	0.342 **		-0.399 **	-0.434 **	0.426 **	0.330 **	-0.140	-0.331 **	-0.094	-0.100	0.41
7	0.050	-0.291 *	0.209	0.037	-0.385 **	-0.347 **		0.424 **	-0.024	-0.479 **	0.312 *	0.290 *	-0.167	-0.213	-0.19
8	-0.070	-0.186	0.002	-0.047	-0.435 **	-0.272	0.236		-0.220	-0.560 **	0.190	0.394 **	0.029	-0.003	-0.07
9	0.287 *	0.241	0.388 **	0.061	0.061	0.274	-0.031	-0.051		0.033	0.004	-0.296 *	0.456 **	0.388 **	0.54
10	-0.016	-0.117	-0.198	-0.184	0.942 **	0.323 *	-0.401 **	-0.385 *	0.026		0.640 **	-0.453 **	0.229	0 207	0.13
11	0.010	-0.325 *	0.170	-0.022	-0.579 **	0.131	0.253	0.133	0.009	-0.624 **		0.357 **	-0.148	-0.162	0.05
12	0.021	-0.108	-0.061	-0.098	-0.428 **	-0.299 *	0.213	0.295 *	0.179	-0.426 **	0.343 **		-0.085	-0.006	-0.11
13	0.350 **	-0.093	0.159	0.093	0.160	-0.029	-0.168	0.003	0.249	0.197	-0.124	-0.056		0.918 **	0.34
14	0.377 **	0.213	0.071	0.121	0.171	-0.037	-0.199	-0.011	0.219	0.188	-0.126	0.025	0.869 **		0.29
15	0.479 *	0.010	0.358 **	0.060	0.178	0.401 **	0.190	-0.026	0.274 *	0.120	0.049	-0.086	0.414 **	0.418 **	
16	-0.039	0.010	0.025	-0.081	-0.101	0.002	0.199	0.172	-0.139	-0.114	0.036	0.059	-0.232	-0.217	-0.021
17	-0.041	-0.045	-0.071	-0.035	0.042	-0.034	0.111	0.059	-0.004	0.016	-0.039	-0.008	-0.129	-0.152	0.054
18	-0.323 *	0.475 **	0.092	0.180	-0.003	0.338 *	-0.166	-0.054	0.024	0.079	-0.083	-0.334 **	-0.171	-0.164	-0.221
19	0.253	-0.481 **	-0.112	-0.177	0.002	-0.306 *	0.179	0.061	0.011	-0.111	0.064	0.300	0.037	0.039	0.302
20	0.233	-0.127	0.148	0.008	0.176	-0.081	-0.179	-0.002	0.305 *	0.210	-0.129	-0.096	0.785 **	0.724 **	0.288
21	-0.057	0.376 **	0.135	0.058	0.312 *	0.350 **	-0.066	-0.044	0.142	0.260	-0.190	-0.397 **	-0.149	-0.133	0.160
22	0.207	-0.158	-0.056	0.023	-0.250	-0.159	-0.185	0.085	0.030	-0.243	0.418 **	0.428 **	0.363 **	0.351 **	0.227
23	-0.025	-0.282 *	-0.054	-0.057	-0.393 **	-0.300 *	-0.116	0.034	-0.069	-0.428 **	0.394 **	0.367 **	0.084	0.096	-0.015
24	-0.004	0.084	-0.168	0.066	-0.001	0.067	-0.159	0.029	-0.055	0.006	-0.201	-0.004	-0.183	-0.104	-0.150
25	0.152	-0.250	-0.080	-0.094	-0.086	-0.156	0.186	0.121	-0.114	-0.050	0.059	0.222	-0.006	0.001	0.087
26	0.036	0.292 *	0.084	0.207	-0.098	0.197	-0.072	0.125	0.146	-0.086	-0.079	-0.093	-0.047	-0.036	-0.006
27	0.043	0.082	-0.120	-0.010	0.078	0.084	-0.025	-0.042	0.082	0.123	-0.118	-0.273	-0.020	-0.053	-0.123
28	0.128	0.157	0.255	0.055	0.019	0.083	0.079	0.008	-0.002	0.020	-0.169	-0.035	0.095	0.030	-0.093
29	-0.049	0.054	0.216	0.115	-0.048	-0.050	0.143	0.046	-0.042	-0.059	-0.056	0.046	0.095	0.022	-0.065
30	-0.175	-0.104	0.002	0.020	-0.077	-0.122	0.199	0.132	0.081	-0.100	-0.089	-0.026	-0.081	-0.081	-0.174

** significant at 1% lelvel; * Significant at 5% level

1 Uppermost internodal length(cm)
2. Second uppermost internodal length (cm)
3. Length of flag leaf (cm)
4. Maximum width of flag leaf (cm)
5. Number of days to 50% flowering
6. Height of plant at harvest (cm)
7. Total number of tillers plant^{-1}
8. Number of panicle bearing tillers plant^{-1}
9. Leaf area plant^{-1} at maximum tillering stage (cm^{-2})
10. Number of days to harvest
11. Ratio of vegetative phase to reproductive phase
12. Number of panicles m^{-2}
13. Number of spikelets panicle^{-1}
14. Number of tertiary branches panicle^{-1}
15. Length of panicle (cm)
16. Spikelet sterility percentage
17. Grain length (mm)
18. Grain breadth (mm)
19. L/B ratio of grain
20. Number of grains panicle^{-1}
21. 1000 grain weight (g)
22. Yield hectare^{-1} (kg)
23. Harvest index
24. Hulling percentage
25. Milling percentage
26. Amylose content (%)
27. Kernel elongation ratio
28. Volume expansion ratio
29. Water uptake
30. Alkali spreading value

(Contd..........)

Table 12 (Contd......)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	-0.003	-0.402 **	0.361 **	0.280 *	0.353 **	-0.075	0.163	-0.065	-0.012	0.167	0.080	0.057	0.160	-0.053	-0.211
2	0.018	-0.023	0.530 **	0.517 **	-0.133	0.417 **	-0.217	-0.380 **	0.083	-0.260 **	0.331 **	0.087	0.174	0.057	-0.123
3	0.026	-0.143	0.099	-0.109	0.140	0.213	-0.118	-0.140	-0.182	-0.091	0.117	-0.133	0.316 *	0.235	0.006
4	-0.106	-0.234	0.226	-0.242	0.084	0.065	0.032	-0.032	0.106	-0.123	0.304 *	-0.015	0.102	0.140	0.000
5	-0.123	0.218	-0.007	0.005	0.205	0.360 **	-0.311 *	-0.550 **	0.001	-0.087	-0.109	0.086	0.023	-0.049	-0.089
6	0.008	-0.094	0.358 **	-0.320 **	-0.088	0.400 **	-0.225	-0.410 **	0.067	-0.157	0.212	0.093	0.107	-0.048	-0.140
7	0.211	-0.160	0.214	0.198	-0.224	-0.179	-0.132	-0.018	-0.187	0.221	-0.095	-0.034	0.073	0.171	0.235
8	0.325 *	0.797 **	-0.065	0.069	0.024	-0.143	0.104	0.274	0.038	0.203	0.157	-0.089	0.026	0.081	0.193
9	-0.256	-0.352 **	0.065	0.006	0.429 **	0.250	0.045	-0.144	-0.077	-0.182	0.170	0.116	-0.029	-0.058	0.132
10	-0.139	0.094	0.079	-0.111	0.247	0.302 *	-0.301 *	-0.598 **	0.008	-0.050	-0.094	0.133	0.024	-0.060	-0.114
11	0.041	-0.150	-0.090	0.070	-0.163	-0.213	0.484 **	0.542 **	-0.205	0.062	-0.091	-0.124	-0.178	-0.058	-0.109
12	0.115	0.041	0.367 **	0.315 *	-0.076	-0.499 **	0.499 **	0.505 **	-0.013	0.230	-0.112	-0.298 *	-0.025	0.044	-0.043
13	-0.212	-0.585 **	-0.207	0.050	1.126 **	-0.167	0.318 *	0.131	-0.220	-0.009	0.054	-0.015	0.167	0.112	-0.099
14	-0.254	-0.624 **	-0.221	0.061	1.007 **	-0.176	0.345 **	0.093	-0.127	-0.006	-0.014	-0.036	0.083	0.026	-0.096
15	0.026	0.319 *	-0.285 *	0.358 **	0.409 **	0.188	0.193	0.022	-0.177	0.099	0.045	-0.138	-0.071	-0.072	-0.203
16		2.227 **	-0.142	0.133	-0.385 **	0.141	-0.306 *	-0.287 *	-0.016	0.154	-0.253	-0.243	0.003	-0.006	0.034
17	0.347 **		-0.688 **	0.961 **	-0.538 **	0.433 **	-0.257	0.058	0.091	0.403 **	-0.288 *	-0.403 **	-0.252	-0.039	-0.419
18	-0.102	-0.130		-0.913 **	-0.202	0.433 **	-0.265	-0.277 *	0.057	-0.272 *	0.182	0.143	-0.060	0.013	0.120
19	0.098	0.211	-0.893 **		0.062	-0.286 *	0.254	0.362 **	-0.059	0.288 *	-0.120	-0.103	-0.046	-0.049	-0.110
20	-0.244	-0.136	-0.157	0.036		-0.151	0.398 **	0.178	-0.209	-0.030	-0.005	0.017	0.146	0.106	-0.125
21	0.086	0.186	0.340 **	-0.226	-0.168		-0.443 **	-0.454 **	-0.038	-0.046	-0.032	0.039	-0.048	-0.054	-0.139
22	-0.259	-0.037	-0.214	0.194	0.320 *	-0.335 *		0.889 **	-0.156	0.153	0.013	-0.035	-0.100	-0.026	-0.195
23	-0.097	-0.043	-0.188	0.216	0.134	-0.337 *	0.691 **		-0.044	0.143	-0.011	-0.022	-0.116	0.000	-0.173
24	-0.016	0.018	0.051	-0.054	-0.167	-0.031	-0.105	-0.036		0.242	0.182	0.038	-0.180	-0.140	-0.037
25	0.131	0.086	-0.258	0.280 *	-0.023	-0.042	0.127	0.110	0.240		-0.150	0.051	-0.116	-0.249 *	-0.076
26	-0.177	-0.065	0.158	-0.110	-0.006	-0.038	-0.007	0.037	0.170	-0.140		0.097	0.295 **	0.282 *	0.291
27	-0.216	-0.092	0.123	-0.086	0.021	0.048	-0.046	-0.055	0.038	0.049	0.087		0.335 **	0.264 *	-0.052
28	-0.010	0.017	-0.062	-0.034	0.102	-0.014	-0.093	-0.082	-0.166	-0.108	0.244	0.305 *		0.762 **	0.245
29	-0.005	-0.010	0.015	-0.050	0.084	-0.048	-0.036	-0.008	-0.138	-0.247	0.265	0.248	0.715 **		0.199
30	0.032	-0.031	0.075	-0.085	-0.120	-0.073	-0.152	-0.125	-0.042	-0.068	0.245	-0.040	0.214	0.175	

** significant at 1% lelvel; * Significant at 5% level

1 Uppermost internodal length(cm)
2. Second uppermost internodal length (cm)
3. Length of flag leaf (cm)
4. Maximum width of flag leaf (cm)
5. Number of days to 50% flowering
6. Height of plant at harvest (cm)
7. Total number of tillers plant^{-1}
8. Number of panicle bearing tillers plant^{-1}
9. Leaf area plant^{-1} at maximum tillering stage (cm^{-2})
10. Number of days to harvest
11. Ratio of vegetative phase to reproductive phase
12. Number of panicles m^{-2}
13. Number of spikelets panicle^{-1}
14. Number of tertiary branches panicle^{-1}
15. Length of panicle (cm)
16. Spikelet sterility percentage
17. Grain length (mm)
18. Grain breadth (mm)
19. L/B ratio of grain
20. Number of grains panicle^{-1}
21. 1000 grain weight (g)
22. Yield hectare^{-1} (kg)
23. Harvest index
24. Hulling percentage
25. Milling percentage
26. Amylose content (%)
27. Kernel elongation ratio
28. Volume expansion ratio
29. Water uptake
30. Alkali spreading value

level. The character 1000 grain weight exhibited significant and negative correlation with yield both at phenotypic (¯0.335*) and genotypic (¯0.443**) levels.

Grain yield was not significantly correlated with any of the physico-chemical characters and cooking qualities. Only genotypic correlation coefficients among yield and yield components are dealth in detail.

Correlation coefficients among yield components showed that harvest index had significant positive association with ratio of vegetative phase to reproductive phase, number of panicles m^{-2} and L/B ratio of grain and significant negative correlation with second uppermost internodal length, number of days to 50 per cent flowering, height of plant, number of days to harvest, percentage spikelet sterility, grain breadth and 1000 grain weight. The character panicles m^{-2} showed positive significant degree of association with total tillers $plant^{-1}$, panicle bearing tillers $plant^{-1}$, ratio of vegetative phase to reproductive phase, L/B ratio of grain and harvest index while its association with second uppermost internodal length, number of days to 50 per cent flowering, number of days to harvest, height of plant, leaf area plant at maximum tillering stage, grain breadth, 1000 grain weight and kernel elongation ratio was found to be significantly negative. Ratio of vegetative phase to reproductive phase was positively and significantly correlated with total tillers $plant^{-1}$, number of panicle m^{-2} and harvest index and negatively and significantly correlated with number of days to 50 per cent flowering and number of days to harvest. The character, 1000 grain weight was found to be positively and significantly correlated with second uppermost internodal length, number of days to 50 per cent flowering, height of plant at harvest, number of days to harvest, grain length and grain breadth and negatively and significantly associated with number of panicles m^{-2}, L/B ratio of grain and harvest index. Number of grains $panicle^{-1}$, number of spikelets $panicle^{-1}$, uppermost internodal length, leaf area $plant^{-1}$ at maximum tillering stage, number of tertiary branches $panicle^{-1}$ and length of panicle were found to be positively and significantly inter correlated. Similarly, number of days to 50 per cent flowering, number of days to harvest, height of plant at harvest and 1000 grain weight were positively and significantly inter correlated. Correlation of number of days to 50 per cent flowering and days to harvest with total tillers $plant^{-1}$, panicle bearing tillers $plant^{-1}$, ratio of vegetative phase to reproductive phase, number of panicles m^{-2} and harvest index were found to be negative and significant. Number of spikelets $panicle^{-1}$ and number of tertiary branches $panicle^{-1}$ were negatively and significantly correlated with grain length. Significant negative correlation was observed for number of grains per panicle with spikelet sterility percentage. Correlation between grain length and harvest index was negative. Negative and significant correlation was observed between spikelet sterility percentage and harvest index.

Plant height at harvest was found to be positively and significantly correlated with number of days to 50 per cent flowering, number of days to harvest, panicle length, grain breadth, 1000 grain weight, first and second uppermost internodal lengths, length of flag leaf and leaf area $plant^{-1}$ at maximum tillering stage and negatively associated with total tillers $plant^{-1}$, panicle bearing tillers $plant^{-1}$, number of panicles m^{-2}, L/B ratio of grain and harvest index. Leaf area $plant^{-1}$ at maximum tillering stage exhibited positive significant association with first and second uppermost internodal lengths, length and width of flag leaf, height of plant, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, length of panicle, grain length and number of grains panicle^{-1}. Panicle length showed positive and significant inter correlation with uppermost internodal length, length of flag leaf, height of plant, leaf area plant^{-1} at maximum tillering stage, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, grain length, L/B ratio and number of grains panicle^{-1} and showed negative significant correlation with grain breadth. Both grain length and grain breadth were found to be positively and significantly correlated with 1000 grain weight and negatively and significantly associated with uppermost internodal length. Grain length alone was positively and significantly correlated with number of panicle bearing tillers plant^{-1}, length of panicle, percentage spikelet sterility, L/B ratio of grain and milling percentage and negatively and significantly associated with leaf area plant^{-1} at maximum tillering stage, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, grain breadth, number of grains panicle^{-1}, amylose content, kernel elongation ratio and alkali spreading value. Grain breadth was found to be positively and significantly associated with second uppermost internodal length and height of plant and had shown significant negative correlation with number of panicles m^{-2}, length of panicle, grain length, L/B ratio of grain, harvest index and milling percentage. L/B ratio of grain had exhibited positive significant association with uppermost internodal length, number of panicles m^{-2}, length of panicle, grain length, harvest index and milling percentage. Significant negative association of L/B ratio of grain with second uppermost internodal length, height of plant at harvest, grain breadth and 1000 grain weight was noticed. Amylose content exhibited positive and significant association with second uppermost internodal length and maximum width of flag leaf.

Correlation studies among physico-chemical properties of rice namely, grain length, grain breadth, L/B ratio of grain, hulling percentage, milling percentage and cooking qualities like amylose content, alkali spreading value, kernel elongation ratio, volume expansion ratio and water uptake revealed that there existed negative and significant correlation of grain length with grain breadth and kernel elongation ratio and positive and significant correlation with L/B ratio of grain. Negative significant correlation of grain breadth was found with grain length and L/B ratio of grain. Milling percentage was positively associated with grain length and L/B ratio and negatively associated with grain breadth and water uptake. Amylose content, was found to be positively and significantly associated with volume expansion ratio, water uptake and alkali spreading value and negatively and significantly correlated with grain length. Association of kernel elongation ratio with volume expansion ratio and water uptake was positive and significant and negative and significant with grain length, and neither associated with amylose content nor alkali spreading value. Alkali spreading value was positively correlated with amylose content and negatively correlated with grain length and no correlation was observed with grain breadth and grain shape. Volume expansion ratio had a significant and positive correlation with amylose content, kernel elongation ratio and water uptake. Water uptake, volume expansion ratio and amylose content were positively and significantly inter related. Water uptake and volume expansion ratio exhibited positive significant association with kernel elongation ratio. Water uptake was found to be negatively and significantly correlated with milling percentage.

4.1.6 Path analysis

The significant genotypic correlations of 10 yield components namely, number of days to 50 per cent flowering, number of days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, percentage spikelet sterility, number of grains $panicle^{-1}$, 1000 grain weight and harvest index, with grain yield were included in path analysis. The estimates of direct and indirect effects of these selected 10 yield component characters on yield are presented in Table 13.

The residual effect of path analysis was found to be 0.0036. It was observed that the characters namely, harvest index, number of days to harvest, number of tertiary branches $panicle^{-1}$, ratio of vegetative phase to reproductive phase, spikelet sterility percentage, number of panicles m^{-2} and 1000 grain weight exerted positive direct influence on yield. The characters, like days to 50 per cent flowering, number of spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ had negative direct effect on grain yield. Harvest index had the highest positive direct effect (1.104) on yield followed by number of days to harvest (0.959) number of tertiary branches $panicle^{-1}$ (0.633), and ratio of vegetative phase to reproductive phase (0.237). The highest negative direct effect was exhibited by number of days to 50 per cent flowering ($^{-}$0.478) followed by number of spikelets $panicle^{-1}$ ($^{-}$0.293). The path coefficient of 1000 grain weight (0.050) was the least followed by that of number of panicles m^{-2} (0.056) and spikelet sterility percentage (0.098). The highest positive indirect effect with yield was exhibited by number of days to 50 per cent flowering via. number of

Table 13 Direct and indirect effects of 10 yield components on grain yield of high yielding rice varieties of diverse origin

Characters	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicle m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Spikelet sterility percentage	Number of grains $panicle^{-1}$	1000 grain weight (g)	Harvest index	Total correlation with grain yield
Number of days to 50% flowering	-0.478	0.903	-0.141	-0.025	-0.054	0.118	-0.012	-0.033	0.018	-0.606	-0.311**
Number of days to harvest	-0.450	**0.959**	-0.152	-0.025	-0.067	0.131	-0.014	-0.040	0.015	-0.658	-0.301*
Ratio of vegetative phase to reproductive phase	0.285	-0.614	**0.237**	0.020	0.043	-0.103	0.004	0.026	-0.011	0.596	0.484**
Number of panicles m^{-2}	0.218	-0.435	0.085	**0.056**	0.025	-0.004	0.011	0.012	-0.025	0.556	0.499**
Number of spikelets $panicle^{-1}$	-0.089	0.219	-0.035	-0.005	**-0.293**	0.581	-0.021	-0.182	-0.008	0.150	0.318*
Number of tertiary branches $panicle^{-1}$	-0.089	0.199	-0.038	0.000	-0.269	**0.633**	-0.025	-0.163	-0.009	0.107	0.345**
Spikelet sterility percentage	0.059	-0.133	0.010	0.006	0.062	-0.161	**0.098**	0.062	0.007	-0.316	-0.306*
Number of grains $panicle^{-1}$	-0.098	0.237	-0.039	-0.004	-0.331	0.639	-0.038	**-0.161**	-0.008	0.201	0.398**
1000 grain weight (g)	0.172	0.289	-0.051	-0.028	0.049	-0.112	0.014	0.024	**0.050**	-0.509	-0.443**
Harvest index	0.263	-0.572	0.128	0.028	-0.040	0.061	-0.028	-0.029	-0.023	**1.104**	0.889**

Bold figures represent direct effects; Residual effect = 0.0036 days to harvest (0.903). This was followed by number of grains panicle^{-1} through number of tertiary branches panicle^{-1} (0.639), ratio of vegetative phase to reproductive phase via. harvest index (0.596), number of spikelets panicle^{-1} via. number of tertiary branches panicle^{-1} (0.581) and number of panicles m^{-2} through harvest index (0.556). The highest negative indirect effects with yield was exhibited by number of days to harvest via. harvest index (¯0.658). This was followed by ratio of vegetative phase to reproductive phase via. number of days to harvest (¯0.614), number of days to 50 per cent flowering via. harvest index (¯0.606), harvest index via. number of days to harvest (¯0.572), 1000 grain weight via. harvest index (¯0.509), number of days to harvest via. number of days to 50 per cent flowering (¯0.450) and number of panicles m^{-2} via. number of days to harvest (¯0.435).

4.1.7 Selection index

A selection model for making selection on several characters simultaneously using discriminant function analysis (Hazel, 1943), with their efficiency over direct selection was developed and presented in Table 14. All possible combinations of selection models with eleven important characters were formulated. Among selection models having equal number of character combinations, those models with maximum efficiency were selected. Thus nine simultaneous selection models were selected using different character combinations and they were ranked based on their efficiency.

Maximum efficiency of 1.0497 was found for the selection index constituting yield and 10 yield component characters namely, days to 50 per cent flowering,

Table 14 Discriminant function for different yield components, genetic advance through selection index, efficiency over direct selection and gain in efficiency

Sl. No.	Combination	Discriminant function	Genetic advance through selection index	Efficiency over direct selection (maximum value)	Gain in efficiency (%)
1	$y, x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}$	$0.467y + -9.447x_1 + 11.843x_2 + 1705.522x_3 + 2.713x_4 + -2.670x_5 + 0.892x_6 + -15.162x_7 + 7.790x_8 + -9.735x_9 + 866.977x_{11}$	1852.42	1.0497	4.97
2	$y, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}$	$0.471y + 3.966x_2 + 1685.444x_3 + 2.731x_4 + -2.474x_5 + -0.159x_6 + -15.067x_7 + 7.814x_8 + -10.518x_9 + 821.975x_{11}$	1851.79	1.0494	4.94
3	$y, x_1, x_2, x_3, x_4, x_6, x_8, x_{10}$	$0.492y + -11.929x_1 + 13.528x_2 + 1631.786x_3 + 2.928x_4 + -6.944x_6 + 7.686x_8 + 905.402x_{11}$	1841.95	1.0438	4.38
4	$y, x_2, x_3, x_4, x_6, x_8, x_{10}$	$0.496y + 3.482x_2 + 1605.186x_3 + 2.983x_4 + -7.616x_6 + 7.852x_8 + 855.141x_{11}$	1840.89	1.0432	4.32
5	$y, x_2, x_3, x_6, x_8, x_{10}$	$0.551y + -2.534x_2 + 1533.857x_3 + -4.583x_6 + 6.299x_8 + 811.097x_{11}$	1821.46	1.0321	3.21
6	y, x_2, x_3, x_6, x_{10}	$0.560y + -0.444x_2 + 1484.778x_3 + 13.171x_6 + 933.009x_{11}$	1808.02	1.0245	2.45
7	y, x_2, x_6, x_{10}	$0.619y + -10.938x_2 + 8.485x_6 + 756.665x_{11}$	1790.25	1.0144	1.44
8	y, x_2, x_{10}	$0.641y + -9.529x_2 + 684.218x_{11}$	1787.87	1.0131	1.31
9	y, x_2	$0.679y + -11.877x_2$	1784.85	1.0114	1.14
	Direct selection based on yield		1764.70	1.0000	

x_1 = Number of days to 50% flowering
x_2 = Number of days to harvest
x_3 = Ratio of vegetative phase to reproductive phase
x_4 = Number of panicles m^{-2}
x_5 = Number of spikelets $panicle^{-1}$
x_6 = Number of tertiary branches $panicle^{-1}$
x_7 = Spikelet sterility percentage
x_8 = Number of grains $panicle^{-1}$
x_9 = 1000 grain weight
x_{10} = Harvest index
y = Yield $hectare^{-1}$

days to harvest, ratio of vegetative phase to reproductive phase, panicles m^{-2}, spikelets $panicle^{-1}$, tertiary branches $panicle^{-1}$, spikelet sterility percentage, grains $panicle^{-1}$ and harvest index. For simplification of the proposed selection models, minimum number of character combinations with maximum efficiency, were mostly adopted. Accordingly, the selection model constituting the characters yield ha^{-1} (y) number of days to harvest (x_2), ratio of vegetative phase to reproductive phase (x_3), number of tertiary branches $panicle^{-1}$ (x_6), number of grains $panicle^{-1}$ (x_8) and harvest index (x_{10}) was selected. This selection model was utilized for ranking the selected 56 genotypes.

Estimates of the selection index using characters namely, yield ha^{-1} (y) days to harvest (x_2), ratio of vegetative phase to reproductive phase (x_3),tertiary branches $panicle^{-1}$ (x_6) number of grains $panicle^{-1}$ (x_8) and harvest index (x_{10}) and ranking given to the 56 genotypes according to the selection index and yield are given in Table 15. The best 10 genotypes based on the selection index and yield were given in Table 16. Based on selection index and yield, first rank, second rank and third rank were obtained for accession numbers namely, V_{48}, V_{17} and V_{27} respectively. Based on selection index, 10 accession numbers namely V_{48}, V_{17}, V_{27}, V_1, V_{29}, V_{45}, V_9, V_{10}, V_{28} and V_4 and based on yield alone, the accession numbers namely V_{48}, V_{17}, V_{27}, V_{45}, V_{29}, V_1, V_{10}, V_{28}, V_4 and V_9 were found to superior in the order of ranking.

4.1.8 Genetic diversity in high yielding rice genotypes of diverse origin

Potent variability in indigenous cultivars is the result of prolonged natural and artificial selection which is heritable and hence important. The D^2 statistic permit

Table 15 Estimates of selection index of 56 high yielding diverse rice varieties using characters, yield hectare^{-1}(y), days to harvest (x_2), ratio of vegetative phase to reproductive phase (x_3), number of tertiary branches panicle^{-1} (x_6), number of grains panicle^{-1} (x_8) and harvest index (x_{10})

Accession Number	Selection index	Rank according to		Accession number	Selection index	Rank according to	
		Selection index	Yield			Selection index	Yield
V_1	4734.8	4	6	V_{29}	4662.8	5	5
V_2	3663.8	28	29	V_{30}	4147.2	11	13
V_3	3486.9	35	36	V_{31}	3659.2	29	40
V_4	4198.1	10	9	V_{32}	3791.3	22	18
V_5	2549.9	52	53	V_{33}	3576.9	32	25
V_6	1970.5	56	56	V_{34}	2752.7	49	49
V_7	3581.9	31	26	V_{35}	3879.4	18	12
V_8	2348.7	54	52	V_{36}	3164.3	43	28
V_9	4503.2	7	10	V_{37}	3249.1	40	38
V_{10}	4498.0	8	7	V_{38}	2490.4	53	55
V_{11}	3519.5	33	35	V_{39}	2990.8	44	44
V_{12}	3872.1	20	24	V_{40}	4132.3	12	11
V_{13}	3873.5	19	22	V_{41}	3773.0	24	14
V_{14}	3457.2	36	20	V_{42}	3202.9	41	43
V_{15}	4117.3	14	15	V_{43}	3175.5	42	42
V_{16}	3304.2	39	41	V_{44}	3763.2	25	33
V_{17}	5807.4	2	2	V_{45}	4594.6	6	4
V_{18}	3683.1	27	31	V_{46}	3647.2	30	30
V_{19}	4125.5	13	23	V_{47}	2214.7	55	54
V_{20}	4069.1	15	16	V_{48}	6418.0	1	1
V_{21}	3418.0	38	34	V_{49}	3779.0	23	32
V_{22}	2767.2	48	48	V_{50}	3918.3	16	17
V_{23}	2681.0	51	51	V_{51}	3444.6	37	37
V_{24}	3754.3	26	27	V_{52}	2865.4	45	46
V_{25}	3803.9	21	19	V_{53}	2831.5	47	47
V_{26}	3902.2	17	21	V_{54}	2690.8	50	50
V_{27}	4785.3	3	3	V_{55}	3505.6	34	39
V_{28}	4245.8	9	8	V_{56}	2848.1	46	45

Table 16 Best 10 genotypes based on selection index and yield

Rank	Selection of genotypes	
	Based on selection index	Based on yield
1	V_{48} (Mattatriveni)	V_{48} (Mattatriveni)
2	V_{17} (IR62030-18-2-2)	V_{17} (IR62030-18-2-2)
3	V_{27} (S9768-PN-25-1)	V_{27} (S9768-PN-25-1)
4	V_{1} (AS2537C)	V_{45} (Karthika)
5	V_{29} (IR50)	V_{29} (IR50)
6	V_{45} (Karthika)	V_{1} (AS2537C)
7	V_{9} (IR53970-21-2-3-2)	V_{10} (IR54883-152-3-3)
8	V_{10} (IR54883-152-3-3)	V_{28} (IR36)
9	V_{28} (IR36)	V_{4} (BR4689-17-1-5)
10	V_{4} (BR4689-17-1-5)	V_{9} (IR53970-21-2-3-2)

precise comparison among all possible pairs of populations before effecting actual crosses in modelling the varieties in a desired genetic architecture. Thus the present investigation has been carried out with 27 high yielding indigenous genotypes collected from various rice research stations of Kerala and 29 high yielding exotic genotypes from various parts of Asia like Pakistan, China, Bangladesh, Srilanka, Indonesia and Philippines to ascertain the nature and magnitude of genetic diversity present in the material.

4.1.8.1 Clustering

The analysis of variance revealed highly significant differences among the genotypes for all the 36 characters studied except for grain pubescence, colour of the grain and presence of awn, indicating the existence of variability among genotypes (Table 8).

Based on the relative magnitude of D^2 values, 56 high yielding rice genotypes were grouped into nine clusters. The clustering pattern of 56 genotypes was given in Table 17. The computed D^2 values varied from 341.84 to 2057.1 showing high divergence among different strains. Clustering pattern revealed that cluster V was the largest group consisting of 14 strains of which 13 were adapted to India and the remaining one belonged to Srilanka. The next highest number of strains (9) was present in both clusters IV and VIII. Of the nine genotypes in cluster IV, all belonged to Philippines except one which was a strain from India. All these nine genotypes had the highest number of grains panicle^{-1} and shortest second uppermost internodal length. Cluster VIII constituted a mixture of genotypes from Pakistan,

Table 17 Clustering pattern of high yielding rice varieties of diverse origin

Cluster	Number of genotypes	Genotype and source
I	3	KACHSIUNG SEN YU 338 (CHINA); IR60133-184-3-2-2 (IRRI); PK 2557-24-2-1 (PAKISTAN)
II	3	Vytilla 2 (INDIA); Vytilla 3 (INDIA); Vytilla 4 (INDIA)
III	6	HSINCHU64(CHINA); Athira (INDIA); BHADRA (INDIA); Kanakam (INDIA); Pavizham (INDIA); Aruna (INDIA)
IV	9	IR54883-152-3-3(IRRI); RP1670-1418-2205-1585 (INDIA); IR50(IRRI); IR36(IRRI); IR62030-18-2-2 (IRRI); IR60832-187-2-2-2 (IRRI); IR62164-14-2-2-2-3 (IRRI); IR56453-184-2-1-2 (IRRI); IR53970-21-2-3-2 (IRRI)
V	14	CR294-548(INDIA); CC1 22-23-4-301 (INDIA); CC1-38-11-6-F-314 (INDIA); AT85-2 (SRILANKA); Jayathi (INDIA); Karthika (INDIA); Asha (INDIA); Ranjini (INDIA); Makam (INDIA); Arathi (INDIA); Kanchana (INDIA); Jyothi (INDIA); Jaya (INDIA); Sabari (INDIA)
VI	2	Mahsuri (INDIA); Remya (INDIA)
VII	4	Hraswa (INDIA); Bhagya (INDIA); Onam (INDIA); Annapoorna (INDIA)
VIII	9	PK3355-5-1-4 (Pakistan); IR54950-181-2-1-2-3 (IRRI); IR61005-37-2-1-2 (IRRI); S9768-PN-25-1 (INDONESIA); MR123 (Malaysia); PK2480-7-31 (Pakistan); IR59682-132-1-1-2 (IRRI); BR4676-72-2-4 (Bangladesh); S9728-22-1-3-1-1 (INDONESIA)
IX	6	Mattatriveni (INDIA); RAVI (RP1664-1529-4254) (INDIA); BR-4689-17-1-5 (Bangladesh); AS2537C (INDIA); Ahallya (INDIA); Kairali (INDIA)

Philippines, Indonesia, Malaysia and Bangladesh. In cluster VI, there were two genotypes of longer duration from Kerala (India). Cluster VII constituted strains of four dwarf plant stature with shortest maturity duration, and they also were from Kerala, India. Out of the six genotypes in cluster III, five belonged to India and the remaining one to China. Cluster I and II had only three genotypes each. The three genotypes of cluster II are the tallest and cultivated in Pokkali areas of Kerala in India. Each genotype of cluster I belonged to different sources of origin namely, China, Philippines and Pakistan. Out of six genotypes in cluster IX, five were cultivated in various regions of India and one belonged to Bangladesh.

It was noticed that the genotypes developed at the same location were grouped in to different clusters. For example, varieties developed at Mankombu rice research station of Kerala, India were grouped in cluster III, V and VI. Similarly genotypes developed from the same pedigree, were distributed in different clusters. For example three varieties namely, Arathi, Aruna and Remya being the derivatives of the cross involving Jaya and Ptb-33 as parents came in three different clusters.

4.1.8.2 Intra and inter-cluster distances

Average D^2 values at intra and inter cluster levels are presented in Table 18. As regards divergence at intra cluster level, the maximum intra-cluster distance (456.10) was noticed in cluster I which consisted three strains each from China, Philippines and Pakistan and the minimum (184.54) in cluster VIII which included nine strains from different geographical areas. The maximum inter cluster

Table 18 Intra and inter-cluster average D^2 values

	I	II	III	IV	V	VI	VII	VIII	IX
I	456.11	1554.91	805.20	611.02	457.45	903.65	1003.58	458.98	819.81
II		224.36	1455.29	2057.10	1293.15	1020.39	2017.45	1685.37	1664.38
III			286.81	1086.02	384.96	628.74	1280.04	767.47	941.95
IV				189.98	560.65	1437.84	586.22	366.43	441.84
V					197.24	661.37	840.74	341.84	523.45
VI						450.96	1894.73	867.57	1484.20
VII							371.34	935.01	456.00
VIII								184.54	574.08
IX									226.97

Underlined figures indicate intra clsuter distances distance (2057.10) was observed between clusters II and IV followed by between clusters II and VII (2017.45), while clusters V and VIII exhibited the lowest value (341.84).

An overall assessment of the clusters showed that there was high divergence between clusters IV and II; VII and II; VII and VI; VIII and II and between IX and II. On the other hand clusters I, V, VIII and IX were closely spaced.

4.2 Experiment No.2

Twelve genetically diverse genotypes, representing nine clusters in experiment number 1 having different parentage which can impart wider genetic base, were subjected to 12 x 12 full diallel crossing (including reciprocals). Out of 132 cross combinations carried out, one cross combination namely, IR60133-184-3-2-2-xS9768-PN-25-1 failed to set seeds even after repeated crossing. Ten cross combinations did not germinate and 25 cross combinations did not survive beyond nursery stage. Since the remaining 96 cross combinations were not sufficient for a 12 x 12 full diallel analysis, the available crosses were split into for 5 x 5 full diallel analysis (20 crosses), 8 x 8 half diallel analysis (28 crosses) and 6 x 3 line x tester analysis (18 crosses). The whole 96 crosses were ranked based on the selection index and yield. Heterobeltiosis, relative heterosis and standard heterosis were estimated for all 96 hybrids. Based on high association of yield components with yield and based on intercorrelations and direct and indirect effects on yield, 18 characters were selected for combining ability and heterosis studies.

4.2.1 Combining ability analysis

4.2.1.1 5 x 5 full diallel analysis using Griffing's method 1

The parental lines designated as P_1, P_4, P_5, P_6 and P_9 (Table 2) were involved in the 5 x 5 full diallel analysis. The ANOVA for treatments including parents (Table 19) showed that treatments differed significantly for all the characters except for alkali spreading value.

Analysis of variance for combining ability (Table 20) showed that mean squares due to general combining ability (*gca*) was significant for all the characters except for ratio of vegetative phase to reproductive phase and spikelet sterility percentage. Mean squares due to specific combining ability (*sca*) were significant for all the characters except for ratio of vegetative phase to reproductive phase. The mean squares due to reciprocal cross effects were significant for all the 17 characters studied. GCA/SCA ratio was higher than unity for all the characters except for leaf area plant^{-1} and maximum tillering stage, ratio of vegetative phase to reproductive phase, number of panicles m^{-2} and spiklet sterility percentage. The estimates of components of variance are given in Table 21. The estimates of genetic effects and their ratio showed that non-additive genetic effect was higher than additive genetic effect for all the characters except for second uppermost internodal length and height of plant at harvest.

4.2.1.1.1 General combining ability effects

General combining ability effect, estimated for the 15 characters are presented in Table 22.

Table 19 Analysis of variance for treatments including parents used for 5x5 full diallel analysis using Griffing's method - 1

	Mean sum of squares																	
Degrees of Freedom	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets panicle^{-1}	Number of tertiary branches panicle^{-1}	Number of grains panicle^{-1}	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area plant^{-1} at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield plant^{-1}
24	361.75**	348.33 **	0.05 *	3192.44 **	14257.39 **	434.48 **	13262.39 **	91.71 **	0.06 **	43.83 **	87.08 **	1528.14 **	138827.76 **	32.03 **	0.36 **	24.68 **	0.82	36.64 **

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

Table 20 Analysis of variance for combining ability in 5x5 full diallel analysis using Griffing's method-1

		Mean sum of squares															
Source	Degrees of Freedom	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets panicle^{-1}	Number of tertiary branches panicle^{-1}	Number of grains panicle^{-1}	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area plant^{-1} at tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Yield plant^{-1}
GCA	4	350.09 **	289.03 **	0.01	1487.42	17351.06 **	408.43 **	15600.61 **	14.75	0.06 **	62.30 **	79.23 **	1854.18 **	33651.91 **	26.05 **	0.36 **	27.43 **	23.45 **
SCA	10	142.47 **	192.41 **	0.01	1882.46 **	2301.59 **	64.71 **	2137.66 **	58.33 **	0.03 **	10.13 **	5.04 **	124.42 *	54251.89 **	11.57 **	0.08 **	6.41 **	15.21 **
Reciprocals	10	151.60 **	109.98 **	0.05 **	1353.50 **	7866.85 **	293.29 **	7536.97 **	45.83 *	0.02 **	17.54 **	67.77 **	967.68 **	98880.80 **	16.45 **	0.22 **	12.23 **	19.37 **
Error	24	3.16	6.54	0.01	293.40	134.03	6.42	101.24	16.74	0.00	0.96	0.35	36.13	1724.53	0.33	0.01	0.29	0.68
GCA/SCA		2.46	1.50	0.60	0.79	7.54	6.31	7.30	0.25	2.00	6.15	15.72	14.90	0.62	2.25	4.50	4.28	[illegible]54

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

Table 21 Estimates of components of genetic variance from 5 x 5 full diallel analysis using Griffing's method-1

Components	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Yield $plant^{-1}$
Variance due to additive genetic effect	34.69	28.25	-0.0004	119.40	1721.70	40.20	1549.94	-0.20	0.0060	6.13	7.89	181.81	3192.74	2.57	0.035	2.71	2.28
Variance due to non-additive genetic effect	139.31	185.87	0.0000	1589.06	2167.56	58.29	2036.42	41.49	0.0300	9.17	4.69	88.29	52527.36	11.24	0.073	6.12	14.53
Variance due to reciprocal effect	74.22	51.72	0.0200	530.05	3866.41	143.44	3717.87	14.55	0.0100	8.29	33.71	465.78	48578.14	16.12	0.213	5.97	9.35
Variance due to error	3.16	6.54	0.0100	293.40	134.03	6.42	101.24	16.74	0.0004	0.96	0.35	36.13	1724.53	0.33	0.007	0.29	0.68
Ratio of additive genetic effect to non-additive genetic effect	0.25	0.15		0.08	0.79	0.69	0.76	-0.005	0.20	0.67	1.68	2.06	0.06	0.23	0.480	0.44	0.16

Table 22 **General combining effects and mean performance (in bold) of five parents from 5 x 5 full diallel analysis using Griffing's method-1**

Parents	Number of days to 50% flowering	Number of days to harvest	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Harvest index	1000 grain weight(g)	Second uppermost internodal length(cm)	Height of plant at harvest(cm)	Leaf area $plant^{-1}$ at maximum tillering stage (cm^2)	Length of panicle(cm)	L/B ratio of grain	Amylose content (%)	Yield $plant^{-1}$(g)
P_1	-6.25 **	-5.51 **	-11.59 *	-13.27 **	-1.72 *	-14.13 **	0.09 **	-0.70 *	-1.63 **	-8.99 **	-16.55	0.07	-0.08 **	1.20 **	0.52 *
	79.50	**110.00**	**46.50**	**102.60**	**16.10**	**77.50**	**0.69**	**25.60**	**16.15**	**77.10**	**160.85**	**22.65**	**2.64**	**25.85**	**8.27**
P_4	6.50 **	3.29 **	2.26	64.40 **	9.66 **	61.76 **	-0.11 **	-2.96 **	2.45 **	15.14 **	56.63 **	1.87 **	0.06 *	1.42 **	1.72 *
	104.50	**132.00**	**82.50**	**248.50**	**33.00**	**233.50**	**0.06**	**21.60**	**24.85**	**125.70**	**308.15**	**27.50**	**3.16**	**24.30**	**12.44**
P_5	4.90 **	6.94 **	4.16	16.20 **	2.54 **	14.88 **	0.02 **	1.09 **	0.05	-0.06	56.08 **	0.22	0.13 **	0.57 **	0.15
	88.00	**125.00**	**53.00**	**115.20**	**23.45**	**112.40**	**0.42**	**29.15**	**18.20**	**91.40**	**51.95**	**23.80**	**3.07**	**23.58**	**3.05**
P_6	-5.85 **	-5.11 **	17.16 **	-27.05 **	-3.51 **	-26.23 **	0.03 **	3.65 **	2.94 **	11.33 **	-14.84	0.43 *	-0.29 **	-0.57 **	0.08
	83.50	**110.50**	**43.00**	**112.25**	**20.50**	**103.95**	**0.72**	**35.70**	**24.75**	**115.00**	**136.15**	**26.45**	**2.66**	**23.17**	**3.61**
P_9	0.70	0.39	-11.99 *	-40.28 **	-6.95 **	-36.28 **	-0.04 **	-1.07 **	-3.80 **	-17.41 **	-81.33 **	-2.59 **	0.18 **	-2.62 **	-2.47 *
	83.00	**113.50**	**56.00**	**109.70**	**18.40**	**107.50**	**0.58**	**24.55**	**14.20**	**76.50**	**288.40**	**21.85**	**3.61**	**19.65**	**4.51**
S.E.(g_i)	0.50	0.72	4.84	3.27	0.72	2.85	0.01	0.28	0.17	1.70	11.75	0.16	0.02	0.15	0.23
CD(5%)	1.04	1.49	9.99	6.75	1.48	5.88	0.01	0.57	0.35	3.51	24.25	0.33	0.04	0.31	0.48
CD(1%)	1.41	2.02	13.54	9.15	2.01	7.97	0.02	0.78	0.47	4.76	32.85	0.45	0.06	0.43	0.65
S.E.(g_i - g_j)	0.79	1.14	7.66	5.18	1.13	4.50	0.01	0.44	0.27	2.69	18.57	0.26	0.04	0.24	0.37
CD(5%)	1.63	2.35	15.81	10.69	2.33	9.29	0.02	0.91	0.56	5.55	38.33	0.54	0.08	0.50	0.76
CD(1%)	2.21	3.19	21.43	14.49	3.16	12.59	0.03	1.23	0.76	7.52	51.94	0.73	0.11	0.67	1.03

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

Number of days to 50% flowering

The parent P_1 (−6.25**) ranked first in negative significant *gca* effect (desirable) followed by P_6 (−5.85**). But these two parents were on par in their effects. The parents P_4 and P_5 exhibited positive significant *gca* effect. Comparing the *per se* performance, short flowering period was seen for P_1 (79.5 days) followed by P_9 (83 days) and P_6 (84 days).

Number of days to harvest

The parents P_1 (-5.51**) and P_6 (-5.11**) recorded negative significant *gca* effects which were on par. Parents P_4 and P_5 exhibited positive significant *gca* effects. Mean performance was the minimum for P_1 (110 days) and was followed by P_6 (111 days).

Number of panicles m^{-2}

Only P_6 (17.16**) exhibited positive significant *gca* effect. P_1 and P_9 showed significant negative effect. *Per se* performance was the maximum for the parent P_4 (82.5).

Number of spikelets panicle^{-1}

P_4 exhibited the maximum positive *gca* effect (64.40**) which was followed by P_5 (16.20**). Significant negative effects were recorded for P_1, P_6 and P_9. With respect to mean performance, the maximum spikelets panicle^{-1} (248.50) was recorded for the parent P_4.

Number of tertiary branches panicle^{-1}

The *gca* effect and mean performance were in the same pattern as that of spikelets panicle^{-1}.

Number of grains panicle^{-1}

The pattern of exhibition of *gca* effect and the mean performance, was similar to those of spikelets panicle^{-1} and tertiary branches panicle^{-1}.

Harvest index

Positive significant *gca* effect was exhibited by P_1 (0.09**) P_6 (0.03**) and P_5 (0.02**) in the presented order. Effect of P_1 was significantly higher than that of P_6 and P_5 which were on par. General combining ability effects of P_4 and P_9 were negative and significant. Maximum *per se* performance for harvest index was observed for P_6 (0.72) followed by P_1 (0.69).

1000 grain weight

Positive significant *gca* effect was recorded for P_6 (3.65**) and,was followed by P_5 (1.09**). P_6 was significantly superior to P_5. Significant negative effect was recorded for P_4, P_9 and P_1. The *per se* performance was the maximum for P_6 (35.7 g) and was followed by P_5 (29.15 g).

Second uppermost internodal length

The parent P_6 followed by P_4 exhibited positive significant *gca* effect. Parent P_9 exhibited the maximum significant negative *gca* effect $^-$3.80** followed by P_1 ($^-$1.63**). The *per se* performance was minimum for P_9 (14.2 cm) followed by P_1 (16.15 cm).

Height of plant at harvest

The *gca* effect and mean performance exhibited the same pattern as that of second uppermost internodal length.

Leaf area plant^{-1} at maximum tillering stage

The parents P_4 (56.63**) and P_5 (56.08**) recorded positive significant *gca* effect which were on par. The parent P_9 showed negative significant *gca* effect. Observed *per se* performance was high for P_4 (308.15cm^2) followed by P_9 (288.40 cm^2). The *per se* performance of parents P_4 and P_5 which had equal *gca* effects were highly spaced (308.15cm^2 and 51.95cm^2 respectively).

Length of panicle

P_4 exhibited the maximum significant positive *gca* effect (1.87**)followed by P_6 (0.43*) while P_9 exhibited negative significant effect. P_4 recorded the maximum value (27.5 cm) for panicle length followed by P_6 (26.45 cm).

L/B ratio of grain

P_9 (0.18**) P_5 (0.13**) and P_4 (0.06*) exhibited positive significant *gca* effects with P_9 having significantly superior effect. P_1 and P_6 exhibited negative significant *gca* effects. Maximum mean value for L/B ratio was recorded for P_9 (3.61) and was followed by P_4 (3.16) and P_5 (3.07).

Amylose content

P_4 (1.42**), P_1 (1.20**) and P_5 (0.57**) showed positive significant *gca* effect with maximum value for P_4 which was on par with P_1. Negative significant effect was observed for P_9 and P_6. Amylose content was the highest for P_1 (25.85%) followed by P_4 (24.30%).

Yield plant^{-1}

The highest positive significant *gca* effect was recorded for P_4 (1.72**) and was followed by P_1 (0.52*). P_9 was found to have negative significant effect. Observed yield was the maximum for P_4 (12.44 g) and was followed by P_1 (8.27 g)

4.2.1.1.2 Specific combining ability effects and their reciprocal effects

The specific combining ability effects of ten crosses and their reciprocal combining ability effects for different characters were estimated and are presented in Table 23 and Table 24 respectively. The array means of the progenies for different characters when different parents were used as common male and common female parents are given in Table 25.

Number of days to 50 per cent flowering

Specific combining ability effects of $P_1 \times P_4$, $P_1 \times P_5$, $P_1 \times P_6$, $P_4 \times P_9$, $P_5 \times P_6$ and $P_5 \times P_9$ were positive and significant. A negative direction was observed for $P_4 \times P_6$ ($^-$5.30**) which was desirable for this character. In this cross ($P_4 \times P_6$) the *gca* effect of P_4 was positive and significant and that of P_6 was negative and

Table 23 Specific combining ability effects and mean performance (in bold) of hybrids from 5x5 full diallel analysis using Grifing's method-1

Cross combinations	Number of days to 50% flowering	Number of days to harvest	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight (g)	Second uppermost internodal length (cm)	Height of plant at harvest (cm)	Leaf area $plant^{-1}$ at maximum tillering stage(cm^2)	Length of panicle(cm)	L/B ratio of grain	Amylose content (%)	Yield $plant^{-1}$(g)
$P_1 \times P_4$	2.85 *	1.76	-29.31 **	3.15	3.60 *	7.27	-2.21	0.06 **	-0.12	-0.39	2.09	-87.49 **	-1.07 **	-0.02	1.46 **	-4.02 **
	87.00	**115.00**	**62.50**	**114.15**	**16.80**	**101.35**	**11.20**	**0.58**	**22.50**	**15.10**	**75.50**	**217.70**	**22.40**	**2.63**	**23.70**	**3.62**
$P_1 \times P_5$	2.45 *	0.11	-0.71	-16.77	-3.79 *	-13.50 *	-3.08	-0.02	-0.25	-1.09 **	-8.91 *	91.04 **	-1.65 **	0.22 **	-1.91 **	-1.58 **
	85.50	**124.00**	**66.00**	**136.25**	**24.60**	**122.75**	**10.15**	**0.65**	**24.15**	**18.80**	**76.15**	**319.80**	**22.30**	**2.55**	**19.94**	**5.30**
$P_1 \times P_8$	3.70 **	8.91 **	44.04 **	11.85	0.02	16.59 **	-5.74 *	-0.04 **	-2.13 **	0.07	1.18	219.36 **	1.65 **	-0.05	-0.82 *	4.15 **
	89.50	**128.50**	**99.00**	**111.50**	**16.50**	**110.50**	**0.90**	**0.44**	**20.20**	**10.75**	**70.90**	**193.65**	**22.10**	**2.45**	**20.40**	**3.99**
$P_1 \times P_9$	-2.10	1.16	6.94	19.58 **	3.83 *	18.89 **	-1.19	-0.06 **	-0.91	1.13 **	2.99	-65.52 *	1.59 **	-0.03	-1.17 **	0.10
	85.00	**124.00**	**90.50**	**134.75**	**25.25**	**123.75**	**8.15**	**0.33**	**23.20**	**18.50**	**83.00**	**277.95**	**23.95**	**2.53**	**21.44**	**5.68**
$P_4 \times P_5$	1.45	4.31 **	26.69 *	58.43 **	5.96 **	56.59 **	-2.32	0.08 **	-1.62 **	2.83 **	1.56	184.19 **	0.33	0.16 **	-0.44	3.15 **
	117.00	**150.00**	**115.50**	**275.50**	**48.00**	**258.00**	**6.35**	**0.42**	**15.50**	**26.00**	**132.50**	**602.50**	**25.85**	**3.20**	**23.97**	**13.90**
$P_4 \times P_8$	-5.30 **	-5.64 **	5.44	-23.20 **	0.52	-28.62 **	4.49	0.09 **	-0.37	-0.96 *	-0.53	77.35 **	1.65 **	0.03	-0.78 *	-0.65
	100.00	**131.00**	**66.00**	**237.75**	**47.25**	**213.25**	**10.10**	**0.47**	**22.35**	**27.00**	**130.70**	**609.40**	**26.70**	**2.88**	**20.06**	**7.78**
$P_4 \times P_9$	8.40 *	7.11 **	9.84	-11.10	-0.54	-10.20	1.09	-0.05 **	-1.83 **	-2.32 **	-6.09	-17.60	-1.66 **	0.29 **	-0.69 *	-1.60 **
	116.50	**137.50**	**82.50**	**284.00**	**47.00**	**268.50**	**5.20**	**0.46**	**16.95**	**23.75**	**123.15**	**589.85**	**26.20**	**3.08**	**24.83**	**6.93**
$P_5 \times P_8$	5.55 **	7.21 **	29.29 **	33.13 **	5.10 **	26.83 **	6.47 *	-0.07 **	-1.73 **	0.94 *	11.75 **	20.86	-0.48	-0.29 **	0.60	1.27 *
	114.50	**145.00**	**132.00**	**262.50**	**42.50**	**246.00**	**6.25**	**0.47**	**25.65**	**19.00**	**93.90**	**712.10**	**26.35**	**2.50**	**22.50**	**11.93**
$P_5 \times P_9$	11.25 **	10.21	-9.31	-10.64	-2.43	-17.54 **	6.82 **	0.08 **	0.22	-1.67 **	-3.49	115.45 **	1.46 **	0.00	0.30	0.30
	121.50	**150.00**	**99.00**	**145.00**	**22.10**	**128.00**	**11.70**	**0.46**	**24.90**	**18.25**	**84.05**	**812.20**	**23.35**	**2.97**	**20.17**	**6.57**
$P_8 \times P_9$	-0.25	1.76	3.19	-41.15 **	-9.95 **	-36.20 **	-1.81	-0.18 **	-0.59	0.19	-12.30 **	-132.06 **	-5.39 **	-0.02	-2.32 **	-2.36 **
	101.50	**134.00**	**66.00**	**48.00**	**3.10**	**47.50**	**1.05**	**0.37**	**31.15**	**27.65**	**97.05**	**202.15**	**20.40**	**2.26**	**18.93**	**1.91**
S.E.(S_{ij})	1.04	1.49	9.99	6.75	1.48	5.87	2.39	0.01	0.57	0.35	3.50	24.21	0.33	0.05	0.31	0.48
CD(5%)	2.15	3.08	20.62	13.93	3.05	12.12	4.93	0.02	1.18	0.72	7.22	49.97	0.68	0.10	0.64	0.99
CD(1%)	2.91	4.17	27.94	18.88	4.14	16.42	6.68	0.03	1.59	0.97	9.79	67.72	0.92	0.14	0.87	1.34
S.E.$S_{(ij)}$ -$S_{(ik)}$	1.59	2.29	15.32	10.35	2.27	9.00	3.66	0.02	0.87	0.53	5.38	37.14	0.51	0.07	0.48	0.90
CD(5%)	3.28	4.73	31.62	21.36	4.69	18.58	7.55	0.04	1.80	1.09	11.10	76.66	1.05	0.14	0.99	1.86
CD(1%)	4.45	6.41	42.85	28.95	6.35	25.17	10.24	0.06	2.40	1.48	15.05	103.88	1.43	0.20	1.34	2.52
S.E.$S_{(ij)}$ -$S_{(ki)}$	1.78	1.98	17.13	8.97	1.96	7.79	3.17	0.02	0.76	0.46	4.66	32.17	0.44	0.06	0.42	0.94
CD(5%)	3.67	4.09	35.36	18.51	4.05	16.08	6.54	0.04	1.57	0.95	9.62	66.40	0.91	0.12	0.87	1.94
CD(1%)	4.98	5.54	47.91	25.09	5.48	21.79	8.87	0.06	2.13	1.29	13.03	89.98	1.23	0.17	1.17	2.63

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

Table 24 Reciprocal combining ability effects and mean performance (in bold) of hybrids from 5x5 full diallel analysis using Griffing's method-1

Cross combinations	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight(g)	Second uppermost internodal length(cm)	Height of plant at harvest(cm)	Leaf area $plant^{-1}$ at maximum tillering stage(cm^2)	Length of panicle(cm)	L/B ratio of grain	Amylose content (%)	Yield $plant^{-1}$(g)
$P_4 \times P_1$	15.00 **	17.50 **	-0.15	-10.50	87.10 **	17.95 **	88.57 **	-3.90	-0.09 **	-2.70 **	4.45 **	25.17 **	86.22 **	1.50 **	0.24 **	1.39 **	0.49
	117.00	**150.00**	**1.11**	**41.50**	**288.35**	**52.70**	**278.50**	**3.40**	**0.41**	**17.10**	**24.00**	**125.85**	**390.15**	**25.40**	**3.11**	**26.48**	**4.60**
$P_5 \times P_1$	14.50 **	10.50 **	-0.02	16.50	-3.12	-4.35 *	-0.47	-1.92	-0.11 **	-0.43	-2.35 **	-1.67	162.10 **	-0.62	0.64 **	0.92 *	-0.33
	114.50	**145.00**	**1.12**	**99.00**	**130.00**	**15.90**	**121.80**	**6.30**	**0.43**	**23.30**	**14.10**	**72.80**	**644.00**	**21.05**	**3.82**	**21.78**	**4.64**
$P_6 \times P_1$	1.00	2.75	-0.15	41.50 **	7.00	1.50	0.75	4.90	0.08 **	4.20 **	9.75 **	25.05 **	345.66 **	3.07 **	0.04	0.41	6.64 **
	91.50	**134.00**	**0.96**	**181.50**	**125.50**	**19.50**	**112.00**	**10.70**	**0.61**	**28.60**	**30.25**	**121.00**	**884.96**	**28.25**	**2.53**	**21.15**	**17.26**
$P_9 \times P_1$	6.25 **	5.00 *	0.00	-16.50	-21.75 *	-6.88 **	-20.25 **	0.33	0.12 **	-2.30 **	-3.68 **	-13.98 **	-90.03 **	-1.85 **	0.45 **	-3.02 **	-1.66 **
	97.50	**134.00**	**1.11**	**57.50**	**91.25**	**11.50**	**83.25**	**8.80**	**0.57**	**18.60**	**11.15**	**55.00**	**97.90**	**20.25**	**3.42**	**21.22**	**2.36**
$P_5 \times P_4$	-5.25 **	-2.50	0.05	8.25	10.50	-6.62 **	10.25	-0.12	0.01	4.60 **	-1.55 **	-23.42 **	45.73	-0.40	0.06	-1.41 **	-2.99 **
	106.50	**145.00**	**1.22**	**132.00**	**296.50**	**34.75**	**278.50**	**6.10**	**0.45**	**24.70**	**22.90**	**85.65**	**693.95**	**25.05**	**3.32**	**22.08**	**7.91**
$P_6 \times P_4$	-5.75 **	-5.50 **	-0.08	49.50 **	-76.62 **	-17.38 **	-71.32 **	3.18	-0.01	1.55 *	-3.45 **	-12.32 **	-138.93 **	0.27	-0.17 *	1.01 *	-0.74
	88.50	**120.00**	**1.09**	**165.00**	**84.50**	**12.50**	**70.60**	**16.45**	**0.45**	**25.45**	**20.10**	**106.05**	**331.55**	**27.25**	**2.55**	**20.69**	**6.30**
$P_9 \times P_4$	-2.00	6.25 **	-0.22 **	8.25	-124.00 **	-21.62 **	-118.20 **	2.80	-0.20 **	0.77	-8.30 **	-39.08 **	-280.82 **	-5.55 **	-0.21 **	-5.71 **	-3.40 **
	112.50	**150.00**	**0.99**	**99.00**	**36.00**	**3.75**	**32.10**	**10.80**	**0.06**	**18.50**	**7.15**	**45.00**	**28.20**	**15.10**	**2.65**	**15.40**	**0.13**
$P_6 \times P_5$	-11.00 **	-3.00	-0.31 **	9.25	-93.25 **	-15.15 **	-95.50 **	10.80 **	-0.05 **	0.95	4.05 **	21.55 **	-298.67 **	-3.15 **	-0.04	-0.90 *	-4.54 **
	92.50	**139.00**	**0.94**	**150.50**	**76.00**	**12.20**	**55.00**	**27.85**	**0.38**	**27.55**	**27.10**	**137.00**	**114.75**	**20.05**	**2.41**	**13.41**	**2.84**
$P_9 \times P_5$	-5.75 **	0.50	-0.17	-25.50 *	-32.75 **	-5.73 **	-31.92 **	3.82	0.04 **	-1.07	-4.55 **	-12.58 **	-370.68 **	-1.22 **	0.25 **	-0.92 *	-2.71 **
	110.00	**151.00**	**0.91**	**48.00**	**79.50**	**10.65**	**64.15**	**19.35**	**0.55**	**22.75**	**9.15**	**58.90**	**70.85**	**20.90**	**3.47**	**18.33**	**1.15**
$P_9 \times P_6$	-8.00 **	-4.00 *	0.13	33.00 *	-9.50	-0.30	-11.20	6.07 *	-0.10 **	-5.58 **	-9.20 **	-23.00 **	-79.05 **	-4.93 **	0.52 **	-3.43 **	-0.79
	85.50	**126.00**	**1.15**	**132.00**	**29.00**	**2.50**	**25.10**	**13.20**	**0.17**	**20.00**	**9.25**	**51.05**	**44.05**	**10.55**	**3.30**	**12.06**	**0.34**
S.E.R(S_{ij})	1.26	1.81	0.08	12.11	8.19	1.79	7.11	2.89	0.01	0.69	0.42	4.25	29.36	0.41	0.06	0.38	0.58
CD(5%)	2.60	3.74	0.17	25.00	16.90	3.69	14.68	5.96	0.02	1.42	0.87	8.77	60.60	0.85	0.12	0.78	1.20
CD(1%)	3.52	5.06	0.22	33.87	22.91	5.01	19.89	8.08	0.03	1.93	1.17	11.89	82.12	1.15	0.17	1.06	1.62
S.E R($_{ij}$)-R($_{ik}$)	1.78	2.56	0.11	17.13	11.58	2.53	10.06	4.09	0.02	0.98	0.59	6.01	41.53	0.57	0.08	0.54	0.78
CD(5%)	3.67	5.28	0.22	35.36	23.90	5.22	20.76	8.44	0.04	2.02	1.22	12.40	85.72	1.18	0.17	1.11	1.61
CD(1%)	4.98	7.16	0.31	47.91	32.39	7.08	28.14	11.44	0.06	2.74	1.65	16.81	116.16	1.59	0.22	1.51	2.18

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

Table 25 Array means of the progenies for different characters when P_1,P_4,P_5,P_6 and P_9 were used as common male and common female parents

Common parent - Male/Female	Other parents	Number of days to 50% flowering		Number of days to harvest		Ratio of vegetative phase to reproductive phase		Number of panicles m^{-2}		Number of spikelets panicle^{-1}		Number of tertiary branches panicle^{-1}		Number of grains panicle^{-1}		Spikelet sterility percentage		Harvest index		1000 grain weight(g)		Second uppermost internodal length(cm)		Height of plant at harvest(cm)		Leaf area plant^{-1} at maximum tillering stage(cm^2)		Length of panicle(cm)		L/B ratio of grain		Amylose content (%)		Yield plant^{-1} (g)	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
P_1	P_4	117.00	87.00	150.00	115.00	-	-	41.50	62.50	288 35	114.15	52.70	16.80	278.50	101.35	-	-	0.41	0.58	17.10	22.50	24.00	15.10	125.85	75.50	390.15	217.70	25.40	22.40	3.11	2.63	26.48	23.70	4.60	3.6
	P_5	114.50	85.50	145.00	124.00	-	-	99.00	66.00	130 00	136.25	15.90	24.60	121.80	122.75	-	-	0.43	0.65	23.30	24.15	14.10	18.80	72.80	76.15	644.00	319.80	21.05	22.30	3.82	2.55	21.78	19.94	4.64	5.3
	P_6	91.50	89 50	134.00	128.50	-	-	181.50	99 00	125.50	111.50	19.50	16.50	112.00	110.50	-	-	0.61	0.44	28.60	20.20	30.25	10.75	121.00	70.90	884.96	193.65	28.25	22.10	2.53	2.45	21.15	20.40	17.26	3.9
	P_9	97.50	85.00	134.00	124.00	-	-	57.50	90.50	91 25	134.75	11.50	25.25	83.25	123.75	-	-	0.57	0.33	18.60	23.20	11.15	18.50	55.00	83.00	97.90	277.95	20.25	23.95	3.42	2.53	21.22	21.44	2.36	5.6
	Mean	105.13	86.75	140.75	125.75	-	-	94.87	79.50	158.78	124.17	24.90	20.79	148.89	114.59	-	-	0.51	0.50	21.90	22.51	19.88	15.79	93.66	76.39	504.25	252.28	23.74	22.69	3.22	2.54	22.66	21.37	7.22	4.6
P_4	P_1	87.00	117.00	115.00	150.00	1.40	1 11	62.50	41.50	114 15	288.35	16.80	52.70	101.35	278.50	-	-	0.58	0.41	22.50	22.50	15.10	24.00	75.50	125.85	217.70	390.15	-	-	2.63	3.11	23.70	26.48	3.62	4.6
	P_5	106.50	117.00	145.00	150.00	1 22	1.11	132.00	115.50	296.50	275.50	34.75	48.00	278.50	258.00	-	-	0.45	0.42	24.70	15.50	22.90	26.00	85.65	132.50	693.95	602.50	-	-	3.32	3.20	22.08	23.97	7.91	13.90
	P_6	88.50	100.00	120.00	131.00	1.09	1.26	165.00	66.00	84.50	237 75	12.50	47.25	70.60	213.25	-	-	0.45	0.47	25.45	22.35	20.10	27.00	106.05	130.70	331.55	609.40	-	-	2.55	2.88	20.69	20.06	6.30	7.7
	P_9	112.50	116.50	150.00	137.50	0.99	1.43	99.00	82.50	36.00	284.00	3.75	47.00	32.10	268.50	-	-	0.06	0.46	18.50	16.95	7.15	23.75	45.00	123.15	28.20	589.85	-	-	2.65	3.08	15.40	24.83	0.13	6.9
	Mean	98.63	112.63	132.50	142.13	1.18	1.23	114.63	76.38	142.79	271.40	16.95	48.74	120.64	254.56	-	-	0.39	0.44	22.79	19.33	16.31	25.19	78.05	128.05	317.85	547.98	-	-	2.79	3.07	20.47	23.84	4.49	8.30
P_5	P_1	85.50	114.50	124.00	145.00	1.16	1.12	66.00	99.00	136.25	130.00	24.60	15.90	122.75	121.80	-	-	0.65	0.43	-	-	18.80	14.10	76.15	72.80	319.80	644.00	22.30	21.05	2.55	3.82	19.94	21.78	5.30	4.64
	P_4	117.00	106.50	150.00	145.00	1 11	1 22	115.50	132.00	275.50	296.50	48.00	34.75	258.00	278.50	-	-	0.42	0.45	-	-	26.00	22.90	132.50	85.65	602.50	693.95	25.85	25.05	3.20	3.32	23.97	22.08	13.90	7.91
	P_6	92 50	114.50	139 00	145.00	0 94	1 57	150.50	132.00	76.00	262.50	12.20	42.50	55.00	246.00	-	-	0.38	0.47	-	-	27.10	19.00	137.00	93.90	114.75	712.10	20.05	26.35	2.41	2.50	13.41	22.50	2.84	11.93
	P_9	[illegible]	121 50	151.00	150 00	0 91	1 25	48.00	99.00	79.50	145.00	10.65	22.10	64.15	128.00	-	-	0.55	0.46	-	-	9.15	18.25	58.90	84.05	70.85	812.20	20.90	23.35	3.47	2.97	18.33	20.17	1.15	6.57
	Mean	101.25	114.25	141.00	146.25	1.03	1.29	95.00	115.50	141.81	208.50	23.86	28.81	124.98	193.58	-	-	0.50	0.45	-	-	20.26	18.56	101.14	84.10	276.98	715.56	22.28	23.95	2.91	3.15	18.91	21.63	5.80	7.76
P_6	P_1	89.50	91 50	128.50	134.00	1 25	0 96	99.00	181.50	111.50	125.50	16.50	19.50	110.50	112.00	0.90	10.70	-	-	20.20	28.60	10.75	30.25	70.90	121.00	193.65	884.96	22.10	28.25	2.45	2.53	20.40	21.15	3.99	17.26
	P_4	114.50	92.50	131.00	120.00	1.26	1.09	66.00	165.00	237.75	84.50	47.25	12.50	213.25	70.60	10.10	16.45	-	-	22.35	25.45	27.00	20.10	130.70	106.05	609.40	331.55	26.70	27.25	2.88	2.55	20.06	20.69	7.78	6.30
	P_6	100.00	88.50	145.00	139.00	1 57	0.94	132.00	150.50	262.50	76.00	42.50	12.20	246.00	55.00	6.25	27.85	-	-	25.65	27.55	19.00	27.10	93.90	137.00	712.10	114.75	26.35	20.05	2.50	2.41	22.50	13.41	11.93	2.84
	P_9	85.50	101.50	126.00	134.00	1.15	0.90	132.00	66.00	29.00	48.00	2.50	3.10	25.10	47.50	13.20	1.05	-	-	20.20	31.15	9.25	27.65	51.05	97.05	44.05	202.15	10.55	20.40	3.30	2.26	12.06	18.93	0.34	1.91
	Mean	97.38	93.50	132.62	131.75	1.31	0.97	107.25	140.75	160.19	83.50	27.19	11.83	148.71	46.28	7.61	14.01	-	-	22.05	28.19	16.50	26.25	86.64	115.28	389.80	383.35	21.43	23.99	2.78	2.44	18.76	18.55	6.01	7.08
P_9	P_1	85.00	97.50	124.00	134.00	1.10	·1.11	90.50	57.50	134.75	91.25	25.25	11.50	123.75	83.25	8.15	8.80	0.33	0.57	23.20	18.60	18.50	11.15	83.00	55.00	277.95	97.90	23.95	20.25	2.53	3.42	21.44	21.22	5.68	2.36
	P_4	116.50	112.50	137.50	150.00	1.43	0.99	82.50	99.00	284.00	36.00	47.00	3.75	268.50	32.10	5.20	10.80	0.46	0.06	16.95	18.50	23.75	7.15	123.15	45.00	589.85	28.20	26.20	15.10	3.08	2.65	24.83	15.40	6.93	0.13
	P_5	121.50	110.00	150.00	151.00	1.25	0.91	99.00	48.00	145.00	79.50	22.10	10.65	128.00	64.15	11.70	19.35	0.46	0.55	24.90	22.75	18.25	9.15	84.05	58.90	812.20	70.85	23.35	20.90	2.97	3.47	20.17	18.33	6.57	1.15
	P_9	101 50	85.50	134.00	126.00	0.90	1.15	66.00	132.00	48.00	29.00	3.10	2.50	47.50	25.10	1.05	13.20	0.37	0.17	31.15	20.00	27.65	9.25	97.05	51.05	202.15	44.05	20.40	10.55	2.26	3.30	18.93	12.06	1.91	0.34
	Mean	106.13	101.38	136.37	140.25	1.17	1.04	84.50	84.13	152.94	58.94	24.36	7.10	141.94	51.15	6.53	13.04	0.41	0.34	24.05	19.96	22.04	9.18	96.81	52.49	470.54	60.25	23.48	16.70	2.71	3.21	21.35	16.75	5.27	1.08

significant. Reciprocal effect of P_4 x P_6 was significant with high effect (earliness) for P_6 x P_4. The crosses P_1 x P_9, P_4 x P_5 and P_6 x P_9 which were having non-significant *sca* effects were found to have significant reciprocal effect. Actual low mean performance was recorded for P_1 x P_9 (85 days) followed by P_1 x P_5 (86 days) and P_9 x P_6 (86 days). The average performance of progenies of those crosses having P_1, P_6 and P_9 as common female parents, was found to be more desirable than when they were used as male parents. Consistent reduction in days to 50 per cent flowering was observed when P_1 was used as female parent.

Number of days to harvest

The cross P_4 x P_6 recorded a desirable negative significant *sca* effect ($^-5.64^{**}$) with parent P_6 having negative *gca* effect. The reciprocal effect of P_4 x P_6 was significant with high effect (earliness) for P_6 x P_4. The crosses P_1 x P_4, P_1 x P_5, P_1 x P_9 and P_6 x P_9 which showed non-significant *sca* effects have shown significant *rca* effects. Comparing the mean performances the minimum number of days to harvest was recorded by the cross P_1 x P_4 (115 days) which was followed by P_6 x P_4 (120 days). The average performance of those crosses having P_1 and P_6 as common female parent, was found to be in desirable direction compared to crosses with these parents as male, with consistent effect for P_1.

Ratio of vegetative phase to reproductive phase

There was no parents and cross combinations which showed significant *gca* and *sca* effects for this particular character. But the crosses P_4 x P_9 and P_5 x P_6 showed significant reciprocal effects. Array means of the progenies with parents of these crosses as common male and common female parents showed that the performance was high when P_5 and P_4 were used as female parent with consistent maximum effect for parent P_5.

Number of panicles m^{-2}

Significant positive *sca* effect was observed for the crosses P_1 x P_6 (44.04**), P_5 x P_6 (29.29**) and P_4 x P_5 (26.69**) which were on par. The effect of P_1 x P_4 was also significant but negative. In the crosses P_1 x P_6 and P_5 x P_6 there was at least one parent (P_6) with positive *gca* effect. The parents of cross P_4 x P_5 were poor general combiners (non-significant *gca* effect). The reciprocal effect of P_1 x P_6 was significant and that of P_5 x P_6 and P_4 x P_5 were non significant. Among P_1 x P_6 and P_6 x P_1, the latter was better in performance. The cross combinations P_4 x P_6, P_5 x P_9 and P_6 x P_9 which were found to have non-significant *sca* effects but significant *rca* effects. In the case of P_4 x P_6, better performance was seen when P_6 was used as the female parent. In the case of P_5 x P_9 and P_6 x P_9, better performance was seen when P_5 and P_9 were used as female parents. With respect to mean performance maximum number of panicles m^{-2} was produced by the cross combinations P_6 x P_1 (181.5) and was followed by P_6 x P_4 (165) and P_6 x P_5 (150.5). From Table 25 it was found that mean performance of crosses when P_6 and P_5 were used as common female parent was found to be higher compared to array performance of crosses with these parents as common male parents. Maximum performance (140.8) was seen when P_6 was used as female parent.

Number of spikelets panicle^{-1}

The crosses $P_4 \times P_5$, $P_5 \times P_6$ and $P_1 \times P_9$ showed positive significant *sca* effects with significant highest value for $P_4 \times P_5$ (58.43**). Negative significant *sca* effects were seen for the crosses $P_6 \times P_9$ and $P_4 \times P_6$. For the cross $P_4 \times P_5$ both parents were having significant positive *gca* effects and for $P_5 \times P_6$, one parent (P_5) was having positive *gca* effect and the other was having negative *gca* effect. For the cross $P_1 \times P_9$ both parents were having negative significant *gca* effects. The reciprocal effect of $P_4 \times P_5$ was non-significant, at the same time reciprocal effects of $P_5 \times P_6$ and $P_1 \times P_9$ were significant. In the cross of $P_5 \times P_6$ the effect was maximum when P_5 was used as female parent. But in the cross $P_1 \times P_9$, it was clear that effect was less when P_1 or P_9 was taken as common female parent than when they were taken as common male parent. Between $P_1 \times P_9$ and its reciprocal, $P_1 \times P_9$ had higher effect. The crosses $P_1 \times P_4$, $P_4 \times P_9$ and $P_5 \times P_9$ which had no significant *sca* effect, but was found to possess significant *rca* effect. Array mean performance of progenies of crosses involving parents which produced significant reciprocal effects showed that when parents P_5 and P_4 were used as common female parent the average performance was higher than the performance obtained when they were as male parents with maximum effect for P_4 as female parent (271.4).

Number of tertiary branches panicle^{-1}

Positive significant *sca* effect was observed for the crosses $P_4 \times P_5$ (5.96**), $P_5 \times P_6$ (5.10**), $P_1 \times P_9$ (3.83*) and $P_1 \times P_4$ (3.60*). Negative significant effect was recorded for $P_6 \times P_9$ and $P_1 \times P_5$. All desirable combinations except $P_1 \times P_9$ were having one parent (P_4 or P_5) with positive significant *gca* effect. In the cross P_1 x P_9 both the parents were having negative significant *gca* effect. The reciprocal effects of the desirable crosses were also significant, with higher effect for P_4 x P_5, P_5 x P_6, P_1 x P_9 and P_4 x P_1. The *sca* effect of P_4 x P_9 was non significant but its *rca* effect was significant. With respect to mean performance of this character, the cross P_4 x P_1 recorded the maximum value (52.7) which was followed by P_4 x P_5, P_4 x P_6 and P_4 x P_9. When P_4 and P_5 were used as common female parents the mean performance of crosses for this character was found to be higher than when they were used as common male parents with consistent effect for P_4 as female parent.

Number of grains panicle^{-1}

The crosses P_4 x P_5, P_5 x P_6, P_1 x P_9 and P_1 x P_6 recorded positive significant *sca* effect with significant high value for P_4 x P_5 (56.59**). P_6 x P_9, P_4 x P_6, P_5 x P_9 and P_1 x P_5 showed negative significant effect. In the case of P_4 x P_5 both parents showed positive significant general combining ability. The parents of P_1 x P_9 and P_1 x P_6 showed negative significant *gca* effects. In the cross P_5 x P_6 , P_5 showed positive significant *gca* effect and P_6 showed negative significant *gca* effect. The crosses P_1 x P_4 and P_4 x P_9 which were found to have non-significant *sca* effect found to possess significant *rca* effect, with more effect for P_4 x P_1 and P_4 x P_9. Observing the mean performance, maximum number of grains panicle^{-1} was recorded by the cross P_4 x P_1 (278.5) and P_5 x P_4 (278.5) and was followed by P_4 x P_9 (268.5). Among the crosses which showed positive significant *sca* effects, except P_1 x P_6 all others exhibited reciprocal effect with direct crosses having better effect. It was observed that when P_4 and P_5 were used as common female parents, the array means of progenies for this character were found to be higher than when they were taken as common male parents with the maximum average value (254.56) when P_4 was taken as female parent.

Spikelet sterility percentage

Specific combining ability of the cross P_1 x P_6 ($^-5.74^{**}$) was negative and significant and that of P_5 x P_9 and P_5 x P_6 were positive and significant. Reciprocal effect of P_1 x P_6 was non significant. The cross P_6 x P_9 whose *sca* effect was non significant, was found to have significant reciprocal effect with lower sterility for the direct cross. Comparing the *per se* performance of crosses, minimum sterility was recorded for P_1 x P_6 (0.90%) followed by P_6 x P_9 (1.05%). The average value for sterility for crosses having P_6 and P_9 as common female parents was higher than that of crosses when they were taken as common male parents.

Harvest index

The crosses P_4 x P_6 (0.09**), P_4 x P_5 (0.08**), P_5 x P_9 (0.08**)and P_1 x P_4 (0.06**) showed positive significant specific combining ability effects and their effects were on par. The *sca* effects, of P_6 x P_9, P_5 x P_6, P_1 x P_9, P_4 x P_9 and P_1 x P_6 were also significant but negative. At least one parent (P_1, P_6, P_5) of desirable crosses was having positive significant *gca* effect. The reciprocal effectsof the desirable crosses P_4 x P_6 and P_4 x P_5 were non significant, but that of P_5 x P_9 and P_1 x P_4 were significant with higher value for P_9 x P_5 and P_1 x P_4 respectively. The cross P_1 x P_5

which had non-significant *sca* effect showed significant reciprocal effects with more effect for P_1 x P_5. The highest per se performance (0.65) was recorded for the cross P_1 x P_5 which was followed by P_6 x P_1 (0.61). Comparing the array means of the progenies with parents included in significant reciprocal crosses as male or female, the performance was found to be higher when the parent P_4 was used as a common female parent than when it was as common male parent. But the increase in performance was not consistent in all crosses.

1000 grain weight

None of the crosses showed positive significant *sca* effect. Crosses P_1 x P_6, P_4 x P_9, P_5 x P_6 and P_4 x P_5 recorded negative significant *sca* effect. Crosses P_1 x P_4, P_1 x P_9, P_6 x P_9 and P_4 x P_6 which had non significant *sca* effects exhibited significant *rca* effect. The mean performance was found to be high for P_6 x P_9 (31.2 g) followed by P_6 x P_1 (28.6 g) and P_6 x P_5 (27.6 g). It was observed that when P_1 and P_6 were used as common female parents, the array means of progenies for this character was found to be higher than when they were used as male parents. The parent P_6 exhibited consistent increase in mean performance when used as common female parent with maximum average effect(28.19g).

Second uppermost internodal length

Specific combining ability effects of crosses P_4 x P_9 ($^-$2.32**), P_5 x P_9 ($^-$1.67**) P_1 x P_5 ($^-$1.09**) and P_4 x P_6 ($^-$0.96*) were found to be negative and significant but their effects were on par. The *sca* effects of P_1 x P_9, P_4 x P_5, and P_5 x P_6 were positive and significant. The parents of P_4 x P_6 were having undesirable (positive significant) *gca* effect, while other desirable cross combinations were having at leat one parent (P_1 or P_9) with desirable *gca* effect (negative significant). Reciprocal effects of all desirable crosses were found to be significant with more effect (shorter second internodal length) for reciprocal crosses. The crosses P_1 x P_4, P_1 x P_6, and P_6 x P_9 which have no significant *sca* effect possessed significant *rca* effect, with more desirable effect for P_1 x P_4, P_1 x P_6 and for P_9 x P_6. With respect to *per se* performance, shortest internode (7.15 cm) was seen for the cross P_9 x P_4 which was followed by P_9 x P_5 (9.15 cm) and P_9 x P_6 (9.25 cm). Array mean performance of progenies of crosses involving parents which produced significant reciprocal effects showed that; when P_1, P_5 and P_9 were taken as common female parent the average performance was more desirable than when they were used as male parents with consistent effect for P_9.

Height of plant at harvest

The crosses P_6 x P_9 ($^-$12.30**) and P_1 x P_5 ($^-$8.91*) showed negative significant specific combining ability effects and their effects were on par. The cross P_5 x P_6 recorded positive significant *sca* effect. The desirable crosses P_6 x P_9 and P_1 x P_5 were having at least one parent with negative significant (desirable) *gca* effect. For P_1 x P_5 there was no significant reciprocal effect, while the reciprocal effect of P_6 x P_9 was significant with more desirable effect for P_9 x P_6. All non-significant crosses with respect to *sca* effect namely P_1 x P_4, P_1 x P_6, P_1 x P_9, P_4 x P_5, P_4 x P_6, P_4 x P_9 and P_5 x P_9 recorded significant reciprocal effects with more desirable effects for P_1 x P_4, P_1 x P_6, P_9 x P_1, P_5 x P_4, P_6 x P_4, P_9 x P_4 and P_9 x P_5. Observed mean performance was minimum for the cross combination P_9 x P_4 (45 cm) which was followed by P_9 x P_6 (51.05 cm) and P_9 x P_1 (55 cm). Array mean performance of progenies of crosses involving parents which produced significant reciprocal effects showed that the average performance was desirable when P_9, P_1 and P_5 were taken as female parents than when they were taken as male parents with consistent effect for P_9.

Leaf area plant^{-1} at maximum tillering stage

Sca effects of P_1 x P_6, P_4 x P_5, P_5 x P_9, P_1 x P_5 and P_4 x P_6 were positive and significant. P_1 x P_6 (219.36**) and P_4 x P_5 (184.19**) which showed the maximum effects were on par. The effects of P_6 x .P_9, P_1 x P_4 and P_1 x P_9 were also significant but negative in direction. The parents of the cross P_1 x P_6 which had maximum *sca* effect, showed negative non-significant *gca* effects. Other superior cross combinations were having at least one parent (P_4 or P_5) with positive significant *gca* effect. All desirable cross combinations except P_4 x P_5 showed significant reciprocal effects with more effects for P_6 x P_1, P_5 x P_9, P_5 x P_1, P_4 x P_6. In the case of P_4 x P_5 the reciprocal effect was non-significant. The crosses P_4 x P_9 and P_5 x P_6 having non-significant *sca* effects were found to have significant reciprocal effects with more effect for the direct crosses. Mean performance was found to be high for the cross P_6 x P_1 (884.96 cm^2) which was followed by P_5 x P_9 (812.20 cm^2). Array mean performance of progenies of crosses involving parents which produced significant reciprocal effects showed that the average array mean performance was high when P_4 and P_5 were used as common female parents, than when they were taken as common male parents with the highest and consistent effect for P_5.

Length of panicle

Positive *sca* effect was recorded for P_1 x P_6 (1.65**), P_4 x P_6 (1.65**), P_1 x P_9 (1.59**) and P_5 x P_9 (1.46**) and were found to be on par. The specific combining ability effects of P_6 x P_9, P_4 x P_9, P_1 x P_5, and P_1 x P_4 were found to be significant but negative. In the case of P_1 x P_6 both parents were having positive significant *gca* effects. For P_1 x P_6, P_6 showed positive significant *gca* effect. In the case of P_1 x P_9 and P_5 x P_9 one of the parents (P_9) was having negative significant *gca* effect and that of the other parent was not significant. Reciprocal effects of all cross combinations except P_4 x P_6 were also significant, with more effect for P_6 x P_1, P_1 x P_9 and P_5 x P_9. The cross P_5 x P_6 showed non-significant *sca* effect and was found to possess significant reciprocal effect. On the basis of mean performance, the maximum panicle length was found for the cross P_6 x P_1 (28.25 cm) which was followed by P_6 x P_4 (27.25 cm) and P_4 x P_9 (26.20 cm). Array mean performance of progenies when each parent as common female parent showed that average performance was high when P_6, P_5 and P_4 were taken as common female parents than when they were taken as male parents with P_4 having the maximum influence.

L/B ratio of grain

Positive *sca* effects were recorded for the cross combinations namely P_1 x P_5 (0.22**) and P_4 x P_5 (0.16**) and their effects were on par. The crosses P_4 x P_9 and

P_5 x P_6 showed negative significant *sca* effects. One of the parents or both parents (P_4 and P_5) of crosses having positive significant *sca* effects showed positive significant *gca* effects. Reciprocal effect of P_4 x P_5 was non-significant and that of P_1 x P_5 was significant with more effect for P_5 x P_1. Crosses namely P_1 x P_4, P_1 x P_9, P_4 x P_6, P_5 x P_9 and P_6 x P_9 which had non-significant *sca* effects, showed significant reciprocal effects. Mean performance was the maximum for P_5 x P_1 (3.82) which was followed by P_9 x P_5 (3.47) and P_9 x P_1 (3.42). Array performance of progenies, when each parent as common female parent and common male parent showed that when parent P_9, P_5 and P_4 were taken as common female parents the performance was higher than when they were taken as common male parents with maximum performance when P_9 was taken as common female parent.

Amylose content

Only one cross, P_1 x P_4 (1.46**) showed positive significant *sca* effect. The crosses P_6 x P_9, P_1 x P_5, P_1 x P_9, P_1 x P_6, P_4 x P_6 and P_4 x P_9 recorded negative significant effects. The general combining ability effects of both parents of P_1 x P_4 were positive and significant. Reciprocal effect of this cross was also significant, with more effect for P_4 x P_1. The crosses P_1 x P_9, P_5 x P_6 and P_5 x P_9 having non-significant *sca* effects were found to have significant reciprocal effects. Mean performance was the maximum for the cross P_4 x P_1 (26.48%) which was followed by P_4 x P_9 (24.83%). Array performance of crosses involving each parent as common female and common male showed that, performance was high when P_4 and P_5 were taken as common female parents than when they were as male parents, with the maximum effect for P_4.

Yield plant^{-1}

Significant positive *sca* effects were recorded for the cross combinations namely P_1 x P_6, P_4 x P_5 and P_5 x P_6 in the given order. The cross P_1 x P_6 (4.15**) having the maximum *sca* effect was on par with that of P_4 x P_5 (3.15**). Crosses P_1 x P_4 and P_6 x P_9 showed negative significant *sca* effects. In the case of P_1 x P_6 and P_4 x P_5, one of the parents (P_4 or P_1) was having positive significant *gca* effect. But in the case of P_5 x P_6 both parents were having non-significant *gca* effects. Reciprocal effects of all desirable cross combinations were significant with more effects for P_6 x P_1, P_4 x P_5 and P_5 x P_6. Crosses P_1 x P_9 and P_5 x P_9 which were having non-significant *sca* effects possessed significant reciprocal effects. Mean performance was the highest for P_6 x P_1 (17.26 g) which was followed by P_4 x P_5 (13.9 g) and P_5 x P_6 (11.93 g). From Table 25 it was found that array performance of progenies was high when P_4, P_6 and P_5 were taken as common female parents. But consistent increase in performance was seen only in the case of crosses in which P_4 was taken as common female parent.

4.2.1.2 8 x 8 half diallel analysis using Griffing's method - 2

The parental lines designated as P_1, P_3, P_4, P_6, P_7, P_8, P_{10} and P_{11} (Table 2) were involved in the 8 x 8 half diallel analysis. The analysis of variance for the treatments including parents (Table 26) showed that the treatments differed significantly for all the characters.

Analysis of variance for combining ability (Table 27) showed that mean squares due to general combining ability (GCA) was significant for all the characters except for ratio of vegetative phase to reproductive phase. Mean squares due to specific combining ability (SCA) was significant for all the characters. *GCA/SCA* ratio was more than unity for all characters except for number of days to harvest and ratio of vegetative phase to reproductive phase. The estimates of components due to *gca* and *sca*, effects and their ratio (Table 28) showed that non-additive gene effect was higher than additive gene effect for all the characters except for 1000 grain weight, second uppermost internodal length and height of plant at harvest.

4.2.1.2.1 General combining ability effects

General combining ability effects estimated for the 18 characters are presented in Table 29.

1. Number of days to 50% flowering

Negative significant *gca* effect was recorded for P_6 (⁻8.02**) and P_1 (⁻4.18**) and their effects were on par. The parent P_4 showed positive significant *gca* effect. Based on *per se* performance reduced flowering period was found for P_3 (69.50 days) which was followed by P_1 (79.50 days).

2. Number of days to harvest

The parents P_1 (⁻3.69**), P_6(⁻3.49**) and P_3 (⁻2.84*) have showed negative significant *gca* effects and they were on par. The parents P_{10}, P_4 exhibited positive

Table 26 Analysis of variance for treatments including parents used for 8 x 8 half diallel analysis using Griffing's method - 2

	Mean sum of squares																	
Degrees of freedom	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$
35	420.06 **	432.88 **	0.10 **	85368.89 **	6922.77 **	247.34 **	8406.26 **	933.07 **	0.05 **	31.00 **	74.34 **	1347.04 **	302440.24 **	18.92 **	0.39 **	47.19 **	1.42 **	67.46 **

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

Table 27 Analysis of variance for combining ability in 8 x 8 half diallel analysis using Griffing's method - 2

		Mean sum of squares																	
Source	Degrees of freedom	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$
Gca	7	284.84 **	109.54 **	0.03	73181.81 **	9547.83 **	312.6 **	11916.67 **	397.93 **	0.030 **	54.12 **	133.290 **	2440.55 **	190106.04 **	21.37 **	0.610 **	56.84 **	1.00 **	30.6
Sca	28	191.33 **	243.17 **	0.06 **	350610.10 **	1939.77 **	76.44	2274.73 **	483.69 **	0.020 **	5.84 **	13.140 **	231.76 **	141498.54 **	6.48 **	0.100 **	15.28 **	0.64 **	34.5
Error	35	22.11	12.88	0.01	287.27	199.93	8.03	174.59	10.71	0.001	1.28	0.353	24.21	1312.38	0.89	0.005	0.40	0.20	2.2
Gca/Sca		1.49	0.45	0.50	2.09	4.92	4.09	5.24	0.82	1.500	9.27	10.140	9.57	1.34	3.30	6.100	3.72	1.56	0.8

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

Table 28 Estimates of components of genetic variance from 8 x 8 half diallel analysis using Griffings's mthod -2

Components	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$
Variance due to additive genetic effect	26.20	9.67	0.002	7289.45	934.79	30.46	1174.21	38.72	0.003	5.28	13.29	241.63	18879.37	2.05	0.060	5.64	0.08	2.85
Variance due to non-additive genetic effect	169.22	230.29	0.050	34772.83	1739.84	68.41	2100.14	472.98	0.020	4.56	12.79	207.55	140186.16	5.59	0.095	14.9	0.44	32.27
Variance due to error	22.11	12.88	0.010	287.27	199.93	8.01	174.59	10.71	0.001	1.28	0.35	24.21	1312.38	0.89	0.005	0.40	0.20	2.23
Ratio of additive genetic effect to non-additive genetic effect	0.15	0.04	0.040	0.21	0.54	0.45	0.56	0.08	0.150	1.16	1.04	1.16	0.13	0.37	0.630	0.38	0.18	0.09

Table 29 General combining ability effects and mean performance (in bold) of 8 parents from 8 x 8 half diallel analysis using Griffing's method-2

Parents	Number of days to 50% flowering	Number of days to harvest	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight(g)	Second uppermost internodal length (cm)	Height of plant at harvest (cm)	Leaf area $plant^{-1}$ at maximum tillering stage (cm^2)	Length of panicle (cm)	L/B ratio of grain	Amylose content (%)	Alkali spreading value	Yield $plant^{-1}$ (g)
P4	10.32 **	4.11 **	-85.36 **	71.97 **	12.26 **	81.99 **	-11.53 **	-0.11 **	-4.20 **	4.78 **	20.76 **	-42.85 **	0.55	0.02	2.94 **	-0.50 **	-0.69
	104.50	**132.00**	**82.50**	**248.50**	**33.00**	**233.50**	**5.70**	**0.06**	**21.60**	**24.85**	**125.70**	**308.15**	**27.50**	**3.16**	**24.30**	**1.00**	**12.44**
P11	0.22	1.11	-1.61	-0.02	-1.20	-2.29	1.20	-0.01	-0.07	0.57 **	-3.94 *	33.99 **	-0.32	0.08 **	0.99 **	0.60 **	-0.49
	83.50	**121.00**	**95.50**	**115.70**	**17.70**	**111.55**	**3.60**	**0.51**	**24.65**	**16.60**	**81.10**	**167.50**	**23.15**	**3.64**	**24.45**	**3.00**	**7.65**
P6	-8.02 **	-3.49 **	193.84 **	-0.99	0.41	-18.30 **	11.36 **	0.03 *	3.97 **	6.09 **	28.18 **	315.11 **	2.94 **	-0.31 **	2.03 **	0.15	4.29 **
	83.50	**110.50**	**43.00**	**112.25**	**20.50**	**103.95**	**7.40**	**0.72**	**35.70**	**24.75**	**115.00**	**136.15**	**26.45**	**2.66**	**23.17**	**2.50**	**3.61**
P10	2.78	4.96 **	-23.11 **	-17.12 **	-2.66 **	-17.84 **	2.34 *	-0.04 **	-0.55	-2.72 **	-6.12 **	-55.04 **	-0.02	0.40 **	-1.42 **	-0.15	-1.11 *
	84.00	**114.00**	**66.00**	**101.70**	**16.90**	**97.50**	**4.15**	**0.42**	**26.65**	**12.50**	**78.90**	**212.55**	**24.45**	**3.80**	**20.89**	**3.00**	**5.20**
P7	0.93	0.11	-48.71 **	1.70	2.57 **	5.72	-2.45 *	-0.01	1.31 **	-2.10 **	-4.83 **	-124.42 **	0.78 **	-0.29 **	-4.21 **	-0.10	-0.62
	83.50	**121.00**	**86.00**	**156.00**	**25.00**	**142.00**	**9.05**	**0.46**	**30.05**	**17.00**	**77.00**	**77.65**	**25.75**	**2.63**	**12.35**	**2.00**	**11.36**
P8	-0.68	-0.29	23.19 **	-20.54 **	-4.55 **	-22.16 **	-0.84	0.01	-1.02 **	-2.20 **	-12.79 **	-0.19	-1.17 **	0.25 **	-0.06	0.15	-0.37
	83.50	**114.00**	**66.00**	**100.50**	**16.10**	**95.20**	**5.25**	**0.56**	**24.30**	**13.25**	**65.70**	**83.40**	**20.65**	**3.63**	**23.29**	**2.00**	**5.68**
P3	-1.38	-2.84 *	-4.36	-26.78 **	-5.57 **	-19.48 **	-1.23	0.06 **	1.07 **	-4.03 **	-13.58 **	-109.46 **	-1.56 **	-0.09 **	-1.91 **	-0.05	-0.74
	69.50	**106.00**	**71.00**	**117.30**	**16.80**	**108.95**	**7.35**	**0.92**	**30.55**	**15.35**	**72.80**	**234.55**	**21.85**	**2.79**	**20.66**	**2.50**	**14.39**
P1	-4.18 **	-3.69 **	-53.86 **	-8.22	-1.26	-7.64	1.14	0.06 **	0.50	-0.40 *	-7.68 **	-17.14	-1.23 **	-0.06 **	1.63 **	-0.10	-0.26
	79.9	**110.00**	**46.50**	**102.60**	**16.10**	**77.50**	**24.50**	**0.69**	**25.60**	**16.15**	**77.10**	**160.85**	**22.65**	**2.64**	**25.85**	**2.50**	**8.27**
S.E. (g_i)	1.39	1.06	5.01	4.18	0.84	3.91	0.97	0.01	0.33	0.17	1.46	10.72	0.28	0.02	0.18	0.13	0.44
CD (5%)	2.82	2.16	10.18	8.49	1.71	7.94	1.97	0.02	0.68	0.48	2.96	21.75	0.57	0.04	0.37	0.27	0.90
CD (1%)	3.79	2.90	13.68	11.41	2.29	10.67	2.65	0.03	0.90	0.35	3.99	29.27	0.76	0.05	0.49	0.35	1.20
S.E. (g_i-g_j)	2.10	1.61	7.58	6.32	1.27	5.91	1.46	0.01	0.51	0.27	2.20	16.20	0.18	0.03	0.28	0.20	0.67
CD (5%)	4.27	3.26	15.39	12.84	2.58	12.00	2.97	0.02	1.03	0.55	4.47	32.89	0.37	0.06	0.57	0.41	1.36
CD (1%)	5.73	4.38	20.69	17.25	3.47	16.13	3.99	0.03	1.39	0.74	6.00	44.23	0.49	0.08	0.76	0.55	1.83

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

significant *gca* effects. Mean performance was the minimum for P_3 (106 days) which was followed by P_1 (110 days) and P_6 (111 days).

3. Number of panicles m^{-2}

The parents P_6 (193.84**) and P_8 (23.19**) exhibited positive significant *gca* effects, with significant superior effect for P_6. The parents P_4, P_1, P_7 and P_{10} exhibited negative significant *gca* effects. Mean performance was the maximum for P_{11} (95.50) which was followed by P_7 (86) and P_4 (82.50).

4. Number of spikelets panicle^{-1}

The parent P_4 exhibited the maximum positive *gca* effect (71.97**). Significant negative effects were recorded for P_3, P_8 and P_{10}. The maximum mean performance (248.50) was recorded for P_4.

5. Number of tertiary branches panicle^{-1}

Positive significant *gca* effects were recorded for P_4 (12.26**) and P_7 (2.57**) with significantly higher effect for P_4. The parents P_3, P_8 and P_{10} were found to have negative significant *gca* effects. Observed mean performance was high for P_4 (33) which was followed by P_7 (25).

6. Number of grains panicle^{-1}

The pattern of exhibition of *gca* effect and *per se* performance was similar to that of number of spikeletspanicle^{-1}.

7. **Spikelet sterility percentage**

Significant negative *gca* effects were recorded for P_4 ($^-$11.53**) and P_7 ($^-$2.45*) with significant higher effect for P_4. The parents P_6 and P_{10} exhibited positive and significant *gca* effects. P_{11} recorded the minimum mean performance (3.6%) and was followed by P_{10} (4.2%).

8. **Harvest index**

Positive significant *gca* effect was recorded for P_3 (0.06**), P_1 (0.06**) and P_6 (0.03*) and their effects were on par. General combining ability effects of P_4 and P_{10} were negative and significant. The maximum *per se* performance was observed for P_3 (0.92) which was followed by P_6 (0.72) and P_1 (0.69).

9. **1000 grain weight**

Positive significant *gca* effects were recorded for P_6 (3.97**), P_7 (1.31**) and P_3 (1.07**) with superior effect for P_6. Significant negative effects were found for P_4 and P_8. Mean performance was the maximum for P_6 (35.7g) which was followed by P_3 (30.55g) and P_7 (30.05g).

10. **Second uppermost internodal length**

Negative significant *gca* effects were recorded for P_3, P_{10}, P_8, P_7 and P_1 with significant highest value for P_3 ($^-$4.03**). The parents P_6, P_4 and P_{11} exhibited positive significant *gca* effects. The *per se* performance was the minimum for P_{10} (12.5 cm) which was followed by P_8 (13.25 cm) and P_3 (15.35 cm).

11. **Height of plant at harvest**

The parents P_3, P_8, P_1, P_{10}, P_7, and P_{11} recorded negative significant *gca* effects with P_3 (−13.58**), P_8 (−12.79**) and P_1 (−7.68**) having significantly higher effects. Positive significant *gca* effects were recorded for P_6 and P_4. Mean performance was the minimum for P_8 (65.70 cm) which was followed by P_3 (72.80 cm), P_7 (77.0 cm) and P_1 (77.1 cm).

12. **Leaf area plant^{-1} at maximum tillering stage**

The parents P_6 (315.11**) and P_{11} (33.99**) recorded positive significant *gca* effects, P_6 having significantly higher effect. Significant negative *gca* effects were recorded for P_7, P_3, P_{10} and P_4. Observed *per se* performance was high for P_4 (308.15 cm^2) followed by P_3 (234.55 cm^2).

13. **Length of panicle**

The parent P_6 exhibited the maximum significant positive *gca* effect (2.94**) which was followed by P_7 (0.78**). Negative significant effects were obtained for P_3, P_1 and P_8. The parent P_4 recorded the maximum mean value (27.50 cm) for panicle length which was followed by P_6 (26.45 cm) and P_7 (25.75 cm).

14. **L/B ratio of grain**

The parents P_{10} (0.4**), P_8 (0.25**) and P_{11} (0.08**) exhibited positive significant *gca* effects with superior effect for P_{10}. Negative significant effects were observed for P_6, P_7, P_3, and P_1. The maximum mean value of L/B ratio was recorded for P_{10} (3.80) followed by P_{11} (3.64) and P_8 (3.63).

15. Amylose content

The parents P_4, P_6, P_1 and P_{11} showed positive significant *gca* effects with significantly superior value for P_4 (2.94**). Negative significant effects were observed for P_7, P_3 and P_{10}. Mean amylose content was the highest for P_1 (25.85%) which was followed by P_{11} (24.45%) and P_4 (24.3%).

16. Alkali spreading value

Positive significant *gca* effect was recorded for P_{11} (0.60**). The parent P_4 recorded negative significant effect. Mean performance was high for P_{11} (3.0) and P_{10} (3.0).

17. Yield plant^{-1}

Positive significant *gca* effect was recorded for P_6 (4.29**). The parent P_{10} recorded negative significant effect. Observed mean yield was the maximum for P_3 (14.39 g) which was followed by P_4 (12.44 g).

4.2.1.2.2 Specific combining ability effects

The specific combining ability effects of 28 cross combinations are given in Table 30.

1. Number of days to 50 per cent flowering

Negative significant *sca* effects were recorded for P_{11} x P_7 ($^-$13.12**) which was followed by P_4 x P_8 ($^-$10.62*) and their effects were on par. The parents of these

Table 30 Specific combining ability effects and mean performance (in bold) of hybrids from 8x8 half diallel analysis using Griffing's method-2

Cross combinations	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight(g)	Second uppermost internodal length(cm)	Height of plant at harvest(cm)	Leaf area $plant^{-1}$ at *maximum tillering* stage(cm^2)	Length of panicle(cm)	L/B ratio of grain	Amylose content(%)	Alkali spreading value	Yield $plant^{-1}$(g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
$P_4 \times P_{11}$	-3.02	-12.88 **	0.41 **	21.79	-47.30 **	-6.35 *	-37.57 **	-4.82	0.07 *	0.85	1.00	-4.43	108.95 **	-2.38 **	-0.27 **	-1.57 **	-0.66	1.39
	105.00	**125.00**	**1.66**	**99.00**	**164.00**	**27.50**	**158.00**	**3.40**	**0.40**	**21.00**	**25.10**	**102.50**	**539.45**	**22.00**	**2.82**	**21.41**	**2.00**	**7.70**
$P_4 \times P_6$	0.23	-2.28	0.10	-206.66 **	27.42 *	11.79 **	33.68 **	-8.28 **	0.09 **	-1.84	-2.63 **	-8.35	-102.22 **	-0.93	0.18 **	-3.96 **	0.29	-3.32 *
	100.00	**131.00**	**1.26**	**66.00**	**237.75**	**47.25**	**213.25**	**10.10**	**0.47**	**22.35**	**27.00**	**130.70**	**609.40**	**26.70**	**2.88**	**20.06**	**2.50**	**7.78**
$P_4 \times P_{10}$	8.93 *	5.77	0.12	2.29	10.55	4.61	17.73	-5.91	0.12 **	-2.07	2.18 **	8.50	297.39 **	-2.28 *	-0.21 **	0.60	0.09 *	-0.96
	119.50	**147.50**	**1.29**	**58.00**	**204.75**	**37.00**	**197.75**	**3.45**	**0.43**	**17.60**	**23.00**	**113.25**	**638.85**	**22.40**	**3.20**	**21.17**	**2.00**	**4.73**
$P_4 \times P_7$	14.28 **	13.12 **	0.06	35.89 *	71.48 **	14.38 **	66.42 **	0.58	0.07 *	-2.78 *	0.37	3.46	10.42	0.22	0.19 **	5.92 **	1.04 *	-1.79
	123.00	**150.00**	**1.31**	**68.00**	**284.50**	**52.00**	**270.00**	**5.15**	**0.42**	**18.75**	**21.80**	**109.50**	**282.50**	**25.70**	**2.90**	**23.70**	**3.00**	**4.40**
$P_4 \times P_8$	-10.62 *	-2.48	-0.12	-36.01 *	-18.78	-5.25 *	-7.20	-4.12	0.10 **	-1.45	3.57 **	-6.19	-135.07 **	0.62	-0.42 **	-3.11 **	-0.21	-2.28
	96.50	**134.00**	**1.08**	**66.00**	**172.00**	**26.25**	**168.50**	**2.05**	**0.47**	**17.75**	**24.90**	**91.90**	**261.25**	**24.15**	**2.84**	**18.82**	**2.00**	**4.16**
$P_4 \times P_3$	4.08	-0.43	0.17	-11.96	-59.04 **	-9.48 **	-68.64 **	6.86 *	-0.08 **	-1.24	1.59 **	-3.79	-99.24 **	-1.68	0.13	0.53	-0.01	-3.78 **
	110.50	**133.50**	**1.40**	**62.50**	**125.50**	**20.00**	**109.75**	**12.65**	**0.33**	**20.05**	**21.10**	**93.50**	**187.80**	**21.45**	**3.05**	**20.61**	**2.00**	**2.29**
$P_4 \times P_1$	13.38 **	16.92 **	-0.14	16.54	85.25 **	18.91 **	88.28 **	-4.76	0.00	-2.62 *	0.86	22.66 **	10.78	1.93 *	0.16 *	2.86 **	0.54	-1.94
	117.00	**150.00**	**1.11**	**41.50**	**288.35**	**52.70**	**278.50**	**3.40**	**0.41**	**17.10**	**24.00**	**125.85**	**390.15**	**25.40**	**3.11**	**26.48**	**2.50**	**4.60**
$P_{11} \times P_6$	-1.17	4.72	0.00	254.09 **	5.16	2.25	-39.03 **	29.69 **	-0.26 **	-0.62	6.63 **	31.75 **	473.54 **	1.59	0.04	1.38 *	1.69 **	-1.29
	88.50	**135.00**	**1.10**	**610.50**	**143.50**	**24.25**	**56.25**	**60.80**	**0.22**	**27.70**	**32.05**	**146.10**	**1262.00**	**28.35**	**2.80**	**23.44**	**5.00**	**10.01**
$P_{11} \times P_{10}$	-6.47	-3.73	-0.07	25.54	-1.20	-0.98	-12.24	8.91 **	0.07 *	-1.14	-2.41 **	-9.15	284.74 **	-1.21	-0.47 **	-1.01	-0.51	0.23
	94.00	**135.00**	**1.02**	**165.00**	**121.00**	**17.95**	**83.50**	**31.00**	**0.48**	**22.65**	**14.20**	**70.90**	**703.05**	**22.60**	**3.00**	**17.60**	**2.50**	**6.12**
$P_{11} \times P_7$	-13.12 **	-5.88	-0.06	-14.86	22.48	6.84 *	28.20 *	-7.50 *	0.04	-2.26 *	1.88 **	2.56	166.77 **	-0.36	-0.48 **	4.34 **	-0.56	2.27
	85.50	**128.00**	**1.12**	**99.00**	**163.50**	**31.00**	**147.50**	**9.80**	**0.49**	**23.40**	**19.10**	**83.90**	**515.70**	**24.25**	**2.30**	**20.17**	**2.50**	**8.65**
$P_{11} \times P_8$	12.48 **	11.52 **	-0.20	-119.76 **	-18.29	-3.29	3.08	-12.96 **	0.03	1.18	-4.37 **	-7.39	-152.76 **	0.04	0.24 **	-0.63	2.69 **	-3.88 **
	109.50	**145.00**	**0.93**	**66.00**	**100.50**	**13.75**	**94.50**	**5.95**	**0.49**	**24.50**	**12.75**	**68.00**	**320.40**	**22.70**	**3.57**	**19.34**	**6.00**	**2.75**
$P_{11} \times P_3$	37.18 **	14.07 **	0.56 **	-59.21 **	105.45 **	17.98 **	113.40 **	-13.12 **	-0.01	0.83	1.95 **	19.91 **	117.66 **	6.54 **	-0.08	-5.27 **	-0.61	4.55 **
	133.50	**145.00**	**1.71**	**99.00**	**218.00**	**34.00**	**207.50**	**5.40**	**0.49**	**26.25**	**17.25**	**92.50**	**481.55**	**28.80**	**2.91**	**12.86**	**2.50**	**10.82**
$P_{11} \times P_1$	2.98	19.92 **	-0.32 **	23.29	-19.10	-11.08 **	-56.34 **	34.51 **	-0.08 *	0.41	1.92 **	-30.89 **	-319.21 **	-3.50 **	0.03	-4.09 **	-0.56	-5.54 **
	96.50	**150.00**	**0.87**	**132.00**	**112.00**	**9.25**	**49.60**	**55.40**	**0.43**	**24.25**	**20.85**	**47.50**	**137.00**	**19.10**	**3.04**	**17.58**	**2.50**	**1.20**
$P_6 \times P_{10}$	-5.22	-0.13	-0.12	130.59 **	19.76	0.95	38.02 **	-15.75 **	0.15 **	-1.54	2.02 **	7.88	211.97 **	2.44 **	-0.33 **	-0.57	-0.06	12.75 **
	87.00	**134.00**	**0.89**	**465.50**	**141.00**	**21.50**	**117.75**	**16.50**	**0.61**	**26.30**	**24.15**	**120.05**	**911.40**	**29.50**	**2.76**	**19.08**	**2.50**	**23.43**

(contd.....)

Table 30 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
$P_6 \times P_7$	-5.87	-13.28 **	0.08	-12.31	-35.56 **	-7.02 *	-11.55	-15.26 **	0.07 *	0.50	-4.65 **	9.44 *	-15.40	-1.76 *	0.00	5.37 **	-0.11	1.08
	84.50	**116.00**	**1.17**	**297.00**	**104.50**	**18.75**	**91.75**	**12.20**	**0.56**	**30.20**	**18.10**	**122.90**	**614.65**	**26.10**	**2.39**	**22.24**	**2.50**	**12.24**
$P_6 \times P_8$	-2.27	5.12	-0.12	575.79 **	65.68 **	5.60	-31.92 *	47.23 **	-0.13 **	-2.67 *	5.10 **	16.44 **	1166.72 **	3.49 **	-0.19 **	1.98 **	-0.86 *	14.48 **
	86.50	**134.00**	**0.93**	**957.00**	**183.50**	**24.25**	**43.50**	**76.30**	**0.38**	**24.70**	**27.75**	**121.95**	**1921.00**	**29.40**	**2.75**	**22.99**	**2.00**	**25.90**
$P_6 \times P_3$	3.93	27.67 **	-0.30 *	398.84 **	-27.58 *	-4.89	-60.60 **	50.47 **	-0.36 **	-1.21	0.13	-4.61	-15.36	-0.07	-0.18 **	-2.86 **	-0.16	-4.54 **
	92.00	**154.00**	**0.77**	**752.50**	**84.00**	**12.75**	**17.50**	**79.15**	**0.19**	**28.25**	**20.95**	**100.10**	**629.65**	**25.45**	**2.42**	**16.31**	**2.50**	**6.51**
$P_6 \times P_1$	6.23	8.52 *	-0.13	-122.66 **	-4.64	-2.45	22.06	-20.35 **	0.06	0.71	5.80 **	10.39 *	147.62 **	2.40 **	-0.09	-1.49 *	-0.11	5.74 **
	91.50	**134.00**	**0.96**	**181.50**	**125.50**	**19.50**	**112.00**	**10.70**	**0.61**	**28.60**	**30.25**	**121.00**	**884.95**	**28.25**	**2.53**	**21.22**	**2.50**	**17.26**
$P_{10} \times P_7$	17.83 **	25.27 **	-0.09	39.64 *	-19.42	-2.70	-73.25 **	51.06 **	-0.16 **	-0.88	1.56 **	-4.66	121.31 **	0.24	0.30 **	-1.30 *	0.19	-3.19 *
	119.00	**163.00**	**0.99**	**132.00**	**104.50**	**20.00**	**30.50**	**69.50**	**0.26**	**24.30**	**15.50**	**74.50**	**381.20**	**25.15**	**3.40**	**12.11**	**2.50**	**2.57**
$P_{10} \times P_8$	13.43 **	25.67 **	-0.19	-43.76 **	45.06 **	8.12 **	39.48 **	1.40	-0.04	2.96 **	3.46 **	16.59 **	-319.78 **	3.14 **	-0.11	-3.38 **	-0.56	-1.26
	113.00	**163.00**	**0.85**	**120.50**	**148.75**	**23.70**	**115.35**	**21.45**	**0.40**	**25.80**	**17.30**	**87.80**	**64.35**	**26.10**	**3.54**	**14.18**	**2.00**	**4.76**
$P_{10} \times P_3$	-1.37	-6.78 *	0.16	-37.71 *	-54.45 **	-9.47 **	-43.45 **	-5.31	-0.10 **	-2.64 *	-3.76 **	-24.16 **	-238.65 **	-4.11 **	0.33 **	-2.26 **	-0.36	-4.45 **
	97.50	**128.00**	**1.23**	**99.00**	**41.00**	**5.10**	**35.10**	**14.35**	**0.38**	**22.30**	**8.25**	**46.25**	**36.20**	**18.45**	**3.64**	**13.46**	**2.00**	**1.20**
$P_{10} \times P_1$	10.93 *	11.07 **	-0.18	-12.71	6.50	0.62	-0.89	3.77	-0.11 **	-1.36	-1.39 *	2.94	-123.53 **	1.10	0.48 **	-1.45 *	-0.31	-2.96 *
	107.00	**145.00**	**0.91**	**74.50**	**120.50**	**19.50**	**89.50**	**25.80**	**0.37**	**22.00**	**14.25**	**79.25**	**243.65**	**24.00**	**3.82**	**17.81**	**2.00**	**3.16**
$P_7 \times P_8$	13.78 **	5.52	0.02	-72.66 **	-63.51 **	-10.86 **	-48.64 **	-4.41	-0.05	0.39	0.70	-12.40 **	-228.40 **	-1.06	-0.45 **	-7.72 **	-0.11	-4.79 **
	111.50	**138.00**	**1.14**	**66.00**	**57.00**	**9.95**	**50.80**	**10.85**	**0.42**	**25.10**	**15.15**	**60.10**	**86.35**	**22.70**	**2.50**	**7.06**	**2.50**	**1.73**
$P_7 \times P_3$	9.48	9.07 **	-0.18	-45.11 **	21.23	3.81	26.98 *	-10.17 **	0.02	-1.10	-5.33 **	14.35 **	202.28 **	3.19 **	0.04	-3.20 **	0.09	-1.83
	106.50	**139.00**	**0.98**	**66.00**	**135.50**	**23.60**	**129.10**	**4.70**	**0.54**	**25.70**	**7.30**	**86.05**	**407.75**	**26.55**	**2.66**	**9.73**	**2.50**	**4.31**
$P_7 \times P_1$	-4.72	-10.08 **	0.36 **	30.89	-23.22	1.40	-17.56	-5.09	-0.01	0.12	0.59	-5.85	-31.25	-0.55	-0.03	-6.86 **	0.14	-1.95
	89.50	**119.00**	**1.53**	**92.50**	**109.60**	**25.50**	**96.40**	**12.15**	**0.51**	**26.35**	**16.85**	**71.75**	**266.55**	**23.15**	**2.61**	**9.61**	**2.50**	**4.67**
$P_8 \times P_3$	2.58	2.47	0.06	-87.51 **	-29.53 **	-4.17	-22.24	0.12	-0.08 *	-2.62 *	-2.98 **	-13.49 **	-209.26 **	-3.06 **	0.29 **	1.18 *	0.84 *	-5.43 **
	98.00	**132.00**	**1.17**	**95.50**	**62.50**	**8.50**	**52.00**	**16.60**	**0.46**	**21.85**	**9.55**	**50.25**	**120.45**	**18.35**	**3.45**	**18.26**	**3.50**	**0.96**
$P_8 \times P_1$	-4.12	-11.68 **	0.38 **	72.99 **	14.91	5.02	20.17	-4.05	0.02	-1.64	-3.26 **	4.10	589.72 **	-0.85	0.39 **	2.93 **	-0.11	5.31 **
	88.50	**117.00**	**1.51**	**206.50**	**125.50**	**22.00**	**106.25**	**14.80**	**0.56**	**21.25**	**12.90**	**73.75**	**1011.75**	**20.90**	**3.58**	**23.55**	**2.50**	**12.18**
$P_3 \times P_1$	-5.42	-4.13	0.12	11.54	-19.10	-4.07	-9.51	-11.36 **	-0.06	0.01	-0.88	-7.95	214.34 **	-2.45 **	-0.46 **	1.02	0.09	-1.26
	86.50	**122.00**	**1.28**	**117.50**	**85.25**	**11.90**	**79.25**	**7.10**	**0.52**	**25.00**	**13.45**	**60.90**	**527.10**	**18.90**	**2.39**	**19.80**	**2.50**	**5.23**
S.E.(S_{ij})	4.26	3.25	0.11	15.37	12.82	2.57	11.98	2.97	0.03	1.03	0.54	4.46	32.85	0.85	0.06	0.57	0.40	1.35
CD(5%)	8.66	6.61	0.22	31.20	26.03	5.22	24.32	6.03	0.06	2.09	1.09	9.06	66.68	1.73	0.13	1.16	0.82	2 75
CD(1%)	11.63	8.87	0.30	41.96	35.00	7.02	32.71	8.11	0.08	2.81	1.47	12.18	89.68	2.32	0.16	1.56	1.09	3.69
S.E.S_{ij}-S_{ik}	6.30	4.81	0.16	22.74	18.97	3.80	17.73	4.39	0.04	1.52	0.80	6.60	48.60	1.26	0.09	0.84	0.60	2.00
CD(5%)	12.81	9.77	0.32	46.16	38.51	7.72	35.99	8.91	0.09	3.09	1.62	13.40	98.66	2.57	0.19	1.71	1.22	4.07
CD(1%)	17.20	13.13	0.44	62.08	51.79	10.37	48.40	11.98	0.11	4.15	2.18	18.02	132.68	3.44	0.25	2.29	1.64	5.46
S.E.S_{ij}-S_{kl}	5.95	4.54	0.15	21.44	17.89	3.58	16.71	4.14	0.04	1.43	0.75	6.22	45.82	1.19	0.09	0.80	0.57	1.89
CD(5%)	12.07	9.21	0.31	43.52	36.31	7.27	33.93	8.40	0.08	2.91	1.53	12.63	93.02	2.42	0.18	1.62	1.15	3.84
CD(1%)	16.24	12.39	0.41	58.53	48.84	9.77	45.62	11.30	0.11	3.90	2.05	16.98	125.09	3.25	0.25	2.18	1.56	5.16

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

crosses were having either positive significant *gca* effects (P_4)or non significant *gca* effects (P_{11}, P_8 and P_7). Nine cross combinations showed positive significant *sca* effects. Observed mean performance was the minimum for P_6 x P_7 (84.5 days) followed by P_{11} x P_7 (85.5 days) and P_6 x P_8 (86.5 days).

2. Number of days to harvest

The cross combinations P_6 x P_7 (⁻13.28**), P_4 x P_{11} (⁻12.88**), P_8 x P_1 (⁻11.68**), P_7 x P_1 (⁻10.08**) and P_{10} x P_3 (⁻6.78*) showed negative significant *sca* effects and they were on par. All desirable cross combinations except P_4 x P_{11} were having at least one parent with desirable *gca* effect. In the case of P_4 x P_{11}, *gca* effects of both the parents were non-significant. Eleven cross combinations showed positive significant *sca* effects. The minimum number of days to harvest was recorded by the cross P_6 x P_7 (116 days) which was followed by P_8 x P_1 (117 days) and P_7 x P_1 (119 days).

3. Ratio of vegetative phase to reproductive phase

Positive significant *sca* effects were recorded for the cross combinations P_{11} x P_3 (0.56**), P_4 x P_{11} (0.41**), P_8 x P_1 (0.38**) P_7 x P_1 (0.36**) and they were on par. The *gca* effects of parents of these crosses were non-significant. Negative significant *sca* effect was recorded for two cross combinations. Mean performance was the highest for P_{11} x P_3 (1.71) which was followed by P_4 x P_{11} (1.66).

4. Number of panicles m^{-2}

Significant positive *sca* effects were observed for seven cross combinations with significant higher effect for P_6 x P_8 (575.79**), P_6 x P_3 (398.84**) and P_{11} x P_6 (254.09**). Either both parents or one of the parents of all desirable crosses except P_{10} x P_7 and P_4 x P_7 were having desirable *gca* effects. In the case of P_{10} x P_7 and P_4 x P_7 both parents were having undesirable *gca* effects. Ten cross combinations showed negative significant *sca* effects. The maximum *per se* performance for number of panicles m^{-2} was recorded by P_6 x P_8 (957) which was followed by P_6 x P_3 (752.50) and P_{11} x P_6 (610.50).

5. Number of spikelets $panicle^{-1}$

Six cross combinations exhibited significant positive *sca* effects with significant maximum effect for P_{11} x P_3 (105.45**) and P_4 x P_1 (85.25**) whose effects were on par. In the case of P_{11} x P_3, both parents were having non significant g*ca* effects and in the case of three cross combinations one parent (P_4) was having positive *gca* effect and in the case of other two combinations either both parents (P_8, P_{10}) or one of the parents were having negative *gca* effects. Significant negative *sca* effects were recorded for seven cross combinations. The maximum value of mean performance was seen for P_4 x P_1 (288.4) and it was followed by P_4 x P_7 (284.5) and P_4 x P_6 (237.8).

6. Number of tertiary branches $panicle^{-1}$

Positive significant *sca* effects were observed for six crosses, of which the highest four combinations P_4 x P_1 (18.91**), P_{11} x P_3 (17.98**), P_4 x P_7 (14.38**) and P_4 x P_6 (11.79**) came under a homogeneous group. Both parents of P_{11} x P_3

were having non significant *gca* effects. Either one of the parents or both parents (P_4, P_7) of other desirable crosses were having desirable *gca* effects except for P_{10} x P_8 whose parents were having negative *gca* effects. Mean performance was the maximum for P_4 x P_1 (52.7) which was followed by P_4 x P_7 (52.0) and P_4 x P_6 (47.3).

7. Number of grains panicle^{-1}

Eight cross combinations showed positive significant *sca* effects with maximum effect for P_{11} x P_3 (113.40**) and P_4 x P_1 (88.28**) and they were on par. Among the eight desirable cross combinations, three were having at least one parent (P_4) with desirable *gca* effect and parents of other crosses were having either non significant *gca* effects or having negative significant *gca* effects or both. Negative significant *sca* effects were recorded for nine cross combinations. The maximum mean performance for number of grains panicle^{-1} was recorded by the cross P_4 x P_1 (278.5) which was followed by P_4 x P_7 (270) and P_4 x P_6 (213.3).

8. Spikelet sterility percentage

Specific combining ability effects of nine cross combinations were negative and significant with significant maximum effect for P_6 x P_1 (−20.35**), whose parents were either having positive significant *gca* effects (P_6) or non significant *gca* effects (P_1). Among the desirable crosses, four crosses were having at least one parent with significant *gca* effect in the desirable direction. But in the case of P_{11} x P_3, P_{11} x P_8 and P_3 x P_1 both parents were having non-significant *gca* effects.

In the case of P_6 x P_{10} both parents were having positive significant *gca* effects (undesirable). Comparing the *per se* performance of crosses, the minimum sterility was recorded for P_4 x P_8 (2.05%) which was followed by P_4 x P_{11} (3.4%) and P_4 x P_1 (3.4%).

9. Harvest index

Eight cross combinations namely P_6 x P_{10}, P_4 x P_{10}, P_4 x P_8, P_4 x P_6, P_4 x P_{11}, P_4 x P_7, P_{11} x P_{10} and P_6 x P_7 showed positive significant *sca* effects and all these crosses come under a homogeneous group. Nine cross combinations exhibited negative significant *sca* effects. Among the eight desirable crosses, three crosses were having at least one parent (P_6) with positive significant *gca* effects. Four crosses were having either both the parents (P_4, P_{10}) or one of the parents which showed negative significant *gca* effects and other parent with non-significant *gca* effects. Mean performance was the maximum for P_6 x P_{10} (0.61) and P_6 x P_1 (0.61) which was followed by P_6 x P_7 (0.56) and P_8 x P_1 (0.56).

10. 1000 grain weight

Only one cross combination namely P_{10} x P_8 showed positive significant *sca* effect (2.96**). One of the (P_{10}) parents of this cross was having non-significant *gca* effect and the other parent (P_8) had negative significant *gca* effect. Six cross combinations showed significant negative *sca* effects. Mean performance was the highest for P_6 x P_7 (30.2 g) which was followed by P_6 x P_1 (28.6 g) and P_6 x P_3 (28.3 g).

11. Second uppermost internodal length

Significant negative *sca* effect was recorded for nine cross combinations. The effects of the highest four combinations namely P_7 x P_3 ($^-5.33^{**}$), P_6 x P_7 ($^-4.65^{**}$), P_{11} x P_8 ($^-4.37^{**}$) and P_{10} x P_3 ($^-3.76^{**}$) were on par. Among the desirable cross combinations, all were having either, both the parents or one of the parents with favourable *gca* effects except for P_4 x P_6 (both parents having undesirable *gca* effects) and P_{11} x P_{10} (one parent having *gca* effect in the favourable direction and other having in the unfavourable direction). Positive significant *sca* effects were observed for 12 crosses. Mean performance was found to the minimum for P_7 x P_3 (7.3 cm) and was followed by P_{10} x P_3 (8.3 cm) and P_8 x P_3 (9.6 cm).

12. Height of plant at harvest

Four crosses showed negative significant *sca* effects with the highest significant effect for P_{11} x P_1 ($^-30.99^{**}$) whose parents showed negative significant *gca* effects. Parents of all favourable crosses were having significant *gca* effects in the favourable direction. Significant positive *sca* effects were recorded for eight cross combinations. Mean performance was the minimum for P_{10} x P_3 (46.3 cm) and was followed by P_{11} x P_1 (47.50 cm) and P_8 x P_3 (50.3 cm).

13. Leaf area plant^{-1} at maximum tillering stage

Significant positive *sca* effects were recorded for 12 cross combinations with the highest effect for P_6 x P_8 (1166.72**) which was followed by P_8 x P_1 (589.72**) and P_{11} x P_6 (473.54**) and they were on par. Seven favourable crosses were having at least one parent (P_6 or P_{11}) with favourable *gca* effect. In the case of remaining five favourable crosses either both parents (P_4, P_{10}, P_3, P_7) were having negative significant *gca* effects or both parents (P_8, P_1) were with non-significant *gca* effects or one parent with negative significant *gca* effect and the other parent with non significant *gca* effect. Ten cross combinations showed negative significant *sca* effects. The maximum mean leaf area was exhibited by the cross P_6 x P_8 (1921 cm^2) which was followed by P_{11} x P_6 (1262 cm^2) and P_8 x P_1 (1011.75 cm^2).

14. Length of panicle

Positive *sca* effects were recorded for seven cross combinations with significant maximum effect for P_{11} x P_3 (6.54**). One parent (P_{11}) of this cross showed non-significant *gca* effect and the other (P_3) showed negative significant *gca* effect. Among the favourable cross combinations four crosses were having at least one parent (P_6 or P_7) with significant *gca* effect in the favourable direction. Other three favourable crosses were having one parent (P_{11} or P_{10} or P_4) with non-significant *gca* effect and the other parent (P_3 or P_8 or P_1) with negative significant *gca* effect. Specific combining ability effects of seven crosses were found to be significant but negative. On the basis of mean performance the maximum panicle length was recorded for the cross P_6xP_{10} (29.5 cm) which was followed by P_6xP_8 (29.4 cm) and P_{11}xP_3 (28.8 cm).

15. L/B ratio of grain

Positive specific combining ability effects were recorded for nine cross combinations with the maximum significant effect for P_{10} x P_1 (0.48**). Six favourable crosses were having at least one parent (P_{10} or P_8 or P_{11}) with positive *gca* effect. Other three favourable crosses were having one parent (P_4) with nonsignificant *gca* effect and the other parent with negative significant *gca* effect. Ten crosses showed negative significant sca effects. Mean performance was the maximum for P_{10} x P_1 (3.82) which was followed by P_{10} x P_3 (3.64) and P_8xP_1 (3.58).

16. Amylose content

Eight cross combinations showed positive significant *sca* effects with the maximum effects for P_4 x P_7 (5.92**), P_6 x P_7 (5.37**) and P_{11} x P_7 (4.34**) whose effects were on par. Six favourable cross combinations were having at least one parent (P_1 or P_4 or P_6 or P_{11}) with favourable *gca* effect. Other two crosses constituted one parent (P_8 or P_{11}) with non-significant *gca* effect and the other parent (P_7 or P_3) with negative significant *gca* effect. Eighteen cross combinations were found to have negative significant *sca* effects. Observed mean amylose content was found to be the maximum for P_4 x P_1 (26.48%) which was followed by P_4 x P_7 (23.70%) and P_8 x P_1 (23.55%). The desired level of amylose content, 16-20% (in non-parboiled unmilled rice) was recorded by P_{10} and P_3.

17. Alkali spreading value

Negative significant *sca* effect was recorded for only one cross namely P_6 x P_8 (-0.86*) whose parents were having non-significant *gca* effects. Significant positive effect was recorded for five cross combinations. The preferable *per se* performance level of 1.7 - 2.3 (non-parboiled unmilled rice) for alkali spreading value was exhibited by eight cross combinations.

18. Yield plant^{-1}

Five cross combinations showed significant positive *sca* effects with maximum significant effects for P_6 x P_8 (14.48**) and P_6 x P_{10} (12.75**) and they were on par. Among the favourable crosses, three crosses were having at least one parent (P_6) with positive *gca* effect. The parents of the remaining two crosses were having non-significant *gca* effects. Ten crosses exhibited significant negative *sca* effects. Mean performance was the maximum for P_6 x P_8 (25.9 g) and was followed by P_6 x P_{10} (23.43 g) and P_6 x P_1 (17.26 g).

4.2.1.3 6x3 line x tester analysis

The parental lines designated as P_3, P_4, P_5, P_7, P_{11} and P_{12} (Table 2) were considered as lines (females) and P_1, P_2 and P_6 as testers (males). ANOVA for combining ability showed that variation in genotypes (parents and hybrids) was highly significant for all the characters (Table 31). General combining ability variance of lines (Table 31) was significant for the following eight characters, namely days to 50 per cent flowering, spikelets panicle^{-1}, tertiary branches panicle^{-1}, spikelet sterility percentage, 1000 grain weight, second uppermost internodal length, height of plant at harvest and amylose content. General combining ability variance of testers was found to be non-significant for all the characters. The mean squares of lines x testers were highly significant for all the characters. The estimates of general combining ability variance and specific combining ability variance and their ratioes (Table 31) revealed that the specific combining ability variance was high for all the characters except for amylose content. For amylose content, general combining ability and specific combining ability variances were found to be nearly equal.

Table 31 Analysis of variance for combining ability and estimates of variances in a 6 x 3 line x tester analysis

Source of variance	Degrees of freedom	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$
		Mean sum of squares																	
Replication	1	34.24 *	0.91	0.0610 *	58.07	421.12	19.20	146.69	3.43	0.001	0.74	1.28	45.19	4790.26	5.80	0.0010	0.06	6.69 **	2.903
Treatment	26	320.22 **	348.78 **	0.0650 **	23110.24 **	9217.40 **	320.81 **	9615.74 **	422.60 **	0.05 **	35.36 **	57.57 **	1322.74 **	707425.10 **	22.00 **	0.3010 **	45.54 **	1.55 **	45.160 **
Female (line)	5	620.13 *	395.04	0.0790	46548.05	25824.29 *	1032.23 *	24181.6	1104 *	0.031	63.83 **	159.95 *	3520.34 *	1349814.00	45.11	0.3530	149.05 **	1.85	68.650
Male (tester)	2	42.25	176.77	0.0690	37071.58	2386.22	114.09	2616.19	414.5	0.006	10.28	30.21	1622.45	903727.50	36.35	0.2430	1.71	1.08	119.720
Female vs Male	10	133.08 **	132.51 **	0.0720 **	22694.88 **	6786.45 **	240.97 **	9059.78 **	311.2 **	0.013 **	7.61 **	42.28 **	771.27 **	715841.40 **	17.20 **	0.3060 **	12.72 **	1.68 *	30.280 **
Error	17	9.07	1.24	0.0200	38.38	335.83	13.85	201.65	63.78	0.002	0.21	0.75	14.13	16557.09	1.78	0.0100	0.83	0.60	1.830
$\sigma^2 gca$		22.01	17.04	0.0002	2123.88	813.20	36.91	482.12	49.77	0.0006	3.27	5.87	200.01	45658.80	2.62	-0.0009	6.96	-0.02	7.100
$\sigma^2 sca$		62.01	65.64	0.0300	11328.25	3225.31	113.56	4429.06	123.7	0.01	3.70	20.76	378.57	349642.19	7.61	0.1500	5.94	0.54	14.220
$\sigma^2 A$		44.02	34.09	0.0000	4247.76	1626.40	73.82	964.24	99.55	0.00	6.54	11.73	400.03	91317.61	5.23	0.0000	13.92	-0.05	14.200
$\sigma^2 D$		62.01	65.64	0.0300	11328.25	3225.31	113.56	4429.06	123.7	0.01	3.70	20.76	378.57	349642.19	7.61	0.1500	5.94	0.54	14.220
$\sigma^2 gca / \sigma^2 sca$		0.35	0.26	0.0070	0.19	0.25	0.33	0.11	0.40	0.06	0.88	0.28	0.53	0.13	0.34	-0.0060	1.17	-0.04	0.500

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

4.2.1.3.1 General combining ability effects

The estimates of general combining ability effects of lines for eight characters are given in Table 32.

Number of days to 50 per cent flowering

The parent P_3 recorded the maximum negative significant *gca* effect ($^-$14.33**) which was followed by P_7 ($^-$6.50**). The parents P_4 and P_5 exhibited positive significant *gca* effects. The mean performance was the minimum for P_3 (69.5 days) which was followed by P_7 (83.5 days) and P_{11} (83.5 days).

Number of spikelets panicle^{-1}

The parents P_4, P_5 and P_{11} recorded positive significant *gca* effects, with significant superior effect for P_4 (84.41**). Significant negative effects were recorded for P_{12}, P_3 and P_7. Mean performance was the highest for P_4 (248.5) which was followed by P_7 (156.0) and P_{12} (141.85).

Number of tertiary branches panicle^{-1}

The parents P_4 and P_5 exhibited positive significant *gca* effects with superior effect for P_4 (19.91**). Significant negative effects were observed for P_{12} and P_3. The mean performance was the maximum for P_4 (33) which was followed by P_7 (25) and P_5 (23.45).

Table 32 General combining ability effects and mean performance of six parents from a 6x3 line x tester analysis

Parents	Number of days to 50% flowering		Number of spikelets panicle^{-1}		Number of tertiary branches panicle^{-1}		Spikelet sterility percentage		1000 grain weight		Second uppermost internodal length		Height of plant at harvest		Amylose content	
Lines	Mean	*gca*	Mean	*gca*	Mean	*gca*	Mean	*gca*	Mean(g)	*gca*	Mean(cm)	*gca*	Mean(cm)	*gca*	Mean(%)	*gca*
P_{12}	90.00	-0.17	141.85	-79.21 **	21.00	-14.86 **	13.50	7.15 *	25.15	3.47 **	16.70	-3.92 **	80.40	-25.22 **	20.95	1.05 *
P_3	69.50	-14.33 **	117.30	-67.61 **	16.80	-14.14 **	7.35	-4.62	30.55	3.14 **	15.35	-6.24 **	72.80	-22.45 **	20.66	0.82 *
P_5	88.00	9.83 **	115.20	46.46 **	23.45	6.11 **	2.45	-9.78 **	29.15	0.98 **	18.20	-0.76 *	91.40	3.50 *	23.58	1.41 **
P_7	83.50	-6.50 **	156.00	-17.17 *	25.00	0.67	9.05	-6.43	30.05	1.74 **	17.00	-1.44 **	77.00	-7.90 **	12.35	-9.79 **
P_{11}	83.50	-1.83	115.70	33.12 **	17.70	2.31	3.60	24.40 **	24.65	2.29 **	16.60	6.09 **	81.10	12.55 **	24.45	1.92 **
P_4	104.50	13.00 **	248.50	84.41 **	33.00	19.91 **	5.70	-10.72 **	21.60	4.69 **	24.85	6.26 **	125.70	39.52 **	24.30	4.58 **
S.E.(g_i)		1.23		7.48		1.52		3.26		0.19		0.35		1.53		0.37
CD(5%)		2.59		15.79		3.21		6.88		0.40		0.75		3.24		0.79
CD(1%)		3.56		21.68		4.40		9.45		0.54		1.03		4.45		1.08
S.E.(g_i-g_j)		1.74		10.58		2.15		4.61		0.27		0.49		2.16		0.52
CD(5%)		3.67		22.32		4.54		9.73		0.57		1.03		4.56		1.10
CD(1%)		5.04		30.66		6.23		13.36		0.78		1.42		6.26		1.51

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

Spikelet sterility percentage

The parents P_4 ($^-10.72^{**}$) and P_5 ($^-9.78^{**}$) recorded negative significant *gca* effects and they were on par. P_{11} and P_{12} were found to have positive significant effects. Mean performance was found to be the minimum for P_5 (2.45 per cent) which was followed by P_{11} (3.6 per cent) and P_4 (5.7 per cent)

1000 grain weight

Positive significant *gca* effects were recorded for the parents namely P_3, P_{11}, P_7 and P_5 with significant maximum effect for P_3 (3.14^{**}). Significant negative effect was found for P_4 and P_{12}. The mean performance was the highest for P_3 (30.55 g) followed by P_7 (30.05 g) and P_5 (29.15 g).

Second uppermost internodal length

Negative significant *gca* effects were observed for the parents P_3 and P_{12}, P_3 having the superior effect ($^-6.24^{**}$). General combining ability effects of P_4 and P_{11} were positive and significant. Observed value for second upper most internodal length was found to be the minimum for P_3 (15.35 cm) which was followed by P_{11} (16.60 cm) and P_{12} (16.70 cm).

Height of plant at harvest

The parents P_{12}, P_3 and P_7 exhibited negative significant *gca* effects for this character, with superior effects for P_{12} ($^-25.22^{**}$) and P_3 ($^-22.45^{**}$) whose effects were on par. The parents P_4, P_{11} and P_5 recorded positive significant *gca* effects.

The *per se* performance was the minimum for P_3 (72.80 cm) followed by P_7 (77.0 cm) and P_{12} (80.40 cm).

Amylose content

Significant positive *gca* effects were observed for P_4, P_{11}, P_5, P_{12} and P_3 with significant superior effect for P_4 (4.58**). The parent P_7 exhibited significant negative *gca* effect. Mean performance was the highest for P_{11} (24.45%) followed by P_4 (24.3%) and P_5 (23.58%).

4.2.1.3.2 Specific combining ability effects

The specific combining ability effects of 18 crosses for 18 characters are presented in Table 33.

Number of days to 50 per cent flowering

Significant negative (desirable) *sca* effects were recorded for the crosses P_4 x P_6, P_5 x P_2, P_{11} x P_6, P_7 x P_1 and P_{12} x P_2 and they were on par. Four cross combinations showed positive significant *sca* effects. Among the desirable crosses, one cross was having atleast one parent with desirable *gca* effect, both parents of two crosses were having non-significant *gca* effects and two crosses were having one parent with non-significant *gca* effect and the other having undesirable *gca* effect. The combination P_3 x P_6 (83.5 days) was the earliest in days to 50 per cent flowering and it was followed by P_3 x P_1 (86.5 days) and P_3 x P_2 (87 days).

Table 33 Specific combining ability effects and mean performance(in bold) of rice hybrids from 6 x 3 line x tester analysis

Cross combinations	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight(g)	Second uppermost internodal length(cm)	Height of plant at harvest(cm)	Leaf area $plant^{-1}$ at maximum tillering stage(cm^2)	Length of panicle(cm)	L/B ratio of grain	Amylose content(%)	Alkali spreading value	Yield $plant^{-1}$(g)
$P_{12} \times P_1$	1.58	4.39 **	0.08	50.17 **	17.51	3.57	10.33	6.50	0.00	0.22	7.17 **	8.54 **	274.42 **	1.29	-0.15	0.60	1.08	3.40 **
	102.50	**142.00**	**1.14**	**66.00**	**71.00**	**9.50**	**47.50**	**33.25**	**0.47**	**19.10**	**21.75**	**55.75**	**73.40**	**19.45**	**3.23**	**21.03**	**4.00**	**1.37**
$P_{12} \times P_2$	-4.92 *	2.06 *	0.00	9.58 *	-1.43	0.03	-6.92	2.25	-0.03	2.86 **	-0.30	4.80	-267.56 **	-1.14	-0.17 *	-1.40 *	0.00	-1.83
	96.00	**142.00**	**0.94**	**66.00**	**73.50**	**9.00**	**59.50**	**19.30**	**0.42**	**22.60**	**12.20**	**64.50**	**78.15**	**18.00**	**3.34**	**19.15**	**2.50**	**1.68**
$P_{12} \times P_6$	3.33	-6.44 **	-0.08	-59.75 **	-16.06	-3.60	-3.41	-8.75	0.03	-3.08 **	-6.87 **	-13.34 **	-6.66	-0.14	0.33 **	0.80	-1.08	-1.57
	101.00	**126.00**	**1.00**	**66.00**	**64.00**	**8.50**	**51.90**	**18.90**	**0.52**	**17.65**	**8.75**	**57.10**	**107.25**	**21.40**	**3.55**	**21.93**	**2.00**	**1.77**
$P_3 \times P_1$	-0.25	-2.28 *	0.03	17.33 **	20.16	5.25	23.63 *	-7.88	-0.02	-0.49	1.19	10.92 **	339.79 **	3.14 **	-0.49 **	-0.41	-0.25	1.09
	86.50	**122.00**	**1.28**	**117.50**	**85.25**	**11.90**	**79.25**	**7.10**	**0.52**	**25.00**	**13.45**	**60.90**	**527.10**	**21.30**	**2.39**	**19.80**	**2.50**	**5.23**
$P_3 \times P_2$	0.25	0.39	0.06	24.25 **	-2.47	-2.16	-11.37	7.27	-0.09 **	1.04 **	1.91 **	0.63	-533.20 **	-0.24	0.35 **	-0.47	0.17	-2.77 *
	87.00	**127.00**	**1.19**	**165.00**	**84.05**	**7.50**	**73.50**	**12.55**	**0.43**	**27.40**	**12.10**	**63.10**	**200.85**	**18.90**	**3.36**	**19.86**	**2.50**	**6.93**
$P_3 \times P_6$	0.00	1.89 *	-0.09	-41.58 **	-17.68	-3.07	-12.26	0.62	0.11 **	-0.54	-3.10 **	-11.56 **	193.41 *	-2.89 **	0.13	0.88	0.08	1.68
	83.50	**121.00**	**1.18**	**188.50**	**74.00**	**9.75**	**61.50**	**16.50**	**0.68**	**26.80**	**12.20**	**61.65**	**695.65**	**18.65**	**2.86**	**21.78**	**3.00**	**11.22**
$P_5 \times P_1$	3.58	1.06	-0.18	17.17 **	-49.16 **	-11.00 **	-44.10 **	-3.52	-0.02	-0.03	-3.64 **	-3.13	51.50	-1.18	0.73 **	0.99	1.08	-2.73 *
	114.50	**145.00**	**1.12**	**99.00**	**130.00**	**15.90**	**121.80**	**6.30**	**0.43**	**23.30**	**14.10**	**72.80**	**644.00**	**21.05**	**3.82**	**21.78**	**4.00**	**4.64**
$P_5 \times P_2$	-10.42 **	-7.28 **	-0.06	42.58 **	-7.59	1.57	-17.85	7.98	0.03	-0.44	3.43 **	8.38 **	144.02	0.44	-0.30 **	-1.99 **	-0.50	3.55 **
	100.50	**139.00**	**1.12**	**165.00**	**193.00**	**31.50**	**177.30**	**8.10**	**0.46**	**23.75**	**19.10**	**96.80**	**1283.25**	**23.65**	**2.92**	**18.93**	**2.00**	**16.47**
$P_5 \times P_6$	6.83 **	6.22 **	0.24 *	-59.75 **	56.75 **	9.43 **	61.96 **	-4.47	0.00	0.47	0.21	-5.26	-195.52 *	0.74	-0.43 **	1.00	-0.58	-0.83
	114.50	**145.00**	**1.57**	**132.00**	**262.50**	**42.50**	**246.00**	**6.25**	**0.47**	**25.65**	**19.00**	**93.90**	**712.10**	**26.35**	**2.50**	**22.50**	**2.50**	**11.93**
$P_7 \times P_1$	-5.08 *	-14.28 **	0.34 **	1.83	-5.93	4.03	-4.94	-1.02	-0.02	1.26 **	-0.21	7.22 *	94.34	-0.66	-0.06	0.02	-0.75	0.43
	89.50	**119.00**	**1.53**	**92.50**	**109.60**	**25.50**	**96.40**	**12.16**	**0.51**	**25.35**	**16.85**	**71.75**	**266.55**	**23.15**	**2.61**	**9.61**	**2.50**	**4.67**
$P_7 \times P_2$	-3.08	3.39 **	-0.21	33.75 **	-25.96	-5.90 *	-28.59 *	4.63	0.03	-0.36	-1.94 **	-3.97	-149.65	-0.04	-0.11	-0.52	0.17	-2.12 *
	91.50	**139.00**	**0.87**	**165.00**	**111.00**	**18.60**	**102.00**	**8.10**	**0.54**	**24.60**	**13.05**	**73.05**	**569.30**	**24.95**	**2.68**	**9.20**	**3.00**	**7.68**
$P_7 \times P_6$	8.17 **	10.89 **	-0.13	-35.58 **	31.88 *	1.87	33.52 **	-3.62	-0.01	-0.89 *	2.15 **	-3.26	55.31	0.91	0.17 *	0.50	0.58	1.69
	99.50	**139.00**	**1.09**	**165.00**	**174.00**	**29.50**	**153.00**	**10.45**	**0.54**	**25.05**	**20.25**	**84.50**	**542.65**	**28.30**	**2.68**	**10.80**	**4.00**	**11.32**
$P_{11} \times P_1$	-2.75	5.72 **	-0.14	-120.33 **	-53.82 **	-13.85 **	-60.05 **	11.40	0.08 *	-0.39	-3.74 **	-37.48 **	-1022.63 **	-5.03 **	-0.10	-3.72 **	-1.42 *	-5.06 **
	96.50	**150.00**	**0.87**	**132.00**	**112.00**	**9.25**	**49.60**	**55.40**	**0.43**	**24.25**	**20.65**	**47.50**	**137.00**	**19.10**	**3.04**	**17.58**	**2.50**	**1.20**
$P_{11} \times P_2$	10.25 **	-1.61	0.08	-127.92 **	102.74 **	18.87 **	131.60 **	-27.30 **	0.08 *	-0.81 *	-2.67 **	-0.42	1235.69 **	4.19 **	0.29 **	2.28 **	0.50	6.69 **
	109.50	**145.00**	**0.98**	**165.00**	**290.00**	**45.00**	**270.50**	**7.00**	**0.41**	**24.70**	**19.85**	**97.05**	**2942.05**	**29.30**	**3.56**	**23.70**	**4.00**	**18.50**
$P_{11} \times P_6$	-7.50 **	-4.11 **	0.06	248.25 **	-48.92 **	-5.02	-71.54 **	15.90 *	-0.16 **	1.21	6.41 **	37.89 **	-213.06 *	0.84	-0.19 *	1.44 *	0.92	-1.63
	88.50	**135.00**	**1.10**	**610.50**	**143.50**	**24.25**	**56.25**	**60.80**	**0.22**	**27.70**	**32.05**	**146.10**	**1261.70**	**28.35**	**2.80**	**23.44**	**5.00**	**10.01**
$P_4 \times P_1$	2.92	5.39 **	-0.12	33.83 **	71.24 **	12.00 **	75.13 **	-5.48	-0.01	-0.56	-0.76	13.91 **	282.59 *	2.64 *	0.07	2.52 **	0.25	2.86 **
	117.00	**150.00**	**1.11**	**41.50**	**288.35**	**52.70**	**278.50**	**3.40**	**0.41**	**17.10**	**24.00**	**125.85**	**390.15**	**25.40**	**3.11**	**26.48**	**2.50**	**4.60**
$P_4 \times P_2$	7.92 **	3.06 **	-0.12	17.75 **	-65.29 **	-12.38 **	-66.87 **	5.17	-0.02	-2.28 **	-0.44	-9.43 **	-429.30 **	-3.18 **	-0.06	2.09 **	-0.33	-3.52 **
	122.00	**150.00**	**1.24**	**66.00**	**173.25**	**31.35**	**165.75**	**4.35**	**0.38**	**16.25**	**22.25**	**115.00**	**245.00**	**20.55**	**3.11**	**26.18**	**1.50**	**3.77**
$P_4 \times P_6$	-10.83 **	-8.44 **	0.00	-51.58 **	-5.95	0.38	-8.26	0.32	0.03	2.84 **	1.20	-4.48	166.71	0.56	-0.01	-4.61 **	0.08	0.66
	100.00	**131.00**	**1.26**	**66.00**	**237.75**	**47.25**	**213.25**	**10.10**	**0.47**	**22.35**	**27.00**	**130.70**	**609.40**	**26.70**	**2.88**	**20.06**	**2.50**	**7.78**
S.E.S(ij)	2.13	0.79	0.10	4.38	12.96	2.63	10.04	5.65	0.03	0.32	0.61	2.66	90.99	0.99	0.07	0.65	0.55	0.96
CD(5%)	4.49	1.66	0.21	9.24	27.34	5.55	21.19	11.92	0.06	0.69	1.30	5.61	191.98	2.10	0.15	1.36	1.16	2.02
CD(1%)	6.17	2.28	0.29	12.69	37.55	7.63	29.10	16.37	0.08	0.94	1.78	7.70	263.68	2.88	0.20	1.87	1.59	2.78
S.E.S(ij)-S(ik)	3.01	1.11	0.14	6.20	18.33	3.72	14.20	7.99	0.04	0.46	0.86	3.76	128.67	1.41	0.10	0.91	0.78	1.35
CD(5%)	6.36	2.35	0.30	13.07	38.67	7.85	29.96	16.85	0.08	0.97	1.82	7.93	271.50	2.97	0.21	1.93	1.64	2.86
CD(1%)	6.73	3.22	0.41	17.95	53.11	10.79	41.15	23.14	0.11	1.33	2.60	10.89	372.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Number of days to harvest

The crosses P_7 x P_1, P_4 x P_6, P_5 x P_2, P_{12} x P_6, P_{11} x P_6 and P_3 x P_1 exhibited desirable negative significant *sca* effects, with superior effect for P_7 x P_1 (⁻14.28**). Nine cross combinations were found to produce significant positive (undesirable) *sca* effects. It was observed that three desirable cross combinations were having atleast one parent with desirable *gca* effect. Other three desirable crosses were having one parent with undesirable *gca* effect and the other parent with nonsignificant *gca* effect. The *per se* performance was observed to be the minimum for the cross P_3 x P_6 (121 days) followed by P_3 x P_1 (122 days) and P_{12} x P_6 (126 days).

Ratio of vegetative phase to reproductive phase

Significant positive *sca* effects were observed for the cross combinations P_7 x P_1 (0.34**) and P_5 x P_6 (0.24**) and they were on par. All other crosses were having non-significant *sca* effects. The parents of both desirable crosses showed average *gca* effects. The maximum mean performance was recorded by the cross P_5 x P_6 (1.57) which was followed by P_7 x P_1 (1.53).

Number of panicles m^{-2}

Significant positive *sca* effects were observed for the crosses, P_{11} x P_6, P_{12} x P_1, P_5 x P_2, P_4 x P_1, P_7 x P_2, P_3 x P_2, P_4 x P_2, P_3 x P_1, P_5 x P_1 and P_{12} x P_2. Significant superior effect was recorded by P_{11} x P_6 (248.25**). Seven cross combinations recorded significant negative effects. Parents of desirable crosses were having only average *gca* effects. The *Per se* performance was the maximum for the cross P_{11} x P_6 (610) followed by P_3 x P_6 (168.50).

Number of spikelets panicle^{-1}

The crosses P_{11} x P_2, P_4 x P_1, P_5 x P_6 and P_7 x P_6 showed positive significant *sca* effects and the effects of former three crosses were on par. Negative significant *sca* effects were seen for four cross combinations. Among the desirable crosses, three were having at least one parent with desirable *gca* effect. The remaining one cross was having one parent with undesirable *gca* effect and the other with nonsignificant *gca* effect. The cross P_{11} x P_2 recorded the maximum mean performance (290) followed by P_4 x P_1 (288.4) and P_5 x P_6 (262.5).

Number of tertiary branches panicle^{-1}

Positive significant *sca* effect was observed for the crosses P_{11} x P_2, P_4 x P_1 and P_5 x P_6 and they were on par. Negative significant effects were recorded for four cross combinations. All the desirable cross combinations except one were having at least one parent with desirable *gca* effect. Parents of one cross combination, were having nonsignificant *gca* effects. The cross P_4 x P_1 recorded the highest *per se* perfromance (52.7) followed by P_4 x P_6 (47.25) and P_{11} x P_2 (45.0).

Number of grains panicle^{-1}

The crosses P_{11} x P_2, P_4 x P_1, P_5 x P_6, P_7 x P_6 and P_3 x P_1 recorded positive significant *sca* effects with very high effect for P_{11} x P_2 (131.60). Five cross combinations showed negative significant *sca* effects. The parents of all desirable crosses showed only average *gca* effects. The maximum mean performance was recorded by the cross combination P_4 x P_1 (278.5) which was followed by P_{11} x P_2 (270.5) and P_5 x P_6 (246).

Spikelet sterility percentage

The cross P_{11} x P_2 exhibited negative significant *sca* effect ($^{-}27.3^{**}$) and P_{11} x P_6 exhibited positive significant *sca* effect. Parents of the desirable crosses were having only average *gca* effects. The *Per se* performance was found to be the minimum for the cross P_4 x P_1 (3.4%) which was followed by P_4 x P_2 (4.4%) and P_5 x P_6 (6.3%).

Harvest index

The crosses P_3 x P_6, P_{11} x P_1 and P_{11} x P_2 recorded positive significant *sca* effects and they were on par. The *sca* effects of two crosses were negative and significant. All desirable crosses were having both parents with average *gca* effects only. The highest *per se* performance (0.68) was recorded for the cross P_3 x P_6 which was followed by P_7 x P_2 (0.54) and P_7 x P_6 (0.54).

1000 grain weight

Positive significant *sca* effects were recorded for the cross combinations namely P_{12} x P_2, P_4 x P_6, P_7 x P_1 and P_3 x P_2 in the order of effect and effects of former two superior crosses were on par. Four cross combinations showed negative significant *sca* effects. The *Per se* performance was found to be the highest for the cross P_{11} x P_6 (27.7g) which was followed by P_3 x P_2 (27.4 g) and P_3 x P_6 (26.8g).

Second uppermost internodal length

Specific combining ability of crosses P_{12} x P_6, P_{11} x P_1, P_5 x P_1, P_3 x P_6, P_{11} x P_2 and P_7 x P_2 were found to be negative and significant with superior effect for P_{12} x P_6 ($^{-}$6.87**). Significant positive *sca* effects were observed for five cross combinations. Among the desirable crosses, two were having at least one parent with desirable *gca* effect, two were having both parents with average *gca* effect and two crosses were having one poor combiner and the other average combiner as parents. With respect to *per se* performance, the shortest internode was observed for the cross P_{12} x P_6 (8.8 cm) which was followed by P_3 x P_6 (10.2 cm) and P_3 x P_2 (12.1 cm).

Height of plant at harvest

The crosses P_{11} x P_1, P_{12} x P_6, P_3 x P_6 and P_4 x P_2 showed negative significant *sca* effects with superior effect for P_{11} x P_1 ($^{-}$37.48**). Six cross combinations recorded positive significant *sca* effects. Two desirable crosses were having at least one parent with desirable *gca* effect, other two desirable crosses were having one parent with undesirable *gca* effect and the other with average *gca* effect. With respect to heigt, the cross P_{11} x P_1 (47.5 cm) was the shortest and was followed by P_{12} x P_1 (55.8 cm) and P_{12} x P_6 (57.1 cm).

Leaf area plant^{-1} at maximum tillering stage

Specific combining ability effects of P_{11} x P_2, P_3 x P_1, P_{12} x P_1, P_4 x P_1 and P_3 x P_6 were positive and significant, with superior effect for P_{11} x P_2 (1235.69**). The effects of six cross combinations were significantly negative. Parents of all desirable crosses were average general combiners. Mean performance was observed to be the highest for the cross P_{11} x P_2 (2942.1 cm^2) and was followed by P_5 x P_2 (1283.3 cm^2) and P_{11} x P_6 (1261.7 cm^2).

Length of panicle

Positive *sca* effects were recorded for P_{11} x P_2, P_3 x P_1 and P_4 x P_1 and their effects were on par. Specific combining ability effects of three cross combinations were found to be significant but negative. Parents of all desirable crosses were average general combiners. Observed mean performance was the maximum for P_{11} x P_2 (29.3 cm) and was followed by P_{11} x P_6 (28.4 cm) and P_7 x P_6 (28.3 cm).

L/B ratio of grain

Positive *sca* effects were recorded for the cross combinations namely P_5 x P_1, P_3 x P_2, P_{12} x P_6, P_{11} x P_2 and P_7 x P_6 with superior effect for P_5 x P_1 (0.73**). Significant negative *sca* effects were observed for five cross combinations. All the desirable crosses were having parents with average *gca* effect. Mean performance was the maximum for the cross P_5 x P_1 (3.8) which was followed by P_{11} x P_2 (3.6) and P_{12} x P_6 (3.6).

Amylose content

Crosses P_4 x P_1, P_{11} x P_2, P_4 x P_2 and P_{11} x P_6 exhibited positive significant *sca* effects and all of them were on par. Four cross combinations showed negative significant *sca* effects. Observed mean performance was the highest for P_4 x P_1 (26.5%) which was followed by P_4 x P_2 (26.2%) and P_{11} x P_2 (23.7%). The suggested preferred level of amylose content 16 - 20% (in non-parboiled unmilled rice) was exhibited by the crosses P_{12} x P_2, P_3 x P_1, P_3 x P_2, P_5 x P_2, P_{11} x P_1 and P_4 x P_6.

Alkali spreading value

The cross combination P_{11} x P_1 showed negative significant *sca* effect. The preferable level of (2 to 2.5 for non-parboiled unmilled rice) *per se* performance was seen for three cross combinations.

Yield plant^{-1}

Significant positive *sca* effects were recorded for the cross combinations namely, P_{11} x P_2 (6.69**), P_5 x P_2 (3.55**), P_{12} x P_1 (3.4**) and P_4 x P_1 (2.86**) and they were on par. Significant negative *sca* effects were observed for five cross combinations. Parents of desirable crosses were all average general combiners except P_1 and P_4 which were good combiners. The maximum mean performance was recorded by the cross P_{11} x P_2 (18.5 g) which was followed by P_5 x P_2 (16.47 g) and P_5 x P_6 (11.93 g).

4.2.1.4 Combined result of 5 x 5 full diallel, 8 x 8 half diallel and 6 x 3 line x tester analysis

Superior general combiners and cross combinations for yield and important yield components observed in 5 x 5 full diallel analysis, 8 x 8 half diallel analysis and 6 x 3 line x tester analysis, along with superior parents and crosses with respect to *per se* performance, are given in Table 34. Scoring of the selected parents based on general combining ability effects is given in Table 35.

Table 34 The best general combiners and the best cross combinations for yield and important yield components observed from 5 x 5 full diallel analysis, 8 x 8 h diallel analysis and 6 x 3 line x tester analysis

Characters	Best general combiners on the basis of *gca* effect						Best parent on the basis of *per se* performance		Best cross combinations on *sca* basis and their parental ranking									Best cross combinatio on the basis of *per s* performance	
	Full diallel		Half diallel		Line x tester				Full diallel			Half diallel			line x tester				
	Parents	*gca* effect	Parents	*gca* effect	Parents	*gca* effect	Parents	Mean	Crosses	*sca* effect	Parental ranking	Crosses	*sca* effect	Parental ranking	Crosses	*sca* effect	Parental ranking	Crosses	Mean
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of days to 50% flowering																			
a For earliness	P_1	-6.25**	P_6	-8.02**	P_3	-14.33**	P_3	69.5 days	P_6 x P_4	-5.30**	H x L	P_{11} x P_7	-13.12**	M x M	P_4 x P_6	-10.83**	L x H	P_3 x P_6	83.5days
	P_6	-5.82 **	P_1	-4.18 **			P_1	79.5 days			L x H	P_4 x P_8	-10.62 *	L x M	P_5 x P_2	-10.42 **	L x M	P_6 x P_7	84.5days
							P_9	83.0 days							P_{11} x P_6	-7.50 **	M x M	P_1 x P_9	85.0days
															P_7 x P_1	-5.08 *	H x M	P_{11} x P_7	85.5days
															P_{12} x P_2	-4.92 *	M x M	P_1x P_5	86.0days
b For lateness	P_4	6.50 **	P_4	10 32 **	P_4	13.00 **	P_4	104.5 days	P_5 x P_9	11.25 **	H x M	P_{11} x P_3	37.18 **	M x M	P_{11} x P_2	10.25 **	M x M	P_9 x P_6	86.0days
	P_5	4.90 **			P_5	9.83 **	P_{12}	90.0 days							P_7 x P_6	8.17 **	L x M		
							P_5	88.0 days							P_4 x P_2	7.92 **	H x M		
															P_5 x P_6	6.83 **	H x M		
Number of days to harvest	P_1	-5.51 **	P_1	-3.69 **			P_3	106.0 days	P_6 x P_4	-5.64**	H x L	P_6 x P_7	-13.28**	H x M	P_7 x P_1	-14.28**	M x H	P_1 x P_4	115 days
	P_6	-5.11 **	P_6	-3.49 **			P_1	110.0 days				P_4 x P_{11}	-12.88**	L x M				P_6 x P_7	116 days
			P_3	-2.84*			P_6	110.5 days				P_8 x P_1	-11.68**	M x H				P_8x P_1	117 days
												P_7 x P_1	-10.08**	M x H				P_7 x P_1	119 days
												P_{10} x P_3	-6.78*	L xH				P_3 x P_6	121days
																		P_3 x P_1	122 days

(Contd.. ....)

Table 34 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ratio of vegetative phase to reproductive phase	-	-	-	-	-	-	-	-	-	-	-	P_{11} x P_3 P_4 x P_{11} P_8 x P_1 P_7 x P_1	0.56** 0.41** 0.38** 0.36**	M x M M x M M x M M x M	P_7 x P_1 P_5 x P_6	0.34** 0.24*	M x M M x M	P_{11} x P_3 P_4 x P_{11} P_5 x P_6 P_7 x P_1 P_8 x P_1 P_4 x P_3	1.71 1.66 1.57 1.53 1.51 1.4
Number of panicles m^{-2}	P_6	17.16**	P_6	193.84**	-	-	P_{11} P_2 P_7	95.5 89.0 86.0	P_6 x P_1 P_5 x P_6 P_4 x P_5	44.04** 29.29** 26.69*	H x L M x H M x M	P_6 x P_8 P_6 x P_3 P_{11} x P_6	575.79** 398.84** 254.09**	H x H H x M M x H	P_{11} x P_6	248.25**	M x H	P_6 x P_8 P_6 x P_3 P_{11} x P_6 P_6 x P_{10} P_6 x P_7 P_8 x P_1	957.0 752.5 610.5 465.5 297.0 206.5
Number of spikelets $panicle^{-1}$	P_4	64.40**	P_4	71.97**	P_4	84.41**	P_4 P_7 P_{12}	248.5 156.0 141.9	P_4 x P_5	58.43**	H x H	P_{11} x P_3 P_4 x P_1	105.45** 85.25**	M x L H x M	P_{11} x P_2 P_4 x P_1 P_5 x P_6	102.74**	H x M H x M H x L	P_5 x P_4 P_{11} x P_2 P_4 x P_1 P_4 x P_7 P_4 x P_9 P_5 x P_6	296.5 290.0 288.4 284.5 284.0 262.5
Number of tertiary branches $panicle^{-1}$	P_4	9.66**	P_4	12.26**	P_4	19.91**	P_4 P_7 P_5	33.0 25.0 23.5	P_4 x P_5 P_5 x P_6 P_1 x P_9 P_4 x P_1	5.96** 5.10** 3.83* 3.60*	H x H H x L L x L H x M	P_4 x P_1 P_{11} x P_3 P_4 x P_7 P_4 x P_6	18.91** 17.98** 14.38** 11.79**	H x M M x L H x H H x M	P_{11} x P_2 P_4 x P_1 P_5 x P_6	18.87** 12.00** 9.43**	M x M H x M H x L	P_4 x P_1 P_4 x P_7 P_4 x P_5 P_4 x P_6 P_4 x P_9 P_{11} x P_2	52.7 52.0 48.0 47.3 47.0 45.0

(Contd..... ...)

Table 34 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of grains panicle^{-1}	P_4	61.76**	P_4	81.91**	-	-	P_4	233.5	P_4 x P_5	56.59**	H x H	P_{11} x P_3	113.40**	M x L	P_{11} xP_2	131.60**	M x M	P_4 x P_1	278.5
							P_7	142.0				P_4 x P_1	88.28**	H x M				P_5 x P_4	278.5
							P_{12}	122.0										P_{11} x P_2	270.5
																		P_4 x P_7	270.0
																		P_4 x P_9	268.5
																		P_4 x P_5	258.0
Spikelet sterility percentage	-	-	P_4	-11.53**	P_4	-10.72**	P_9	2.20%	P_1 x P_6	-5.74*	M x L	P_6 x P_1	-20.35**	L x M	P_{11} xP_2	-27.30**	L x M	P_1 x P_6	0.90%
					P_5	-9.78**	P_5	2.50%										P_6 x P_9	1.10%
							P_{11}	3.60%										P_4 x P_8	2.10%
																		P_4 x P_{11}	3.40%
																		P_4 x P_{10}	3.50%
																		P_4 x P_1	3.40%
Harvest index	P_1	0.09**	P_3	0.06**	-	-	P_3	0.92	P_4 x P_6	0.09**	L x H	P_6 x P_{10}	0.15**	H x L	P_3 x P_6	0.11**	H x H	P_3 x P_6	0.68
			P_1	0.06**			P_6	0.72	P_4 x P_5	0.08**	L x H	P_4 x P_{10}	0.12**	L x L	P_{11} x P_1	0.08*	M x H	P_1 x P_5	0.65
			P_6	0.03*			P_1	0.69	P_9 x P_5	0.08**	L x H	P_4 x P_8	0.10**	L x M	P_{11} x P_2	0.08*	M x M	P_6 x P_1	0.61
									P_4 x P_1	0.06**	H x L	P_4 x P_6	0.09**	L x H				P_6 x P_{10}	0.61
												P_4 x P_{11}	0.07*	L x M				P_9 x P_1	0.57
												P_4 x P_7	0.07*	L x M				P_6 x P_7	0.56
												P_{11} x P_{10}	0.07*	M x L				P_8 x P_1	0.56
												P_6 x P_7	0.07*	H x M					
1000 grain weight	P_6	3.65**	P_6	3.97**	P_3	3.14**	P_6	35.7 g	-	-	-	P_{10} x P_8	2.96**	M x L	P_{12} x P_2	2.86**	M x M	P_6 x P_9	31.2g
							P_3	30.6 g							P_4 x P_6	2.84**	L x H	P_6 x P_7	30.2g
							P_7	30.1 g										P_6 x P_1	28.6g
																		P_6 x P_3	28.3g
																		P_{11} x P_6	27.7g
																		P_6 x P_5	27.6g

(Contd..........)

Table 34 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Second uppermost internodal length	P_9	-3.80**	P_3	-4.03**	P_3	-6.24**	P_{10}	12.5 cm	P_4 x P_9	-2.32**	L x H	P_7 x P_3	-5.33**	H x H	P_{12} x P_6	-6.87**	H x M	P_9 x P_4	7.2cm
							P_8	13.3 cm	P_5 x P_9	-1.67**	M x H	P_6 x P_7	-4.65**	L x H				P_7 x P_3	7.3cm
							P_9	14.2 cm	P_1 x P_5	-1.09**	H x M	P_{11} x P_8	-4.37**	L x H				P_{10} x P_3	8.3cm
									P_4 x P_6	-0.96*	L x L	P_{10} x P_3	-3.76**	H x H				P_{12} x P_6	8.8cm
																		P_9 x P_5	9.2cm
																		P_9 x P_6	9.3cm
Height of plant at harvest																			
a For short stature	P_9	-17.41**	P_3	-13.58**	P_{12}	-25.22**	P_8	65.7 cm	P_9 x P_6	-12.30**	H x L	P_{11} x P_1	-30.99**	M x H	P_{11} x P_1	-37.48**	M x H	P_9 x P_4	45.0cm
			P_8	-12.79**	P_3	-22.45**	P_3	72.8 cm	P_1 x P_5	-8.91*	H x M							P_{10} x P_3	46.3cm
			P_1	-7.68**			P_7	77 cm										P_{11} x P_1	47.5cm
																		P_8 x P_3	50.3cm
																		P_9 x P_6	51.1cm
																		P_9 x P_1	55.0cm
b For tall stature	P_4	15.14**	P_6	28.18**	P_4	39.52**	P_4	125.7 cm	P_5 x P_6	11.75**	M x L	P_{11} x P_6	31.75**	M x H	P_{11} x P_6	37.89**	M x H	P_{11} x P_6	146.1cm
							P_6	115 cm				P_4 x P_1	925.17**	H x L				P_6 x P_5	137.0cm
							P_5	91.4 cm				P_{11} x P_3	19.91**	M x L				P_4 x P_5	132.5cm
												P_{10} x P_8	16.59**	M x L				P_4 x P_6	130.7cm
												P_6 x P_8	16.44**	H x L				P_4 x P_1	125.95cm
																		P_4 x P_9	123.2cm
Leaf area plant^{-1} at maximum tillering stage	P_4	56.63**	P6	315.11**	-	-	P_4	308.2 cm^2	P_6 x P_1	219.36**	M x M	P_6 x P_8	1166.72**	H x M	P_{11} x P_2	1235.69**	H x M	P_{11} x P_2	2942.1 cm^2
	P_5	56.08**					P_9	288.4 cm^2	P_4 x P_5	184.19**	H x H	P_8 x P_1	589.72**	M x M				P_6 x P_8	1921.0 cm^2
							P_3	234.6 cm^2				P_{11} x P_6	473.54**	H x H				P_5 x P_2	1283.3 cm^2
																		P_{11} x P_6	1262.0 cm^2
																		P_8 x P_1	1011.8 cm^2
																		P_6 x P_{10}	911.4 cm^2

(Contd.........)

Table 34 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length of panicle	P_4	1.87**	P_6	2.94**	-	-	P_4 P_6 P_7	27.5 cm 26.5 cm 25.8 cm	$P_1 \times P_6$ $P_4 \times P_6$ $P_1 \times P_9$ $P_5 \times P_9$	1.65** 1.65** 1.59** 1.46 **	H x M H x H M x L M x L	$P_{11} \times P_3$	6.54**	M x L	$P_{11} \times P_2$ $P_3 \times P_1$ $P_4 \times P_1$	4.19** 3.14* 2.64*	M x M L x L M x L	$P_6 \times P_{10}$ $P_6 \times P_8$ $P_{11} \times P_2$ $P_{11} \times P_3$ $P_{11} \times P_6$ $P_7 \times P_6$	29.5 cm 29.4 cm 29.3 cm 28.8 cm 28.4 cm 28.3 cm
L/B ratio of grain	P_9	0.18**	P_{10}	0.40**	-	-	P_{10} P_{11} P_8	3.8 3.6 3.6	$P_5 \times P_1$ $P_4 \times P_5$	0.22** 0.16**	H x L H x H	$P_{10} \times P_1$	0.48**	H x L	$P_5 \times P_1$	0.73**	H x L	$P_5 \times P_1$ $P_{10} \times P_1$ $P_{10} \times P_3$ $P_8 \times P_1$ $P_{11} \times P_8$ $P_{11} \times P_2$	3.82 3.82 3.64 3.58 3.57 3.56
Amylose content	P_4 P_1	1.42** 1.20**	P_4	2.94**	P4	4.58**	P_1 P_{11} P_4	25.90% 24.50% 24.30%	$P_4 \times P_1$	1.46**	H x H	$P_4 \times P_7$ $P_6 \times P_7$ $P_{11} \times P_7$	5.92** 5.37** 4.34**	H x L H x L H x L	$P_4 \times P_1$ $P_{11} \times P_2$ $P_4 \times P_2$ $P_{11} \times P_6$	2.52** 2.28** 2.09** 1.44*	H x H H x M H x M H x M	30 crosses exhibited the preferable level of amylose content	
Alkali spreading value			P_4	-0.50**	-	-	P_4 P_2 P_5 P_7 P_8 P_9	1.0 2.0 2.0 2.0 2.0 2.0				$P_6 \times P_8$	-0.86*	M x M	$P_{11} \times P_1$	-1.42**	L x M	20 crosses exhibited the preferable score value	

(Contd....)

Table 34 (Contd....)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield plant^{-1}	P_4	1.72**	P_6	4.29**	-	-	P_3	14.4 g	P_6 x P_1	4.15**	M x H	P_6 x P_8	14.48**	H x M	P_{11} x P_2	6.69**	M x M	P_6 x P_8	25.90 g
							P_4	12.4 g	P_4 x P_5	3.15 **	H x M	P_6 x P_{10}	12.75**	H x L	P_5 x P_2	3.55**	M x M	P_6 x P_{10}	23.43 g
							P_7	11.4 g							P_{12} x P_1	3.40**	M x M	P_{11} x P_2	18.50 g
															P_4 x P_1	2.86**	H x M	P_6 x P_1	28.25 g
																		P_5 x P_2	16.47 g
																		P_4 x P5	13.9 g
																		P_6 x P_7	12.24 g
																		P_8 x P_1	12.18 g
																		P_5 x P_6	11.93 g
																		P_7 x P_6	11.32 g

** significant at 1% lelvel; * Significant at 5% level H = High M = Medium L = Low

Table 35 Scoring of the selected parents based on general combining ability effects (from 5x5 full diallel analysis, 8x8 half diallel analysis and 6x3 line x tester analysis)

Parents	Number of days to 50% flowering	Number of days to harvest	Number of panicles m^{-2}	Number of spikelets panicle^{-1}	Number of tertiary branches panicle^{-1}	Number of grains panicle^{-1}	Spikelet sterility percentage	Harvest Index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area plant^{-1} at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield plant^{-1}	Total score for 18 characters	Total score for former 10 characters
P_1	-4.18 **	-3.69 **	-53.86 **	-8.22	-1.26	-7.64	1.14	0.06 **	-0.5	-0.40 *	-7.68 **	-17.14	-1.23 **	-0.06 **	1.63 **	-0.10	0.52 *		
	+1	**+1**	**-1**	**0**	**0**	**0**	**0**	**+1**	**0**	**+1**	**+1**	**0**	**-1**	**-1**	**+1**	**0**	**+1**	**+4**	**+2**
P_3	-1.38	-2.84 *	-4.36	-26.78 **	-5.57 **	-19.5 **	-1.23	0.06 **	1.07 **	-4.03 **	-13.6 **	-109.46 **	-1.56 **	-0.09 **	-1.91 **	-0.05	-0.7		
	0	**+1**	**0**	**-1**	**-1**	**-1**	**0**	**+1**	**+1**	**+1**	**+1**	**-1**	**-1**	**-1**	**-1**	**0**	**0**	**-2**	**0**
P_4	10.32 **	4.11 **	-85.36 **	71.97 **	12.26 **	81.99	-11.53 **	-0.11 **	-4.20 **	4.78 **	20.76 **	-42.85 **	0.55	0.02	2.94 *	-0.50 **	1.72 **		
	-1	**-1**	**-1**	**+1**	**+1**	**+1**	**+1**	**+1**	**-1**	**-1**	**-1**	**-1**	**0**	**0**	**1**	**+1**	**+1**	**-1**	**-1**
P_5	4.90 **	6.94 **	4.16	16.2 **	2.54 **	14.88 **	-9.78 **	0.02 **	1.09 **	0.05	-0.06	56.08 **	0.22	0.13 **	0.57 **	-	0.15		
	-1	**-1**	**0**	**+1**	**+1**	**+1**	**+1**	**+1**	**+1**	**0**	**0**	**+1**	**0**	**+1**	**+1**	**0**	**0**	**+7**	**+4**
P_6	-8.02 **	-3.49 **	193.8 **	-0.99	0.41	-18.30 **	11.36 **	0.03 *	3.97 **	6.09 **	28.18 **	315.11 **	2.94 **	-0.31 **	2.03 **	0.15	4.29 **		
	+1	**+1**	**+1**	**0**	**0**	**-1**	**-1**	**+1**	**+1**	**-1**	**-1**	**+1**	**+1**	**-1**	**+1**	**0**	**+1**	**+4**	**+3**
P_7	0.93	0.11	-48.71 **	1.7	2.57 **	5.72	-2.45	-0.01	1.31 **	-2.1 **	-4.83 **	-124.42 **	0.78 **	-0.29 **	-4.21 **	-0.10	-0.6		
	0	**0**	**-1**	**0**	**+1**	**0**	**+1**	**0**	**+1**	**+1**	**+1**	**-1**	**+1**	**-1**	**-1**	**0**	**0**	**+2**	**+2**
P_8	-0.68	-0.29	23.19 **	-20.54 **	-4.55 **	-22.2 **	-0.84	0.01	-1.02 **	-2.2 **	-12.8 **	-0.19	-1.17 **	0.25 **	-0.06	0.15	-0.4		
	0	**0**	**+1**	**-1**	**-1**	**-1**	**0**	**0**	**-1**	**+1**	**+1**	**0**	**-1**	**+1**	**0**	**0**	**0**	**-1**	**-3**
P_9	0.70	0.39	-11.99 **	-40.28 **	-6.95 **	-36.3 **	-	-0.04 **	-1.07 **	-3.8 **	-17.4 **	-81.33 **	-2.59 **	0.18 **	-2.62 **	-	-2.5 **		
	0	**0**	**-1**	**-1**	**-1**	**-1**	**0**	**-1**	**-1**	**+1**	**+1**	**-1**	**-1**	**+1**	**-1**	**0**	**-1**	**-7**	**-6**
P_{10}	2.78	4.96 **	-23.11 **	-17.12 **	-2.66 **	-17.8 **	2.34 *	-0.04 **	-0.55	-2.72 **	-6.12 **	-55.04 **	-0.02	0.4 **	-1.42 **	-0.15	-1.1 *		
	0	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**0**	**+1**	**+1**	**-1**	**0**	**+1**	**-1**	**0**	**-1**	**-7**	**-7**
P_{11}	0.22	1.11	-1.61	-0.02	-1.2	-2.29	1.2	0.01	-0.07	0.57 **	-3.94 *	33.99 **	-0.32	0.08 **	0.99 **	0.60 **	-0.5		
	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-1**	**+1**	**+1**	**0**	**+1**	**+1**	**-1**	**0**	**+2**	**0**
P_{12}	-0.17	-	-	-79.21 **	-14.86 **	-	7.15	-	-3.47 **	-3.92 **	-25.2 **	-	-	-	1.05 *	-	-		
	0	**0**	**0**	**-1**	**-1**	**0**	**-1**	**0**	**-1**	**+1**	**+1**	**0**	**0**	**0**	**+1**	**0**	**0**	**-1**	**-4**

Bold figures indicate score values ** Significant at 1% level * Significant at 5% level

For the parent P_2 variability was not significant for all characters

Score: Significant desirable = +1

Significant undesirable = -1

Non significant = 0

Weightage for scoring was given as shown below:

		Score
Significant desirable *gca* or *sca* effect	=	+1
Significant undesirable *gca* or *sca* effect	=	-1
Nonsignificant *gca* or *sca* effect	=	0

Scoring of rice hybrids of diverse parentage based on specific combining ability effects is given in Table 36. Crosses showing significant desirable specific combining ability effects and their parental ranking are given in Table 37. Ranking of selected parents (based on total score of *gca* effects), 12 best rice hybrids based on total score of *sca* effects (considering yield and yield components together), based on significant *sca* effect for yield and best crosses on the basis of *per se* performance for yield are given in Table 38. Cross combinations showing the pronounced influence of cytoplasm for grain yield and different yield components and respective parents responsible for cytoplasmic effect are presented in Table 39.

4.2.2 Estimation of components of variation and genetic parameters by Hayman's approach

Diallel analysis by Hayman's method provides an over all genetic evaluation which would be helpful in selecting the parents and their potential crosses in early segregating generations. In the present study, the genetic components of variance were worked out in 5 x 5 full diallel analysis using Hayman's approach (1954) for 18 characters.

Table 36 Scoring of rice hybrids of diverse parentage based on specific combining ability effects

Rice hybrids	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$	Total score for 18 characters	Total score for former 10 characters
$P_1 \times P_9$	0	0	0	0	+1	+1	+1	0	-1	0	-1	0	-1	+1	0	-1	0	0	0	+2
$P_4 \times P_5$	0	-1	0	+1	+1	+1	+1	0	+1	-1	-1	0	+1	0	+1	0	0	+1	+5	+3
$P_4 \times P_9$	-1	-1	0	0	0	0	0	0	-1	-1	+1	0	0	-1	-1	-1	0	-1	-7	-4
$P_5 \times P_9$	-1	-1	0	+1	+1	+1	-1	-1	+1	0	+1	0	+1	+1	0	0	0	0	+3	0
$P_6 \times P_9$	0	0	0	0	-1	-1	-1	0	-1	0	0	+1	-1	-1	0	-1	0	-1	-7	-4
$P_4 \times P_{11}$	0	+1	+1	0	-1	-1	-1	0	+1	0	0	0	+1	-1	-1	-1	0	0	-2	0
$P_4 \times P_6$	0	0	0	-1	+1	+1	+1	+1	+1	0	+1	0	-1	0	+1	-1	0	0	+4	+4
$P_4 \times P_{10}$	-1	0	0	0	0	0	0	0	+1	0	-1	0	+1	-1	-1	0	-1	0	-3	0
$P_4 \times P_7$	-1	-1	0	+1	+1	+1	+1	0	+1	-1	0	0	0	0	+1	+1	-1	0	+3	+2
$P_4 \times P_8$	+1	0	0	-1	0	-1	0	0	+1	0	-1	0	-1	0	-1	-1	0	0	-4	0
$P_4 \times P_3$	0	0	0	0	-1	-1	-1	-1	-1	0	-1	0	-1	0	0	0	0	-1	-8	-5
$P_{11} \times P_{10}$	0	0	0	0	0	0	0	-1	+1	0	+1	0	+1	0	-1	0	0	0	+1	0
$P_{11} \times P_7$	+1	0	0	0	0	+1	+1	+1	0	-1	-1	0	+1	0	-1	+1	0	0	+3	+3
$P_{11} \times P_8$	-1	-1	0	-1	0	0	0	+1	0	0	+1	+1	-1	0	+1	0	-1	-1	-3	-1
$P_{11} \times P_3$	-1	-1	+1	-1	+1	+1	+1	+1	0	0	-1	-1	+1	+1	0	-1	0	+1	+2	+2
$P_6 \times P_{10}$	0	0	0	+1	0	0	+1	+1	+1	0	-1	0	+1	+1	-1	0	0	+1	+5	+4
$P_6 \times P_7$	0	+1	0	0	-1	-1	0	+1	+1	0	+1	-1	0	-1	0	+1	0	0	+1	+1
$P_6 \times P_8$	0	0	0	+1	+1	0	-1	-1	-1	-1	-1	-1	+1	+1	-1	+1	+1	+1	+1	-2
$P_6 \times P_3$	0	-1	+1	+1	-1	0	-1	-1	-1	0	0	0	0	0	-1	-1	0	-1	-6	-3
$P_6 \times P_1$	0	-1	0	-1	0	0	0	+1	0	0	-1	-1	+1	+1	0	-1	0	+1	-1	-1
$P_{10} \times P_7$	-1	-1	0	+1	0	0	-1	-1	-1	0	-1	0	+1	0	+1	-1	0	-1	-5	-4
$P_{10} \times P_8$	-1	-1	0	-1	+1	+1	+1	0	0	+1	-1	-1	-1	+1	0	-1	0	0	-2	+1
$P_{10} \times P_3$	0	+1	0	-1	-1	-1	-1	0	-1	-1	+1	+1	-1	-1	+1	-1	0	-1	-6	-5
$P_{10} \times P_1$	-1	-1	0	0	0	0	0	0	-1	0	+1	0	-1	0	+1	-1	0	-1	-4	-3
$P_7 \times P_6$	-1	0	0	-1	-1	-1	-1	0	0	0	0	+1	-1	0	-1	-1	0	-1	-8	-5
$P_7 \times P_3$	0	-1	0	-1	0	0	+1	+1	0	0	+1	-1	+1	+1	0	-1	0	0	+1	0
$P_8 \times P_3$	0	0	0	-1	-1	0	0	0	-1	-1	+1	+1	-1	-1	+1	+1	-1	-1	-4	-4
$P_8 \times P_1$	0	+1	+1	+1	0	0	0	0	0	0	+1	0	+1	0	+1	+1	0	+1	+8	-3
$P_{12} \times P_1$	0	-1	0	+1	0	0	0	0	0	0	-1	-1	+1	0	0	0	0	+1	0	0
$P_{12} \times P_2$	+1	-1	0	+1	0	0	0	0	0	+1	0	0	-1	0	-1	-1	0	0	-1	+2
$P_{12} \times P_6$	0	+1	0	-1	0	0	0	0	0	-1	+1	+1	0	0	+1	0	0	0	+2	-1
$P_3 \times P_1$	0	+1	0	+1	0	0	+1	0	0	0	0	-1	+1	+1	-1	0	0	0	+3	+3
$P_3 \times P_2$	0	0	0	+1	0	0	0	0	-1	+1	-1	0	-1	0	+1	0	0	-1	-1	+1
$P_3 \times P_6$	0	-1	0	-1	0	0	0	0	+1	0	+1	+1	+1	-1	0	0	0	0	+1	-1
$P_5 \times P_1$	0	0	0	+1	-1	-1	-1	0	0	0	+1	0	0	0	+1	0	0	-1	-1	-2
$P_5 \times P_2$	+1	+1	0	+1	0	0	0	0	0	0	-1	-1	0	0	-1	-1	0	+1	0	+3
$P_5 \times P_6$	-1	-1	+1	-1	+1	+1	+1	0	0	0	0	0	0	0	-1	0	0	0	-1	+2
$P_7 \times P_1$	+1	+1	+1	0	0	0	0	0	0	+1	0	-1	0	0	0	0	0	0	+3	+4
$P_7 \times P_2$	0	-1	0	+1	0	-1	-1	0	0	0	+1	0	0	0	0	0	0	-1	-2	-2
$P_{11} \times P_1$	0	-1	0	-1	-1	-1	-1	0	+1	0	+1	+1	-1	-1	0	-1	+1	-1	-5	-4
$P_{11} \times P_2$	-1	0	0	-1	+1	+1	+1	+1	+1	-1	+1	0	+1	+1	+1	+1	0	+1	+8	+2
$P_{11} \times P_6$	+1	+1	0	+1	-1	0	-1	-1	-1	0	-1	-1	+1	0	-1	+1	0	0	-4	[illegible]
$P_4 \times P_1$	0	-1	0	+1	+1	+1	+1	0	0	0	0	-1	+1	+1	0	+1	0	+1	+6	+3
$P_4 \times P_2$	-1	-1	0	+1	-1	-1	-1	0	0	-1	0	+1	-1	-1	0	+1	0	-1	-6	-5

Score : Significant desirable = +1 Significant undesirable = -1 Non significant = 0

Table 37 Crosses showing significant desirable specific combining ability (*sca*) effects and their parental ranking (*gca* basis)

Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index
$P_6 \times P_4$ H x L	$P_6 \times P_4$ H x L	$P_{11} \times P_3$ M x M	$P_6 \times P_1$ H x L	$P_4 \times P_5$ H x H	$P_4 \times P_5$ H x H	$P_4 \times P_5$ H x H	$P_6 \times P_1$ L x M	$P_3 \times P_6$ L x H
$P_{11} \times P_7$ M x M	$P_6 \times P_7$ H x M	$P_4 \times P_{11}$ M x M	$P_5 \times P_6$ M x H	$P_5 \times P_6$ H x L	$P_5 \times P_6$ H x L	$P_5 \times P_6$ H x L	$P_6 \times P_{10}$ L x L	$P_3 \times P_5$ L x H
$P_2 \times P_8$ L x M	$P_4 \times P_{11}$ L x M	$P_8 \times P_1$ M x M	$P_4 \times P_5$ M x M	$P_1 \times P_9$ H x H	$P_1 \times P_9$ L x L	$P_1 \times P_9$ L x L	$P_6 \times P_7$ L x H	$P_9 \times P_5$ L x H
$P_5 \times P_2$ L x M	$P_8 \times P_1$ M x H	$P_7 \times P_1$ M x M	$P_6 \times P_8$ H x H	$P_{11} \times P_3$ M x L	$P_4 \times P_1$ H x L	$P_1 \times P_6$ L x L	$P_{11} \times P_3$ M x M	$P_1 \times P_4$ H x L
$P_{11} \times P_6$ M x M	$P_7 \times P_1$ M x H	$P_5 \times P_6$ M x M	$P_3 \times P_1$ H x M	$P_4 \times P_1$ H x M	$P_{11} \times P_3$ M x L	$P_{11} \times P_3$ M x L	$P_{11} \times P_8$ M x M	$P_6 \times P_{10}$ H x L
$P_7 \times P_1$ H x M	$P_{10} \times P_3$ L x H		$P_{11} \times P_6$ M x H	$P_4 \times P_7$ H x M	$P_4 \times P_7$ H x H	$P_4 \times P_1$ H x M	$P_3 \times P_1$ M x M	$P_4 \times P_{10}$ L x L
$P_{12} \times P_2$ M x M	$P_5 \times P_2$ L x M		$P_6 \times P_{10}$ H x M	$P_6 \times P_8$ M x L	$P_4 \times P_6$ H x M	$P_4 \times P_7$ H x M	P7 x P3 H x M	$P_4 \times P_8$ L x M
	$P_{12} \times P_6$ M x H		$P_8 \times P_1$ H x L	$P_{10} \times P_8$ L x L	$P_{10} \times P_8$ L x L	$P_{10} \times P_8$ L x L	$P_4 \times P_6$ H x L	$P_4 \times P_{11}$ L x M
	$P_{11} \times P_6$ M x H		$P_{10} \times P_7$ M x L	$P_4 \times P_6$ H x M	$P_{11} \times P_7$ M x H	$P_6 \times P_{10}$ L x L	$P_{11} \times P_7$ M x H	$P_4 \times P_7$ L x M
	$P_3 \times P_1$ H x H		$P_4 \times P_7$ L x L	$P_{11} \times P_2$ H x M	$P_{11} \times P_2$ M x M	$P_4 \times P_6$ H x L	$P_{11} \times P_2$ L x M	$P_{11} \times P_{10}$ M x L
			$P_{12} \times P_1$ M x L	$P_7 \times P_6$ L x M		$P_{11} \times P_7$ M x M		$P_8 \times P_7$ H x M
			$P_5 \times P_2$ M x M			$P_7 \times P_3$ M x L		$P_3 \times P_6$ H x H
			$P_4 \times P_1$ M x L			$P_{11} \times P_2$ M x M		$P_{11} \times P_1$ M x H
			$P_7 \times P_2$ L x M			$P_7 \times P_6$ M x L		$P_{11} \times P_2$ M x M
			$P_3 \times P_2$ M x M			$P_3 \times P_1$ L x M		
			$P_4 \times P_2$ M x M					
			$P_3 \times P_1$ M x L					
			$P_5 \times P_1$ M x L					
			$P_{12} \times P_2$ M x M					

1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Alkali spreading value	Yield $plant^{-1}$
$P_{10} \times P_8$ M x L	$P_4 \times P_9$ L x H	P9 x P6 H x L	$P_6 \times P_1$ M x M	$P_6 \times P_1$ H x M	$P_5 \times P_1$ H x L	$P_4 \times P_1$ H x H	$P_6 \times P_8$ M x M	$P_6 \times P_1$ H x H
$P_{12} \times P_2$ M x M	$P_5 \times P_9$ M x H	P1 x P5 H x M	$P_4 \times P_5$ H x H	$P_4 \times P_6$ H x H	$P_4 \times P_5$ H x H	$P_4 \times P_7$ H x L	$P_{11} \times P_1$ L x M	$P_4 \times P_5$ H x M
$P_3 \times P_6$ L x H	$P_1 \times P_5$ H x M	P11 x P1 M x H	$P_5 \times P_9$ H x L	$P_1 \times P_9$ M x L	$P_{10} \times P_1$ H x L	$P_6 \times P_7$ H x L		$P_5 \times P_6$ M x M
$P_7 \times P_1$ H x M	P4 x P6 L x L	P10 x P3 M x H	$P_5 \times P_1$ H x M	$P_5 \times P_9$ M x L	$P_8 \times P_1$ H x L	$P_{11} \times P_7$ H x L		$P_6 \times P_8$ H x M
$P_3 \times P_2$ H x M	$P_7 \times P_3$ H x H	P8 x P3 H x H	$P_4 \times P_6$ H x M	$P_{11} \times P_3$ M x L	$P_{10} \times P_3$ H x L	$P_8 \times P_1$ M x H		$P_6 \times P_{10}$ H x L
	$P_6 \times P_7$ L x H	$P_7 \times P_8$ M x H	$P_6 \times P_8$ H x M	$P_6 \times P_8$ H x L	$P_{10} \times P_7$ H x L	$P_6 \times P_8$ H x M		$P_8 \times P_1$ M x H
	$P_{11} \times P_8$ L x H	$P_{11} \times P_1$ L x M	$P_8 \times P_1$ M x M	$P_7 \times P_3$ H x L	$P_8 \times P_3$ H x L	$P_{11} \times P_6$ H x H		$P_{11} \times P_3$ M x M
	$P_{10} \times P_3$ H x H	$P_{12} \times P_6$ H x M	$P_{11} \times P_6$ H x H	$P_{10} \times P_8$ M x L	$P_{11} \times P_8$ H x H	$P_8 \times P_3$ M x L		$P_{11} \times P_2$ M x M
	$P_8 \times P_1$ H x H	$P_3 \times P_6$ H x M	$P_4 \times P_{10}$ L x L	$P_6 \times P_{10}$ H x M	$P_4 \times P_7$ M x L	$P_{11} \times P_2$ H x M		$P_5 \times P_2$ M x M
	$P_8 \times P_3$ H x H	$P_4 \times P_2$ L x M	$P_{11} \times P_{10}$ H x L	$P_4 \times P_1$ M x L	$P_4 \times P_6$ M x L	$P_4 \times P_2$ H x M		$P_{12} \times P_1$ M x H
	$P_{11} \times P_{10}$ L x H		$P_3 \times P_1$ L x M	$P_{11} \times P_2$ M x M	$P_4 \times P_1$ M x L			$P_4 \times P_1$ H x H
	$P_{10} \times P_1$ H x H		$P_6 \times P_{10}$ H x L	$P_3 \times P_1$ L x L	$P_3 \times P_2$ L x M			
	$P_{12} \times P_6$ H x M		$P_7 \times P_3$ L x L		$P_{12} \times P_6$ M x L			
	$P_{11} \times P_1$ L x M		$P_{11} \times P_7$ H x L		$P_{11} \times P_2$ H x M			
	$P_5 \times P_1$ H x M		$P_{10} \times P_7$ L x L		$P_7 \times P_6$ L x L			
	$P_3 \times P_6$ H x M		$P_{11} \times P_3$ H x L					
	$P_{11} \times P_2$ L x M		$P_{11} \times P_2$ H x M					
	$P_7 \times P_2$ H x M		$P_{12} \times P_1$ M x M					
			$P_4 \times P_1$ L x M					
			$P_3 \times P_6$ L x H					

H = High M = Medium L = Low

Table 38 Ranking of selected parents and 12 best rice hybrids

Rank	Parent	Rice hybrids on the basis of total score of *sca* effects	Rice hybrids based on *sca*' effect of yield	Rice hybrids on the basis of *per se* performance of yield
I	Karthika	IR 36 X Mattatriveni	Vytilla 3 X Mattatriveni (4)	Vytilla 3 x IR36
II	Vytilla 3	PK 3355 - 5 - 1- 4 X Bhadra	Mahsuri x Karthika (8)	Vytilla 3 X IR60 133 - 184 - 3- 2
III	Mattatriveni	Mahsuri x Mattatriveni	Karthika x Vytilla 3 (4)	PK 3355 - 5 - 1- 4 X Bhadra
IV	Kachsiung Sen Yu 338	Vytilla 3 X IR60 133 - 184 - 3- 2	Vytilla 3 x IR36 (7)	Vytilla 3 X Mattatriveni
V	PK 3355 - 5 - 1- 4	Mahsuri x Karthika	Vytilla 3 X IR60 133 - 184 - 3- 2 (7)	Karthika x Bhadra
VI	Hraswa	Mahsuri x Vytilla 3	IR 36 X Mattatriveni (8)	Mahsuri x Karthika
VII	Mahsuri	Kachsiung Sen Yu 338 x Mattatriveni	PK 3355 -5-1-4 x Kachsiung Sen Yu 338 (8)	Vytilla 3 x Kachsiung Sen Yu 338
VIII	IR 36	Hraswa x Mattatriveni	PK 3355 - 5 - 1- 4 X Bhadra (11)	IR 36 X Mattatriveni
IX	S9768 - PN-25-1	PK3355 -5-1-4 x Kachsiung Sen Yu 338	Karthika x Bhadra (4)	Karthika x Vytilla 3
X	IR 62030-18-2-2	Karthika x Bhadra	S9768 - PN-25-1 x Mattatriveni (3)	Kachsiung Sen Yu 338 x Vytilla 3
XI	IR60 133 - 184 - 3- 2	Mahsuri x Kachsiung Sen Yu 338	Mahsuri x Mattatriveni (8)	
XII	Bhadra	PK 3355 -5-1-4 x Hraswa		

Figures in paranthesis indicate suitability of hybrids for number of characters

Table 39 Cross combinations showing the pronounced influence of cytoplasm for grain yield and related characters and respective parents responsible for cytoplasmic effect

Characters	Crosses showing reciprocal effects	Parents showing cytoplasmic effect	Cross showing reciprocal effect other than cytoplasmic effect
Number of days to 50% flowering	P_6 x P_4, P_1 x P_9, P_9 x P_6, P_5 x P_4	P_1,P_6,P_9	P_5 X P_4
Number of days to harvest	P_6 x P_4, P_1 x P_4, P_1 x P_5, P_1 x P_9, P_9 x P_6	P_1,P_6	P_9 X P_6
Ratio of vegetative phase to reproductive phase	P_4 x P_9, P_5 x P_6	P_5,P_4	-
Number of panicles m^{-2}	P_6 x P_1, P_6 x P_4, P_5 x P_9, P_9 x P_6	P_5,P_6	P_9 X P_6
Number of spikelets $panicle^{-1}$	P_5 x P_6, P_4 x P_1, P_4 x P_9, P_5 x P_9, P_1 x P_9	P_4,P_5	P_1 X P_9
Number of tertiary branches $panicle^{-1}$	P_4 x P_5, P_5 x P_6, P_4 x P_1, P_4 x P_9, P_1 x P_9	P_4,P_5	P_1 X P_9
Number of grains $panicle^{-1}$	P_4 x P_5, P_5 x P_6, P_4 x P_1, P_4 x P_9, P_1 x P_9	P_4,P_5	P_1 X P_9
Spikelet sterility percentage	-	-	-
Harvest index	-	-	-
1000 grain weight	P_1 x P_4, P_1 x P_9, P_6 x P_9, P_6 x P_4	P_6, P_1	-
Second uppermost internodal length	P_9 x P_4, P_9 x P_5, P_1 x P_6, P_5 x P_1, P_1 x P_4, P_9 x P_6, P_6 x P_4	P_9, P_1, P_5	P_6 X P_4
Height of plant at harvest	P_9 x P_6, P_1 x P_4, P_5 x P_4, P_6 x P_4, P_1 x P_6, P_9x P_1	P_9, P_5, P_1	P_6 X P_4
Leaf area $plant^{-1}$at maximum tillering stage	P_5 x P_9, P_5 x P_1, P_4 x P_6, P_4 x P_9, P_5 x P_6, P_6 x P_1	P_5, P_4	P_6 X P_1
Length of panicle	P_6 x P_1, P_5 x P_9, P_5 x P_6, P_1 x P_9	P_5, P_6	P_1 X P_9
L/B ratio of grain	P_5 x P_1, P_4 x P_1, P_4 x P_6, P_9 x P_5, P_9 x P_6	P_4, P_5, P_9	-
Amylose content	P_4 x P_1, P_5 x P_6, P_5 x P_9, P_1 x P_9	P_4,P_5	P_1 X P_9
Yield $plant^{-1}$	P_6 x P_1, P_4 x P_5, P_5 x P_6, P_5 x P_9, P_1 x P_9	P_4,P_5,P_6	P_1 X P_9

The analysis of variance for parents and hybrids together (Table 19) showed that the treatments differed significantly for all the characters except for alkali spreading value. Estimates of genetic components of variance for different quantitative and qualitative characters are presented in Table 40. The t^2 was estimated for all the characters and was found to be non-significant except for the ratio of vegetative phase to reproductive phase.

The additive component (D) and the non-additive component (H_1) were positive and significant for the characters, namely, number of days to 50 per cent flowering, number of days to harvest, number of spikelets panicle^{-1}, number of grains panicle^{-1}, spikelet sterility percentage, harvest index, 1000 grain weight, second uppermost internodal length, height of plant at harvest, L/B ratio of grain, amylose content and yield plant^{-1}. For the characters leaf area plant^{-1} at maximum tillering stage and number of panicles m^{-2}, only the non-additive component (H_1) was significant. But the magnitude of both H_1 and H_2 were much greater than that of additive genetic component (D) and were positive and significant for all the characters except for second uppermost internodal length, height of plant at harvest and 1000 grain weight.

For the characters namely, spikelet sterility percentage, harvest index and L/B ratio of grain only H_1 component was found to be greater than additive component (D). H_1 and H_2 were of equal magnitude for the ratio of vegetative phase to reproductive phase. H_2 was less than H_1 for all the characters except for 1000 grain

Table 40 Estimates of genetic components of variance for different quantitative and qualitative characters by Hayman's Approach

Characters	Additive variance	Dominance variance		Dominance effect	Covariance of additive and dominance effects	Environmental variance	Mean degree of dominance	Proportion of genes with positive and negative effect in parents	Proportion of dominant and recessive genes in parents	Number of groups of genes controlling the character and exhibiting dominance	Heritability%(narrow sense)		
	D	H_1	H_2	h^2	F	E	$(H_1/D)^{1/2}$	$H_2/4H_1$	KD/KR	h^2/H_2		t^2	$(ML_1-ML_0)^2$
Number of days to 50% flowering	94.16 **	330.87 **	278.61 **	499.74 **	7.66	3.16	1.87	0.21	1.04	1.79	21.90	1.87	125.44
Number of days to harvest	89.78 **	404.46 **	371.73 **	867.24 **	9.51	6.54	2.12	0.23	1.05	2.33	17.57	0.31	217.86
Ratio of vegetative phase to reproductive phase	0.00	0.00	0.00	-0.01	0.00	0.01 **	0.00	-0.04	0.00	19.44	-3.36	9.86 *	0.00
Number of panicles m^{-2}	-50.82 **	3905.20 **	3178.13 **	4556.68 **	198.64	293.40	0.00	0.20	0.00	1.43	-1.05	5.27	1186.11
Number of spikelets $panicle^{-1}$	3727.62	6003.01 **	4335.13 *	261.67	-1491.31	134.03	1.27	0.18	0.73	0.06	31.7	0.26	86.86
Number of tertiary branches $panicle^{-1}$	36.75 *	168.89 **	116.57 **	-0.65	-71.74	6.43	2.14	0.17	0.37	-1.01	12.13	1.12	0.86
Number of grains $panicle^{-1}$	3628.06 **	5609.74 **	4072.84 *	194.29	-1034.79	101.24	1.24	0.18	0.79	0.05	33.98	0.11	64.77
Spikelet sterility percentage	68.75 **	134.03 **	83.18	-6.65	120.40 *	16.74 *	1.40	0.16	4.36	-0.08	46.04	2.95	1.02
Harvest index	0.07 **	0.08 **	0.05 *	0.01	0.08 **	0.00	1.64	0.16	3.15	0.16	96.94	0.09	0.00
1000 grain weight	28.27 **	18.24 **	18.35 **	55.1 **	3.62 *	0.96 **	0.80	0.25	1.17	3.00	60.53	4.00	13.93
Second uppermost internodal length	23.92 **	11.09	9.37	0.80	-5.90	0.35	0.68	0.21	0.69	0.09	56.51	2.24	0.26
Height of plant at harvest	462.68 **	220.65 *	176.59	65.31	-220.49 *	36.13 *	0.69	0.20	0.49	0.37	44.14	0.56	22.11
Leaf area $plant^{-1}$ at maximum tillering stage	9886.79	136864.34 **	105054.70 **	104166.19 **	28925.47	1724.53	3.72	0.19	2.30	0.99	7.93	0.01	26317.47
Length of panicle	5.60	25.64	22.49 **	7.88	-1.54	0.33	2.14	0.22	0.88	0.35	16.43	1.16	2.02
L/B ratio of grain	0.15 **	0.18 **	0.14 **	0.05	0.06	0.01	1.09	0.19	1.42	0.36	50.23	0.25	0.01
Amylose content	4.94 **	14.00 **	12.25 **	21.10 **	-4.16	0.29	1.68	0.22	0.60	1.72	20.38	0.14	5.32
Yield $plant^{-1}$	14.97 **	38.35 **	29.07 **	0.54	15.14	0.68	1.60	0.19	1.92	0.02	36.6	0.03	0.24

** Significant at 1% level * Significant 5% lelvel weight and ratio of vegetative phase to reproductive phase. The value of h^2, which gives the dominance effect, was significant for the characters, number of days to 50 per cent flowering, number of days to harvest, number of panicles m^{-2}, leaf area $plant^{-1}$ at maximum tillering stage, 1000 grain weight and amylose content.

The `F' value was positive and significant for the characters, harvest index, spikelet sterility percentage and 1000 grain weight. The `F' value was negative and significant for the character height of plant at harvest. For the remaining 13 characters the `F' value was non-significant. The potence ratio $(H_1/D)^{1/2}$ was less than one for 1000 grain weight, second uppermost internodal length and height of plant at harvest. The value of $(H_1/D)^{1/2}$ was equal to zero for the characters namely, ratio of vegetative phase to reproductive phase and number of panicles m^{-2}. The ratio was equal to one for harvest index and L/B ratio of grain and greater than one for the remaining 10 characters.

The proportion of genes with positive and negative effects in the parents is given by the ratio $H_2/4H_1$. The value of this ratio was equal to 0.25 for the character, 1000 grain weight. The value was less than 0.25 for the remaining 16 characters.

The proportion of dominant and recessive genes in the parents is given by the estimate $(4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F$ which is expressed as KD/KR. This ratio was more than one for the characters, namely, harvest index, spikelet sterility percentage, 1000 grain weight, L/B ratio of grain, leaf area plant^{-1} at maximum tillering stage and yield plant^{-1}. For the characters, number of tertiary branches panicle^{-1}, number of spikelets panicle^{-1}, number of grains panicle^{-1}, length of panicle, second uppermost internodal length, height of plant at harvest and amylose content, the ratio KD/KR was less than one. The ratio was equal to zero for the characters, ratio of vegetative phase to reproductive phase and number of panicles m^{-2}. For the characters, number of days to 50 per cent flowering and number of days to harvest the KD/KR ratio was nearly equal to one.

The ratio of h^2/H_2 was greater than one for the characters namely, days to 50 per cent flowering, days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, 1000 grain weight and amylose content. For the remaining characters the ratio was less than one. Environmental effect was significant for ratio of vegetative phase to reproductive phase, spikelet sterility percentage, 1000 grain weight and height of plant at harvest. High estimates of heritability (60-100%) in narrow sense were observed for the characters namely, harvest index and 1000 grain weight. Moderate estimates of narrow sense heritability (30-60%) were recorded for second uppermost internodal length, L/B ratio of grain, spikelet sterility percentage, height of plant at harvest, yield plant^{-1}, number of grains panicle^{-1} and number of spikelets panicle^{-1}.

The $(ML_1 - ML_0)^2$ was a positive value for all the characters except for ratio of vegetative phase to reproductive phase, harvest index and L/B ratio of grain for which the values of $(ML_1 - ML_0)^2$ were zero.

The values of $V_r + W_r$ are presented in Table 41. In the present study, among the five parents namely Mattatriveni, Mahsuri, Karthika, Vytilla 3 and IR62030-18-2-2, more number of dominant genes for the characters days to 50 per cent flowering, number of tertiary branches panicle^{-1}, 1000 grain weight and leaf area plant^{-1} at maximum tillering stage were observed in the variety Mahsuri. At the same time Mahsuri possessed more number of recessive genes for the characters ratio of vegetative phase to reproductive phase, harvest index and yield. Vytilla 3 possessed more number of dominant genes for number of grains panicle^{-1}, spikelet sterility percentage and L/B ratio of grain and more number of recessive genes for number of panicles m^{-2}, number of tertiary branches panicle^{-2} 1000 grain weight and length of panicle. Maximum number of dominant genes for the characters ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1} second uppermost internodal length, height of plant, length of panicle, amylose content and yield were found in the variety IR62030-18-2-2. This variety was found to possess more number of recessive genes for the characters, number of days to 50 per cent flowering, number of days to harvest and L/B ratio of grain. While Mattatriveni was found to possess more number of dominant genes for ratio of vegetative phase to reproductive phase, it was found to have more number of recessive genes for the characters spikelet sterility percentage and amylose content. The variety Karthika was found to possess more number of recessive genes for the characters, number of spikelets panicle^{-1}, second uppermost internodal length, height of plant at harvest and leaf area plant^{-1} at maximum tillering stage and more number of dominant

Table 41 Estimates of $V_r + W_r$ values for 18 characters in 5 x 5 full diallel cross (Hayman's approach)

Varieties	Number of days to 50% flowering	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelet sterility percentage	Harvest index	1000 grain weight	Second uppermost internodal length	Height of plant at harvest	Leaf area $plant^{-1}$ at maximum tillering stage	Length of panicle	L/B ratio of grain	Amylose content	Yield $plant^{-1}$
Mattatriveni	150.92	155.18	0.00	1090.12	3936.40	105.15	4271.73	125.45	0.02	14.13	17.52	493.4	17974.04	4.78	0.15	16.35	5.38
Mahsuri	69.64	106.66	0.01	743.67	4430.32	43.79	4262.53	9.23	0.07	12.85	31.98	593.12	9294.68	13.75	0.08	11.1	21.09
Karthika	143.81	101.89	0.01	1438.38	9483.83	150.61	8657.14	34.89	0.01	25.19	42.29	813.57	67369.38	5.23	0.18	4.79	19.56
Vytilla 3	72.69	170.59	0.01	1786.38	4200.44	160.97	3111.30	-1.21	0.04	48.07	17.77	685.26	34941.34	30.65	0.05	13.36	20
IR 62030 - 18 - 2 - 2	323.15	310.34	0.00	309.36	3695.73	93.44	3306.63	22.94	0.03	23.34	10.19	121.22	13160.91	3.81	0.22	2.01	2.91

genes for the characters, number days to harvest and harvest index. Mattatriveni possessed more number of dominant genes for the character ratio of vegetative phase to reproductive phase. It also possessed more number of recessive genes for the characters spikelet sterility percentage and days to 50 per cent flowering. This variety also possessed more number of dominant genes for yield and other important yield attributes like number of spikelets panicle^{-1}, harvest index, 1000 grain weight and length of panicle.

4.2.3 Application of selection index for ranking rice hybrids

The selection index formulated in experiment number 1 was utilized for estimating the selection index scores of hybrids and they are ranked on the basis of these scores (Appendix ii). The best 10 hybrids, based on the selection index and yield are given in Table 42. The ranking of the varieties based on yield and selection index were different.

4.2.4 Estimation of heterosis

4.2.4.1 Relative heterosis and heterobeltiosis

The relative heterosis (over mid parent) and hetero beltiosis (over better parent) of 96 hybrids for 17 traits are given in Appendix iii. The summarised information on number of crosses showing significant heterosis, range of relative heterosis and heterobeltiosis, top ranking 10 favourable crosses and genetic divergence of parents involved in favourable crosses are presented in Table 43.

Table 42 Best 10 hybrids based on selection index and yield

	Selection of hybrids	
Sl. No.	Based on selection index	Based on yield
1	PK3355-5-1-4 x Hraswa	Vytilla 3 x IR36
2	Mahsuri x IR62030-18-2-2	Vytilla 3 x IR60133-184-3-2
3	Karthika x Mahsuri	PK3355-5-1-4 x Bhadra
4	Mahsuri x PK3355-5-1-4	Vytilla 3 x Mattatriveni
5	Mahsuri x Kachsiung Sen Yu 338	Karthika x Bhadra
6	Mahsuri x Mattatriveni	PK3355-5-1-4 x Karthika
7	Mahsuri x Vytilla 3	PK3355-5-1-4 x IR62030-18-2-2
8	Mahsuri x Karthika	Mahsuri x Karthika
9	PK3355-5-1-4 x Karthika	Mattatriveni x Bhadra
10	IR36 x Mattatriveni	Vytilla 3 x Kachsiung Sen Yu 338

Table 43 Number of crosses showing significant heterosis, range of relative heterosis and heterobeltiosis, favourable crosses and genetic divergence of parents involved in favourable crosses

Characters	Relative heterosis						Heterobeltiosis					
	Number of crosses showing significant heterosis with frequencies of significant unfavourable heterosis in paranthesis	Percentage of favourable crosses based on total number of crosses	Range of heterosis	Top ten crosses showing favourable heterosis	Relative Heterosis	Parental diversity (D^2)	Number of crosses showing significant heterosis with frequencies of significant unfavourable heterosis on paranthesis	Percentage of favourable crosses based on total number of crosses	Range of heterosis	Top ten crosses showing favourable heterosis	Hetero-beltiosis	Parental diversity (D^2)
1	2	3	4	5	6	7	8	9	10	11	12	13
Number of days to 50% flowering	66(64)	2.1	-9.15 to 74 51	$P_6 \times P_4$	-5.85**	1020.3	82(78)	4.2	-16.75 to 92.09	$P_1 \times P_4$	-16.75**	1484 20
				$P_1 \times P_4$	-5.43*	1484.2				$P_6 \times P_4$	-15.31**	1020.30
										$P_4 \times P_6$	-4.31**	1020.30
										$P_1 \times P_5$	-2.84**	523 45
Number of days to harvest	82(80)	2.1	7.49 to 42.98	$P_3 \times P_7$	-7.49*	1003.58	87(85)	2.1	-9.09 to 45.28	$P_6 \times P_4$	-9.09**	1020.30
				$P_1 \times P_4$	-4.96*	1484.20				$P_1 \times P_5$	-0.80**	523.45
Ratio of vegetative phase to reproductive phase	28(16)	12.5	-38 52 to 83.91	$P_{11} \times P_3$	83.91**	935.01	30(22)	8.3	-42.75 to 68.14	$P_{11} \times P_3$	68.14**	935.01
				$P_4 \times P_{11}$	63.14**	867.57				$P_4 \times P_{11}$	62.75**	867 57
				$P_4 \times P_3$	50.54**	1894.73				$P_4 \times P_3$	37.93**	1894.73
				$P_3 \times P_{10}$	40.20**	1003.58				$P_7 \times P_1$	35.24**	819.81
				$P_7 \times P_1$	39.23**	819.81				$P_8 \times P_1$	29.49*	441.84
				$P_4 \times P_9$	31.95**	1437.84				$P_4 \times P_9$	23.71*	1437.84
				$P_8 \times P_1$	31.45**	441.84				$P_1 \times P_4$	23.35*	1484.20
				$P_1 \times P_4$	30.23*	1484.20				$P_5 \times P_6$	23.23*	1293.15
				$P_3 \times P_1$	29.29*	456.00						
				$P_3 \times P_9$	26.37*	586.22						
				$P_3 \times P_{12}$	24.40*	935.01						
				$P_5 \times P_6$	23 96*	1293.15						

(Contd .. ..)

Table 43 (Contd...)

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of panicles m^{-2}	50(1)	51	-53.52 to 1655.96	$P_6 \times P_8$	1655.96**	2057.10	52(4)	50	-61.63 to 1350.00	$P_6 \times P_8$	1350.00**	2057.10
				$P_6 \times P_3$	1220.18**	2017.45				$P_6 \times P_3$	959.86**	2017.45
				$P_{11} \times P_6$	781.59**	1685.37				$P_6 \times P_{10}$	605.30**	1554.91
				$P_6 \times P_{10}$	754.13**	1554.91				$P_4 \times P_6$	539.27**	1685.37
				$P_5 \times P_3$	525.81**	840.74				$P_5 \times P_3$	446.48**	840.74
				$P_2 \times P_{10}$	449.03**	805.20				$P_2 \times P_{10}$	378.09**	805.20
				$P_2 \times P_6$	437.88**	1455.29				$P_2 \times P_6$	298.88**	1455.29
				$P_6 \times P_7$	360.47**	1554.91				$P_6 \times P_1$	290.32**	1664.38
				$P_6 \times P_1$	305.59**	1664.38				$P_6 \times P_7$	245.35**	1554.91
				$P_{10} \times P_2$	289.68**	805.20				$P_{10} \times P_2$	289.68**	805.20
Number of spikelets panicle^{-1}	52(30)	22.9	-79.90 to 175.47	$P_{11} \times P_2$	175.47**	767.47	55(40)	15.6	-85.51 to 150.65	$P_{11} \times P_2$	150.65**	767.47
				$P_5 \times P_6$	130.82**	1293.15				$P_5 \times P_6$	127.86**	1293.15
				$P_{11} \times P_5$	100.09**	341.84				$P_{11} \times P_5$	99.65**	341.84
				$P_{11} \times P_3$	87.12**	935.01				$P_{11} \times P_3$	85.85**	935.01
				$P_5 \times P_2$	83.77**	384.96				$P_5 \times P_2$	67.53**	384.96
				$P_6 \times P_8$	72.50**	2057.1				$P_6 \times P_8$	63.47**	2057.10
				$P_5 \times P_8$	69.22**	560.65				$P_5 \times P_8$	58.42**	560.65
				$P_4 \times P_1$	64.26**	1484.2				$P_{11} \times P_9$	54.71**	366.43
				$P_5 \times P_3$	63.05**	661.37				$P_{10} \times P_8$	44.30*	611.02
				$P_{11} \times P_9$	58.83**	366.43				$P_9 \times P_{10}$	41.07**	611.02
Number of tertiary branches panicle^{-1}	42(28)	20.8	-87.15 to 154.96	$P_{11} \times P_2$	154.96**	767.47	46(35)	11.5	-88.64 to 154.24	$P_{11} \times P_2$	154.24**	767.47
				$P_4 \times P_1$	114.66**	1484.2				$P_{11} \times P_3$	92.09**	935.01
				$P_{11} \times P_3$	97.10**	935.01				$P_5 \times P_6$	81.24**	1293.15
				$P_5 \times P_6$	93.40**	1293.15				$P_{11} \times P_5$	64.18**	341.84
				$P_{11} \times P_5$	87.12**	341.84				$P_4 \times P_1$	59.70**	1484.20
				$P_4 \times P_9$	82.88**	1437.84				$P_4 \times P_7$	57.58**	903.65
				$P_4 \times P_7$	79.31**	903.65				$P_4 \times P_5$	45.45**	661.37
				$P_4 \times P_6$	76.64**	1020.39				$P_4 \times P_6$	43.18**	1020.39
				$P_4 \times P_5$	70.06**	661.37				$P_4 \times P_9$	42.42**	1437.84
				$P_5 \times P_2$	53.47**	384.96				$P_1 \times P_9$	37.23*	[illegible]

(Contd..... .....)

Table 43 (Contd:..)

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of grains panicle^{-1}	54(38)	16.7	-84.63 to 166.83	$P_{11} \times P_2$	166 83**	767 47	56(45)	11.5	-86 25 to 142.49	$P_{11} \times P_2$	142.49**	767 47
				$P_5 \times P_6$	127.41**	1293 15				$P_5 \times P_6$	118.86**	1293.15
				$P_{11} \times P_3$	88.21**	935 01				$P_{11} \times P_5$	88.17**	341.84
				$P_{11} \times P_5$	88.88**	341.84				$P_{11} \times P_3$	86.02**	1484.20
				$P_4 \times P_1$	79.10**	1484.2				$P_5 \times P_2$	57.95**	384.96
				$P_5 \times P_2$	74.29**	384.96				$P_{11} \times P_9$	40.25**	366.43
				$P_5 \times P_4$	61.03**	661.37				$P_5 \times P_8$	35.23*	560.65
				$P_4 \times P_9$	57.48**	1437 84				$P_1 \times P_2$	34.59*	941.95
				$P_4 \times P_5$	49.18**	661.37				$P_9 \times P_{10}$	32.6	611.02
				$P_5 \times P_8$	46.44**	560.65						
Spikelet sterility percentage	39(34)	5.2	-94.36 to 1713.75	$P_1 \times P_6$	-94.36**	1664.38	31(31)	0	-87 84 to 2730.61	-	-	-
				$P_1 \times P_{12}$	-90.79**	574.08						
				$P_1 \times P_{11}$	-81.49*	574 08						
				$P_4 \times P_1$	-77.48*	1484 2						
				$P_1 \times P_7$	-76.45*	819.81						
Harvest index	71(53)	18.8	-91.37 to 126.83	$P_{10} \times P_4$	126.83**	903.65	78(75)	3.1	-89.49 to 41.47	$P_5 \times P_{10}$	41.47**	457.45
				$P_3 \times P_4$	85 92**	661.37				$P_{10} \times P_4$	29 74**	903.65
				$P_4 \times P_{10}$	79.06**	903.65				$P_7 \times P_2$	18.58*	805.20
				$P_4 \times P_5$	75 78**	661 37						
				$P_4 \times P_7$	61.20**	903.65						
				$P_1 \times P_4$	55.59**	1484 2						
				$P_4 \times P_8$	49.96	1439.84						
				$P_4 \times P_2$	45.71**	628.74						
				$P_4 \times P_9$	45.15**	1437.84						
				$P_8 \times P_4$	31.30**	1437.84						
1000 grain weight	59(59)	0	-41.99 to 5.52	-	-	-	81(81)	0	-46.83 to 0.4	-	-	-

(Contd....)

Table 43 (Contd...)

1	2	3	4	5	6	7	8	9	10	11	12	13
second uppermost internodal length	67(30)	38.5	-57.78 to 68.73	$P_9 \times P_4$	-63.38**	1437.84	67(40)	28.1	-52.46 to 109 43	$P_9 \times P_7$	-52.46**	611 02
				$P_{12} \times P_6$	-57.78**	1685.37				$P_7 \times P_3$	-52.44**	1003.58
				$P_9 \times P_7$	-56.73**	611.02				$P_{12} \times P_3$	-52.44**	935.01
				$P_7 \times P_3$	-54.87**	1003.58				$P_9 \times P_6$	-49.65**	1437.84
				$P_{12} \times P_3$	-54.45**	935.01				$P_{12} \times P_6$	-47.60**	1685.37
				$P_9 \times P_6$	-52.50**	2057.1				$P_{10} \times P_8$	-40.00	903.65
				$P_3 \times P_6$	-49.13**	2017.45				$P_9 \times P_5$	-35.56**	560.65
				$P_1 \times P_6$	-47.43**	1664.38				$P_9 \times P_6$	-34 86**	2057 10
				$P_9 \times P_5$	-43.52**	560.65				$P_{10} \times P_3$	-34.00	1003.58
				$P_8 \times P_4$	-41.47**	1437.84				$P_3 \times P_6$	-33.55**	2017 45
Height of plant at harvest	47(17)	31 3	-71.28 to 49.01	$P_{12} \times P_3$	71.28**	935.01	49(29)	20.8	-69.78 to 85.62	$P_{12} \times P_3$	-69.78**	935.01
				$P_9 \times P_4$	-55.49**	1437.84				$P_9 \times P_7$	-51.63**	611.02
				$P_9 \times P_7$	51.63**	611.02				$P_9 \times P_4$	-41 18**	1437 84
				$P_9 \times P_6$	-46.68**	2057.1				$P_{11} \times P_1$	-38.39**	574.08
				$P_{12} \times P_6$	-41.56**	1685.37				$P_{10} \times P_3$	-36.47**	1003.58
				$P_{11} \times P_1$	-39.95**	574.08				$P_1 \times P_{12}$	-36 45**	574 08
				$P_{10} \times P_3$	-39.02**	1003.58				$P_9 \times P_6$	-33 27**	2057 10
				$P_8 \times P_4$	-38.87**	1437.84				$P_1 \times P_{11}$	-30 29**	574.08
				$P_{12} \times P_4$	-37.89**	867.57				$P_{12} \times P_6$	-28 98**	1685 37
				$P_1 \times P_{12}$	-37.78**	574.08				$P_9 \times P_1$	-28 04**	441 84
Leaf area plant^{-1} at maximum tillering stage	55(5)	52.1	-90.55 to 1652.00	$P_{11} \times P_2$	1652.00**	767.47	57(12)	46.9	-91.66 to 1647.58	$P_{11} \times P_2$	1647.58**	767.47
				$P_6 \times P_8$	1649.94**	2057.1				$P_6 \times P_8$	1310.94**	2057.10
				$P_5 \times P_2$	1065.00**	384.96				$P_5 \times P_8$	740.83**	560.65
				$P_5 \times P_3$	964.18**	840.74				$P_5 \times P_2$	662.25**	384.95
				$P_5 \times P_8$	936.20**	560.65				$P_{11} \times P_6$	653.43**	1685.37
				$P_{11} \times P_5$	838.76**	341.84				$P_5 \times P_3$	595.31**	840.74
				$P_{11} \times P_9$	777.67**	366.43				$P_{11} \times P_9$	593.71**	366.43
				$P_{12} \times P_6$	731.22**	1685.37				$P_8 \times P_1$	529.00**	[illegible]41 84
				$P_8 \times P_1$	728.45**	441 84				$P_5 \times P_5$	515 59**	[illegible]23 45
				$P_5 \times P_6$	657.15**	1293 15				$P_{11} \times P_5$	514.98**	341 84

(Contd..........)

Table 43 (Contd...)

1	2	3	4	5	6	7	8	9	10	11	12	13
Length of panicle	50(35)	15.6	-38.80 to 36.76	P_{11} x P_2	36.76**	767.47	53(45)	8.3	-60.11 to 26.57	P_{11} x P_2	26.57**	767.47
				P_{11} x P_3	28.00**	935.01				P_{11} x P_3	24.41**	935.01
				P_6 x P_8	24.84**	2057.1				P_{11} x P_9	12.74**	366.43
				P_1 x P_2	18.30**	941.95				P_6 x P_{10}	11.53*	1554.91
				P_{11} x P_9	16.00**	366.43				P_6 x P_8	11.15*	2057.10
				P_6 x P_{10}	15.91**	1554.91				P_1 x P_2	10.60*	941.95
				P_{10} x P_8	15.74**	611.02				P_{11} x P_5	10.50*	341.84
				P_6 x P_1	15.07**	1664.38				P_6 x P_1	6.81*	1664.38
				P_{11} x P_5	14.31**	1685.37						
				P_5 x P_8	12.71**	560.65						
L/B ratio of grain	53(37)	15.6	-27.97 to 33.80	P_5 x P_1	33.80**	523.45	48(46)	2.1	-37.40 to 24.43	P_5 x P_1	24.43**	
				P_3 x P_2	26.20**	1280.04				P_3 x P_2	20.43**	
				P_{10} x P_1	18.63**	819.81						
				P_8 x P_6	18.10**	2057.10						
				P_{12} x P_6	17.16**	1685.37						
				P_{11} x P_2	15.21**	767.47						
				P_8 x P_1	14.19**	441.84						
				P_{12} x P_7	13.10**	458.98						
				P_{12} x P_2	12.48**	767.47						
				P_{12} x P_3	12.12**	935.01						
Amylose content	71(60)	11.5	-49.66 to 59.14	P_7 x P_{11}	59.14**	458.98	70(69)		-69.69 to 7.74	P_4 x P_2	7.74**	628.74
				P_{12} x P_7	32.11**	458.98						
				P_4 x P_7	29.31**	903.65						
				P_6 x P_7	25.16**	1554.91						
				P_3 x P_7	21.26**	1003.58						
				P_4 x P_2	17.84**	628.74						
				P_4 x P_9	12.98**	1437.84						
				P_{12} x P_9	11.01**	366.43						
				P_{11} x P_7	9.60*	458.98						
				P_8 x P_{12}	8.66*	366.43						

(Contd.....)

Table 43 (Contd...)

1	2	3	4	5	6	7	8	9	10	11	12	13
Yield plant^{-1}	56(39)	17.7	-98.47 to 457.29	P_6 x P_8	457.29**	2057.1	66(54)	12.5	-98.95 to 426.36	P_5 x P_2	426.36**	384.96
				P_5 x P_2	433.60**	384.96				P_6 x P_8	355.99**	2057.10
				P_6 x P_{10}	431.59**	1554.91				P_6 x P_{10}	350.58**	1554.91
				P_5 x P_6	258.11**	1293.15				P_5 x P_6	229.88**	1293.15
				P_{11} x P_2	243.23**	767.47				P_{11} x P_2	141.83**	767.47
				P_6 x P_1	190.53**	1664.38				P_6 x P_1	108.77**	1664.38
				P_{11} x P_5	173.77**	341.84				P_{11} x P_5	91.37**	341.84
				P_2 x P_{12}	147.67**	767.47				P_{11} x P_9	87.84**	366.43
				P_{11} x P_9	137.10**	366.43				P_2 x P_{12}	87.38**	767.47
				P_1 x P_2	132.98**	941.95				P_2 x P_{10}	73.08**	805.20
										P_1 x P_2	60.58**	941.95
										P_5 x P_9	45.95**	560.65

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

Number of days to 50 per cent flowering

In the present study, early flowering parent was considered as the better parent. The extent of heterosis over mid parent ranged from -9.15 (P_3 x P_7) to 74.51 (P_{11} x P_3) per cent. Sixty four crosses showed significant positive relative heterosis whereas two crosses showed significant negative heterosis. The extent of heterosis over better parent ranged from -16.75 (P_1 x P_4) to 92.09 (P_{11} x P_3). Seventy eight crosses were positively significant over the better parent and four crosses were negatively significant over the better parent.

Number of days to harvest

Short duration parent was considered as the better parent. Eighty hybrids showed significant positive heterosis and two hybrids showed significant negative heterosis over the mid parent. Over the better parent, 85 hybrids showed significant positive heterosis and two hybrids showed significant negative heterosis. Heterosis ranged from -7.49 (P_3 x P_7) to 42.98 (P_{10} x P_8) per cent over mid parent whereas the range was -9.09 (P_6 x P_4) to 45.28 (P_6 x P_3) per cent over better parent.

Ratio of vegetative phase to reproductive phase

The relative heterosis ranged from -38.52 (P_{10} x P_2) to 83.91 (P_{11} x P_3) per cent and the heterobeltiosis ranged from -42.75 (P_{10} x P_2) to 68.14 (P_{11} x P_3) per cent. Out of 26 hybrids having significant heterosis over the mid parent 12 showed heterosis in the positive direction. Eight hybrids showed positive significant heterosis and 22 hybrids showed negative significant heterosis over the better parent.

Number of panicles m^{-2}

Relative heterosis ranged from -53.52 (P_4 x P_1) to 1655.96 (P_6 x P_8) per cent and heterobeltiosis ranged from -61.63 (P_9 x P_7) to 1350.0 (P_6 x P_8) per cent. Fifty crosses showed positive significant relative heterosis, while 52 crosses showed positive significant heterobeltiosis. One cross showed negative significant heterosis over the mid parent and four crosses showed negative significant heterosis over the better parent.

Number of spikelets panicle^{-1}

Heterosis ranged from -79.90 (P_9 x P_4) to 175.47 (P_{11} x P_2) per cent over the mid parent and 22 crosses showed positively significant heterosis, while 30 crosses showed negatively significant heterosis. The range of heterosis was -85.51 (P_9 x P_4) to 150.65 (P_{11} x P_2) per cent over the better parent. Fifteen crosses showed significant heterobeltiosis in the positive direction and 40 crosses showed significant heterobeltiosis in the negative direction.

Number of tertiary branches panicle^{-1}

The range of heterosis over the mid parent was 87.15 (P_9 x P_6) to 154.96 (P_{11} x P_2) per cent and over the better parent was -88.64 (P_9 x P_4) to 154.24 (P_{11} x P_2) per cent. When 20 crosses showed positive and significant relative heterosis, only 12 crosses showed positive and significant heterobeltiosis. Twenty eight crosses showed significant heterosis over the mid parent, while 34 crosses showed significant heterosis over the better parent.

Number of grains panicle^{-1}

Relative heterosis ranged from -84.63 (P_2 x P_6) to 166.83 (P_{11} x P_2) per cent, while heterobeltiosis ranged from -86.25 (P_9 x P_4) to 142.49 (P_{11} x P_2) per cent. Sixteen crosses exhibited significant positive relative heterosis, while 38 crosses showed significant negative relative heterosis. When eleven crosses showed significant positive heterobeltiosis, 45 crosses exhibited significant heterobeltiosis in the negative direction.

Spikelet sterility percentage

Heterosis ranged from -94.36 (P_1 x P_6) to 1713.75 (P_2 x P_{10}) per cent over the mid parent and -87.84 (P_1 x P_6) to 2730.61 (P_5 x P_3) per cent over the better parent. Only five crosses showed favourable heterosis over the mid parent and none of the hybrids showed favourable heterobeltiosis. Thirty nine crosses showed unfavourable heterosis over the mid parent and 31 crosses showed unfavourable heterosis over the better parent.

Harvest index

Per cent heterosis over the mid parent ranged from 91.37 (P_8 x P_5) to 126.83 (P_{10} x P_4), whereas the range was -89.49 (P_4 x P_9) to 41.47 (P_5 x P_{10}) per cent over the better parent. Eighteen crosses showed significant heterosis in positive direction where as 53 crosses showed significant heterosis in negative direction over the mid parent. Three crosses showed positive and 75 crosses showed negative heterosis over the better parent.

1000 grain weight

None of the crosses did show significant favourable heterosis over the mid parent and the better parent. The range of heterosis was from -41.99 (P_{12} x P_6) to 5.52 (P_8 x P_5) per cent and from -46.83 (P_4 x P_5) to 0.4 (P_8 x P_{12}) per cent over the mid parent and the better parent respectively.

Second uppermost internodal length

In the present study, parent with reduced length of second uppermost internode was considered as the better parent. Heterosis ranged from -57.78 (P_{12} x P_6) to 68.73 (P_{10} x P_{11}) per cent over the mid parent and 52.46 (P_9 x P_7) to 109.43 (P_6 x P_8) per cent over the better parent. Sixty seven hybrids were significantly heterotic over the mid parent and the better parent, out of which 37 crosses showed negative (favourable) heterosis over the mid parent and 27 crosses exhibited negative heterosis over the better parent.

Height of plant at harvest

Dwarf plant was considered as the better parent. Relative heterosis ranged from -71.28 (P_{12} x P_3) to 49.01 (P_{11} x P_6) per cent and heterobeltiosis ranged from -69.78 (P_{12} x P_3) to 85.62 (P_6 x P_8) per cent. Thirty crosses exhibited favourable relative heterosis whereas 17 crosses showed unfavourable relative heterosis. Twenty crosses showed heterobeltiosis in the favourable direction and 29 crosses showed heterobeltiosis in the unfavourable direction.

Leaf area $plant^{-1}$ at maximum tillering stage

Heterosis over the mid parent ranged from -90.55 (P_9 x P_4) to 1652.00 (P_{11} x P_2) per cent and heterosis over the better parent ranged from -91.66 (P_9 x P_7) to 1647.58 (P_{11} x P_2) per cent. Nearly half of the hybrids showed positive significant heterosis over the midparent and the better parent.

Length of panicle

Heterosis over the mid parent ranged from -38.8 (P_9 x P_4) to 36.76 (P_{11} x P_2) per cent whereas the range was -60.11 (P_9 x P_6) to 26.57 (P_{11} x P_2) per cent over the better parent. Forty two crosses showed significant positive heterosis, while nine crosses showed significant negative heterotic effect over the mid parent. Thirty eight crosses manifested significant positive heterosis, whereas 18 crosses showed negative heterotic effect over the better parent.

L/B ratio of grain

The range of heterosis over the mid parent was -27.97 (P_6 x P_9) to 33.8 (P_5 x P_1) per cent and over the better parent was -37.4 (P_6 x P_9) to 24.43 (P_5 x P_1) per cent. Sixteen hybrids showed positive significant heterosis over the mid parent and two hybrids exhibited positive significant heterosis over the better parent. Thirty seven hybrids showed negative significant relative heterosis while 46 hybrids showed negative significant heterobeltiosis.

Amylose content

Heterosis over the mid parent ranged from -49.66 ($P_7 \times P_1$) to 59.14 ($P_7 \times P_{11}$) per cent, where as the range was -69.69 ($P_7 \times P_8$) to 7.74 ($P_4 \times P_2$) per cent over the better parent. Eleven crosses showed positive significant heterosis while 60 crosses showed negative significant heterosis over the mid parent. Only one cross did show positive significant heterosis, while 69 crosses showed negative significant heterosis over the better parent.

Yield plant^{-1}

Heterosis ranged from -98.47 ($P_9 \times P_4$) to 457.29 ($P_6 \times P_8$) per cent over the mid parent and -98.95 ($P_9 \times P_4$) to 426.36 ($P_5 \times P_2$) per cent over the better parent. Seventeen crosses showed significant relative heterosis in positive direction while 39 crosses exhibited negative significant relative heterosis. Twelve crosses showed positive significant heterosis, while 54 crosses showed negative significant heterosis over the better parent.

4.2.4.2 Standard heterosis

The hybrids which were found to be positively and significantly heterotic over the better parent were compared with the best parent for each character. Standard heterosis of top ranking ten crosses which showed significant favourable heterobeltiosis for yield and yield attributing characters are presented in Table 44. Promising hybrids for recombination breeding with respect to yield and different yield attributes are listed in Table 45.

Table 44 Standard heterosis of top ten crosses showing significant favourable heterobeltiosis for yield and yield attributing characters.

Characters	Standard parent	Mean value	Crosses showing significant favourable heterobeltiosis	Mean value	Standard heterosis
1	2	3	4	5	6
Number of days to 50% flowering	Hraswa	69.5 days	$P_1 \times P_4$	87.00 days	25.18 **
			$P_6 \times P_4$	88.50 days	27.34 **
			$P_4 \times P_6$	100.00 days	43.88 **
			$P_1 \times P_5$	85.50 days	23.02 **
Number of days to harvest	Hraswa	106 days	$P_6 \times P_4$	120.00 days	13.21 **
			$P_1 \times P_5$	124.00 days	16.98 **
Ratio of vegetative phase to reproductive phase	Bhadra	1.38	$P_{11} \times P_3$	1.71	0.239 **
			$P_4 \times P_{11}$	1.66	0.203 **
			$P_4 \times P_3$	1.40	0.014
			$P_3 \times P_{10}$	1.43	0.036 *
			$P_7 \times P_1$	1.53	0.109 **
			$P_8 \times P_1$	1.51	0.940 **
			$P_4 \times P_9$	1.43	0.036 *
			$P_1 \times P_4$	1.40	0.014
			$P_5 \times P_6$	1.57	0.138 **
Number of panicles m^{-2}	PK3355-5-1-4	95.5	$P_6 \times P_8$	957.0	902.09 **
			$P_6 \times P_3$	752.5	687.96 **
			$P_8 \times P_{10}$	465.5	387.43 **
			$P_{11} \times P_6$	610.5	539.27 **
			$P_5 \times P_3$	388.0	306.28 **
			$P_2 \times P_{10}$	425.5	345.55 **
			$P_2 \times P_8$	355.0	271.73 **
			$P_6 \times P_1$	181.5	90.05 **
			$P_8 \times P_7$	297.0	210.99 **
			$P_{10} \times P_2$	302.0	216.23 **

(Contd............)

Table 44 (Contd.......)

1	2	3	4	5	6
Number of spikelets panicle^{-1}	Mahsuri	248.5	P_{11} x P_2	290.0	16.70 *
			P_5 x P_6	262.5	5.64
			P_{11} x P_5	231.0	-7.04
			P_{11} x P_3	218.0	-12.27
			P_5 x P_2	193.0	-22.33 **
			P_6 x P_8	183.5	-26.16 **
			P5 x P8	182.5	-26.56 **
			P_{11} x P_9	179.0	-27.97 **
			P_{10} x P_8	146.8	-40.93 **
			P_9 x P_{10}	154.8	-37.71 **
Number of tertiary branches panicle^{-1}	Mahsuri	33	P_{11} x P_2	45.0	36.36 **
			P_{11} x P_3	34.0	3.03
			P_5x P_6	42.5	28.79 **
			P_{11} x P_5	38.5	16.67
			P_4 x P_1	52.7	59.70 **
			P_4 x P_7	52.0	57.58 **
			P_4 x P_5	48.0	45.45 **
			P_4 x P_6	47.3	43.33 **
			P_4 x P_9	47.0	42.42 **
			P_1 x P_9	25.3	-23.33 *
Number of grains panicle^{-1}	Mahsuri	233.5	P_{11} x P_2	270.50	15.85 *
			P_5 x P_6	246.00	5.35
			P_{11} x P_5	211.50	-9.42
			P_{11} x P_3	207.50	-11.13
			P_5 x P_2	177.30	-24.07 **
			P_{11} x P_9	156.50	-32.98 **
			P_5x P_8	152.00	-34.90 **
			P_1 x P_2	122.80	-47.41 **
			P_9 x P_{10}	142.60	-38.93 **
Spikelet sterility percentage	IR62030-18-2-2	2.10%	-	-	-
Harvest index	Hraswa	0.92	P_5 x P10	0.597	-35.1 **
			P_{10} x P_4	0.541	-41.2 **
			P_7 x P_2	0.541	-41.2 **

(Contd............)

Table 44 (Contd.......)

1	2	3	4	5	6
1000 grain weight	Vytilla 3	35.700 9	-	-	-
Second uppermost internodal length	IR60133-184-3-2	12.50 cm	P_9 x P_7	6.75 cm	-46.00 **
			P_7 x P_3	7.30 cm	-41.60 **
			P_{12} x P_3	7.30 cm	-41.60 **
			P_9 x P_4	7.15 cm	-42.80 **
			P_{12} x P_6	8.75 cm	-30.00 **
			P_{10} x P_4	12.45 cm	-0.40
			P_9 x P_5	9.15 cm	-26.80 **
			P_9 x P_6	9.25 cm	-26.00 **
			P_{10} x P_3	8.25 cm	-34.00
			P_3 x P_6	10.20 cm	-18.40 *
			P_3 x P_7	10.20 cm	-18.40 *
Height of plant at harvest	IR36	65.70 cm	P_{12} x P_3	22.00 cm	-66.51 **
			P_9 x P_7	37.00 cm	-43.68 **
			P_9 x P_4	45.00 cm	-31.51 **
			P_{11} x P_1	47.50 cm	-27.70 **
			P_{10} x P_3	46.30 cm	-29.53 **
			P_1 x P_{12}	49.00 cm	-25.42 *
			P_9 xP_6	51.10 cm	-22.22 *
			P_1 x P_{11}	53.80 cm	-18.11
			P_{12} x P_6	57.10 cm	-13.09
			P_9 x P_1	55.10 cm	-16.13
Leaf area plant^{-1} at maximum tillering stage	Mahsuri	308.15 cm^2	P_{11} x P_2	2942.10 cm^2	854.76 **
			P_6 x P_8	1921.00 cm^2	523.40 **
			P_5 x P_8	701.30 cm^2	127.58 **
			P_5 x P_2	1283.30 cm^2	316.45 **
			P_{11} x P_8	1262.00 cm^2	309.54 **
			P_5 x P_3	1630.90 cm^2	429.26 **
			P_{11} x P_9	2000.70 cm^2	549.26 **
			P_8 x P_1	1011.80 cm^2	228.35 **
			P_1 x P_5	319.80 cm^2	3.78
			P_{11} x P_5	1030.10 cm^2	234.29 **

(Contd............)

Table 44 (Contd.......)

1	2	3	4	5	6
Length of panicle	Mahsuri	273.50 cm	P_{11} x P_2	29.30 cm	6.55
			P_{11} x P_3	28.80 cm	4.73
			P_{11} x P_9	26.10 cm	-5.09
			P_6 x P_{10}	29.50 cm	7.27
			P_6 x P_8	29.40 cm	6.91
			P_1 x P_2	25.10 cm	-8.73 *
			P_{11} x P_5	26.30 cm	-4.36
			P_6 x P_1	28.30 cm	2.91
L/B ratio of grain	IR60133-184-3-2	3.8	P_5 x P_1	3.82	0.53
			P_3 x P_2	3.36	-11.58 **
Amylose content	Mattatriveni	25.85%	P_4 x P_2	26.18%	1.28
Yield plant^{-1}	Hraswa	14.39 g	P_5 x P_2	16.470 g	14.45
			P_6 x P_8	25.900 g	79.99 **
			P_6 x P_{10}	23.430 g	62.82 **
			P_5 x P_6	11.930 g	-17.10
			P_{11} x P_2	18.500 g	28.56 *
			P_6 x P_1	17.260 g	19.94
			P_{11} x P_5	14.640 g	1.74
			P_{11} x P_9	14.410 g	0.14
			P_2 x P_{12}	11.430 g	-20.57
			P_2 x P_{10}	9.000 g	-37.46 **

** Significant at 1% * Significant at 5% lelvel

Table 45 Promising hybrids for recombination breeding with respect to yield and different yield components

Characters	Parent	*gca* effect	Crosses	*sca* effect	selected hybrids
1	2	3	4	5	6
Number of days to 50% flowering	P_1	-4.18 **	$P_6 \times P_1$	6.23	$P_6 \times P_1$
	P_6	-8.02 **			
Number of days to harvest	P_1	-3.69 **	$P_6 \times P_3$	27.67 **	
	P_3	-2.84 *	$P_6 \times P_1$	8.52 *	
	P_6	-3.49 **	$P_3 \times P_6$	1.89 *	
			$P_3 \times P_1$	-2.28 *	$P_3 \times P_1$
Number of panicles m^{-2}	P_6	193.84 **	$P_6 \times P_8$	575.79 **	$P_6 \times P_8$
	P_8	23.19 **			
Number of spikelets $panicle^{-1}$	P_4	71.97 **	$P_4 \times P_5$	58.43 **	$P_4 \times P_5$
	P_5	16.2 **			
Number of tertiary branches $panicle^{-1}$	P_4	12.26 **	$P_4 \times P_5$	5.96 **	$P_4 \times P_5$
	P_5	2.54 **	$P_4 \times P_7$	14.38 **	$P_4 \times P_7$
	P_7	2.57 **			
Number of grains $panicle^{-1}$	P_4	81.99 **	$P_4 \times P_5$	56.59 **	$P_4 \times P_5$
	P_5	14.88 **			
Spikelet sterility percentage	P_4	-11.53 **	$P_4 \times P_5$	-2.32	$P_4 \times P_5$
	P_5	-9.78 **	$P_4 \times P_7$	0.58	$P_4 \times P_7$
	P_7	-2.45 *			
Harvest index	P_1	0.06 **	$P_1 \times P_5$	-0.02	$P_1 \times P_5$
	P_3	0.06 **	$P_6 \times P_1$	0.06	$P_6 \times P_1$
	P_5	0.02 **	$P_3 \times P_1$	-0.06	$P_3 \times P_1$
	P_6	0.03 **	$P_5 \times P_6$	-0.07 **	$P_3 \times P_6$
			$P_3 \times P_6$	0.11 **	
			$P_6 \times P_3$	-0.36 **	
1000 grain weight	P_3	1.07 **	$P_6 \times P_7$	0.05	$P_6 \times P_7$
	P_5	1.09 **	$P_6 \times P_3$	-1.21	$P_6 \times P_3$
	P_6	3.97 **	$P_7 \times P_3$	-1.1	$P_7 \times P_3$
	P_7	1.31** **	$P_3 \times P_6$	-0.54	$P_3 \times P_6$
			$P_5 \times P_6$	-1.73 **	
Second uppermost internodal length	P_3	-4.03 **	$P_1 \times P_9$	1.13 **	
	P_7	-2.1 **	$P_{10} \times P_8$	3.46 **	
	P_8	-2.2 **	$P_7 \times P_8$	0.70	$P_7 \times P_8$
	P_9	-3.8 **	$P_{12} \times P_1$	7.17 **	
	P_{10}	-2.72 **	$P_3 \times P_1$	-0.88	$P_3 \times P_1$
	P_{12}	-3.92 **	$P_7 \times P_1$	0.59	$P_7 \times P_1$
	P_1	-0.4 *	$P_{10} \times P_1$	-1.39 **	$P_{10} \times P_1$
			$P_{10} \times P_3$	-3.76 **	$P_{10} \times P_3$
			$P_7 \times P_3$	-5.33 **	$P_7 \times P_3$
			$P_8 \times P_3$	-2.98 **	$P_8 \times P_3$
			$P_8 \times P_1$	-3.26 **	$P_8 \times P_1$

(Contd.....)

Table 45 (Contd...)

1	2	3	4	5	6
Height of plant at harvest	P_1	-7.68 **	$P_1 \times P_9$	2.99	$P_1 \times P_9$
	P_3	-13.58 **	$P_{11} \times P_{10}$	284.74 **	
	P_7	-4.83 **	$P_{11} \times P_7$	166.77 **	
	P_8	-12.79 **	$P_{11} \times P_8$	-7.39	$P_{11} \times P_8$
	P_9	-17.41 **	$P_{11} \times P_3$	19.91 **	
	P_{10}	-6.12 **	$P_{10} \times P_7$	-4.66	$P_{10} \times P_7$
	P_{11}	-3.94 *	$P_{10} \times P_8$	16.59 **	
	P_{12}	-25.22 **	$P_{10} \times P_1$	2.94	$P_{10} \times P_1$
			$P_7 \times P_3$	14.35 **	
			$P_8 \times P_1$	4.10	$P_8 \times P_1$
			$P_{12} \times P_1$	8.54 **	
			$P_3 \times P_1$	-7.95	$P_3 \times P_1$
			$P_7 \times P_1$	-31.25	$P_7 \times P_1$
			$P_{11} \times P_1$	-30.9 **	$P_{11} \times P_1$
			$P_{10} \times P_3$	-24.16 **	$P_{10} \times P_3$
			$P_7 \times P_8$	-12.4 **	$P_7 \times P_8$
			$P_8 \times P_3$	-13.49 **	$P_8 \times P_3$
Leaf area plant^{-1} at maximum tillering stage	P_5	56.08 **	$P_5 \times P_6$	20.86	$P_5 \times P_6$
	P_6	315.11 **	$P_{11} \times P_6$	473.54 **	$P_{11} \times P_6$
	P_{11}	33.99 **			
Length of panicle	P_6	2.94 **	$P_6 \times P_7$	-1.76 *	–
	P_7	0.78 **			
L/B ratio of grain	P_5	0.13 **	$P_5 \times P_9$	0.00	$P_5 \times P_9$
	P_8	0.25 **	$P_{11} \times P_{10}$	-0.47 **	
	P_9	0.18 **	$P_{10} \times P_8$	-0.11	$P_{10} \times P_8$
	P_{10}	0.4 **	$P_{11} \times P_8$	0.24 **	$P_{11} \times P_8$
	P_{11}	0.08 **			
Amylose content	P_1	1.63 **	$P_4 \times P_5$	-0.44	$P_4 \times P_5$
	P_4	2.94 *	$P_{12} \times P_1$	0.60	$P_{12} \times P_1$
	P_5	0.57 **	$P_{12} \times P_6$	0.80	$P_{12} \times P_6$
	P_6	2.03 **	$P_5 \times P_6$	0.60	$P_5 \times P_6$
	P_{12}	1.05 *	$P_4 \times P_1$	2.86 **	$P_4 \times P_1$
Yield plant^{-1}	P_1	0.52 *	$P_4 \times P_6$	-0.65	$P_4 \times P_6$
	P_4	1.72 **	$P_6 \times P_1$	5.74 **	$P_6 X P_1$
	P_6	4.29 **	$P_4 \times P_1$	2.86 **	$P_4 \times P_1$

** significant at 1% lelvel; * Significant at 5% level

Promising hybrids selected on the basis of mean performance for yield, *sca* effect for yield, heterobeltiosis and standard heterosis for yield are presented in Table 46.

4.2.4.3 Relationship between heterosis and genetic divergence in rice

Simple correlation between genetic divergence, relative heterosis and heterobeltiosis was carried out. The correlations between D^2 values and both relative heterosis and heterobeltiosis were found to be non-significant (Appendix iii).

4.3 Experiment No.3

4.3.1 Generation mean analysis

Twelve characters which were found to have high heritability and significant correlation with yield namely, number of days to 50 per cent flowering, number of days to harvest, number of panicles plant^{-1}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, spikelet sterility percentage, 1000 grain weight, second upper most internodal length, height of plant at harvest, harvest index and grain yield plant^{-1} were taken for the generation mean analysis. Six generations namely P_1, P_2, F_1, F_2, B_1C_1 and B_2C_1 of the ten crosses namely, P_3 x P_1, P_3 xP_6, P_3 x P_{10}, P_4 x P_3, P_4 x P_6, P_4 x P_8, P_4 x P_{10}, P_7 x P_6, P_8 x P_1 and P_9 x P_{11} were included in the analysis.

The means of each generation were calculated (Appendix iv) from the replicated trial and scaling test was applied to study the adequacy of additive

Table 46 **Best hybrids identified based on mean performance, *sca* effect and heterosis of yield**

		Heterosis	
Mean performance	*sca* effect	Over better parent	Standard parent
Vytilla 3 x IR36	Vytilla 3 x Mattatriveni (4)	Karthika x Bhadra (4)	Vytilla 3XIR36 (3)
Vytilla 3 x IR60133-184-3-2	Mahsuri x Karthika (8)	Vytilla 3 x IR36 (5)	Vytiila 3 X IR60133-184-3-2 (2)
PK3355-5-1-4 x Bhadra	Karthika x Vytilla 3 (4)	Vytilla 3 x IR60133-184-3-2 (3)	PK3355-5-1-4 X Bhadra (5)
Vytilla 3 x Mattatriveni	Vytilla 3 x IR36 (7)	Karthika x Vytilla 3 (5)	
Karthika x Bhadra	Vytilla 3 x IR60133 -184-3-2 (7)	PK3355-5-1-4 x Bhadra (6)	
*PK3355-5-1-4 x Karthika	IR36 x Mattatriveni (8)	Vytilla 3 x Mattatriveni (3)	
*PK3355-5-1-4 x IR62030-18-2-2	PK3355 -5-1-4 x Kachsiung Sen yu - 338 (8)	*PK3355-5-1-4 x Karthika (6)	
Mahsuri x Karthika	PK3355 -5-1-4 x Bhadra (11)	*PK3355 -5-1-4 x IR62030 -18-2-2 (5)	
*Mattatriveni x Bhadra	Karthika x Bhadra (4)	Bhadra x S9768 -PN-25-1(1)	
Vytilla 3 x Kachsiung sen yu -338	S9768 - PN -25-1 x Mattatriveni (3)	Bhadra x IR60133-184-3-2 (2)	
IR36 x Mattatriveni	Mahsuri x Mattatriveni (8)		
Karthika x Vytilla 3			

Figures in paranthesis indicate suitability of hybrids for number of characters

* crosses not taken for combining ability studies

dominance model. The scaling tests A, B, C and D revealed significant deviation from zero in all the crosses, for all the characters except in $P_8 \times P_1$, for the character, number of days to 50 per cent flowering and in $P_9 \times P_{11}$ for number of spikelets panicle^{-1}. The high estimates of scales indicates the inadequacy of simple additive dominance model as well as presence of non-allelic interactions. Hence joint scaling test (6 parameter model) was carried out. The estimates of m,d,h,i,j and l parameters for 12 metric traits in ten crosses are presented in Table 47.

Number of days to 50 per cent flowering

Mean effect was significant for all the crosses. The additive gene effect was significant in all the crosses except in $P_3 \times P_1$, $P_3 \times P_6$ and $P_3 \times P_{10}$. The dominance gene effect was significant in all the crosses except in $P_4 \times P_3$, $P_4 \times P_6$ and $P_4 \times P_8$. Among the crosses, which showed significant additive effects, the crosses $P_4 \times P_3$ and $P_9 \times P_{11}$ exhibited negative effects. Similarly significant negative dominance effect was shown by the crosses $P_7 \times P_6$ and $P_9 \times P_{11}$. In the crosses, where both `d' component and `h' component were significant, the `h' component was found to be greater than `d' component. Interaction effect was significant in all the crosses except in $P_8 \times P_1$. Significant negative additive x additive interaction was exhibited by only one cross namely $P_7 \times P_6$. Significant positive additive x additive effect was shown by four crosses. The crosses $P_4 \times P_3$, $P_4 \times P_8$ and $P_4 \times P_{10}$ exhibited significant negative additive x dominance gene effect. Four cross combinations showed significant positive additive x dominance effect. Dominance x dominance gene effect was significant for all the crosses except for $P_4 \times P_{10}$, with negative effects for the

Table 47 Estimates of gene effects and inbreeding depression for yield and its components in ten crosses of rice

Character	Cross combination	Mean (m)	Additive (d)	Dominance (h)	Additive x additive (i)	Addittive x dominance (j)	Dominance x dominance (l)	Inbreeding depression	Epistasis
1	2	3	4	5	6	7	8	9	10
Number of days to 50% flowering	P_3 x P_1	106.5 ± 0.5**	-1.0 ± 1.0	49.5 ± 3.0**	36.0 ± 2.8**	4.5 ± 1.0**	-37.0 ± 4.9**	15.5 ± 1.1**	Duplicate
	P_3 x P_6	68.0 ± 1.0**	-1.0 ± 1.4	20.3 ± 4.9**	18.0 ± 4.9**	8.3 ± 1.4**	21.5 ± 7.0**	15.5 ± 1.1**	Complementry
	P_3 x P_{10}	76.0 ± 2.0**	0.0 ± 0.0	59.8 ± 8.0**	56.0 ± 8.0**	10.8 ± 0.3**	-77.5 ± 8.1**	10.5 ± 2.1**	Duplicate
	P_4 x P_3	84.0 ± 4.0**	-7.0 ± 0.0**	21.3 ± 16.0	2.0 ± 16.0	-26.3 ± 0.3**	63.5 ± 16.0**	26.5 ± 4.0**	Complementry
	P_4 x P_6	83.0 ± 4.0**	14.5 ± 0.5**	20.5 ± 16.1	21.0 ± 16.0	4.5 ± 0.6**	27.0 ± 16.3	17.0 ± 4.1**	Complementry
	P_4 x P_8	90.0 ± 1.0**	9.0 ± 1.0**	-8.3 ± 4.5	-6.0 ± 4.5	-2.8 ± 1.0**	42.5 ± 5.8**	6.5 ± 1.1**	Duplicate
	P_4 x P_{10}	49.0 ± 4.6**	8.5 ± 0.4**	83.5 ± 14.2**	53.0 ± 4.6**	-36.0 ± 4.2**	-13.0 ± 13.9	32.0 ± 5.5**	Duplicate
	P_7 x P_6	232.5 ± 4.6**	1.0 ± 0.4*	-301.0 ± 10.6**	-141.0 ± 4.6**	1.0 ± 2.3	168.0 ± 6.7**	-24.5 ± 1.8**	Duplicate
	P_8 X P_1	83.5 ± 1.5**	4.0 ± 1.0**	13.8 ± 6.8*	-	-	-	5.0 ± 2.9	-
	P_9 x P_{11}	94.7 ± 3.1**	-3.3 ± 0.6**	-21.7 ± 8.0**	-5.0 ± 3.0	-0.5 ± 2.5	18.5 ± 5.1**	3.0 ± 0.7**	Duplicate
Number of days to harvest	P_3 x P_1	106.5 ± 0.5**	-1.0 ± 1.0	49.5 ± 3.0**	36.0 ± 2.8**	4.5 ± 1.0**	-37.0 ± 4.9**	15.5 ± 1.1**	Duplicate
	P_3 x P_6	108.0 ± 1.0**	-12.0 ± 1.4**	37.5 ± 4.9**	28.0 ± 4.9**	-3.5 ± 1.4*	-23.0 ± 6.9**	13.0 ± 1.0**	Duplicate
	P_3 x P_{10}	109.5 ± 1.5**	0.0 ± 0.0	30.0 ± 6.9**	26.0 ± 6.0**	9.5 ± 0.0**	-32.0 ± 9.2**	7.0 ± 3.8	Duplicate
	P_4 x P_3	114.0 ± 2.0**	0.0 ± 0.0	48.5 ± 8.0**	28.0 ± 8.0**	-17.0 ± 0.0**	9.0 ± 8.10**	26.5 ± 2.1**	Complementry
	P_4 x P_6	118.0 ± 0.0**	9.0 ± 0.0**	32.5 ± 3.0**	30.0 ± 0.00**	0.50 ± 0.00**	-13.0 ± 6.0*	13.0 ± 3.0**	Duplicate
	P_4 x P_8	123.0 ± 1.0**	0.0 ± 0.0	-0.25 ± 4.1	-8.0 ± 4.0*	-10.8 ± 0.3**	44.5 ± 4.5**	11.0 ± 1.4**	Duplicate
	P_4 x P_{10}	123.0 ± 1.0**	-12.5 ± 3.5**	49.0 ± 10.4**	31.0 ± 8.1**	-20.0 ± 3.5**	0.00 ± 19.5	24.5 ± 6.6**	Complementry
	P_7 x P_6	124.0 ± 1.0**	0.0 ± 1.0	4.5 ± 4.5	-12.0 ± 4.5**	-2.5 ± 1.0*	51.0 ± 5.7**	15.0 ± 1.0**	Complementry
	P_8 x P_1	117.0 ± 0.0**	-5.0 ± 0.0**	8.3 ± 3.0**	6.0 ± 0.0**	-5.8 ± 0.3**	-16.5 ± 6.0**	0.0 ± 3.0	Duplicate
	P_9 x P_{11}	117.0 ± 0.0**	-0.5 ± 1.1	19.5 ± 2.3**	15.0 ± 2.2**	4.5 ± 1.2**	-7.0 ± 4.5	8.0 ± 0.0**	Duplicate

(Contd.....)

Table 47 (Contd....)

1	2	3	4	5	6	7	8	9	10
Number of panicles plant^{-1}	$P_3 \times P_1$	11.6± 0.9**	2.0 ± 0.2**	-26.6 ± 3.4**	-28.4 ± 3.4**	1.7 ± 0.2**	21.1 ± 3.5**	-8..0 ± 0.6**	Duplicate
	$P_3 \times P_6$	40.8 ± 4.1**	0.44 ± 0.1**	-71.5 ± 8.6**	-39.2 ± 4.1**	-1.7 ± 1.1	35.8 ± 4.6**	-8.9 ± 1.0**	Duplicate
	$P_3 \times P_{10}$	49.7 ± 1.8**	0.2 ± 0.08*	-94.1 ± 3.7**	-47.8 ± 1.8**	1.0 ± 0.5**	48.3 ± 2.0**	-10.8 ± 0.4**	Duplicate
	$P_4 \times P_3$	44.6 ± 2.7**	-0.11 ± 0.1	-76.3±5.6**	-42.7 ± 2.7**	-2.1 ± 0.7**	33.6± 2.9**	-13.0 ± 0.7**	Duplicate
	$P_4 \times P_6$	13.3 ± 0.6**	-1.0 ± 0.4**	-39.7± 2.7**	-40.2 ± 2.7**	-1.3± 0.4**	34.4 ± 3.0**	-11.3 ± 0.6**	Duplicate
	$P_4 \times P_8$	13.6 ± 0.8**	1.0 ± 0.5*	-36.2± 3.4**	-36.4± 3.4**	1.1± 0.5*	26.1 ± 3.8**	-11.6± 0.8**	Duplicate
	$P_4 \times P_{10}$	44.1 ± 4.5**	0.04 ± 0.05	-80.1 ± 9.7**	-42.5 ± 4.5**	0.73 ± 1.5	37.7 ± 5.3**	-11.8 ± 1.1**	Duplicate
	$P_7 \times P_6$	24.3 ± 1.4**	0.37 ± 0.2	-45.1 ± 3.0**	-22.8 ± 1.4**	-0.15 ± 0.5	25.5 ± 1.6**	-3.4 ± 0.4**	Duplicate
	$P_8 \times P_1$	12.4 ± 0.7**	0.63 ± 0.6	-30.1± 3.2**	-34.7 ± 3.2**	0.38± 0.6	35.8 ± 3.9**	-6.1± 0.8**	Duplicate
	$P_9 \times P_{11}$	19.6 ± 2.3**	-0.25± 0.1*	-23.5 ± 6.8**	-17.9± 2.3**	3.6 ± 2.3	7.9± 4.6	-5.9 ± 0.5**	Duplicate
Number of spikelets panicle^{-1}	$P_3 \times P_1$	234.6± 29.0**	-13.3 ± 2.9**	-308.9 ± 59.6**	-115.6 ± 28.9**	8.3± 6.1	159.7± 36.8**	-34.8 ± 13.1**	Duplicate
	$P_3 \times P_6$	150.0 ± 12.6**	-0.85 ± 3.8	-150.7 ± 30.1**	-42.9 ± 12.0**	-20.0 ± 9.7	74.8 ± 19.4**	-19.3 ± 4.8**	Duplicate
	$P_3 \times P_{10}$	359.5 ± 17.1**	-0.87 ± 3.1	-669.8 ± 35.6**	-252.4 ± 16.8**	-14.7 ± 6.9*	394.3 ± 19.6**	-39.2 ± 5.10**	Duplicate
	$P_4 \times P_3$	246.7 ± 12.4**	48.4 ± 9.1**	-139.5 ±36.8**	-92.1 ± 8.4**	7.3± 19.9	16.2± 24.7	-57.6 ± 2.0**	Duplicate
	$P_4 \times P_6$	213.0 ± 54.8**	47.5 ± 9.0**	-188.7 ± 111.8	-57.6± 54.0**	-23.0 ± 18.3	201.6 ± 58.7**	56.9 ± 14.9**	Duplicate
	$P_4 \times P_8$	215.5 ± 31.1**	51.7± 8.8*	-112.2± 66.2	-64.2± 29.8*	-173.4 ± 18.3**	68.8 ± 35.8	-4.6± 7.4**	Duplicate
	$P_4 \times P_{10}$	228.1 ± 92.8**	47.5 ± 8.7**	-26.8 ± 215.0	-72.5 ± 92.4	-283.9 ± 50.8**	-2.3 ±125.2	-15.0 ± 19.8	Complementry
	$P_7 \times P_6$	402.4 ± 9.0**	29.3 ± 4.1**	-674.0 ± 47.8**	-265.2 ± 8.0**	-48.2 ± 8.5**	445.7 ± 86.9**	-2.8 ± 43.0	Duplicate
	$P_8 \times P_1$	193.7 ± 19.4**	-16.7 ± 1.9**	-174.3 ± 40.0**	-77.4± 19.3**	91.3 ± 4.0**	106.0 ± 25.5**	-7.6± 9.3*	Duplicate
	$P_9 \times P_{11}$	134.2 ± 23.8**	15.1± 6.6*	-16.9± 54.6**	-	-	-	0.52 ± 8.1	-

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Table 47 (Contd....)

1	2	3	4	5	6	7	8	9	10
Number of tertiary branches panicle[-1]	P_3 x P_1	60.4± 3.2**	-3.6 ± 0.3**	-104.2 ± 6.8**	-43.6 ± 3.2**	8.4± 0.6**	55.8± 5.6**	-10.4 ± 2.4**	Duplicate
	P_3 x P_6	25.3 ± 3.4**	-1.9 ± 0.5**	-22.5 ± 9.9*	-10.2 ± 3.4**	0.8 ± 3.3	6.9 ± 6.5	-6.1 ± 0.4**	Duplicate
	P_3 x P_{10}	79.5 ± 3.4**	-2.4 ± 0.13**	-160.7 ± 8.4**	-63.9 ± 3.4**	-0.95 ± 2.2	92.9 ± 5.1**	-10.7 ± 0.7**	Duplicate
	P_4 x P_3	52.7 ± 1.7**	8.0 ± 0.8**	-47.0 ±4.8**	-31.4 ± 1.6**	2.6± 1.9	14.3± 3.2**	-12.8 ±0.6**	Duplicate
	P_4 x P_6	41.9 ± 11.6**	6.2 ± 0.9**	-35.9 ± 24.1	-18.6± 11.5	-15.8 ± 1.7**	41.3 ± 17.1*	13.04 ± 6.9	Duplicate
	P_4 x P_8	37.8 ± 29.3	5.9± 0.8**	-11.5± 59.4	-14.5± 29.3	-0.51 ± 4.4	-1.1± 30.3	-6.5± 7.3	Complementry
	P_4 x P_{10}	31.7± 4.3**	5.6 ± 0.8**	28.2 ± 9.6**	-8.1 ± 4.2	-65.5 ± 1.9**	-22.9 ±7.7**	-3.1 ± 3.2	Duplicate
	P_7 x P_6	92.5 ± 2.2**	4.2 ± 0.6**	-172.8 ± 10.0**	-71.3 ± 2.1**	-9.1 ± 2.5**	109.8 ± 15.6**	-4.1 ± 7.5	Duplicate
	P_8 x P_1	40.5 ± 2.8**	-1.5 ± 0.4**	-50.1 ± 6.2**	-21.6± 2.8**	16.0 ± 1.2**	31.6 ± 3.9**	-1.4± 1.2	Duplicate
	P_9 x P_{11}	42.4 ± 7.6**	3.5±0.9**	-58.5± 17.0**	-23.5 ± 7.5**	-10.5 ± 3.7**	37.5 ± 9.7**	-1.1 ± 1.8	Duplicate
Number of grains panicle[-1]	P_3 x P_1	253.4± 49.3**	-8.8 ± 20.9	-380.2 ± 110.7**	-148.3 ± 44.6**	-60.7± 42.3	208.1± 65.9**	-33.8 ± 15.4*	Duplicate
	P_3 x P_6	250.8 ± 8.4**	-3.1 ± 4.1	-452.9 ±19.7**	-153.7 ± 7.3**	113.5 ± 8.4**	263.6 ±11.9**	-28.8 ± 2.3**	Duplicate
	P_3 x P_{10}	354.6 ± 24.8**	-3.9 ± 3.6	-662.5 ± 50.9**	-256.7 ± 24.5**	-1.6 ± 8.1	385.1 ± 26.4**	-42.4 ± 6.1**	Duplicate
	P_4 x P_3	308.7 ± 14.2**	47.9 ± 6.6**	-328.4 ± 33.0**	-172.8 ± 12.6**	18.5± 13.3	129.6± 23.4**	-67.0 ± 7.9**	Duplicate
	P_4 x P_6	247.4 ± 62.4**	41.8 ± 6.9**	-335.9 ± 128.1**	-105.4± 62.0	-47.0 ± 17.1**	301.8 ± 68.4**	58.4 ± 18.4**	Duplicate
	P_4 x P_8	184.8 ± 18.1**	43.6± 6.8**	-77.0± 39.6	-44.5± 16.7*	-156.4 ± 13.7**	60.7± 22.9*	7.1± 5.4	Duplicate
	P_4 x P_{10}	259.5± 83.5**	41.1 ± 6.7**	-128.2 ± 186.4	-116.7 ± 83.3	-290.7 ± 38.5**	66.4 ± 106.6	-14.3 ± 20.9	Duplicate
	P_7 x P_6	381.0 ± 13.2**	26.9 ± 3.7**	-618.5 ± 38.8**	-254.0 ± 12.7**	-45.0 ± 7.5**	391.1 ± 56.0**	-16.6 ± 27.2	Duplicate
	P_8 x P_1	194.0 ± 29.1**	-6.5 ± 20.7	-161.2 ± 76.0*	-90.8± 20.4**	69.5 ± 41.9	73.4 ± 48.4	-25.6± 6.4**	Duplicate
	P_9 x P_{11}	195.9 ± 23.5**	7.4±3.3*	-197.4± 53.8**	-84.0 ± 23.3**	-43.0 ± 12.6**	125.2 ± 33.8**	-4.8 ± 8.9	Duplicate

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Table 47 (Contd....)

1	2	3	4	5	6	7	8	9	10
Spikelet sterility percentage	P_3 x P_1	-38.6± 14.8**	-6.4 ± 4.2	132.8 ± 31.2**	56.6 ± 14.2**	90.5± 8.5**	-87.1± 16.7**	1.05 ± 3.6	Duplicate
	P_3 x P_6	-121.3 ± 8.8**	2.5 ± 0.6**	359.5 ± 23.2**	130.3 ± 8.7**	-145.8 ± 6.1**	-222.9 ± 19.0**	12.9 ± 6.7	Duplicate
	P_3 x P_{10}	0.70 ± 6.7	2.7 ± 0.6**	1.8 ± 14.1	8.2 ± 6.6	-6.2 ± 1.4**	5.4 ± 10.8	5.0 ± 4.5	Complementry
	P_4 x P_3	-47.8 ± 1.9**	-0.6 ± 0.8	141.8 ± 5.9**	58.8 ± 1.7**	-22.2± 2.1**	-81.3± 6.8**	9.9 ± 3.0**	Duplicate
	P_4 x P_6	-25.7 ± 0.8**	2.0 ± 0.6**	97.6 ± 3.4**	34.1± 0.5**	9.7 ± 1.3**	-61.8 ± 5.4**	2.5 ± 2.6	Duplicate
	P_4 x P_8	8.4 ± 0.00**	3.8± 0.3**	-13.2± 1.2**	-6.7± 0.6**	2.0 ± 0.7**	1.0± 2.4	-6.4± 0.8**	Duplicate
	P_4 x P_{10}	-30.7± 14.7**	2.1 ± 0.7**	92.5 ± 44.0*	39.0 ± 14.7**	23.8 ± 14.7	-58.3 ± 29.4*	2.5 ± 1.4	Duplicate
	P_7 x P_6	9.0 ± 1.0**	0.58 ± 0.5	-18.0 ± 7.3	-2.0 ± 0.8*	1.1 ± 1.3	19.5 ± 13.4	5.6 ± 6.7	Duplicate
	P_8 x P_1	1.1 ± 0.2**	0.15 ± 0.2	12.0 ± 6.5	10.5± 0.7**	6.8 ± 6.5	31.1 ± 13.0**	13.8± 0.6**	Complementry
	P_9 x P_{11}	-48.1 ± 0.8**	1.43± 0.06**	140.4± 2.7**	52.8 ± 0.8**	-42.5 ± 0.8**	-88.0± 2.6**	4.2 ± 1.0**	Duplicate
1000 grain weight	P_3 x P_1	35.4± 0.9**	0.76 ± 0.4	-24.5 ± 2.4**	-6.9 ± 0.8**	1.3± 1.0	14.1± 2.2**	-1.67 ± 0.8*	Duplicate
	P_3 x P_6	53.4 ± 2.9**	-5.0 ± 0.05**	-77.8 ± 5.9**	-19.1 ± 2.9**	23.3 ± 0.6**	51.2 ± 3.2**	-0.5 ± 0.9	Duplicate
	P_3 x P_{10}	45.5 ± 2.8**	-0.45 ± 0.2*	-52.7 ± 5.8**	-15.8 ± 2.8**	4.5 ± 0.7**	35.5 ± 3.2**	0.30 ± 0.9	Duplicate
	P_4 x P_3	51.1 ± 0.9**	1.2 ± 0.03**	-79.0 ± 3.8**	-20.7 ± 0.9**	-21.3± 0.9**	48.0± 5.4**	-3.5 ± 2.6	Duplicate
	P_4 x P_6	58.9 ± 5.2**	-3.8 ± 0.04**	-91.4 ± 11.0**	-23.4± 5.2**	8.7 ± 1.7**	54.9 ± 6.0**	-4.6 ± 1.3**	Duplicate
	P_4 x P_8	38.2 ± 3.9**	3.3± 0.08**	-54.9± 8.6**	-9.8± 3.9*	-11.7 ± 1.7**	34.5± 4.8**	-1.6± 0.9	Duplicate
	P_4 x P_{10}	46.9± 0.7**	0.72 ± 0.2**	-77.6 ± 1.8**	-16.0 ± 0.6**	4.5 ± 0.7**	48.3 ± 1.3**	-2.6± 0.3**	Duplicate
	P_7 x P_6	52.7 ± 5.7**	-2.5 ± 0.2**	-79.3 ± 11.8**	-15.9 ± 5.7**	7.0 ± 1.1**	51.6 ± 6.2**	-0.9 ± 1.6	Duplicate
	P_8 x P_1	43.2 ± 2.6**	1.3 ± 0.4**	-56.8 ± 5.5**	-16.7± 2.6**	-2.6 ± 0.9**	34.9 ± 3.0**	-2.2± 0.8**	Duplicate
	P_9 x P_{11}	40.5 ± 1.9**	-1.7± 0.09**	-56.2± 4.2**	-14.6 ± 1.9**	-0.3 ± 0.7	35.7± 2.3**	-1.3 ± 0.4**	Duplicate

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Table 47 (Contd....)

1	2	3	4	5	6	7	8	9	10
Second upper most internodal length	$P_3 \times P_1$	45.9± 0.5**	1.6 ± 0.1**	-76.1 ± 1.4**	-26.0 ± 0.5**	-7.7± 0.4**	43.6± 1.2**	-5.3± 0.5**	Duplicate
	$P_3 \times P_6$	12.1 ± 1.3**	-2.2 ± 0.1**	8.9 ± 2.6**	11.5 ± 1.3**	-8.8 ± 0.3**	-10.9 ± 1.3**	-3.7 ± 0.3**	Duplicate
	$P_3 \times P_{10}$	41.4 ± 0.6**	3.6± 0.1**	-73.9 ± 1.4**	-23.6 ± 0.6**	-9.1 ± 0.4**	45.9 ± 0.8**	-2.5 ± 0.2**	Duplicate
	$P_4 \times P_3$	28.2 ± 1.2**	1.8 ± 0.2**	-15.0 ± 2.5**	-5.0 ± 1.2**	12.4± 0.5**	7.9± 1.3**	-1.6± 0.3**	Duplicate
	$P_4 \times P_6$	35.1 ± 2.3**	-0.43 ± 0.2*	-31.0 ± 5.3**	-9.7± 2.3**	13.4 ± 1.2**	22.9 ± 3.2**	1.7 ± 0.7*	Duplicate
	$P_4 \times P_8$	33.9 ± 4.9**	4.6± 0.5**	-29.1± 10.1**	-13.4± 4.9**	-7.2 ± 1.3**	20.1± 5.2**	0.5± 1.2	Duplicate
	$P_4 \times P_{10}$	21.9± 6.3**	5.4 ± 0.2**	8.5 ± 13.4	-2.3 ± 6.3	-2.5 ± 2.0	-7.4 ± 7.2	-1.3 ± 1.6	Duplicate
	$P_7 \times P_6$	36.1 ± 0.9**	-3.8 ± 0.6**	-43.7 ± 2.6**	-13.4 ± 0.8**	4.1 ± 1.2**	27.8 ± 1.7**	-1.0 ± 0.3**	Duplicate
	$P_8 \times P_1$	31.1 ± 5.8**	-1.2 ± 0.4**	-32.6 ± 11.9**	-14.1± 5.8*	5.9 ± 1.4**	14.3 ± 6.2*	-5.5 ± 1.4**	Duplicate
	$P_9 \times P_{11}$	26.3 ± 6.7**	-0.12± 0.3	-31.7± 14.6*	-10.3 ± 6.7	-6.0 ± 2.6*	21.5± 8.1*	0.3± 1.6	Duplicate
Height of plant at harvest	$P_3 \times P_1$	152.9± 2.5**	-6.94 ± 0.07**	-187.9 ± 8.1**	-76.0 ± 2.5**	1.9± 0.7	95.9± 12.7**	-22.0± 6.2**	Duplicate
	$P_3 \times P_6$	106.8 ± 5.4**	-30.8 ± 0.8**	-109.7± 11.2**	-6.1 ± 5.3	53.9 ± 1.8**	64.5 ± 6.4**	-6.5 ± 1.9**	Duplicate
	$P_3 \times P_{10}$	198.7 ± 8.8**	-7.0± 0.2**	-336.4 ± 17.8**	-121.8 ± 8.8**	16.2 ± 1.5**	208.6 ± 9.2**	-11.88 ± 2.2**	Duplicate
	$P_4 \times P_3$	121.3 ± 7.1**	30.3 ± 1.3**	-48.4 ± 19.6*	-21.03 ± 7.0**	-15.3± 2.6**	20.6± 27.1	-8.8± 13.1	Duplicate
	$P_4 \times P_6$	513.5 ± 301.5	301.9 ± 300.6	-1215.9 ± 903.0	-77.9± 24.1**	-539.1 ± 601.1	831.8 ± 601.7	18.1 ± 6.8**	Duplicate
	$P_4 \times P_8$	190.1 ± 32.2**	29.3± 1.4**	-214.4± 65.6**	-89.4± 32.2**	-77.1 ± 6.1**	116.3± 33.6**	-20.3± 8.0*	Duplicate
	$P_4 \times P_{10}$	142.4± 34.4**	23.4 ± 1.4**	-47.9 ± 80.9	-35.3 ± 34.4	-110.3 ± 19.0	18.8 ± 48.1	-10.0 ± 8.1	Duplicate
	$P_7 \times P_6$	207.7 ± 2.2**	-25.2 ± 0.9**	-315.2 ± 10.7**	-101.4 ± 2.0**	44.7 ± 2.7**	192.1 ± 17.5**	-13.6 ± 8.5	Duplicate
	$P_8 \times P_1$	131.2 ± 18.8**	-6.0 ± 0.07**	-113.7 ± 38.0**	-53.0± 18.8**	19.1 ± 1.7**	56.6 ± 21.2**	-14.5 ± 6.7*	Duplicate
	$P_9 \times P_{11}$	160.9 ± 23.5**	1.5± 0.6*	-227.1± 48.6**	-80.1 ± 23.5**	-9.0 ± 5.2	136.7± 26.1**	-11.0± 6.7	Duplicate

Table 47 (Contd....)

1	2	3	4	5	6	7	8	9	10
Harvest index	$P_3 \times P_1$	1.2± 0.1**	0.02 ± 0.003**	-1.8 ± 0.2**	-0.66 ± 0.1**	-0.26± 0.02**	1.1± 0.2**	-0.08± 0.1	Duplicate
	$P_3 \times P_6$	0.81 ± 0.02**	0.07 ± 0.005**	-0.69± 0.06**	-0.28 ± 0.02**	-0.16 ± 0.02**	0.57 ± 0.04**	0.08 ± 0.001**	Duplicate
	$P_3 \times P_{10}$	0.75 ± 0.1**	0.12± 0.005**	-0.3 ± 0.2	-0.27 ± 0.09**	-0.28 ± 0.03**	0.012 ± 0.1	-0.14 ± 0.03**	Duplicate
	$P_4 \times P_3$	0.83 ± 0.02**	-0.28 ± 0.005**	-0.57 ± 0.06**	-0.50 ± 0.02**	0.52± 0.01**	0.07± 0.08	-0.23± 0.04**	Duplicate
	$P_4 \times P_6$	-0.11 ± 0.13	-0.21 ± 0.001**	-1.7 ± 0.3**	0.36± 0.13**	-0.11 ± 0.02**	-1.1 ± 0.1**	0.01 ± 0.03	Duplicate
	$P_4 \times P_8$	0.06 ± 0.05	-0.21± 0.003**	1.14± 0.1**	0.20± 0.05**	0.14 ± 0.01**	-0.74± 0.06**	0.02± 0.02	Duplicate
	$P_4 \times P_{10}$	0.48± 0.3	-0.15 ± 0.002**	0.30 ± 0.7	-0.28 ± 0.3	0.63 ± 0.2**	0.25 ± 0.5	0.03 ± 0.08	Duplicate
	$P_7 \times P_6$	0.8± 0.2**	-0.04 ± 0.002**	-0.87 ± 0.4*	-0.38 ± 0.2	-0.05 ± 0.05	0.62± 0.2**	0.03 ± 0.04	Duplicate
	$P_8 \times P_1$	0.94 ± 0.1**	-0.04 ± 0.003**	-1.0 ± 0.3**	-0.43± 0.1**	-0.17 ± 0.02**	0.58 ± 0.1**	-0.05 ± 0.04	Duplicate
	$P_9 \times P_{11}$	1.2 ± 0.09**	0.07± 0.006**	-0.01± 0.2	-0.71 ± 0.09**	-0.008± 0.04	0.75± 0.1**	-0.17± 0.03**	Duplicate
Yield plant^{-1}	$P_3 \times P_1$	73.0± 2.7**	-3.0 ± 1.5*	-141.1 ± 6.6**	-67.7 ± 2.3**	2.6± 3.0	73.3± 5.0**	-15.5± 1.7**	Duplicate
	$P_3 \times P_6$	49.5 ± 0.3**	-0.72± 0.04**	-98.3± 1.0**	-46.6 ± 0.3**	4.2 ± 0.3**	60.0 ± 0.9**	-4.12 ± 0.3**	Duplicate
	$P_3 \times P_{10}$	82.5 ± 14.3**	-1.5± 0.2**	-167.4 ± 28.5**	-78.8 ± 14.3**	4.6 ± 0.4**	91.7 ± 14.3**	-15.1 ± 3.6**	Duplicate
	$P_4 \times P_3$	106.5 ± 2.6**	5.1 ± 0.08**	-198.3 ± 5.2**	-99.2 ± 2.6**	-11.3± 0.3**	94.2± 2.6**	-28.6± 0.7**	Duplicate
	$P_4 \times P_6$	79.5 ± 5.5**	4.4 ± 0.07**	-156.4 ± 11.2**	-72.2± 5.5**	-12.5 ± 0.4**	84.0 ± 6.1**	-14.5 ± 1.8**	Duplicate
	$P_4 \times P_8$	19.8 ± 0.2**	-1.1± 0.11**	-63.1± 0.9**	-58.2± 0.8**	-4.4 ± 0.3**	63.8± 1.1**	-15.6± 0.20**	Duplicate
	$P_4 \times P_{10}$	86.7± 4.5**	3.6 ± 0.2**	-166.9 ± 12.0**	-77.9 ± 4.5**	-6.8 ± 3.5	85.0 ± 7.6**	-19.7 ± 0.7**	Duplicate
	$P_7 \times P_6$	64.7± 8.7**	3.8 ± 1.8*	-132.3 ± 18.4**	-56.6 ± 8.5**	-5.2 ± 3.8	79.9± 12.2**	-5.6 ± 4.4	Duplicate
	$P_8 \times P_1$	69.6 ± 9.3**	-1.3 ± 1.5	-138.5 ± 19.0**	-62.6± 9.2**	5.9 ± 3.1	81.1 ± 9.8**	-8.4 ± 2.3**	Duplicate
	$P_9 \times P_{11}$	1.2 ± 0.09**	0.07± 0.006**	-1.5± 0.2**	-0.71 ± 0.1**	-0.008± 0.04	0.75± 0.12**	-0.17± 0.03**	Duplicate

** Significant at 1%level * Significant at 5%level crosses P_3 x P_{10} and P_3 x P_1. Among the interaction effects, in all the crosses, `i' and `l' components were found to be predominant except in P_4 x P_3 (`j' and `l' were predominant) and P_4 x P_{10} (`i' and `j' were predominant). Over dominance effect was seen in all the crosses except in P_4 x P_8, in which partial dominance was observed. The direction of `h' and `l' components was the same in the crosses P_3 x P_6, P_4 x P_3 and P_4 x P_6 and opposite in the remaining crosses.

Number of days to harvest

Mean effect was highly significant for all the crosses. Significant additive effects were recorded for four cross combinations, out of which three combinations namely P_3 x P_6, P_4 x P_{10} and P_8 x P_1 showed negative direction. All the crosses except P_4 x P_8 and P_7 x P_6 exhibited significant dominance effect in the positive direction. For these two crosses additive and dominance effects were not significant, only interaction effects were significant. Dominance effect was found to be higher in magnitude than additive effect. All components of interaction were found to be significant in all the crosses except `l' component in the crosses P_4 x P_3, P_4 x P_{10} and P_9 x P_{11}. Favourable additive x additive gene effect was observed in three crosses, additive x dominance gene effect was observed in six crosses and dominance x dominance gene effect was observed in five crosses. Predominance of `l' type interaction was observed in the crosses $P_4$ x $P_6$ and $P_9$ x $P_{11}$. Predominance of both `i' and `j' type interactions were observed in $P_4$ x $P_3$ and $P_4$ x $P_{10}$. In the crosses $P_3$ x $P_1$, $P_3$ x $P_6$ and $P_3$ x $P_{10}$ `i' and `l' type interactions were predominant. In the crosses $P_4$ x $P_8$, $P_7$ x $P_6$ and $P_8$ x $P_1$, `l' type interaction was predominant. All the crosses showed overdominance effect. The direction of `h' and `l' components were opposite in seven crosses and in the same direction in three crosses.

Number of panicles plant^{-1}

Significant mean effect was observed in all the 10 crosses. Positive significant additive effect was recorded for the crosses, P_3 x P_1, P_3 x P_6, P_3 x P_{10} and P_4 x P_8. Two crosses exhibited significant negative additive effect and four crosses showed non-significant effect. Dominance effect was significant and negative in all the crosses with higher magnitude than additive effect. Among the interactions, additive x additive (i) and dominance x dominance (l) interactions were predominant with significant effect, in all the 10 crosses, but `i' component was in negative direction and `l' component in positive direction. Additive x dominance interaction was significant in five crosses with positive direction for three cross combinations. All the crosses exhibited overdominance effect. The direction of `h' and `l' components were opposite for all the crosses.

Number of spikelets panicle^{-1}

Mean effect was significant for all the crosses. The crosses P_4 x P_3, P_4 x P_6, P_4 x P_8, P_4 x P_{10}, P_7 x P_6 and P_9 x P_{11} recorded significant positive additive effect. Two crosses exhibited significant negative additive effect and two other crosses showed non-significant effect. Dominance effect was significant and it was in negative direction for all the cross combinations. Except in P_4 x P_{10}, the magnitude of `h' component was very much higher than `d' component. Interaction effect was significant in all the crosses except in P_9 x P_{11}. Additive x additive (i) gene interaction was significant in all the crosses except in P_4 x P_6 and P_4 x P_{10} and the effects were in the negative direction. Positive significant `j' type interaction was shown by the cross $P_8$ x $P_1$. Four crosses exhibited negative significant `j' type interaction and five crosses showed non-significant effect. Dominance x dominance (l) interaction was positive and significant in all the crosses except in four crosses. Except in P_4 x P_8 and P_4 x P_{10} in all crosses `i' and `l' type interactions were predominant. In the crosses P_4 x P_8 and P_4 x P_{10} `j' type interaction was predominant. Overdominance effect was seen in all the crosses except in $P_4$ x $P_{10}$, in which partial dominance effect was observed. Components `h' and `l' were in opposite direction in all the crosses except in P_4 x P_{10}.

Number of tertiary branches panicle^{-1}

All the crosses showed significant mean effect except P_4 x P_8. The crosses P_4 x P_3, P_4 x P_6, P_4 x P_8, P_4 x P_{10}, P_7 x P_6 and P_9 x P_{11} showed significant positive additive effect. All other crosses showed significant negative additive effect. Dominance effect was significant in all the crosses except in P_4 x P_6 and P_4 x P_8. Positive significant dominance effect was exhibited by only one cross namely P_4 x P_{10}. The magnitude of dominance effect was found to be higher than additive effect in all the cross combinations. The digenic interaction effect was significant in all the crosses except in P_4 x P_8, but in this cross, the scaling test was significant. Seven crosses showed significant negative `i' type interaction and three crosses showed non-significant `i' type interaction effects. The crosses P_3 x P_1 and P_8 x P_1 exhibited significant positive `j' type gene interaction. Four crosses each showed negative significant `j' type interaction effect and non-significant interaction effect. Dominance x dominance (l) interaction was found to be significant in all the crosses except in two crosses and all significant effects were positive except that of P_4 x P_{10}. In all the crosses, which showed significant interaction effects, except in P_4 x P_{10} `i' and `l' type interactions were predominant. All the crosses showed overdominance effect for this character. The `h' and `l' components were in opposite direction in all the crosses except in P_4 x P_{10}.

Number of grains panicle^{-1}

All the crosses showed significant mean effect with positive significant additive effect for P_4 x P_3, P_4 x P_6, P_4 x P_8, P_4 x P_{10}, P_7 x P_6 and P_9 x P_{11}. The additive effects of remaining crosses were nonsignificant. Dominance effect was negative and significant in all the crosses except in P_4 x P_8 and P_4 x P_{10}. Dominance effect was higher than additive effect. All the crosses exhibited significant negative `i' type digenic interaction except in two crosses. The cross $P_3$ x $P_6$ exhibited positive significant `j' type interaction. Five other crosses showed significant negative `j' type interaction and four crosses were with non-significant `j' type interaction effect. Dominance x dominance (l) interaction was positive and significant for all crosses, except for P_4 x P_{10} and P_8 x P_1. Except in P_4 x P_8 and P_4 x P_{10}, in all other cross combinations, `i' and `l' type gene interactions were predominant. In P_4 x P_8 and P_4 x P_{10} `j' type interaction was predominant. Overdominance effect was observed in all the crosses. In all the crosses `h' and `l' components were in opposite direction.

Spikelet sterility percentage

Mean effects were significant for all the crosses. Six crosses showed significant positive additive effect and four crosses exhibited non-significant effect. One cross namely P_4 x P_8 exhibited favourable negative significant dominance effect. Six crosses showed positive significant dominance effect and three crosses showed non-significant dominance effect. Other than P_3 x P_{10}, dominance effect was predominant than additive effects in all crosses. Favourable negative significant 'i' type interaction was shown by the cross P_4 x P_8. All crosses except one showed positive significant 'i' type interaction. Four crosses showed negative significant 'j' type interaction effect and three crosses showed positive significant 'j' type interaction effect. In the other three crosses, 'j' type interaction was non-significant. In six crosses 'l' type gene interaction was significantly negative. Except in P_3 x P_{10} in all crosses overdominance effect was observed while in P_3 x P_{10} partial dominance was observed. In all the crosses except in two 'h' and 'l' components were in opposite direction while in P_3 x P_{10} and P_8 x P_1, these components were in the same direction.

1000 grain weight

In all the crosses, mean effect was significant with positive significant additive effect for the crosses P_4 x P_3, P_4 x P_8, P_4 x P_{10} and P_8 x P_1. All other crosses except one showed negative significant additive effect. Dominance effect was found to be predominant to additive effect in magnitude and was significantly negative in all the crosses. Among interaction effects, dominance x dominance interaction was found to be predominant with significant positive effect in all the crosses.

Additive x additive interaction was negatively significant in all the crosses. Positive significant `j' type interaction was recorded for five crosses and negative significant effect for three crosses. For the remaining two crosses the `j' type interaction was non-significant. All the crosses exhibited overdominance effect. The direction of `h' and `l' components were opposite in all the crosses.

Second uppermost internodal length

Mean effect was significant in all the crosses with favourable negative significant additive effect for the crosses, P_3 x P_6, P_4 x P_6, P_7 x P_6 and P_8 x P_1. The remaining crosses except one showed positive significant additive effect. All the crosses exhibited significant dominance effect with favourable negative effect for eight crosses. Dominance effect was found to be higher in magnitude than additive effect. Digenic interaction effect was significant in all the crosses except in the cross P_4 x P_{10}. But scaling test was significant in this cross. Among digenic interaction effects `i' and `l' type interactions were predominant in all the crosses except in P_4 x P_3 (`j' predominant) and $P_4$ x $P_6$ (`l' predominant). Additive x additive interaction (i) was negative and significant (favourable) for all the crosses except in P_3 x P_6 (positive and significant) and P_4 x P_{10} (non-significant). Additive x dominance (j) interaction was significant in all the crosses except in one cross and with favourable negative effect for six crosses. In all, but one cross dominance x dominance interaction (l) was significant with favourable negative effect for P_3 x P_6. All the crosses recorded overdominance effect. The crosses P_4 x P_6, P_7 x P_6 and P_8 x P_1 exhibited significant additive effect and additive x additive type interaction in the favourable direction. The direction of `h' and `l' components were opposite in all the 10 crosses.

Height of plant at harvest

Mean effect was significant in all the crosses except one. Additive effect was significant in all the crosses except one. Five crosses namely P_3 x P_1, P_3 x P_6, P_3 x P_{10}, P_7 x P_6 and P_8 x P_1 showed favourable negative additive effect. All the crosses except two exhibited significant dominance effect in the negative direction. Dominance effect was higher in magnitude than additive effect. Additive x additive type interaction was negative and significant in all the crosses except in one. Favourable negative significant `j' type interaction was exhibited by two crosses, positive significant `j' type interaction was exhibited by four crosses and non-significant effect was shown by four cross combinations. All crosses except three showed positive significant `l' type interaction. Among interaction effects, `i' and `l' type interactions were predominant in all the crosses except in $P_3$ x $P_6$, $P_4$ x $P_6$ (`j' and `l' predominant) and $P_4$ x $P_{10}$ (`j' predominant). Predominance of overdominance effect was observed in all the 10 crosses. In the crosses P_3 x P_1, P_3 x P_{10}, P_7 x P_6 and P_8 x P_1 both `d' and `i' components were significant and negative. The `h' and `l' components were opposite in direction in all the crosses.

Harvest index

All the crosses except three showed significant mean effect. All the crosses exhibited significant additive effect, among which four crosses namely P_3 x P_1,

P_3 x P_6, P_3 x P_{10} and P_9 x P_{11} exhibited positive effect. In all other crosses except three, dominance effect was significant with positive direction for the crosses P_4 x P_6 and P_4 x P_8. Dominance effect was found to be higher in magnitude than additive effect. Positive significant additive x additive gene interaction was exhibited by the crosses P_4 x P_6 and P_4 x P_8. The remaining crosses except two crosses showed negative significant `i' type interaction. Positive significant `j' type interaction was exhibited by the crosses P_4 x P_3, P_4 x P_8 and P_4 x P_{10}. All the remaining crosses, except two showed negative significant `j' type interaction effect. The crosses $P_3$ x $P_1$, $P_3$ x $P_6$, $P_7$ x $P_6$, $P_8$ x $P_1$ and $P_9$ x $P_{11}$ exhibited positive significant `l' type interaction and the remaining crosses except three showed negative significant `l' type interaction. Among the digenic interaction effects `i' and `l' components were predominant in all the crosses except in $P_3$ x $P_{10}$, $P_4$ x $P_3$ (`i' and `j' interactions predominant) and $P_4$ x $P_{10}$ (`j' interaction predominant). Over dominance effect was predominant in all the crosses except in P_9 x P_{11} which exhibited partial dominance effect. The direction of `h' and `l' components were opposite in all the crosses.

Yield plant^{-1}

Mean effect was significant for all the crosses. In all the crosses, additive effect (except for one cross), dominance effect, additive x additive interaction effect, additive x dominance interaction effect (except for five crosses) and dominance x dominance interaction effect were significant. However, their relative magnitude revealed the predominance of dominance effect, additive x additive and dominance x dominance interaction effects. The crosses P_4 x P_3, P_4 x P_6, P_4 x P_{10},

P_7 x P_6 and P_9 x P_{11} exhibited significant positive additive effect. The dominance effect and additive x additive interaction effect were negative in all the crosses, while dominance x dominance type interaction was positive in all the crosses. Positive significant `j' type interaction was shown by $P_3$ x $P_6$ and $P_3$ x $P_{10}$. Predominance of overdominance effect was observed in all the crosses. The `h' and `l' components were in opposite direction in all the 10 crosses.

4.3.2 Inbreeding depression

The inbreeding depression in 10 crosses for 12 characters are presented in Table 47.

Number of days to 50 per cent flowering

There was significant reduction in number of days to 50 per cent flowering in F_2 generation compared to F_1 generation except in the cross P_7 x P_6 in which flowering period was more in F_2.

Number of days to harvest

The duration of F_1 progenies was higher than F_2 segregants for all the crosses.

Number of panicles plant^{-1}

For this character, inbreeding depression was significant but negative in all the crosses.

Number of spikelets panicle^{-1}

Significant negative inbreeding depression was shown by the crosses P_3 x P_1, P_3 x P_6, P_3 x P_{10} and P_4 x P_3. The cross P_4 x P_6 exhibited significant positive inbreeding depression. Remaining crosses recorded non-significant inbreeding depression.

Number of tertiary branches panicle^{-1}

The crosses P_3 x P_1, P_3 x P_6, P_3 x P_{10} and P_4 x P_3 recorded significant negative inbreeding depression. All other crosses showed non-significant inbreeding effect.

Number of grains panicle^{-1}

The cross P_4 x P_6 exhibited significant positive inbreeding depression while the crosses P_3 x P_1, P_3 x P_6, P_3 x P_{10}, P_4 x P_3 and P_8 x P_1 showed significant negative inbreeding depression. Others showed non-significant effect.

Spikelet sterility percentage

Significantly reduced spikelet sterility in F_2 generation was observed in the crosses P_4 x P_3, P_8 x P_1 and P_9 x P_{11}. In the cross P_4 x P_8, compared to F_1 the spikelet sterility was higher in F_2. In the remaining crosses the depression was non-significant.

1000 grain weight

Four crosses namely P_3 x P_1, P_4 x P_6, P_4 x P_{10}, P_8 x P_1 and P_9 x P_{11} exhibited significant negative inbreeding depression. For all other crosses the depression was non-significant.

Second uppermost internodal length

The favourable reduced length of second uppermost internode in F_2 generation was recorded in the cross P_4 x P_6. In six crosses significantly increased internodal length in F_2 generation and in three crosses non-significant effect for inbreeding was noticed.

Height of plant at harvest

Significant inbreeding depression in the favourable direction (reduced height) was shown by the cross P_4 x P_6. Inbreeding depression in the remaining crosses were either towards unfavourable direction or non-significant.

Harvest index

The cross P_3 x P_6 showed significant positive inbreeding depression while P_3 x P_{10}, P_4 x P_3 and P_9 x P_{11} exhibited significant negative inbreeding depression. All other crosses showed non-significant inbreeding effect.

Yield plant^{-1}

All the crosses except one, showed significant negative inbreeding depression. The cross P_7 x P_6 exhibited non-significant inbreeding effect.

4.3.3 Inheritance of kernel colour in rice

The inheritance of kernel colour was worked out for 19 crosses and ratios were tested for 9 crosses using the chi-square test for different genetic ratios (Table 48).

Table 48 Segregation pattern for kernel colour of rice in F_2 generations

Crosses	Kernel colour of			Total number of F_2 plants observed	Segregation for kernel colour in F_2 generation					Phenotypic ratio Red:White	Chi-square value
					Number of red kernelled types						
	Female parent	male parent	F_1 generation		Deep red	Yellowish red	Light red	Total	Number of white kernelled types		
P_8 x P_1	White	Deep red	Yellowish red	48	6	28	10	44	4	15:1	0.36
P_7 x P_1	White	Deep red	Yellowish red	46	8	25	7	40	6	13:3	0.98
P_6 x P_8	Deep red	White	Yellowish red	49	12	30	1	43	6	13:3	1.36
P_{11} x P_5	White	Deep red	Yellowish red	49	8	29	2	39	10	13:3	0.086
P_1 x P_7	Deep red	White	Yellowish red	49	17	19	6	42	7	13:3	0.641
P_6 x P_{10}	Deep red	White	Yellowish red	48	9	21	6	36	12	3:1	0.00
P_7 x P_8	White	Deep red	White	50	1	2	nil	3	47	1:15	0.0053
P_4 x P_6	White	Deep red	White	41	0	2	nil	2	39	1:15	0.132
P_9 x P_{11}	White	White	White	44	0	2	4	6	38	1:15 and 3:13	0.34 & 0.755
P_4 x P_3	White	Yellowish red	Yellowish red	26	14	3	2	19	7	9:7 and 13:3	2.99 & 1.14
P_4 x P_7	White	White	Yellowish red	24	0	20	4	24	nil	All F_2 red	-
P_{11} x P_7	White	White	Yellowish red	25	0	25	nil	25	nil	All F_2 red	-
P_1 x P_9	Deep red	White	Deep red	46	25	19	2	46	nil	All F_2 red	-
P_5 x P_2	Deep red	Yellowish red	Yellowish red	49	6	22	21	49	nil	All F_2 red	-
P_5 x P_6	Deep red	Deep red	Deep red	51	4	43	4	51	nil	All F_2 red	-
P_3 x P_6	Deep red	Deep red	Deep red	50	9	38	3	50	nil	All F_2 red	-
P_3 x P_1	Yellowish red	Deep red	Yellowish red	47	12	31	4	47	nil	All F_2 red	-
P_2 x P_6	Yellowish red	Deep red	Yellowish red	45	15	24	6	45	nil	All F_2 red	-
P_1 x P_5	Deep red	Deep red	Deep red	50	7	30	13	50	nil	All F_2 red	-

For the crosses P_7 x P_1, P_6 x P_8, P_{11} x P_5, P_1 x P_7 and P_4 x P_3, one parent was red kernelled type and the other white kernelled type. F_1 of these crosses showed red kernel colour. F_2 of these crosses segregated into 13 red : 3 white. In the case of the cross P_8 x P_1, one parent was red kernelled and the other white kernelled and its F_1 was red kernelled type. F_2 plants of this cross produced red kernelled and white kernelled types in the ratio 15:1. The cross P_6 x P_{10} whose parents were red kernelled and white kernelled types respectively gave red kernelled F_1 plants, but the F_2 segregated into 3 red : 1 white. For the crosses P_7 x P_6 and P_4 x P_6 one of the parents was white kernelled and the another red kernelled but the F_1 plants were white kernelled types. F_2 of these crosses showed plants in the ratio 1 red : 15 white. The parents of the crosses P_4 x P_7 and P_{11} x P_7 were both white kernelled ones, but interestingly their F_1 progenies were red kernelled types. F_2 plants of these crosses were all red types.

It was observed that within the red colour itself there was variation like light red, yellowish red and deep red.

In the case of the cross P_9 x P_{11}, both parents and F_1 progenies were white kernelled types but its F_2 segregation for red and white kernel types fit for both 1:15 and 3:13 (red : white) modified Mendelian ratios.

The parents, F_1s and F_2s of the crosses P_1 x P_9, P_5 x P_2, P_5 x P_6, P_3 x P_6, P_3 x P_1, P_2 x P_6 and P_1 x P_5 were red types with variation in the red colour in F_2 generations.

4.3.4 Evaluation of F_2 generations

The 22 F_2 generations and 20 back cross generations were evaluated for selecting superior segregants. Among 22 F_2 generations, seven crosses were found to have very low variability with respect to yield and yield attributes. They also exhibited marginally good yield. The characters of these early stabilized lines are given in (Table 49). Promising segregants isolated from F_2 generations are given in Table 50. Segregants from back cross generations were not promising with respect to yield and its attributes.

Table 49 Salient characteristics of promising early stabilized (low variability) crosses in the F_2 generations

Designation of cross	Cross combination	Mean yield plant^{-1}(g)	Harvest index	Number of grains panicle^{-1}	Number of tertiary branches panicle^{-1}	Mean number of panicles plant^{-1}	1000 grain weight(g)	Duration of crop(days)	Height of plant (cm)	Grain type	Colour of kernel	Amylose content(%)	Alkali spreading value	Evaluation for stemborer and thrips resistance		
														No. of infested plants per 100 plants	Location severity index (average of 12 parents)	Remarks
C-4	Mattatriveni x Karthika	19.4 (8.2; 3.0)	0.582 (0.553; 0.439	155 (114; 117)	28 (21; 22)	10 (1.4; 1.5)	25.1 (27.2; 309)	107 (114; 128)	92 (84; 93)	LB	R (R,R)	28 (25.8;23.6)	3.1 (2.5;2)	7	34.40%	Moderately resistant to stem borer and thrips
C-8	Mattatriveni x IR62030-18-2-2	22.4 (8.2; 4.5)	0.571 (0.553; 0.512)	160 (114; 119)	30 (21; 22)	10 (1.4; 1.5)	26.2 (27.2; 24.2)	107 (114; 116)	88 (84; 82)	LB	R (R,W)	26.2 (25.8;19.6)	3.1 (2.5;2)	5	34.40%	Moderately resistant to stem borer and thrips
C-15	Hraswa x Mattatriveni	20 (2.1; 8.2)	0.605 (0.608; 0.553)	113 (94;114)	22 (13; 21)	12 (2; 1.4)	26.1 (29.3; 27.2)	106 (103; 114)	83 (70; 84)	LB	R (R,R)	26.7 (20.7;25.8)	3.1 (2.5;2.5)	8	34.40%	Moderately resistant to stem borer and thrips
C-20	Hraswa x IR60133-184-3-2-2	21.8 (2.1; 5.2)	0.601 (0.608; 0.353)	120 (94; 102)	22 (13; 18)	14.7 (2; 1.6)	28.1 (29.3; 30.2)	110 (103; 122)	83 (70; 84)	LB	R (R,W)	27.6 (20.7;20.9)	3 (2.5;3.0)	12	34.40%	Tolerant to stem borer and thrips
C-34	Karthika x Bhadra	22.7 (3.0; 3.0)	0.594 (0.439; 0.347)	224 (117; 98)	28 (22; 17)	10.2 (1.5; 1.9)	26.1 (30.9; 24)	124 (128; 133)	88 (93; 85)	LB	R (R,R)	24.2 (23.6;20.1)	3 (2;2)	27	34.40%	Susceptible to stem borer and thrips
C-84	PK3355-5-1-4 x Kachensiung Sen Yu 338	31.2 (7.6; 11.5)	0.639 (369; 0.381)	201 (112; 142)	28 (18; 25)	10.7 (2.9; 2.6)	26.4 (24.7; 30.0)	113 (121; 121)	85 (79; 132)	LB	R (W, W)	22 (24.5;12.4)	3.1 (3.0;2)	14	34.40%	Tolerant to stem borer and thrips
C-50	Kachensiung Sen Yu 338 x Mattatriveni	20 (11.5; 8.2)	0.531 (0.381; 0.553)	154 (142; 114)	30 (25; 21)	11.1 (2.6; 1.4)	28.1 (30.0; 27.2)	111 (121; 114)	95 (132; 84)	LB	R (W, R)	24.7 (12.4;25.8)	3.1 (2:2.5)	18	34.40%	Tolerant to stem borer and thrips

Figures in paranthesis correspond to that of female parent and male parent LB = Long Bold R = Red W = White

C-7	Mattatriveni x IR36	1
C-17	Hraswa x Vytilla 3	1
C-19	Hraswa x IR62030-18-2-2	1
C-24	Mahsuri x Hraswa	1
C-26	Mahsuri x Vytilla 3	2
C-27	Mahsuri x Kachsiung Sen Yu 338	1
C-28	Mahsuri x IR36	1
C-29	Mahsuri x IR62030 - 18 - 2 - 2	1
C-30	Mahsuri x IR60133 - 184 - 3 - 2 - 2	2
C-31	Mahsuri x PK3355 - 5 - 1 - 4	2
C-35	Karthika x Hraswa	1
C-40	Karthika x IR60133 - 184 - 3 - 2 - 2	1
C-42	Vytilla 3 x Mattatriveni	3
C-52	Kachsiung Sen Yu 338 x Hraswa	1
C-54	Kachsiung Sen Yu 338 x Vytilla 3	1
C-57	IR36 x Mattatriveni	1
C-80	PK3355-5-1-4 x Bhadra	1
C-81	PK3355-5-1-4 x Hraswa	1
C-82	PK3355-5-1-4 x Karthika	1
C-83	PK3355-5-1-4 x Vyttila 3	1

Discussion

5. DISCUSSION

Improvement over existing varieties is a continuous process in plant breeding. Any successful hybridization programme for varietal improvement depends mainly on the selection of parents having genetic variability, so that the desirable character combinations may be selected for higher grain yield. Thus the genetic diversity in breeding for higher productivity has obvious importance. The estimates of correlation coefficients and path coefficients are necessary pre-requisites in formulating a successful breeding programme. For improvement of any plant character through hybridization, it is necessary to understand the nature of gene action and genetic architecture of the donor parents for that character. With this objective of developing a plant type of high yielding and acceptable quality, an attempt has been made through variability study, character association study, genetic diversity analysis, diallele analysis, line x tester analysis and generation mean analysis. The results are discussed below.

5.1 Experiment No.1

5.1.1 Genetic variability

The analysis of variance showed highly significant differences among the genotypes for all the characters suggesting the presence of substantial genetic variability among the genotypes. The wide range of variation noticed in all the characters confirmed that the materials selected were genetically diverse and thus were appropriate for the study. Variability for different characters was previously observed by several workers like Govindaswami *et al.* (1973), Lal *et al.* (1983), Singh *et al.* (1984), Sardana and Sasikumar (1987), Chaubey and Richharia (1990) and Gomathinayagam *et al.* (1990) for number of days to 50 percent flowering, number of earbearing tillers plant^{-1}, plant height, panicle length, number of grains panicle^{-1}, 1000 grain weight, grain yield plant^{-1}, leaf angle, number of secondary branches panicle^{-1} and for harvest index.

Rice with low amylose is moist and chewy when cooked, while high amylose rice cooks dry, fluffs and readily hardens upon cooling. Preference for varieties with different amylose contents varies widely from region to region. By and large, rice varieties with intermediate amylose content are preferred in South and South East Asia and the world's major import market (Chauhan and Nanda, 1983). Therefore, breeding for superior genotypes having intermediate amylose content, and high yield potential should be the strategy for a successful breeding programme suitable for South and South East Asia. Large variability for gelatinization temperature and amylose content observed in the present investigation was in agreement with the findings of Sadananda *et al.* (1987). Among 27 high yielding genotypes of Kerala included in the present study the varieties namely Asha, Athira, Bhadra, Jaya, Jayathi, Kairali, Mahsuri and Ranjini have intermediate level of amylose content which are preferred more in cooking qualities than the rest.

5.1.1.1 Effect of parboiling and milling on amylose content and alkali spreading value

Increased percentage of amylose content in parboiled milled rice than in nonparboiled unmilled rice is due to the inclusion of bran in the estimation of amylose content in nonparboiled unmilled rice and may be due to some effect of parboiling, resulting in conversion of nondetectable starch to detectable starch. Increased alkali spreading score in parboiled milled rice showed the influence of parboiling on gelatinisation temperature. The separate effect of parboiling and milling on amylose content and alkali spreading value has to be studied.

The preferred level of amylose content and alkali spreading value in milled rice is 20-25 per cent and 3-4 respectively in south and south east Asian countries (Chauhan and Nanda, 1983). The present investigation suggests a decrease of 28.82 per cent in amylose content and a decrease of 73.82 per cent in alkali spreading score in nonparboiled unmilled rice.. Hence the preferred level of amylose content and alkali spreading score value in nonparboiled unmilled rice suggested to be 16 per cent to 20 per cent and 2 to 2.5 respectively.

Among the selected varieties for hybridisation, Bhadra and IR62030-18-2-2-2 suggested to be better in cooking qualities compared to others.

Unlike water absorption, high volume expansion on cooking has been considered for ages as one of the few best indices of consumer preference. More volume of cooked rice from a given quantity of rice is a matter of great satisfaction to the rice consumer, irrespective of the nature of expansion. Varieties showing volume expansion of 5.0 ml and above are considered desirable (Rao and Vasudevamurthy, 1952). Large variability for water uptake and volume expansion was reported by Hussain *et al.* (1987). But in the present study the range was not much wide and mean value was found to be below the desirable level.

In the present study seed coat colour and brown rice colour varied widely. These findings confirm the results of Hussain *et al.* (1987) and Chauhan *et al.* (1989). High variability for awning as evidenced in this study was also observed by Chauhan *et al.* (1989).

5.1.2 Genotypic and phenotypic coefficients of variation

High magnitude of PCV and GCV for quantitative characters namely, spikelet sterility percentage, grain yield hectare^{-1}, number of total tillers plant^{-1}, orientation of leaf, harvest index, number of tertiary branches panicle^{-1} and number of panicles m^{-2} and qualitative character alkali spreading value indicates the existence of large variability and scope of genetic improvement of these traits through selection. Similar results were also obtained by Shamsuddin (1986), Gomathinayagam *et al.* (1990) and Rao and Shrivastava (1994) for yield; Singh *et al.* (1984) and Patil *et al.* (1993) for number of panicles m^{-2}; Singh *et al.* (1984) and Chauhan *et al.* (1993) for spikelet sterility percentage and harvest index; Sharma and Dubey (1997) for grain yield and number of secondary branches panicle^{-1}. Moderate level of variability for quantitative characters namely, leaf area $plant^{-1}$ at maximum tillering stage, length of flag leaf, height of plant at harvest, ratio of vegetative phase to reproductive phase, second uppermost internodal length, number of panicle bearing tillers $plant^{-1}$, number of secondary branches $panicle^{-1}$, number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, 1000 grain weight and for qualitative traits like L/B ratio of grain, milling percentage, amylose content, water uptake and volume expansion, indicates the usefulness of these characters in rice improvement programme. Slightly deviating from this results, Sardana and Sasikumar (1987) and Chauhan (1996) reported high variability for plant height, 1000 grain weight and number of ear bearing tillers. Similarly Rao and Shrivastav (1994) observed high variability for number of grains $panicle^{-1}$ and number of spikelets $panicle^{-1}$. Qualitative characters like water uptake and volume expansion expressed high genotypic and phenotypic variability which is in agreement with the reports of Hussain *et al.* (1987). Low variability for quantitative characters namely, number of days to panicle initiation, number of days to 50 per cent flowering, maximum width of flag leaf, number of days to harvest, uppermost internodal length and length of panicle and for qualitative characters namely, grain length, grain breadth, hulling percentage and kernel elongation, reflects little possibility of improving these characters through selection. Similar findings of low variability for number of days to 50 per cent flowering, number of days to maturity and panicle length were reported by Pathak and Patel (1989).

Considerable influence of environmental factors was observed in the case of leaf area $plant^{-1}$, orientation of leaf, number of total tillers $plant^{-1}$, number of panicle bearing tillers $plant^{-1}$, spikelet sterility percentage, harvest index and yield $hectare^{-1}$, as these characters showed high PCV than GCV. This is in agreement with the results of Sharma and Dubey (1997). Similarly Singh *et al.* (1986) reported higher PCV for number of total tillers plant^{-1} and yield plant^{-1}. Closeness between genotypic and phenotypic coefficients of variation observed in developmental characters like number of days to panicle initiation, number of days to harvest, ratio of vegetative phase to reproductive phase and for all qualitative characters except for amylose content and alkali spreading value, suggested that these characters might be less influenced by environmental factors as reported by Maurya *et al.* (1986).

5.1.3 Heritability

Knowledge of the heritable fraction of the variability enables the plant breeder to base selection on the phenotypic performances. In the present study quantitative characters namely, ratio of vegetative phase to reproductive phase, number of days to 50 per cent flowering, height of plant at harvest, number of days to panicle initiation, second uppermost internodal length, number of panicles m^{-2}, length of flag leaf, uppermost internodal length, 1000 grain weight, length of panicle, number of tertiary branches panicle^{-1}, number spikelets panicle^{-1}, number of total tillers plant^{-1}, yield hectare^{-1}, spikelet sterility percentage and number of grains panicle^{-1} and all the qualitative characters studied exhibited high degree of broad sense heritability. This result reveal that these characters are less influenced by environment and there could be greater correspondence between phenotypic and breeding values. Similar reports were also made by Singh *et al.* (1986), Kihupi and Doto (1989), Roy and Kar (1992) and Patil *et al.*(1993) for number of days to 50 per cent flowering and maturity, plant height, 1000 grain weight and number of grains panicle^{-1}; Anandakumar (1992) for plant height and length of flag leaf; Hussain *et al.* (1987) for water uptake and L/B ratio of grains and Chaubey and Richharia (1990) for yield plant^{-1}, number of spikelets plant^{-1} and panicle length. Moderate heritability estimate for number of panicle bearing tillers is in agreement with the result of Chaubey and Richharia (1990) and Roy and Kar (1992), but incontrary to the result of Kihupi and Doto (1989) who reported low heritability for this character. Roy and Kar (1992) reported moderate heritability for harvest index which is further confirmed by this investigation.

5.1.4 Genetic advance and Genetic gain

The heritability indicates only the effectiveness with which selection of genotype can be based on the phenotypic performance, but fails to show the genetic progress (Johanson *et al.*, 1955). High heritability does not, therefore, necessarily mean greater genetic gain. Genetic advance as the per cent of mean was calculated inorder to ascertain the relative utility of genetic gain. High expected genetic advance was observed for quantitative characters namely, spikelet sterility percentage, yield hectare^{-1}, number of total tillers plant^{-1}, orientation of leaf, number of tertiary branches panicle^{-1}, harvest index, panicles m^{-2}, height of plant at harvest, second uppermost internodal length, 1000 grain weight, number of spikelets panicle^{-1}, number of grains panicle^{-1}, length of flag leaf, ratio of vegetative phase to reproductive phase, leaf area plant^{-1} at maximum tillering stage and number of panicle bearing tillers plant^{-1} and for qualitative characters namely, alkali spreading value, water uptake per unit weight of uncooked rice, L/B ratio of grain, amylose content, milling percentage and volume expansion ratio. This indicates that considerable level of improvement could be achieved in these traits by selection from segregating population. Similarly moderate estimate of genetic advance was observed for quantitative characters like number of days to panicle initiation, number of days to 50 per cent flowering, maximum width of flag leaf, number of days to harvest, uppermost internodal length, length of panicle, number of secondary branches panicle^{-1} and qualitative characters namely, grain length, grain breadth and kernel elongation ratio. Out of quantitative and qualitative characters, only hulling percentage exhibited low expected genetic advance. High expected genetic advance was also reported by Singh *et al.* (1986), Reddy *et al.* (1988), and Rao and Shrivastav (1994) for plant height; Kihupi and Doto (1989) for spikelet sterility percentage and plant height; Singh *et al.* (1986) for 1000 grain weight, number of grains panicle^{-1} and orientation of leaf; Patil *et al.* (1993) and Rao and Shrivastav (1994) for yield m^{-2}, number of grains panicle^{-1} and panicles m^{-2}; Rao and Shrivastav (1994) for number of panicle bearing tillers plant^{-1} and number of spikelets panicle^{-1}. In contrast to moderate expected genetic advance exhibited by panicle length in this study Mehetre *et al.* (1994) reported high expected genetic advance for this character.

According to Panse (1957) a high heritability value does not necessarily, lead to a high genetic gain. If the heritability was mainly due to the non-additive genetic effects (dominance and epistasis), the expected genetic gain would be low and when it was chiefly due to the additive gene effects, a high genetic advance would be expected. In the present investigation regarding the quantitative characters, number of panicles m^{-2}, number of tertiary branches $panicle^{-1}$, number of total tillers $plant^{-1}$, yield $hectare^{-1}$ and spikelet sterility percentage and qualitative character alkali spreading value, the heritability estimate (broad sense) was high coupled with a high expected genetic gain and high genotypic coefficient of variation. Similar results for number of grains $panicle^{-1}$ and yield were reported by Bhattacharyya (1978), Shamsuddin (1986), Remina *et al.* (1992) and Ganesan *et al.* (1995) and for alkali spreading value by Chauhan and Nanda (1983). Sardana *et al.* (1989) observed high heritability coupled with low genetic advance for panicles m^{-2} which is in contrast with the present result. High heritability and high expected genetic gain coupled with moderate GCV were exhibited by height of plant at harvest, second uppermost internodal length, length of flag leaf, ratio of vegetative phase to reproductive phase, number of spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ and quality characters like L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake per unit weight of uncooked rice. Similar results for plant height was reported by Remina *et al.* (1992). These results suggest that quantitative characters namely, number of panicles m^{-2}, number of tertiary branches $panicle^{-1}$, number of total tillers $plant^{-1}$, yield $hectare^{-1}$, spikelet sterility percentage, height of plant at harvest, second uppermost internodal length, length of flag leaf, number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$ and ratio of vegetative phase to reproductive phase and qualitative characters namely, alkali spreading value, L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake per unit weight of uncooked rice are under additive gene effects and hence could be relied upon for further improvement in yield through selection based on phenotypic performance. Similar results of high estimate of heritability coupled with high expected genetic advance were observed by Chaubey and Richharia (1990) for plant height and number of spikelets panicle^{-1}, Pathak and Patel (1989) and Roy and Kar (1992) for plant height and 100 grain weight; Singh *et al.* (1984) for plant height, number of grains panicle^{-1}, spikelet sterility and yield hectare^{-1} and Hussain *et al.* (1987) for water uptake and L/B ratio. Deosarkar (1989) reported high heritability coupled with moderate to low expected genetic gain for volume expansion and L/B ratio and high heritability and expected genetic gain for amylose content. High heritability estimate with low GCV estimate and moderate estimate of expected genetic advance were observed for the characters number of days to panicle initiation, number of days to 50 per cent flowering, number of days to harvest, uppermost internodal length and length of panicle, which might be due to the variation in environmental components involved with these traits. Similar results were observed for number of days to 50 per cent flowering by Mehetre *et al.* (1994); for panicle length and number of days to 50 per cent flowering by Chakraborty and Hazarika (1994). The present result of high heritability coupled with moderate expected genetic advance and low GCV for grain length, grain breadth and kernel elongation ratio is in agreement with the results of Hussain *et al.* (1987). High heritability and the moderate estimate for GCV and moderate expected genetic advance exhibited for the character namely, number of secondary branches panicle^{-1} suggest that this character also is an important component of yield as has been reported by Ramalingam *et al.* (1994).

Moderate to high GCV and high expected genetic advance along with moderate heritability estimate were observed for the characters namely, number of panicle bearing tillers plant^{-1}, leaf area plant^{-1} at maximum tillering stage, harvest index and orientation of leaf, which indicates that additive and non-additive gene effects are equally important in the inheritance of these characters. Chauhan *et al.* (1993) also have reported high heritability and high genetic gain for harvest index. Low value for GCV and moderate value for heritability and expected genetic advance were observed for the characters, namely, maximum width of flag leaf, which indicates the scope for improving this character through selection seems to be very meagre.

For the character, hulling percentage, the heritability value was high coupled with its lower estimate of GCV and expected genetic advance. This shows that the heritability of this character was mainly due to the non-additive genetic effects (dominance and epistasis) as suggested by Panse (1957). Because of this inheritance pattern, straight selection based on this character is unlikely to succeed. However, this character can be improved through hybridization and selection.

In general the quantitative characters namely, panicles m^{-2}, number of tertiary branches panicle^{-1}, number of total tillers plant^{-1}, yield hectare^{-1}, spikelet sterility percentage, height of plant at harvest, second uppermost internodal length, length of flag leaf, ratio of vegetative phase to reproductive phase, number of spikelets panicle^{-1} and number of grains panicle^{-1} and among qualitative characters alkali spreading value, L/B ratio of grain, water uptake, amylose content, milling percentage and volume expansion ratio, provide a good base for selection as they are controlled by genes with additive effects.

5.1.5 Correlation

Studies on association of characters gain importance in plant breeding, because they aid the plant breeders to know the inter-character influence and help to strike economic and reliable balances between various characters. More over genotypic correlations have their own importance because of their stability and reliability as these relationships arise through genetic reasons namely, linkage or pleiotropy. Since yield is a complex character, the practice of unilateral selection often results in retrograde or less optimum progress in isolating superior genotypes. Therefore the knowledge of inter relationships of characters, plays a vital role in developing appropriate selection criteria for the improvement of complex characters like grain yield. The results of correlation studies between grain yield per hectare and twentynine yield components are discussed below.

Among the correlation coefficients of 29 characters with grain yield, for the characters uppermost internodal length, total tillers plant^{-1}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1} length of panicle, kernel elongation ratio and water uptake of grain, the phenotypic correlation coefficients were higher than genotypic correlation coefficients, which indicates the influence of environment on these characters. Out of 29 characters only seven yield components namely, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight and harvest index were significantly correlated with yield at genotypic and phenotypic levels. Three characters namely, number of days to 50 per cent flowering, number of days to harvest and spikelet sterility percentage exhibited significant correlations only at genotypic level. This suggests that the influence of environment on these characters is very high. Genotypic correlation coefficients are discussed in detail.

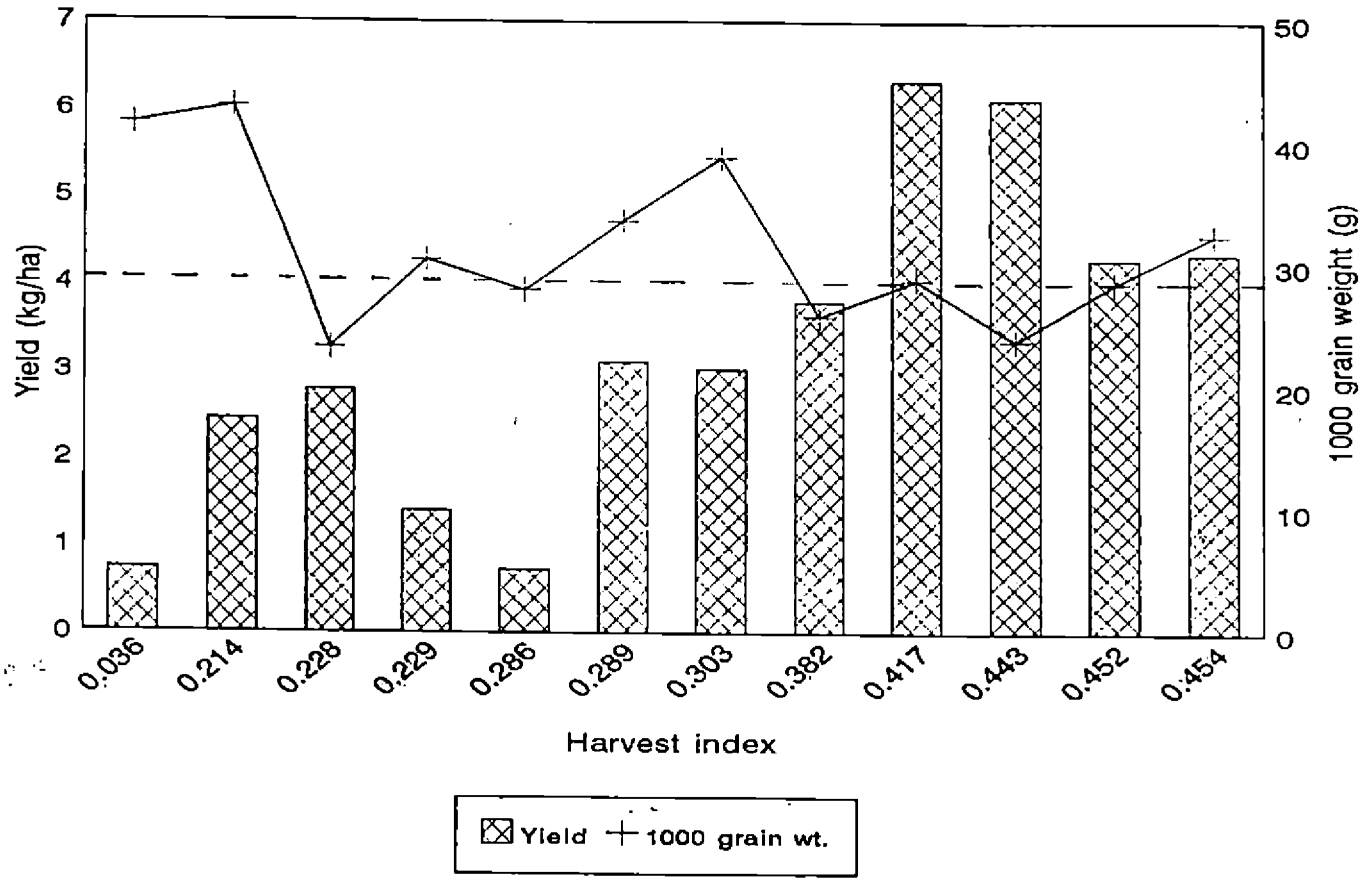
The highest significant positive genotypic correlation of yield was with harvest index. This was followed by the correlations of the characters, namely, number of panicles m^{-2}, ratio of vegetative phase to reproductive phase, number of grains panicle^{-1}, number of tertiary branches panicle^{-1} and number of spikelets panicle^{-1} and significant negative correlations of 1000 grain weight, number of days to 50 per cent flowering, number of days to harvest and spikelet sterility percentage with grain yield. This reveals that improvement in grain yield per hectare could be achieved by exercising selection simultaneously for increased harvest index, increased number of panicles m^{-2}, increased vegetative phase, increased number of grains panicle^{-1}, increased number of spikelets panicle^{-1} and reduced 1000 grain weight, early flowering and maturing and decrease in spikelet sterility percentage. The above results were in agreement with the reports of Xiang *et al.* (1986), Lu *et al.* (1988), Wada (1991), Katoch *et al.* (1993) and Chauhan (1996) for harvest index; Singh *et al.* (1984), Panwar *et al.* (1989) and Reuben and Kisanga (1989) for number of panicles m^{-2}; Bhattacharyya (1981) and Panwar *et al.* (1989) for grains panicle^{-1} and spikelets panicle^{-1}; Dhanraj *et al.* (1987), Lu *et al.* (1988), Paramasivan (1988), Paramasivan and Rangasamy (1988a), Bai *et al.* (1992), Reddy and Nerkar (1992), Rosamma *et al.* (1992), Arumugachamy *et al.* (1993), Katoch *et al.* (1993), Manuel and Rangasamy (1993) and Ramalingam *et al.* (1995) for grains panicle^{-1}; Sharma and Choubey (1985), Prasad *et al.* (1988), Chaubey and Richharia (1990) and Chauhan (1996) for number of spikelets.panicle^{-1}; Mehetre *et al.* (1994) for days to 50 per cent flowering and days to maturity; Dhanraj *et al.* (1987) for days to 50 per cent flowering and Amirthadevarathinam (1983a) for days to ripening; Bhattacharyya (1980), Singh *et al.* (1984) and Prasad *et al.* (1988) for spikelet sterility. The negative significant correlation of 1000 grain weight with yield observed in the present study confirmed the finding of Rather *et al.* (1997). In contrary to this result several scientists namely, Shamsuddin (1986), Prasad *et al.* (1988), Pathak and Patel (1989) Malik *et al.* (1990), Paramasivan (1991) and Ramalingam *et al.* (1995) had observed positive significant correlation of 1000 grain weight to grain yield.

The high degree of significant positive association both at phenotypic and genotypic levels between harvest index and grain yield suggest that harvest index is a highly reliable component of yield and can very well be utilized as an yield indicator in yield trials. The strong and negative correlations of days to flowering and maturity with grain yield, suggest the possibility of developing high yielding genotypes coupled with earliness. The high positive significant association of ratio of vegetative phase to reproductive phase indicates the favourable influence of delayed panicle initiation on grain yield. The negative influence of days to 50 per cent flowering and positive influence of days to panicle initiation reveal the negative influence of days from panicle initiation to 50 per cent flowering. This also suggests that while making selections for yield, one must go for varieties which have high efficiency of transportation of photosynthates from the source to the sink between panicle initiation and 50 per cent flowering. The correlation of 1000 grain weight to panicles m^{-2} and final yield was negative, while the correlation between panicles m^{-2} and yield was positive. This points to the fact that while selecting for yield we should go for an optimum level of grain weight. The significant positive correlation of number of spikelets $panicle^{-1}$ with number of grains $panicle^{-1}$ and significant negative correlation of number of spikelet $panicle^{-1}$ with spikelet sterility percentage clearly suggest that during selection, we must go for higher number of spikelets $panicle^{-1}$ with reduced spikelet sterility percentage. The higher significant positive correlation of number of tertiary branches $panicle^{-1}$ with yield reveals the role of panicle compactness in determining higher grain yield potential.

In the present study, absence of significant correlation of the important quality characters namely, amylose content and alkali spreading value with yield suggests that these characters can be recombined as desired.

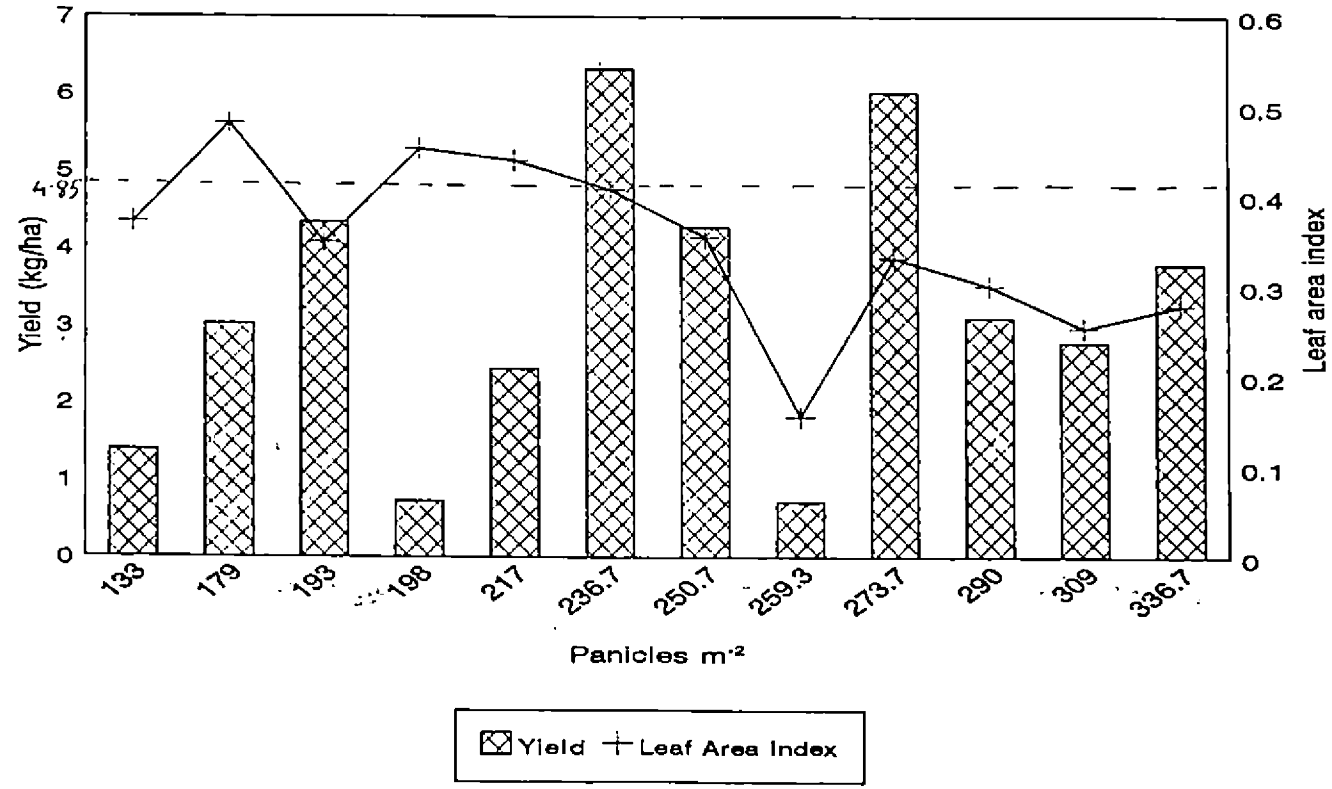
Inter correlations among yield components revealed that heavy selection pressure on high harvest index would bring forth correlated response for desirable characters such as high ratio of vegetative phase to reproductive phase, high number of panicles m^{-2} and high L/B ratio of grain and short second uppermost internodal length, reduced number of days to 50 per cent flowering and reduced number of days to harvest, short stature of plant, low spikelet sterility, decrease in grain breadth and optimum 1000 grain weight. From Fig.1 it is evident that, if we are giving importance to both harvest index and 1000 grain weight, the optimum value for them would be between 0.417 and 0.452 for harvest index and 28.89 g for 1000 grain weight, for a higher yield of 4700 kg ha^{-1}. Negative significant correlation between harvest index and plant height was also reported by Chauhan *et al.* (1993). Similarly significant positive inter correlations of number of panicles m^{-2}, ratio of vegetative phase to reproductive phase with different yield components reveal that selection for high harvest index and reduced number of days to 50 per cent flowering and reduced number of days to harvest will bring forth correlated response for higher number of panicles m^{-2} and high ratio of vegetative phase to reproductive phase which are highly correlated with yield. The positive significant correlations between number of panicles m^{-2} and number of productive tillers $plant^{-1}$ and L/B ratio of grain indicate that for slender grained genotypes there will be more number of panicles m^{-2} and more number of effective tillers $plant^{-1}$. The significant negative correlations of panicles m^{-2} with second uppermost internodal length, height of plant and leaf area per plant at maximum tillering stage reveal that, increased height, lengthier second internod and higher leaf area $plant^{-1}$ at maximum tillering stage will lead to reduced number of panicles m^{-2} which in turn will reduce the grain yield. Similarly reduced panicles m^{-2} for wider and heavy grained genotypes was evident from their negative significant intercorrelation coefficients as reported by Takita (1986). The intercorrelations of 1000 grain weight with various characters suggest that selection for heavy grains, should be based on long duration, tall plants with long second uppermost internode

Fig.1 Graphical representation of association between 1000 grain weight, harvest index and yield ha^{-1} of selected 12 genotypes



and slender wider grains with reduced shape, reduced harvest index and reduced number of panicles m^{-2}. Awan and Cheema (1986) also reported positive correlation of 1000 grain weight with plant height and uppermost second internodal length, but Gomathinayagam (1988) was of the the opinion that there was a negative correlation between 1000 grain weight and duration of crop. The present findings of positive association of grain length with 1000 grain weight is in agreement with the results of Hussain *et al.* (1987) and De and Rao (1988). Negative association of grain shape with 1000 grain weight observed in the present investigation is contrary to the result of Hussain *et al.* (1987) who reported positive association between these two traits. The positive significant intercorrelations among number of grains $panicle^{-1}$, number of spikelets $panicle^{-1}$, uppermost internodal length, leaf area $plant^{-1}$ at maximum tillering stage, number of tertiary branches $panicle^{-1}$ and panicle length reveal the efficient source sink relationship. But in the light of negative correlation of panicle m^{-2} with leaf area $plant^{-1}$ at maximum tillering stage, it can be suggested an optimum leaf area $plant^{-1}$ (Fig.2) at maximum tillering stage will increase sink size. Similar inter correlations were earlier reported by Bhattacharyya (1980) between spikelets $panicle^{-1}$, grains $panicle^{-1}$, panicle length and plant height; Singh (1980), Mehetre *et al.* (1994) and Dssawant (1995) between grains $panicle^{-1}$, panicle length and plant height; Bhattacharyya (1981) and Prasad *et al.* (1988) between spikelets $panicle^{-1}$ and grains $panicle^{-1}$; Malik *et al.* (1990) and Manuel and Rangaswamy (1993) between grains $panicle^{-1}$ and plant height. From Fig.2, it is clear that if we are giving importance to both panicles m^{-2} and leaf area index at maximum tillering stage, the optimum value for them would be 236.7 and 0.408 (122.4 cm^2 leaf area $plant^{-1}$) respectively for an optimum yield of 4850 kg ha^{-1}. Reddy and Nerker (1992)

Fig.2 Graphical representation of association between Leaf Area Index, panicles m^{-2} and yield ha^{-1} of selected 12 genotypes



observed a positive significant correlation between grains panicles^{-1} and panicle length. The negative significant association of days to 50 per cent flowering and days to harvest with ratio of vegetative phase to reproductive phase and the number of panicles m^{-2} again emphasis the need for selection for early duration varieties, with longer days for panicle initiation and short period from panicle initiation to flowering. The negative significant association of duration of crop with total number of tillers and number of panicle bearing tillers plant^{-1} was also observed by Gomathinayagam (1988). The negative trend of height at harvest with yield and its positive association with yield reducing characters like 1000 grain weight, duration of the crop along with negative association with yield attributes namely, number of panicles m^{-2} and harvest index indicate that while selecting for higher yield one must go for semidwarf plant type.

From the genotypic and phenotypic correlation coefficients it was evident that second uppermost internodal length ($r_g = 0.891^{**}$, $r_p = 0.865^{**}$) plays a higher role as compared to uppermost internodal length ($r_g = 0.306^{*}$, $r_p = 0.316$) in determining height of the plant. Intercorrelations of panicle length with other yield components reveal that when panicle length increases number of spikelets panicle^{-1}, number of grains panicle^{-1} and number of tertiary branches panicle^{-1} increase, which have positive significant correlation with yield. Hence, eventhough panicle length had no direct significant correlation with yield it has significant indirect influence on yield. Negative correlation between panicle length and grain breadth indicates that wide grains and short panicle length are associated characters. The correlation coefficients of grain length and grain breadth with 1000 grain weight (r = 0.433**) suggest that both slenderness and boldness play equal role in determining weight of grain. Jun (1985) reported positive significant association of grain length with grain weight. Amylose content exhibited positive and significant correlation with second internodal length which inturn was highly correlated with plant height. Positive trend in the association between plant height and amylose content was also reported earlier by Chauhan and Nanda (1983).

Genotypic correlations among physico-chemical characters (grain length, grain breadth, L/B ratio of grain, hulling percentage, milling percentage) and cooking qualities (amylose content, alkali spreading value, kernel elongation ratio, volume expansion ratio and water uptake) were separately studied. The positive significant correlation of grain length with L/B ratio of grain and negative significant correlation with grain breadth indicate that when size of grain increases its shape will also increase but there will be reduction in boldness. These results are in agreement with the results of Hussain *et al.* (1987). The positive significant association of grain length and shape of grain with milling percentage and negative significant correlation of grain breadth with milling percentage indicate that longer grained types are better than wider grained ones, for higher milling recovery. Chauhan *et al.* (1995) reported that there was no relationship between kernel shape and milling recovery. Hulling and milling recovery were not influenced by amylose content and alkali spreading value. This result is in conformity with the results of Hussain *et al.* (1987).

Positive correlation of amylose content with water uptake, volume expansion and alkali spreading value indicate that high amylose type rice varieties will absorb more water with low gelatinization temperature and will produce more volume of cooked material. Positive and significant correlation between amylose content and water uptake was also reported by Hussain *et al.* (1987), but Chauhan *et al.* (1995) reported negative association between these two traits. Madan and Bhat (1984) reported positive and significant association of amylose content with volume of cooked rice and water absorption. The negative significant correlation between grain length and amylose content, and absence of correlation between amylose content and grain breadth and L/B ratio, explain the reduced amount of amylose in slender grains. Kernel elongation ratio was found to be not related with either amylose content or alkali spreading value but related significantly and positively with volume expansion ratio and water uptake and negatively and significantly correlated with grain length. Alkali spreading value which is an indirect measurement of gelatinization temperature, showed significant positive association with amylose content which suggests that when amylose content of a variety increases its gelatinization temperature decreases. This is in agreement with the results of Tomar and Nanda (1981). Chauhan *et al.* (1994) observed positive non-significant association between these two traits. Contrary to present finding, Chauhan *et al.* (1995) reported significant negative association between amylose content and alkali spreading value. The negative significant association of alkali spreading value with grain length and the absence of association between alkali spreading value, grain breadth and shape of grain indicate that long grains have reduced amylose content and require more gelatinization temperature compared to bold grains. The observed positive significant association among water uptake, volume expansion and amylose content indicate that estimation of amylose content of the grain is a good method to determine cooking quality and consumer preference of Keralites. This was in conformity with the result of Tomar and Nanda (1982).

In breeding programmes to improve a number of traits simultaneously, a significant correlation of the traits with yield would be considered desirable. In the present study, the strong positive correlation of harvest index, number of panicles m^{-2}, ratio of vegetative phase to reproductive phase, number of grains $panicle^{-1}$, number of tertiary branches $panicle^{-1}$ and number of spikelets $panicle^{-1}$ and strong negative correlation of days to 50 per cent flowering, number of days to harvest and percentage spikelet sterility percentage with grain yield suggest that these are the principal yield determining attributes. The lack of association between amylose content and yield suggests that selection for both the characters together is possible. Correlation studies among physico-chemical and cooking qualities showed that amylose content was positively and significantly correlated with most of the cooking qualities and showed negative significant correlation with grain length. Hence selection for improved amylose content would result in correlated improved response in other cooking qualities.

5.1.6 Path analysis

Though the correlation studies are helpful in measuring the association between yield and yield components, they do not provide the exact picture of the direct and indirect causes of such associations which can be obtained through path analysis (Wright, 1923). Path analysis is very useful to pinpoint the important yield components which can be utilized for formulating selection parameters.

In the present study the path coefficient analysis performed, taking 10 quantitative yield components which were significantly correlated with yield at genotypic level, is discussed. The cause and effect relationship between yield and its 10 components is illustrated in Fig.3.

The very low residual effect obtained in path analysis indicates that the causative factors included in the analysis have been adequate to explain variability in yield. Thus 99.6 per cent variation in grain yield was contributed genotypically by the 10 yield components namely, number of days to 50 per cent flowering, number of days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, spikelet sterility percentage, number of grains $panicle^{-1}$, 1000 grain weight and harvest index. The highest positive direct effect was exhibited by harvest index. This was mainly due to the high positive significant correlation between harvest index and yield. The slightly diminished correlation coefficient of harvest index with yield compared to its high direct effect might be due to the combined effect of its negative indirect effect through days to harvest and positive indirect effect through days to 50 per cent flowering. Positive direct effect of harvest index was earlier reported by Liao and Liu (1983), Lu *et al.* (1988) and Katoch *et al.* (1993). Second highest positive direct effect on grain yield was contributed by the character namely, number of days to

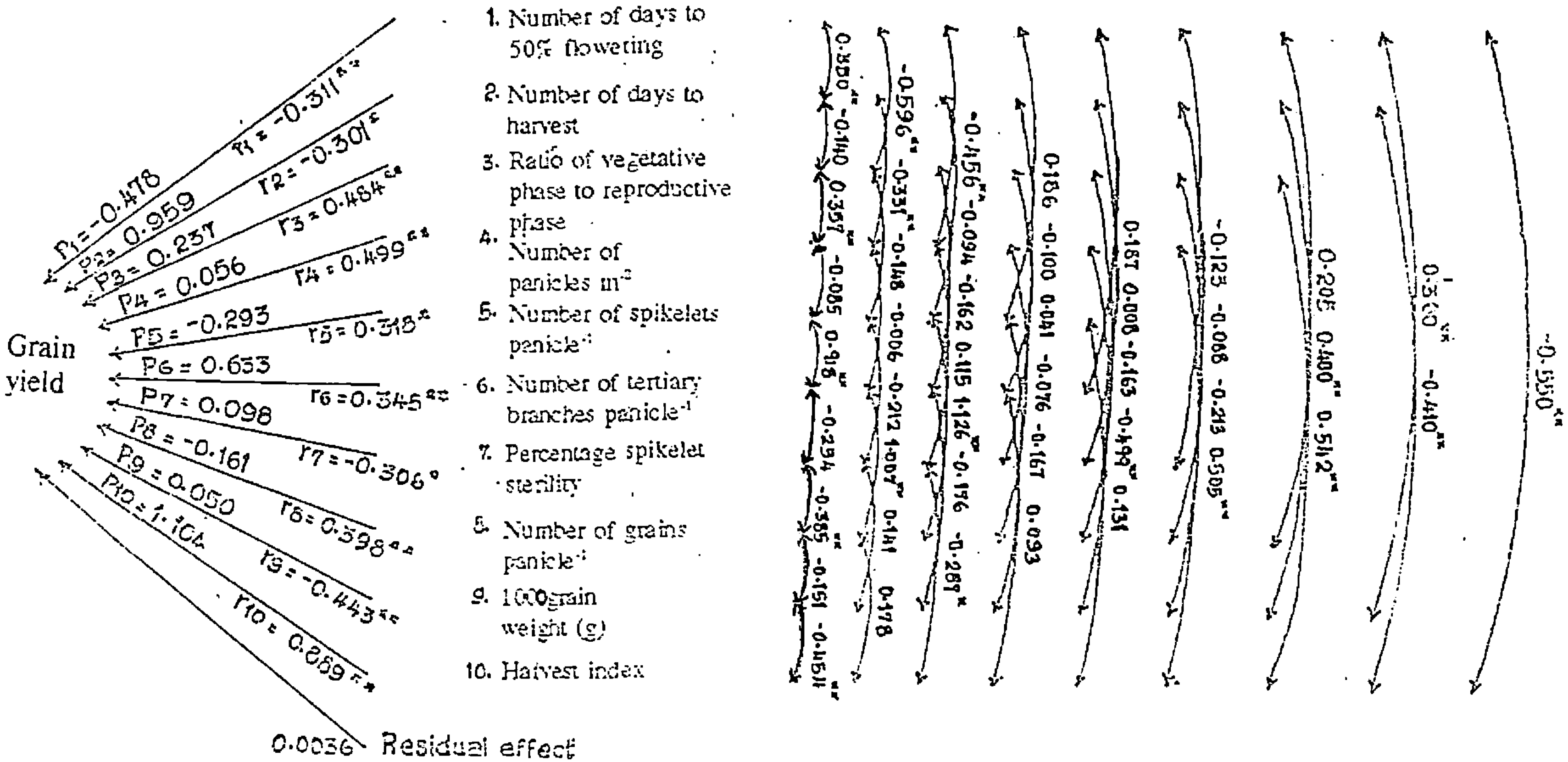


FIG. 3 PATH DIAGRAM CONSTRUCTED USING THE GENOTYPIC CORRELATION COEFFICIENTS AMONG YIELD AND TEN OF ITS COMPONENT TRAITS IN RICE

harvest. Further the negative indirect influence jointly exerted by number of days to 50 per cent flowering and harvest index was highly effective in cancelling out the large positive direct effect of days to harvest, leading to negative and significant association of this character with yield. High positive direct effect exerted by number of days to harvest on yield and at the same time its negative significant correlation with yield indicate that there should be an optimum number of days to harvest for maximising yield. Gomathinayagam (1988) reported positive direct effect of duration of crop, while Rather *et al.* (1997) observed negative direct effect for days to maturity. The negative indirect effects of number of tertiary branches panicle^{-1} through number of spikelets panicle^{-1} and number of grains panicle^{-1} resulted its reduced correlation with grain yield compared to its high direct effect. High positive direct effect and positive significant correlation of number of tertiary branches reflects the role of compact panicle for increased yield potential. The positive correlation of ratio of vegetative phase to reproductive phase with yield was expounded partly by its positive direct effect and partly by its positive indirect effect through days to 50 per cent flowering. The negative correlation obtained between days to 50 per cent flowering and yield was a reflection of its direct effect. Its high positive indirect influence through days to harvest was nullified mainly by its high negative indirect influence through harvest index. Negative direct effect and significant negative correlation of days to 50 per cent flowering suggest the importance of early flowering varieties. In contrary to this result Amirthadevarathinam (1983a), Sardana *et al.* (1989) and Rather *et al.* (1997) observed positive direct effect for days to 50 per cent flowering on grain yield. Significant positive correlation coefficient and positive direct effect of the character, namely, ratio of vegetative phase to reproductive phase and negative correlation and negative direct effect of days to 50 per cent flowering together with negative correlation and positive direct effect of days to harvest, reveal that for higher yield there should be a long vegetative phase (days for panicle initiation), early emergence of panicles (ie. short period from panicle initiation to flowering) which can be achieved through efficient translocation of photosynthates from source (leaf and culm) to sink (spikelets) and increased ripening period (period from flowering to harvest). The positive indirect contribution of spikelets panicle^{-1} and grains panicle^{-1} through tertiary branches panicle^{-1} were of such a magnitude that it led to a positive significant correlation with yield, though they exerted a negative direct influence on yield. These yield components, spikelets panicle^{-1} and grains panicle^{-1} showing positive genetic association with grain yield but exhibiting negative direct effect on yield was quite interesting. This may be due to genetic factors, influencing physiological causes and developmental sequences. These traits may not be also very much stable in expressivity and stability (Paramasivan and Rangasamy, 1988a). This result was in agreement with the results of Prasad *et al.* (1988) for spikelet panicle^{-1} and Panwar *et al.* (1989) and Rather *et al.* (1997) for grains panicle^{-1}. Positive direct effect of spikelets panicle^{-1} was earlier reported by Ghorai and Pande (1982) and Panwar *et al.* (1989) and for grains panicle^{-1} by Singh (1980), Gomathinayagam *et al.* (1988), Lu *et al.* (1988), Paramasivan and Rangasamy (1988a), Prasad *et al.* (1988), Malik *et al.* (1990), Krishnayya *et al.* (1991), Reddy and Nerkar (1992), Arumugachamy *et al.* (1993), Mehetre *et al.* (1994) and Dsswant (1995). Negative direct effect of number of spikelets panicle^{-1} and number of grains panicle^{-1} on grain yield and their high positive indirect effect on yield through tertiary branches panicle^{-1} indicate that, for yield improvement much weightage should be given for compact panicle with optimum number of spikelets panicle^{-1} and optimum number of grains panicle^{-1}. This was confirmed by the high correlation of spiklets panicle^{-1} and grains panicle^{-1}, with tertiary branches panicle^{-1}. The direct effect of 1000 grain weight showed the least path coefficient value followed by panicles m^{-2}. The significant negative correlation of 1000 grain weight with yield may therefore be ascribed to its negative indirect influence, through harvest index. 1000 grain weight had comparatively high positive indirect effect towards yield, through number of days to harvest and negative indirect effect through days to 50 per cent flowering, indicating that time taken for filling up of grains from flowering to harvest will increase the grain weight and grain yield. This was confirmed by the significant positive correlation of 1000 grain weight with days to harvest. Positive direct effect of 1000 grain weight along with its negative correlation with yield was earlier reported by Rather *et al.* (1997). Singh (1980), Sinha and Banerjee (1987), Paramasivan and Rangasamy (1988a), Prasad *et al.* (1988) and Dssawant (1995) also reported positive direct influence of 1000 grain weight on yield. The high positive correlation of number of panicles m^{-2} towards yield was not reflected as such in the direct effect, but it is reflected with higher positive indirect effect through harvest index. Spikelet sterility percentage exhibited low positive direct effect on yield compared to its significant negative correlation, which might be due to its high negative indirect effect mainly through harvest index.

Correlation and path analysis studies conducted in the present investigation reveal that, in yield improvement programmes of rice, breeder should give emphasis for high harvest index with optimum level of biomass, compact panicle with higher number of tertiary branches with optimum number of grains panicle^{-1} with optimum weight, optimum plant height, fully fertile optimum number of spikelets panicle^{-1}, early flowering with optimum crop duration, efficient translocation of photosynthates from source to sink, shorter duration for panicle emergence with long ripening period.

5.1.7 Selection index

Selection index is the best linear predictor of an individual's breeding value (Hazel, 1943). This technique provides information on yield components and thus aids in indirect selection for the improvement in yield. The yield is a complex character which often is the result of intrinsic response by component characters. Hence, the discriminant function analysis was carried out with a view to evolving a selection index for isolating superior genotypes from those tested. Based on genotypic correlations and direct effect of yield components on yield, nine simultaneous selection models were tried.

The selection index constituting 11 yield components, namely, yield ha^{-1}, days to 50 percentage flowering, days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, spikelet sterility percentage, number of grains panicle^{-1}, and harvest index were observed to have the maximum efficiency. But for making the selection procedures easier, a selection index is to be formulated with the minimum number of easily measurable characters. Hence, in this study a selection index was formulated, using the characters having high association with yield, namely, days to 50 percentage flowering, ratio of vegetative phase to reproductive phase, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, harvest index, and grain yield ha^{-1}, which had a gain in efficiency of 3.21 per cent over direct selection. By using the above selection model, the 10 genotypes recommended for yield improvement are Mattatriveni, IR62030-18-2-2, S9768-PN-25-1, AS2537C, IR50, Karthika, IR53970-21-2-3-2, IR54883-152-3-3, IR36, BR4689-17-1-5. The same genotypes also ranked the top ten based on yield alone, but there was difference in ranking order.

Hence, from the results of the selection index analysis carried out, in the present study, it can be concluded that in yield improvement programmes, in addition to yield hectare^{-1} we should give emphasis for the characters, namely, harvest index, days to harvest, number of tertiary branches panicle^{-1}, ratio of vegetative phase to reproductive phase and number of grains panicle^{-1}

5.1.8 Genetic diversity

Genetic improvement mainly depends upon the amount of genetic variability, present in the population. The more diverse the parents, the greater are the chances of obtaining higher amount of heterotic expression in F_1s and broad spectrum of variability in segregating generations.

5.1.8.1 Clustering

D^2 analysis employing a combined classificatory approach with respect to 36 different characters, revealed that the 56 strains, studied could be grouped into nine clusters. The clusters I, III, IV, VIII and IX included genotypes from different geographical regions. This leads to the inference that factors other than geographic diversity might be responsible for such grouping and there was no parallelism between geographical distribution and genetic diversity. It might perhaps be due to

(a) Free exchange of breeding materials from one place to other (Verma and Mehta, 1970).

(b) Varieties evolved under similar selection pressure will cluster together irrespective of their geographic origin (Singh and Bains, 1968) and

(c) Interaction of some similar genotypes at different places (Singh *et al.*, 1980a).

Similar observations of non-correspondence of genetic divergence and geographic diversity had been made by Singh (1983), Kotatah *et al.* (1986), De and Rao (1987), Pande and Ghorai (1987), Singh *et al.* (1987), Anandakumar and Subramanian (1989), Selvakumar *et al.* (1989), De *et al.* (1992), Kumar and Subramanian (1992), Roy and Panwar (1993), Vivekanandan and Subramanian (1993).

Genotypes from China, Bangladesh and India were scattered in different clusters. Murty and Arunachalam (1966) explained that such a wide adaptability could be possible due to reasons such as heterogeneity, genetic architecture of the populations, past history of the selection, developmental factors and degree of general combining ability. Hence, for pedigree breeding, intercrossing these groups of parents from the same geographic region which were divergent among themselves are more desirable than choosing the parents from other region (Kumar and Subramanian, 1992). In the present study varieties developed at the same location were found to be grouped in different clusters. For example, varieties developed at Monkombu Rice Research Station of Kerala were found to be grouped in clusters III, V and VI. These results confirm the earlier findings of Raut *et al.* (1985) who suggested that genetic drift and human selection could cause greater diversity than the geographic distance. It is, therefore, suggested that genetic diversity must form the sound basis for selection of parents for hybridization. Similarly, varieties Arathi, Aruna and Remya developed from same pedigree were found to be scattered in three different clusters. Similar results were reported by Kotatah *et al.* (1986), Selvakumar *et al.* (1989) and Mall and Maurya (1992). But according to Bansal *et al.* (1990) clustering pattern was influenced by the pedigree of the breeding lines.

Out of the 12 IRRI cultures included in this study eight were found to be associated in a single cluster (cluster IV), showing similarity in their architecture. Similarly genotypes from Indonesia, were found to be grouped in a single cluster (cluster VIII), which indicates that, to some extent, genetic divergence was related to geographic divergence. Such parallelism were reported by Chatterjee *et al.* (1978) and Maharajan *et al.* (1987) in rice.

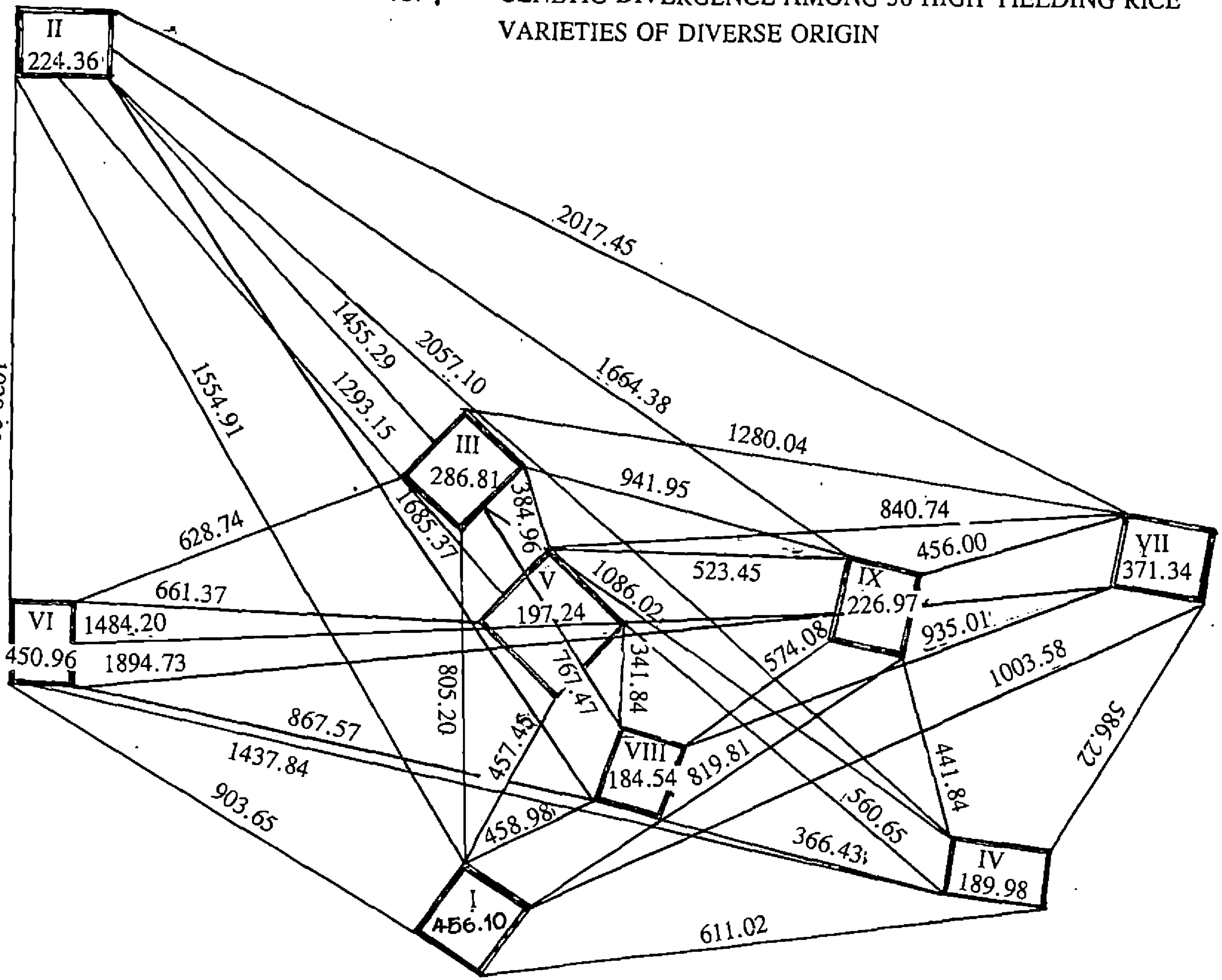
5.1.8.2 Inter and intra cluster distances

Estimates of intra and inter-cluster distances also led credence to the above conclusion. The statistical distances, represent the index of genetic diversity among clusters. The magnitude of heterosis was largely dependent on the degree of genetic diversity in the parental lines. The greater the distance between the clusters, the wider will be genetic diversity between the genotypes.

Spacial diagram of clusters and their mutual relationship is represented in Fig.4. Intra cluster D^2 distance was the minimum for the cluster VIII. Unidirectional selection, exercised in the past, would have resulted in uniform features with the consequence of less divergence between the genotypes. The maximum intra-cluster distance observed in cluster I, indicates that there existed wide genetic divergence among members. This could be made use of in yield improvement through combination breeding. Angadi (1976) reported that varieties in a cluster with high order of divergence among themselves would be the best breeding materials for achieving maximum genetic advance with regard to yield. Selection within a cluster, might also be exercised based on the highest mean performance of the varieties, for desirable traits, such as number of grains panicle^{-1} and productive tillers.

It was well established by several workers [Singh *et al.* (1987), De *et al.* (1988), Roy and Panwar (1993)] that the intercluster distance in D^2 analysis plays a key role in the selection of varieties, as parents, for hybridization. Varieties belonging to the clusters with maximum intercluster distances were obviously genetically more divergent. In the present study varieties in the clusters II (consisting of three varieties from Pokkali areas of Kerala in India) and IV (possessing eight genotypes from IRRI and one from India) were the most genetically divergent, followed by varieties in clusters II and VII. If crosses can be done using the above varieties, wider range of recombinants can be obtained. Genotypes of cluster II and VII eventhough were of the same geographic region, showed high intercluster distance. The above genotypes if used, in intercrossing, can result in wider range of recombinants. The highest divergence between clusters II and IV could be made use

FIG. 4 GENETIC DIVERGENCE AMONG 56 HIGH YIELDING RICE VARIETIES OF DIVERSE ORIGIN



of in heterosis as well as in recombination breeding. The least inter-cluster distance was registered between clusters V and VIII. Both these clusters, comprised high yielding strains originated in various geographical areas. This again supports, the fact that geographic distribution was not related to genetic diversity.

5.2 Experiment No. 2

5.2.1 Combining ability analysis

The success of a plant breeding programme, greatly depends on correct choice of parents for hybridization and the gene action of different economic traits. Combining ability analysis provides such information so as to frame the breeding programme effectively. Therefore in the present investigation combining ability analysis was undertaken to gather information on general combining ability (*gca*) effects, specific combining ability (*sca*) effects and reciprocal cross effects (*rca*) in relation to yield and yield components.

Twelve genetically diverse parents selected from nine clusters were subjected to 12 x 12 full diallel crosses. Out of 132 cross combinations carried out one cross combination namely IR60133-184-3-2-2 (Philippines) x S9768-PN-25-1 (Indonesia) failed to set seeds even after repeated crossing. This indicates the possibility for the existence of some degree of barriers in crossing at the level of geographical races. The seeds of ten cross combinations did not germinate, which may be due to endosperm abortion leading to zygotic lethality. Twenty five cross combinations did not sruvive beyond nursery stage. So the possibility of delicately balanced process of meiosis and gametogenesis leading to hybrid inviability acting in distant crosses cannot be ruled out.

5.2.1.1 General combining ability and specific combining ability

The results of 5 x 5 full diallel, 8 x 8 half diallel and 6 x 3 line x tester analyses are discussed together.

In all the three analyses, estimates of mean squares due to progenies were highly significant for all the 18 characters studied except for alkali spreading value in 5 x 5 full diallel analysis. This indicates the diversity among progenies. Further, analysis for combining ability revealed that mean squares due to general combining ability was highly significant for all characters, except for ratio of vegetative phase to reproductive phase and spikelet sterility percentage in 5 x 5 full diallel analysis and for ratio of vegetative phase to reproductive phase in 8 x 8 half diallel analysis and for eight characters in line x tester analysis. Similarly the mean squares due to specific combining ability was highly significant for all characters, except for ratio of vegetative phase to reproductive phase in 5 x 5 full diallel analysis. This suggests the importance of both additive and non-additive gene effects in the expression of characters namely days to 50 per cent flowering, days to harvest, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, number of grains $panicle^{-1}$, harvest index, 1000 grain weight, second uppermost internodal length, height of plant at harvest, leaf area $plant^{-1}$ at maximum tillering stage, length of panicle, L/B ratio of grain, amylose content and yield $plant^{-1}$. Hence any approach that facilitates simultaneous exploitation of additive and non-additive gene effects would be most desirable for the improvement of these traits. Perhaps diallel selective mating, recurrent selection and reciprocal recurrent selection might prove valuable, under such situation for the improvement of these characters.

The ratio of components of variance ($\hat{\sigma}^2_{gca}$/ $\hat{\sigma}^2_{sca}$) was found to be less than unity for all the characters in all the three types of analysises except for second uppermost internodal length, height of plant at harvest in full diallel analysis; for 1000 grain weight, second uppermost internodal length and height of plant at harvest in half diallel analysis and for amylose content in line x tester analysis. It is thus clear that although the mean squares for *gca*, which suggests of additive genetic variance, was significant, yet the dominant component may be predominant. Importance of both additive and non-additive gene effects with preponderance of non-additive gene action for yield and yield contributing characters were earlier reported by Singh *et al.* (1980b), Panwar *et al.* (1985), Singh and Singh (1985), Sarathe and Singh (1986), Sardana and Borthakur (1987), Ghosh and Hossain (1988), Peng and Virmani (1990a), Lokaprakash *et al.* (1991), Singh and Singh (1991), Manuel and Prasad (1992), Katre and Jambhale (1996), Sharma *et al.* (1996), Ganesan *et al.* (1997) and Rogbell and Subbaraman (1997) for the characters namely yield plant^{-1}, grains panicle^{-1}, 1000 grain weight, days to flowering, days to maturity, spikelet sterility percentage, harvest index, panicle length, height of plant, number of spikelets panicle^{-1}, L/B ratio of grain. Predominance of additive gene action for second uppermost internodal length, height of plant, 1000 grain weight and amylose content was clear from the ratio of components of variance which was greater than unity. It was further substantiated by the moderate to high narrow sense heritability for the characters second uppermost internodal length, height of plant at harvest and 1000 grain weight. This is in agreement with the reports of Kalaimani and Sundaram (1988a), Kaushik and Sharma (1988) and Lokaprakash *et al.* (1991) for the character plant height. The pronounced non-additive gene effects and moderate to high narrow sense heritability for yield plant^{-1} and the important yield components namely number of grains panicle^{-1}, number of spikelets panicle^{-1}, harvest index and L/B ratio of grain indicate the possibility of production of hybrids, if commercial seed production is feasible. For the development of lines reciprocal recurrent selection technique can be suggested. However, rice being a highly self pollinated crop forming single seed per pollination, this selection procedure is not practicable. So a possible choice is the use of biparental mating in early generations among selected crosses or use of selection procedure such as diallel selective mating (Jenson, 1970) to exploit both the additive and non-additive genetic components.

5.2.1.1.1 General combining ability

Among 12 parents taken for combining ability studies, the genotypes P_4 (Mahsuri), P_6 (Vytilla 3) and P_1 (Mattatriveni) were adjudged as good general combiners for grain yield (Table 35). Considering the total score for 18 characters, the parent P_5 (Karthika) recorded a high score of seven, followed by P_6 (Vytilla 3) and P_1 (Mattatriveni). Hence the genotype P_5 can also be considered as a good general combiner. Further it was found that P_4 (Mahsuri) was also a good general combiner for the character namely number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, reduced sterility percentage, amylose content and alkali spreading value. The parent P_6 (Vytilla 3) was found to be a good general combiner for the characters namely number of days to 50 per cent flowering (earliness), number of days to harvest (short duration), number of panicles m^{-2}, harvest index, 1000 grain weight, leaf area plant^{-1} at maximum tillering stage, length of panicle and amylose content. The parent P_1 (Mattatriveni) was a good general combiner for the characters namely number of days to 50 per cent flowering (earliness), number of days to harvest (short duration), harvest index, reduced second internodal length, height of plant (short stature) and amylose content. The parent P_5 (Karthika) is a good general combiner for number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, reduced sterility, harvest index, 1000 grain weight, leaf area plant^{-1} at maximum tillering stage, L/B ratio of grain and amylose content. Even though P_5 was an average combiner for yield, it was a good general combiner for nine yield components and average combiner for six yield components. Hence P_5 (Karthika) can be considered as the best general combiner followed by P_6 (Vytilla 3), P_4 (Mahsuri) and P_1 (Mattatriveni).

The good general combiners for different characters were P_6 and P_8 for number of panicles m^{-2}; P_4 and P_{11} for number of spikelets panicle^{-1}; P_4, P_5 and P_1 for number of tertiary branches panicle^{-1}; P_4 and P_5 for number of grains panicle^{-1}; P_4, P_7 and P_5 for reduced sterility; P_1, P_6, P_5 and P_3 for harvest index; P_6, P_5, P_7, P_3 and P_{11} for 1000 grain weight; P_9, P_1, P_3, P_{10}, P_8, P_7 and P_{12} for second uppermost internodal length (short); P_4, P_5, P_6 and P_{11} for leaf area Plant^{-1} at maximum tillering stage; P_4, P_6 and P_7 for length of panicle; P_9, P_5, P_4, P_{10}, P_8 and P_{11} for L/B ratio of grain; P_4, P_1, P_5 P_6, P_{11}, P_{12} and P_3 for amylose content and P_4 for reduced alkali spreading value.

Selection of parents for days to flowering and plant height depends upon the objectives and target environment the breeder has in mind. For drought proned and rainfed cropping situations earliness and short height are preferred, whereas for ill-drained and deep water situations generally late and taller varieties are suitable. For earliness, the parents P_1, P_6 and P_3 and for lateness the parent P_4 were the best general combiners. For short stature the parents P_9, P_3, P_8, P_1 and P_{12} and for tall stature the parents P_4 and P_6 were the best general combiners. Hence, in breeding programme for incorporating earliness and short stature together the parents P_1 (Mattatriveni) and P_3 (Hraswa) can be utilized. Similarly for tallness and late maturity together the parent P_4 (Mahsuri) is the best.

Relation between *per se* performance of parents and *gca* effect indicated that *Per se* performance and *gca* effect were not related for all characters as reported by Dhaliwal and Sharma (1990). Thus, the *gca* effects which reflect the breeding behaviour of an individual should be used as the criterion for the selection of parents in hybridization programme.

5.2.1.1.2 Specific combining ability

The specific combining ability of 55 hybrids which could be analysed through 5 x 5 full diallel analysis, 8 x 8 half diallel analysis and 6 x 3 line x tester analysis is discussed below.

The high specific combining ability (*sca*) mainly due to dominance and interaction effects existing between the hybridizing parents. Also, the two parents, if they carry different genes for the traits in question, will tend to complement each other and would produce hybrids of superior genetic constitution.

In the present study the crosses, P_6 x P_1, P_4 x P_5, P_5 x P_6, P_6 x P_8, P_6 x P_{10}, P_8 x P_1, P_{11} x P_3, P_{11} x P_2, P_5 x P_2, P_{12} x P_1 and P_4 x P_1 exhibited significant *sca* effects for the character yield plant^{-1}. The cross P_{11} x P_2 showed significant *sca* effect for 10 yield components out of 17 yield components studied; P_4 x P_1 showed significant *sca* effect for nine yield components; P_4 x P_5, P_8 x P_1 and P_{11} x P_3 showed significant *sca* effects for seven yield components; P_6 x P_8 and P_6 x P_{10} for six yield components and P_6 x P_1 and P_5 x P_6 for five yield components. The crosses P_5 x P_2 and P_{12} x P_1 showed significant *sca* effects for three and two yield components respectively. Thus the crosses which were high in *sca* effect for grain yield were also high in *sca* effects for most of the yield components.

Based on total score of *sca* effects considering yield and all yield components together (Table 36), the best hybrids were P_8 x P_1, P_{11} x P_2, P_4 x P_1, P_6 x P_{10}, P_4 x P_5, P_4 x P_6, P_7 x P_1, P_3 x P_1, P_{11} x P_7, P_5 x P_2, P_4 x P_7 and P_{11} x P_3 in the order of higher score. On the basis of *per se* performance for yield, the best crosses were P_6 x P_8, P_6 x P_{10}, P_{11} x P_2, P_6 x P_1, P_5 x P_2, P_4 x P_5, P_6 x P_7, P_8 x P_1, P_5 x P_6 and P_7 x P_6 in the order of performance. Best hybrids based on total *sca* score, based on *sca* effect for yield and based on *per se* performance are given in Table 38. From the table, the crosses namely P_6 x P_{10}, P_{11} x P_2, P_5 x P_2, P_4 x P_5 and P_8 x P_1 were found common in the list based on total *sca* score, *sca* effect for yield and based on *Per se* performance for yield. Based on *sca* effect for yield and *per se* performance for yield, in addition to the above mentioned crosses, the crosses namely P_6 x P_1, P_5 x P_6 and P_6 x P_8 were also found common. Hence, the hybrids namely P_6 x P_{10}, P_{11} x P_2, P_5 x P_2, P_4 x P_5, P_8 x P_1, P_6 x P_1, P_5 x P_6 and P_6 x P_8 may prove to be important crosses for hybrid seed production in this tract, subject to incorporation of male sterility and fertility restoration system in an effective manner.

Both parents of the crosses P_6 x P_1 and P_4 x P_1, which recorded favourable *sca* effect for yield, showed high *gca* effect for yield plant^{-1} and for most of the yield contributing traits. These two crosses have desirable *sca* effects for most of the yield contributing traits also. In these two crosses, heterosis was developed from high x high combiners. This may be due to the interaction between positive and positive alleles from both parents (additive x additive type gene interaction) and hence can be fixable in subsequent generations, provided no repulsion phase linkages are involved. Hence these two crosses may be utilized for hybrid seed production programme and also for different selection procedures to get the desirable recombinants. In otherwords, some useful transgressive segregants can be expected from the segregating population of the two crosses as suggested by Peng and Virmani (1990a). This will help in both fixing and increasing the frequency of pleiotropic genes and chromosome blocks of favourably linked genes in superior lines. The high yield potential on the basis of *sca* effect in the cross combination P_6 x P_{10} evolving from high x low combiners, was attributed to interaction between positive alleles from a good combiner and negative alleles from a poor combiner (Peng and Virmani, 1990a). The high yield from such crosses would be unfixable in subsequent generations. Dominant x recessive type of interaction might have yielded this combination with non-additive, non-fixable genetic component for grain yield. This particular cross was a good cross combination for six yield components also. Hence, this cross would serve as a source population for producing transgressive desirable early segregants in later generations and could be exploited by sibmating followed by selection among the segregants. In the case of crosses P_4 x P_5, P_5 x P_6, P_6 x P_8, P_8 x P_1 and P_{12} x P_1 which were good specific combinations for yield were having at least one parent with good general combining ability for yield plant^{-1}. It was found that the cross P_8 x P_1 was a good cross combination for seven yield components, P_6 x P_8 for six yield components, P_5 x P_6 for four yield components and P_{12} x P_1 for two yield components. Hence these crosses might result in desirable segregants. Biparental mating and selection procedures may result in rapid gain. Both parents of the cross P_4 x P_5 were good general combiners for the characters namely number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, leaf area plant^{-1} at maximum tillering stage and L/B ratio of grain. The parent P_8 was a good general combiner for the character number of panicles m^{-2} and medium combiner for the characters namely, yield plant^{-1}, number of days to 50 per cent flowering, number of days to harvest, spikelet sterility percentage, harvest index, leaf area plant^{-1} at maximum tillering stage, amylose content and alkali spreading value. The crosses P_{11} x P_3, P_{11} x P_2 and P_5 x P_2 evolved from medium x medium combiners for yield plant^{-1} were desirable crosses for yield plant^{-1} on the basis of *sca* effect. The superiority of medium x medium combination might be due to the concentration of genes and interaction between favourable genes contributed by the parents. Among the parents of the above three crosses, the parent P_5 even though a medium general combiner for yield, was a good combiner for nine important yield components. Similarly the parents P_{11} was a good general combiner for five and the parent P_3 for four yield components. The parent P_{11} was a medium general combiner for all the remaining characters. Hence the possibility of getting good segregants from the above crosses is high.

The best cross combinations for different yield components on the basis of *sca* effect are presented in Table 34.

The cross P_6 x P_7, is one of the good combinations on the basis of *per se* performance but its *sca* effect was non-significant. One of the parents of this cross (P_6) is a good general combiner and the other an average general combiner for yield $plant^{-1}$. So from this cross the possibility of getting good segregants is bleak. The high *per se* performance may be due to environmental influence. The cross P_4 x P_6 was an average cross combination based on *sca* effect for yield $plant^{-1}$. But it was a good cross combination for almost all the favourable yield components (Table 37). Besides, both the parents of this cross were good general combiners for yield and most of the yield contributing characters. This indicates that parents with high *gca* effects will not necessarily generate top specific hybrid combinations as suggested by Peng and Virmani (1990a). This may be due to the fact that all the genes may not be acting purely additively in one of the parents or in both the parents. Hence this cross also can be used for both hybrid seed production programme and for pedigree selection programme with more suitability for the latter.

Out of 11 crosses identified as desirable for yield $plant^{-1}$ on the basis of their *sca* effects, four crosses were evolved from high x medium combiners, four from medium x medium combiners, two from high x high combiners and one from high x low combiners. Out of 204 crosses (96 crosses for 18 characters) with high *sca* effects for the different characters, in 115 cross combinations, atleast one parent was a good general combiner. This suggests that either additive x additive and/or additive x dominance genetic interactions were predominant. In the remaining 88 crosses the parental combinations were either medium x medium, medium x low or low x low. The superiority of these crosses may be due to complementary and duplicate type gene interactions. This also indicates that in hybrid rice programme, improvement in yield and yield components can be achieved also by incorporating poor general combiners as parents. Darrah and Hallaur (1972) pointed out that poor combining parents, though, lacked the additive effects of good inbred, they were highly responsive to heterozygosity in the way of non-additive effects. The crosses showing desirable *sca* effects for different yield components and their parental ranking are given in Table 37. The estimates of *sca* effects revealed that the superior crosses between high x high general combiners were P_3 x P_1 for short maturity duration; P_6 x P_8 for number of panicles m^{-2}; P_4 x P_5 and P_1 x P_9 for number of spikelets $panicle^{-1}$; P_4 x P_5 and P_4 x P_7 for number of tertiary branches $panicle^{-1}$; P_4 x P_5 for number of grains $panicle^{-1}$; P_3 x P_6 for harvest index; P_7 x P_3, P_{10} x P_3, P_8 x P_1, P_8 x P_3, P_{10} x P_1 for reduced second uppermost internodal length; P_8 x P_3 for short stature; P_4 x P_5 and P_{11} x P_6 for leaf area $plant^{-1}$ at maximum tillering stage; P_4 x P_6 for length of panicle; P_4 x P_5 and P_{11} x P_8 for L/B ratio of grain and P_4 x P_1 and P_{11} x P_6 for amylose content. These high x high crosses might involve additive x additive interaction and therefore there is a high probability for deriving good homozygous lines from the progeny. Crosses, superior among high x low general combiners and high x medium general combiners were also determined. However, heterosis involved in these combinations might involve additive x dominance interaction and therefore might tend to be unfixable in the segregating generations, but can be used for heterosis breeding. Crosses between low x low combiners, such as P_4 x P_7 for number of panicles m^{-2}; P_{10} x P_8 for number of spikelets panicle^{-1}; P_1 x P_9 and P_{10} x P_8 for number of tertiary branches panicle^{-1}; P_1 x P_9, P_1 x P_6, P_{10} x P_8 and P_6 x P_{10} for number of grains panicle^{-1}; P_6 x P_{10} for spikelet sterility percentage; P_4 x P_{10} for harvest index; P_4 x P_6 for second uppermost internodal length; P_4 x P_{10}, P_7 x P_3, P_{10} x P_7 for leaf area plant^{-1} at maximum tillering stage; P_3 x P_1 for length of panicle and P_7 x P_6 for L/B ratio of grain, exhibited good *sca* effect for the respective characters. This again indicates that there is non-additive gene action. Production of superior *sca* effects by involving all kinds of combinations namely high x high, high x low, low x high, low x low, medium x medium, medium low was reported earlier by Dhaliwal and Sharma (1990), Katre and Jambhale (1996) and Ramalingam *et al.* (1997).

Comparing the *sca* effects and *per se* performance for different characters revealed that the *sca* effects for the characters, ratio of vegetative phase to reproductive phase, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, spikelet sterility percentage, second uppermost internodal length, leaf area plant^{-1} at maximum tillering stage, L/B ratio of grain and grain yield, were found to be related with the mean performance of the crosses. Thus the cross giving high *sca* effects can be exploited and superior segregants from them can be derived for these characters. But in the case of characters, days to 50 per cent flowering, days to harvest, number of panicles m^{-2}, harvest index, 1000 grain weight, height of plant and length of panicle, crosses having significant *sca* effects failed to record high *per se* performance indicating, thereby, that selection of superior combinations on the basis of *sca* effects may not always give high *per se* performance.

5.2.1.2 Reciprocal combining ability

The result of reciprocal effect observed in the 5 x 5 full diallel analysis is discussed below.

Variation due to reciprocal cross effects was significant for all the characters, which were subjected to combining ability analysis. This corroborates the results of Dhaliwal and Sharma (1990) for the characters, namely, days to 50 per cent flowering, plant height, number of panicles plant^{-1}, length of panicle, number of grains panicle^{-1}, 1000 grain weight and grain yield plant^{-1}.

Reciprocal cross effects usually arise due to the cytoplasmic determinants which are transmitted from the gamate to the zygote. It is an established fact that grain characters are influenced considerably by cytoplasmic factors mainly due to the contribution of the female parent in grain development. To know which particular parent, is contributing towards the cytoplasmic effect, the array means of the progenies were compared when a particular parent was used as a male or as a female parent (Table 25). From Table 25, cross combinations showing pronounced influence of cytoplasm on yield and related characters and the parents responsible for cytoplasmic effect are identified and presented in Table 39. The parents showing pronounced cytoplasmic effect were P_1, P_6 and P_9 for days to 50 per cent flowering; P_1 and P_6 for days to harvest; P_4 and P_5 for ratio of vegetative phase to reproductive phase; P_5 and P_6 for number of panicles m^{-2}; P_4 and P_5 for number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, leaf area plant^{-1} at maximum tillering stage, and for amylose content; P_1 and P_6 for 1000 grain weight; P_9, P_1 and P_5 for second uppermost internodal length and height of plant at harvest; P_5 and P_6 for panicle length; P_4, P_5 and P_9 for L/B ratio of grain and P_4, P_5 and P_6 for grain yield plant^{-1}. This suggests that the parents namely P_4 (Mahsuri), P_5 (Karthika), P_6 (Vytilla 3), P_1 (Mattatriveni) and P_9 (IR62030-18-2-2) have pronounced cytoplasmic effect on yield and various yield contributing characters. Similar observations of maternal influence for earliness, plant height and tiller number were earlier reported by Thyagarajan and Sivasubramanian (1990). Among the five parents showing cytoplasmic effect for various characters, the parents namely, P_4, P_5 and P_6 have cytoplasmic effect on important yield attributes namely days to 50 per cent flowering, days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1} and 1000 grain weight. Thus, the cytoplasmic factors of these parents can also be utilized for the exploitation of heterosis and development of hybrid derivatives. Plates 4A to 4F and the centre plate illustrate the cytoplasmic effect of female parent on grain yield plant^{-1} and different yield components.

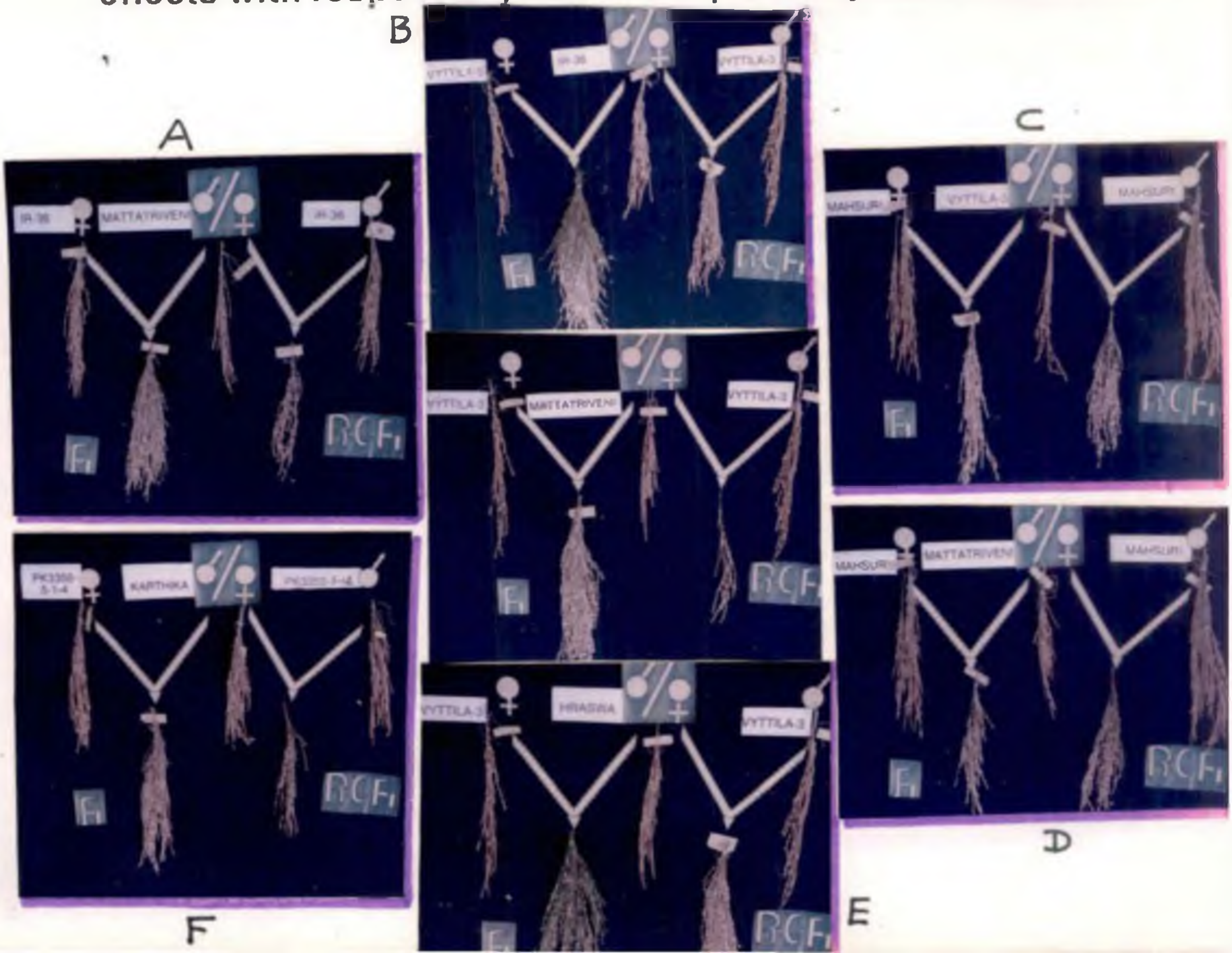
5.2.2 Estimation of components of variation and genetic parameters by Hayman's approach

The analysis of variance for parents and hybrids together showed substantial genetic variability among the progeny of the crosses for all the characters except for alkali spreading value.

Plate 3 Wet cloth method of hybridization

Plate 4

Direct and reverse F_1 crosses showing significant reciprocal effects with respect to yield and important yield components



In diallel analysis, Hayman (1954) emphasized the fulfilment of certain assumptions. In the present study of 5 x 5 full diallel analysis the t^2 value was non-significant for 16 characters indicating the fulfilment of diallel assumptions for these traits. The significance of t^2 for the character, ratio of vegetative phase to reproductive phase, indicates the failure of one or a few assumptions for diallel mating design and the probable presence of complementary type interaction.

The presence of positive and significant additive component (D) and non-additive component (H_1) for the characters, namely, number of days to 50 per cent flowering, number of days to harvest, number of spikelets panicle^{-1}, number of grains panicle^{-1}, spikelet sterility percentage, harvest index, 1000 grain weight, second uppermost internodal length, height of plant at harvest, L/B ratio of grain, amylose content and yield plant^{-1} suggest that both additive and non-additive gene actions have significant roles in the inheritance of these characters. Similar results were reported by Kaushik and Sharma (1988), Ram *et al.* (1991), Lokaprakash *et al.* (1991) and Mohanty *et al.* (1995) for the characters days to 50 per cent flowering, days to harvest, height of plant, number of spikelets panicle^{-1}, 1000 grain weight, number of grains panicle^{-1}, harvest index and yield plant^{-1}. Only non-additive component (H_1) was significant for the characters leaf area plant^{-1} at maximum tillering stage and number of panicles m^{-2} which indicates the role of only non-additive gene action in determining these characters. The higher magnitude of H_1 component than `D' component for all the characters except for second uppermost internodal length, height of plant and 1000 grain weight, indicate the greater importance of non-additive gene action for the characters, namely days to 50 per cent flowering, days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, number of grains $panicle^{-1}$, spikelet sterility percentage, harvest index, leaf area $plant^{-1}$ at maximum tillering stage, length of panicle, L/B ratio of grain, amylose content and yield $plant^{-1}$. It also suggests the importance of additive gene action for the characters namely, second uppermost internodal length, height of plant and 1000 grain weight. This is in agreement with earlier findings by Ram *et al.* (1991) and Lokaprakash *et al.* (1991) who reported non-additive gene action for days to flowering and maturity, sterility percentage, harvest index, number of spikelets $panicle^{-1}$, panicle length and yield $plant^{-1}$. Lokaprakash *et al.* (1991) observed predominance of additive gene action for the character plant height. These results confirm the results obtained through Griffing's approach. These resultsalso suggest that there is a possibility to break the yield plateau of rice by exploiting the non-additive genetic components. This findings was further justified by the ratio $(H_1/D)^{1/2}$ ($>$ 1) which reveals the over dominance, for the characters, namely, days to 50 per cent flowering, days to harvest, leaf area $plant^{-1}$ at maximum tillering stage, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, length of panicle, number of grains $panicle^{-1}$, spikelet sterility percentage, amylose content and yield $plant^{-1}$. $(H_1/D)^{1/2} = 1$ for the characters, harvest index and L/B ratio of grain, which in suggest of complete dominance for these characters. On the other hand, partial dominance $[(H_1/D)^{1/2} < 1]$ was observed for the characters 1000 grain weight, second uppermost internodal length and height of plant at harvest. There was no dominance $[(H_1/D)^{1/2} = 0]$ for the characters, ratio of vegetative phase to reproductive phase and number of panicles m^{-2}. Kalaimani and Sundaram (1987a), Ram *et al.* (1991) and Lokaprakash *et al.* (1991) reported over dominance effect for the characters, number of grains $panicle^{-1}$, days to flowering and harvest, spikelet sterility, number of spikelets $panicle^{-1}$, panicle length and yield $plant^{-1}$. Partial dominance for plant height and 1000 grain weight were earlier reported by Ram *et al.* (1991) and Lokaprakash *et al.* (1991).

The characters days to 50 per cent flowering, days to harvest, number of panicles m^{-2}, 1000 grain weight, leaf area $plant^{-1}$ at maximum tillering stage and amylose content exhibited significant h^2 values. This indicates the dominance effect of these characters. The progeny mean was more than the parental mean with respect to all the characters. This shows that higher effect of all the characters was the dominant one.

Positive and significant `F' value for the characters, harvest index, spikelet sterility percentage and 1000 grain weight indicate higher frequency of dominant genes in the parents for these characters. A similar observation for the characters, sterility and 1000 grain weight was made by Ram *et al.* (1991) and Mohanty *et al.* (1995). The `F' value was negative and significant for the character height of plant at harvest which suggests that recessive alleles were more frequent than dominant ones as reported by Ram *et al.* (1991). This was further corroborated by the lower value of KD/KR for height of plant. The non-significant `F' value for days to 50 per cent flowering, days to harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets panicle^{-1}, number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, second upper most internodal length, length of panicle, leaf area plant^{-1} at maximum tillering stage, L/B ratio of grain, amylose content and yield plant^{-1} suggest that dominant and recessive genes were in equal proportion for these characters. Similar results were earlier reported by Ram *et al.* (1991) for the characters, yield, days to flowering and maturity, number of grains panicle^{-1} and panicle length.

The value of the ratio $H_2/4H_1$ for the character 1000 grain weight was equal to 0.25 which indicates the symmetry between positive and negative alleles in the parents. The value of this ratio was less than 0.25 for the remaining 16 characters, which indicates asymmetry between positive and negative alleles in the parents. The results also confirm earlier reports by Lokaprakash *et al.* (1991) and Mohanty *et al.* (1995) for the characters, namely, days to flowering and maturity, yield plant^{-1}, harvest index, number of spikelets panicle^{-1}, number of grains panicle^{-1}, number of secondary branches panicle^{-1}, sterility percentage and plant height.

The ratio of the total number of dominant and recessive alleles (KD/KR) was more than one for the characters, namely, harvest index, spikelet sterility percentage, 1000 grain weight, L/B ratio of grain, leaf area at maximum tillering stage and yield plant^{-1} which indicate that these characters have a higher frequency of dominant genes in the parents. The ratio was less than one for the characters, number of tertiary branches panicle^{-1}, number of spikelets panicle^{-1}, number of grains panicle^{-1}, length of panicle, second uppermost internodal length, height of plant at harvest and amylose content. This reveals that these characters are controlled by more number of recessive alleles than dominant alleles. The ratio of KD/KR was equal to zero for the characters, ratio of vegetative phase to reproductive phase and number of panicles m^{-2} which suggests that these characters are under the control of recessive alleles only. This was further confirmed by the potence ratio for these characters which was equal to zero. The characters, namely, days to 50 per cent flowering and days to harvest are under the control of equal number of dominant and recessive alleles, as revealed by their KD/KR ratio, which was nearly equal to one.

The estimates of the number of gene groups that control the characters and exhibiting dominance, revealed that, for the characters, namely, second upper most internodal length, height of plant at harvest, leaf area $plant^{-1}$ at maximum tillering stage, number of spikelets $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, panicle length, number of grains $panicle^{-1}$, spikelet sterility percentage, L/B ratio of grain, harvest index and yield, genes showing dominance effect do not occur in a group. The action of these genes may be predominantly duplicate or complementary with other genes showing dominance effects. Dominance effect of the character, number of panicles m^{-2} was found to be controlled by at least one gene group. In the case of characters, days to 50 per cent flowering, days to harvest and amylose content, at least two gene groups with dominance effects are controlling the characters. With respect to the character 1000 grain weight, at least three gene groups have dominance effect. For the character, ratio of vegetative phase to reproductive phase a number of gene groups are found to exhibit dominance effect.

Moderate to high estimates of narrow sense heritability was obtained for the characters, second uppermost internodal length, height of plant, L/B ratio of grain, spikelet sterility percentage, yield plant^{-1}, number of spikelets panicle^{-1}, number of grains panicle^{-1}, harvest index and 1000 grain weight. These characters thus appear to be very much amenable for the improvement through selection, since major part of phenotypic variability was due to additive gene effect. similar findings were earlier reported by Kaushik and Sharma (1988), Ram *et al.* (1991), Lokaprakash *et al.* (1991) and Mohanty *et al.* (1995) for the characters, number of grains panicle^{-1}, 1000 grain weight, plant height, number of spikelets panicle^{-1}, harvest index and yield plant^{-1}. Low estimates of narrow sense heritability, for number of days to flowering and harvest, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of tertiary branches panicle^{-1}, leaf area plant^{-1} at maximum tillering stage, length of panicle and amylose content reveal non-additive gene effect for these characters.

The value for $(ML_1 - ML_0)^2$ was positive for all the characters except for ratio of vegetative phase to reproductive phase, harvest index and L/B ratio of grain. This indicates that the dominance was in the direction of higher magnitude of the characters except for the characters, ratio of vegetative phase to reproductive phase, harvest index and L/B ratio of grain. For these three characters $(ML_1 - ML_0)^2$ was zero which indicates that the dominance effect is in significant with respect to these characters.

The lowest value of Vr+Wr corroborates with the presence of more number of dominant genes while the highest value to more number of recessive genes (Mohanty *et al.*, 1995). From $V_r + W_r$ values of different characters for five parents namely, Mattatriveni, Mahsuri, Karthika, Vytilla 3 and IR62030-18-2-2, it is revealed that among the five parents studied, IR62030-18-2-2 possessed more number of recessive genes for the characters, day to 50 per cent flowering and harvest and more number of dominant genes for yield and important yield attributes, like number of panicles m^{-2}, number of spikelets panicle^{-1}, length of panicle and amylose content. Similarly Mattatriveni also possessed more number of recessive genes for days to 50 per cent flowering and spikelet sterility and more number of dominant genes for yield and important yield attributes like ratio of vegetative phase to reproductive phase, number of spikelets panicle^{-1}, harvest index, 1000 grain weight and panicle length. So to increase yield in short duration rice, the varieties IR62030-18-2-2 and Mattatriveni may be utilized. The variety Mahsuri was found to possess more number of dominant genes, for the characters, days to 50 per cent flowering, number of tertiary branches panicle^{-1}, 1000 grain weight and leaf area plant^{-1} at maximum tillering stage and more number of recessive genes for the characters ratio of vegetative phase to reproductive phase, harvest index and yield. Mohanty *et al.* (1995) reported more number of dominant genes for days to 50 per cent flowering in Mahsuri. The variety Vytilla 3 possessed more number of dominant genes for number of grains panicle^{-1}, spikelet sterility percentage and L/B ratio of grain and more number of recessive genes for number of panicles m^{-2}, number of tertiary branches panicle^{-1}, 1000 grain weight and length of panicle. The variety IR62030-18-2-2 has more number of dominant genes for the characters, ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, second uppermost internodal length, height of plant, length of panicle, amylose content and yield and more number of recessive genes for the characters, number of days to 50 per cent flowering, number of days to harvest and L/B ratio of grain. The variety Mattatriveni was found to possess more number of dominant genes for ratio of vegetative phase to reproductive phase and more number of recessive genes for the characters, spikelet sterility percentage and amylose content. While Karthika possessed more number of dominant genes for the characters, number of days to harvest and harvest index, it was found to possess more number of recessive genes for the characters number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, second uppermost internodal length, height of plant at harvest and leaf area $plant^{-1}$ at maximum tillering stage.

The present study reveals importance of both additive and non-additive gene effects in governing yield and most of the yield attributes with predominance of non-additive gene action for all the characters, except for 1000 grain weight, second uppermost internodal length and height of plant, which have predominant, additive gene action. In this situation, where both non-additive and additive components were important for the expression of characters, especially when the former component is predominant, simple pedigree method of selection would be ineffective for its improvement. At the same time population improvement programme which may allow to accumulate the fixable gene effects as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects will prove to be the most effective method (Joshi, 1979). The characters second uppermost internodal length, height of plant at harvest and 1000 grain weight were found to be under the control of additive gene action and had moderate to high narrow sense heritability. So these characters can be improved through pedigree breeding. At the same time moderate to high narrow sense heritability and predominant non-additive gene action were observed for the characters, yield, number of spikelets panicle^{-1}, number of grains panicle^{-1}, harvest index, L/B ratio of grain and spikelet sterility percentage. This again suggests the use of reciprocal recurrent selection technique for improving these characters. However, rice being a highly self pollinated crop, forming single seed per pollination, this selection procedure is not practicable. So a possible choice is the use of biparental mating among selected crosses or use of selection procedure such as diallel selective mating (Jensen, 1970) to exploit both the additive and non-additive genetic components. To increase grain yield in early duration rice, the varieties IR62030-18-2-2 and Mattatriveni are suggested for crop improvement programmes.

5.2.3 Application of selection index for ranking rice hybrids

The pattern of ranking of hybrids based on the selection index and based on yield varied. This indicates that selection index constituted for parents in the first experiment with respect to yield and yield components did not hold true in the selection of best hybrids. In the first experiment, the varieties ranked as first ten based on selection index and yield were the same. Since the genetic constitution of the hybrids and its interaction with environment significantly differed, the selection index constituted for the parents can not be used in the selection of hybrids.

5.2.4 Estimation of heterosis

Commercial exploitation of heterosis in rice is explored at present in all the rice growing countries. Hybrid vigour has been extensively exploited in rice for enhancing the yield. To identify the potential of hybrids, the magnitude and direction of heterosis are of paramount importance. Before undertaking a hybrid breeding programme, it is essential to determine the presence of significant heterosis in yield and yield contributing characters for exploitation of hybrid vigour.

Estimates of relative heterosis and heterobeltiosis for yield indicated that 17 hybrids out of 96 hybrids evaluated, gave higher yield than the mid parent, while 12 hybrids were better than the respective better parent which yielded 6.6 to 25.9 g plant^{-1}. Three hybrids namely P_6 x P_8, (Vytiila 3 x IR36), P_6 x P_{10} (Vytilla 3 x IR60133-184-3-2-2) and P_{11} x P_2 (PK3355-5-1-4 x Bhadra) were found to be outstanding as compared to the standard check parent (Hraswa) and yielded 18.5 to 25.9 g plant^{-1}. The hybrid P_6 x P_8 out yielded the check parent by 80% followed by P_6 x P_{10} (62.8%) and P_{11} x P_2 (28.6%). It was very interesting to note that the most superior hybrid Vytilla 3 x IR36 for yield was a highly sterile one with 76.3 per cent spikelet sterility. The higher yield for this cross was due to very high number of panicles plant^{-1} (29). This particular cross also showed very high leaf area plant^{-1} at maximum tillering stage. Superiority of yield of the cross

Vytilla 3 x IR60133-184-3-2-2 was due to large number of panicles $plant^{-1}$ (14) and due to high leaf area $plant^{-1}$ at maximum tillering stage. The superiority of the cross PK3355-5-1-4 x Bhadra for yield over check parent was due to its superiority for several characters, namely, number of grains $panicle^{-1}$, number of tertiary branches $panicle^{-1}$, number of spikelets $panicle^{-1}$ and leaf area $plant^{-1}$ over the corresponding check parent. The top ranking five hybrids, which showed positive significant relative heterosis and heterobeltiosis, other than the three mentioned earlier were P_5 x P_2, P_5 x P_6, P_6 x P_1, P_{11}, x P_5 and P_{11} x P_9. Their per plant yield was with the range of 11.9 g to 17.3 g. Paramasivan and Rangasamy (1988); Sahai and Chaudhary (1991), Ganeshan *et al.* (1997) and Mishra and Pandey (1998) reported heterosis for grain yield in rice.

Reports indicated that in self-pollinated plant, the hybrids to be economically advantageous must give 20-50 per cent higher grain yield than the best available commercial variety and the better parent (Swaminathan *et al.,* 1972). In the present study, three hybrids namely Vytilla 3 x IR36 (Plate 5A), Vytilla 3 x IR60133-184-3-2-2 (Plate 5B) and PK3355-5-1-4 x Bhadra (Plate 5C) showed standard heterosis to the extent of 29-80 per cent. All the eleven hybrids which were superior to the better parent showed heterobeltiosis, more than 50 per cent (Table 43). This suggests that the extent of heterosis in rice is significant enough to explore the prospects of commercial exploitation, in warm tropical humid conditions. It is suggested that the higher yielding hybrids must be screened for their stability in yield over seasons, prior to their multiplication and recommendation to the farmers. For commercial hybrid seed production, cytoplasmic male sterility system and fertility restoration system should be incorporated in an effective manner.

Estimates of relative heterosis, heterobeltiosis and standard heterosis for yield and yield components of hybrids indicated that significant favourable heterosis in yield was largely attributed to significant favourable heterosis in the component characters namely number of spikelets panicle^{-1}, panicle length, leaf area plant^{-1} at maximum tillering stage and number of grains panicle^{-1} and also in some cases number of panicles m^{-2} and number of tertiary branches panicle^{-1}. It reveals that there is ample scope for obtaining high yielding lines, if the selection is based on number of spikelets panicle^{-1}, panicle length, number of grains panicle^{-1}, leaf area plant^{-1} at maximum tillering stage, number of panicles m^{-2} and number of tertiary branches panicle^{-1}. Similar results for panicle length and number of spikelets panicle^{-1} were earlier reported by other workers (Anandakumar and Rangasamy, 1986; Patnaik *et al.*, 1991 and Mishra and Pandey, 1998). Grafius (1959) suggested that there would be no separate gene system for yield *per se* and that the yield is an end product of the multiplicative interaction between the yield and its components. This would indicate that heterosis for yield should be through heterosis for individual yield components or of partial dominance of component characters. This was confirmed in the present investigation, where none of the superior crosses showed heterosis for yield alone.

It is interesting to note that, all the hybrids showing significant heterosis for yield, showed either negative or non significant heterosis for the characters, harvest index and ratio of vegetative phase to reproductive phase which were found to be the most important yield determining characters in the present study. This may be due to the fact that all the parents involved in the crosses were high yielding varieties, in which harvest index and ratio of vegetative phase to reproductive phase were high which might be the maximum limit for high yield potential for these two characters. It also indicates, further scope for improving these two characters by utilizing better combiners other than the varieties used in the present study. This corroborates the result of Mishra and Pandey (1998).

Overdominance effects may be the chief genetic cause for heterobeltiosis based on inter and intraallelic interaction in nature (Singh and Richharia, 1980). In the present study, for yield and all yield components, except for the characters, namely, ratio of vegetative phase to reproductive phase, spikelet sterility percentage and number of tertiary branches panicle^{-1}. more than 50 per cent of hybrids showed significant heterobeltiosis (including both favourable and unfavourable). This indicates the overdominance effect for these characters. Out of these heterobeltiotes, only few hybrids showed favourable overdominance for all the characters except for leaf area plant^{-1} at maximum tillering stage and number of panicles m^{-2}, for which overdominance showed by majority of the hybrids was in the favourable direction. Almost all the hybrids having significant favourable relative heterosis and heterobeltiosis for these characters were found to be superior to the respective check parent also. None of the crosses did show favourable heterosis over mid parent, better parent and check parent with respect to the character 1000 grain weight.

Similarly, none of the hybrids manifested significant negative heterosis over better parent and standard parent for the character, days to 50 per cent flowering and days to harvest. This indicates that all the hybrids were late maturing than the standard check parent. For the character, second uppermost internodal length, 28 per cent of total hybrids and for height of plant at harvest, 21 per cent of total hybrids showed favourable heterobeltiosis. Almost all of the heterobeltiotes were found to be shorter than the check parent. The per cent of hybrids which showed favourable heterosis for different characters are given in Table 43. For all characters, except for number of panicles m^{-2} and leaf area $plant^{-1}$ at maximum tillering stage, majority of the crosses recorded negative heterosis. This may be due to the disharmony between gene combinations among different parental lines.

Too short or too tall, and too early or too late hybrids did not find place among the high yielding ones (Peng and Virmani, 1990b). The best three hybrids (over check parent) identified in the present study, namely P_6 x P_8, P_6 x P_{10} and P_{11} x P_2 matured in 134-145 days. The hybrids P_6 x P_8 and P_6 x P_{10} were 120-122 cm tall while P_{11} x P_2 was 97 cm tall.

5.2.5 Hybrids for recombination breeding

The criterion for selection of hybrids for recombination breeding is that the parents should have significant desirable *gca* effect and the hybrids with non-significant *sca* effect (Verma *et al.*, 1995; Vivekanandan and Giridharan, 1997).

Hybrids showing positive *sca* effects evolved from parents of high *gca* effect may be utilized for both recombination breeding and heterosis breeding. Accordingly the hybrids were evaluated (Table 45). Hybrids suitable for recombination breeding for yield alone are found to be Mahsuri x Vytilla 3 (P_4 x P_6), Vytilla 3 x Mattatriveni (P_6 x P_1) and Mahsuri x Mattatriveni (P_4 x P_1). Among these three crosses P_6 x P_1 is a good cross for the characters harvest index and number of days to 50 per cent flowering which are considered as two important yield components. Hence the cross Vytilla 3 x Mattatriveni (Plate 6A) is the best cross for recombination breeding followed by Mahsuri x Vytilla 3 (Plate 6B) and Mahsuri x Mattatriveni (Plate 6C). Selected hybrids for recombination breeding for different yield components are presented in Table 39.

5.2.6 Hybrids for heterosis breeding

Exploitation of hybrids for heterosis breeding is best judged by mean performance, *sca* effects and magnitude of heterosis (Vivekanandan and Giridharan, 1997). Evaluation of hybrids on the above basis (Table 46) revealed that the hybrids namely Vyttila 3 x IR36 (Plate 7A), Vyttila 3 x IR60133-184-3-2 (Plate 7B) and PK3355-5-1-4 x Bhadra (Plate 7C) gave the highest yield even out performing the standard parent for yield. The next outstanding hybrids are Vyttila 3 x Mattatriveni (Plate 7D), Karthika x Bhadra (Plate 7E), PK3355-5-1-4 x Karthika (Plate 8A) and PK3355-5-1-4 x IR62030-18-2-2 (Plate 8B) which outyielded the better parent.

From Table 46, it is evident that high heterotic crosses show high *sca* effect also.

Plate 5 Hybrids which out yielded the check parent

B

A

C

Plate 6 Hybrids for recombination breeding

A

B

C

Plate 7 Hybrids for heterosis breeding

B

A

C

D

E

5.2.7 Relationship between heterosis and genetic divergence

The results revealed that, there is no relationship between genetic divergence and heterosis. It is further revealed that superior hybrids can be formed from all types of divergent groups, namely hybrids among parents of high divergence, intermediate divergence, and low divergence with maximum number of superior hybrids derived from parents of intermediate divergent groups. The top seven hybrids which showed significant relative heterosis and heterobeltiosis for yield are P_6 x P_8, P_5 x P_2, P_6 x P_{10}, P_5 x P_6, P_{11} x P_2, P_6 x P_1 and P_{11} x P_5 in the decreasing order of heterosis. Among these, the cross P_6 x P_8 was from parents having the highest genetic distance, while P_5 x P_2 was derived from parents of low divergent groups. The remaining crosses were derived from parents of intermediate divergent groups.

The crosses Vytilla 3 x Mattatriveni, Mahsuri x Vytilla 3 and Mahsuri x Mattatriveni which are selected for recombination breeding, were produced by crossing parents belonged to intermediate divergent groups. Vytilla 3 x IR36, Vytilla 3 x IR60133-184-3-2 and PK3355-5-1-4 x Bhadra are the best selected hybrids for heterosis breeding. The parents of Vytilla 3 x IR36 belonged to the maximum divergent groups, while the parents of the other two hybrids belonged to intermediate divergent groups. The existence of useful heterosis at the intermediate genetic distance level indicates that desirable gene combinations exist, which can result good yield performance. This result is in agreement with the findings of Patnaik *et al.* (1991) in rice. Chauhan and Singh (1982) observed heterosis upto a certain level (optimum level) beyond which the overall heterosis for yield is partly cancelled due to a negative heterosis for certain components. Sarathe and Perraju (1990) opined that parents having fairly high to medium genetic diversity may be selected for hybridization programme in order to get a good opportunity for getting high heterotic effects and its utilization in different breeding procedures for better recombinants.

Thus the genetic divergence for very high expression of heterosis has its limitations, and the possibility of obtaining high heterotic hybrid from highly divergent groups, even though less in frequency cannot be ruled out since the parents of the highest yielding cross combination Vytilla 3 x IR36, belonged to the maximum divergent groups (Cluster II and IV).

It is observed that the crosses between extremely divergent parents, create a situation, where the harmonious functioning of allelles to produce desirable enzyme system is rather disturbed (Prasad and Singh, 1986). Consequently the physiological functions are not as efficient as in a situation where the alleles have a similar pressure (Singh *et al.*, 1981). In the present study, only one cross (Vytilla 3 x IR36), which was derived from parents of maximum divergent groups, gave good yield performance. But this cross was highly sterile. Higher yield was due to large number of panicles m^{-2}. As the reverse cross of Vytilla 3 x IR36 was not that much outstanding compared to the direct cross, we can not say that the high performance of Vytilla 3 x IR36 was the effect of divergence. The higher number of panicles of this cross may be due to cytoplasmic effect as described earlier. The spikelet sterility might have been due to cytoplasmic effect.

It is suggested that rice breeders, while selecting the parents for recombination breeding may stress on parents with intermediate genetic distance rather than wide ones and the parents for heterosis breeding can be selected from all the divergent groups.

5.2.8 Identification of alternative cytoplasmic male sterile (CMS) source in rice

The results of combining ability analysis and heterosis studies in rice, revealed the possibility of production of hybrids subject to incorporation of male sterility and fertility restoration system in an effective manner. Cytoplasmic male sterility (CMS) is the most effective genetic tool for developing F_1 rice hybrids. Wild Abortive (WA) evolved in China is the major source of male sterile cytoplasm that has widely been used in hybrid development. This has led to genetic vulnerabilities of this crop to pest and diseases. Besides, when this WA system is made use of in the tropical climate it very often breaks down. Hence to overcome these hurdles, identification and use of additional source of cytosterility suitable to tropical conditions are to be considered are of paramount importance.

In the present investigation, while evaluating 96 F_1 progenies, two highly sterile F_1 progenies from the crosses Vytilla 3 x IR36 (Plates 9A and 9B) and Vytilla 3 x Hraswa (Plates 10A and 10B) were obtained. At the same time the F_1 progenies of their reverse crosses namely IR-36 x Vytilla 3 (Plates 9C and 10D) and Hraswa x Vytilla 3 (Plates 10C and 10E) were fully fertile (Table 51). This suggests

Plate 8 Hybrids for heterosis breeding

A

B

Plate 9 Identification of alternative CMS source

A

Sterile direct cross of
VYTILLA 3 x IR 36

B

Panicle of
VYTILLA 3 x IR 36
showing spikelet sterility

C

Fertile cross of
IR 36 x VYTILLA 3
(Reverse cross)

Plate 10 Identification of alternative CMS source

A

Sterile direct cross of
VYTILLA 3 x HRASWA

B

Panicle of
VYTILLA 3 x HRASWA
showing spikelet sterility

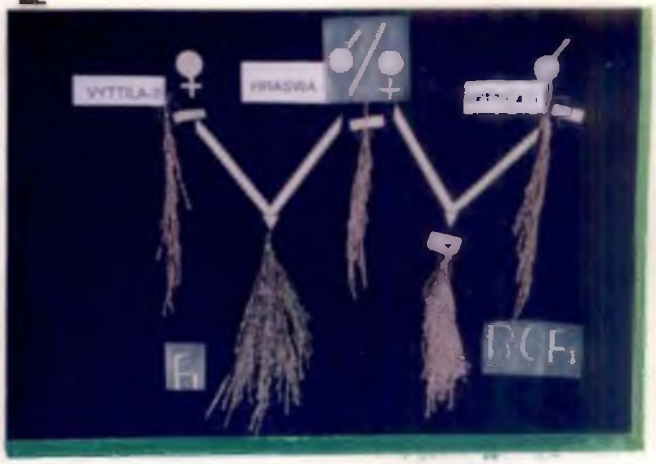
C

Fertile cross of
HRASWA x VYTILLA 3
(Reverse cross)

D

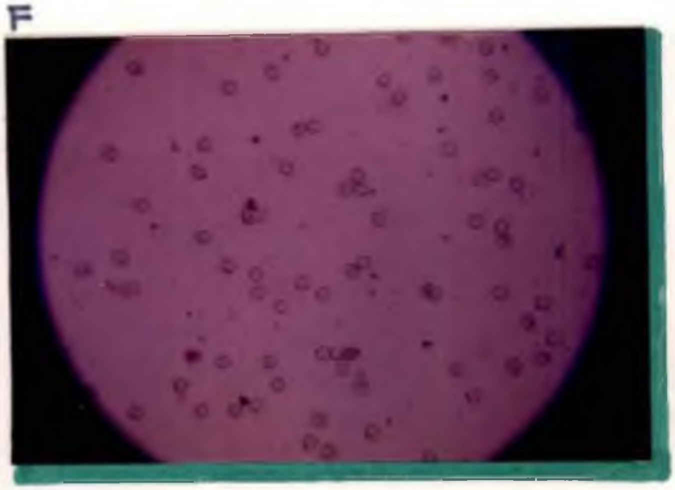
Significant spikelet sterility
variability in the direct cross
(VYTILLA 3 x IR 36) and
reverse cross (IR 36 X VYTILLA 3)

E



Significant spikelet sterility
variability in the direct cross
(VYTILLA 3 x HRASWA)
and reverse cross
(HRASWA x VYTILLA 3)

F



100% pollen sterility in one
of the F_2 plants of
VYTILLA 3 X IR 36

that Vytilla 3 (an improved saline resistant rice variety for Kerala condition) does possess sterility inducing cytoplasm. Fifty per cent pollen sterility was also observed in both the crosses when Vytilla 3 was used as female parent. Similar phenomena were also manifested in F_2 segregants of the cross Vytilla 3 x IR36, where one out of 100 plants showed 100 per cent pollen sterility (Plate 10F). In the F_2 generations of both the crosses, several segregants exhibited a wide range of pollen sterility (Range of spikelet sterility percentage = 50% to 91.5%). This clearly indicates, the possibility to obtain a fully cytoplasmic male sterile line suitable for warm humid climatic condition experienced in Kerala. This can be achieved either by repeated back crossing with IR36 or Hraswa or by selecting from the segregating generations. Similarly, Virmani *et al.* (1985) had attained a highly sterile BC_4F_1 progeny from the back cross ARC13829-26/IR1079-2-3-1.

The array mean performances for the character namely, spikelet sterility percentage, of the crosses, when Vytilla 3 was taken as common female and male parents were worked out (Table 52). It was found that spikelet sterility was consistently higher when Vytilla 3 was taken as female parent. This again confirms the cytoplasmic effect of the variety Vytilla 3 on increased spikelet sterility. This was further confirmed by the high *sca* effect and heterosis of the crosses Vytilla 3 x IR36 and Vytilla 3 x Hraswa for increased spikelet sterility. The cytoplasm of Vytilla 3 was found to have significant favourable influence. on number of days to 50 per cent flowering, number of days to harvest, number of panicles m^{-2}, 1000 grain weight, panicle length and yield as such (Table 39). This reveals that the cytoplasmic gene

Table 51 Spikelet sterility percentage and yield plant^{-1} of crosses exhibiting male sterility in F_1 generations

Crosses	Spikelet sterility percentage			Yield plant^{-1}			
					Heterosis over		
	Mean	Standard hererosis(%)	*sca* effect	Mean (g)	Better parent(%)	standard parent(%)	*sca* effect
Direct crosses							
Vytilla 3 x IR 36	76.3	3533.39**	47.23**	25.9	355.99**	79.99**	14.48**
Vytilla 3 x Hraswa	79.15	3669.05**	50.47**	6.51	-54.76**	-54.76**	-4.54**
Reciprocal Crosses							
IR 36 x Vytilla 3	7.10	2.38	-	6.49	14.26	-54.90**	-
Hraswa x Vytilla 3	11.5	6.86	0.62	11.22	-22.06	-22.03	1.68

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

Table 52 Array mean performance for spikelet sterility percentage showing influence of Vytilla 3 cytoplasm on increased spikelet sterility

Other parents	Array mean performance when Vytilla 3 was taken as common	
	Male parent	Female parent
P_8	7.1	76.3
P_7	10.5	12.2
P_5	6.3	27.9
P_4	10.1	16.5
P_1	16.5	79.2
P_1	0.9	10.7
Mean	8.6	37.1

responsible for male sterility may have pleotropic effect on the above mentioned characters.

If heterosis is very high for a specific cross for an economic character like yield, it is possible to utilize the cross as a commercial hybrid, provided the pollinating system of the crop permits commercial seed production and if, there exists, a cytoplasmic male sterility and fertility restoration system (Arunachalam, 1989). In the present study, the hybrid Vytilla 3 x IR36 showed significant positive heterosis and *sca* effect for the characters namely grain yield plant^{-1}, number of panicles m^{-2}, number of spikelets panicle^{-1}, leaf area plant at maximum tillering stage and length of panicle. For the hybrid Vytilla 3 x Hraswa, significant positive *sca* effect was observed for the characters namely ratio of vegetative phase to reproductive phase and number of panicles m^{-2} and significant heterosis for the character number of panicles m^{-2}. So among these two crosses Vytilla 3 x IR36 will be the better combination for developing a CMS line.

The identified male sterile F_1 crosses were tall in nature while their maintainers (IR36 and Hraswa) were semidwarf in nature. Combining ability studies showed that IR36 and Hraswa have significant negative *gca* effects for the character, height of plant. This indicates that either by repeated backcrossing with these recurrent parents for developing CMS lines, or by selection from segregants, the semidwarf nature of IR36 and Hraswa can be restored. This is further confirmed by the fact that Vytilla 3 cytoplasm did not have any influence on height of the plant.

The very high tillering ability of the two crosses in F_1, was found to decrease to the normal level in the F_2. This reveals, the maternal influence on the heterozygous F_1s, but not in the segregating F_2s. This effect of maternal source is very important for developing hybrid seed (Thyagarajan and Sivasubramanian, 1990). The ability of `A' line in increasing the tillering ability with different restorers has to be considered in developing hybrid rice varieties. Among the proposed `A' lines IR36 and Hraswa, the former was found to be a good general combiner and the latter a medium combiner for the character, number of panicles m^{-2}.

From the combining ability studies, the genotypes Karthika, Mattatriveni, Mahsuri and Vytilla 3 were found to be good general combiners for yield and most of the yield contributing characters. So, these varieties can be proposed to be the possible restorers for the proposed `A' lines. Since the proposed `A' lines will be of semidwarf types, the restorers also should be semidwarf for commercial seed production. Hence the proposed restorers, for the proposed `A' lines namely, IR36 and Hraswa, are Mattatriveni and Karthika. From the available crosses, IR36 x Mattatriveni was found to be a high yielding one (12.18 g plant^{-1}) (Plate 11B). Further the hybrid Vyttila 3 x Mattatriveni also gave a high yield (17.26 g plant^{-1}) (Plate 11A). The hybrid Hraswa x Mattatriveni (Plate 11C) was also found to be high yielding. From the above results it is confirmed that Mattatriveni is highly compatible with the varieties Vytilla 3, IR36 and Hraswa for higher yield. So, it is proposed that the variety Mattatriveni will be highly compatible with a genotype having nucleoplasm of IR36 or Hraswa and cytoplasm of Vytilla 3, that is

Plate 11 **Identification of *Mattatriveni* as restorer line for the proposed `A' lines**

A

Cross showing compatibility of
MATTATRIVENI with VYTILLA 3

B

Cross showing compatibility of
MATTATRIVENI with IR 36

C

Cross showing compatibility of
MATTATRIVENI with HRASWA

the proposed IR36 `A' line and Hraswa `A' line. Hence it is suggested that Mattatriveni will act as a good restorer line (R line), for the proposed IR36 `A' line and Hraswa `A' line.

From the present investigation the cytoplasm of Vyttila 3 was identified as an alternative source for cytoplasmic male sterility in rice. The varieties IR36 (international check) and Hraswa (extra short duration rice variety recommended for cultivation in Kerala) are the proposed maintainers. Mattatriveni could be a good restorer for the proposed IR36 `A' line and Hraswa `A' line. The proposed future line of studies based on these results, suggests that, the efforts must be made for the following:

1. Conversion of the already obtained male sterile F_1 crosses (Vytilla 3 x IR36 and Vytilla 3 x Hraswa) to CMS lines by repeated back crossing with the respective recurrent parents.
2. Screening from the segregating populations for 100 per cent cytoplasmic male sterile lines.
3. Confirmation of the restoring ability of the variety Mattatriveni and further identification of other restorers.
4. Detailed study should be conducted to incorporate the sterile cytoplasm of Vytilla 3 into other elite genotypes other than IR36 and Hraswa.
5. Screening for the availability of CMS cytoplasm in the other Vytilla lines.

5.3 Experiment No.3

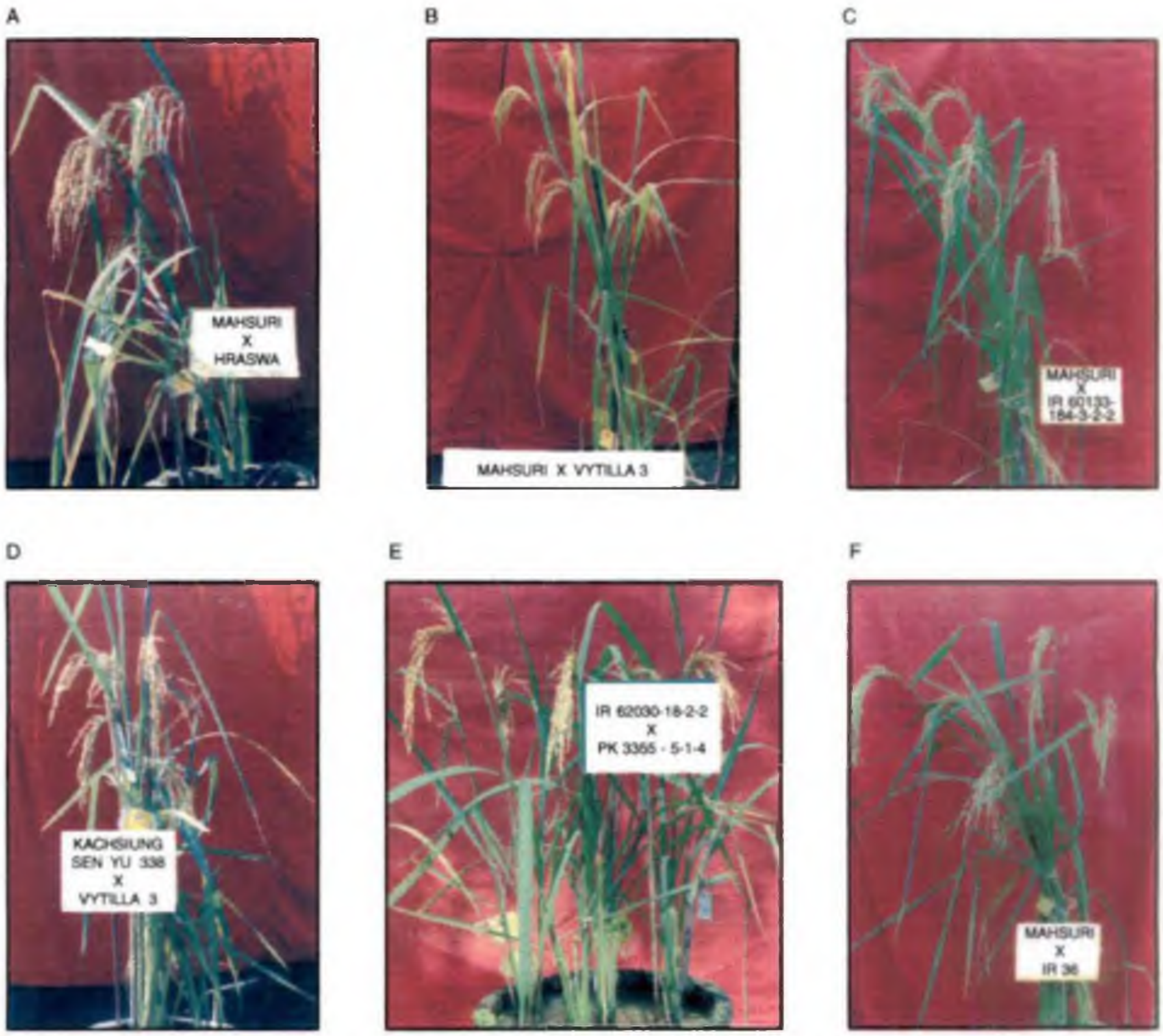
5.3.1 Generation mean analysis

The success of any plant breeding programme depends, to a greater extent, on the knowledge of the genetic architecture of the population handled by the breeder. Generation mean study enables the gene action to be analysed crosswise, and provides quantified information on mean effect (m), additive effect (d), dominance effect (h), additive x additive (i) interaction effect (which is fixable), additive x dominance (j) interaction effect and dominance x dominance (l) interaction effect, the relative magnitudes of which will indicate whether development of hybrids would be economic. To have a clear picture of genetic mechanism of the population the measurable absolute value of generation mean must be partitioned into its genetic components. Hence an attempt was made in the present study to understand the genetic architecture of rice yield and its important component characters.

The scaling tests revealed the presence of epistatic interactions for all the 12 characters in all the 10 crosses except in P_8 x P_1 (for days to 50% flowering) and P_9 x P_{11} (for number of spikelets panicle^{-1}). This further indicates the presence of sufficient variability in the parental lines for the 12 characters and the complex nature of inheritance of yield and important yield attributes in the materials.

The estimates of mean effects (m) were highly significant in almost all the 10 crosses for all the 12 characters. A cross having a high mean estimate as well as positive significant additive effect is expected to have the greatest practical value in any scheme of improvement. In the present study, the crosses $P_4 \times P_3$, $P_4 \times P_6$, $P_4 \times P_{10}$, $P_7 \times P_6$ and $P_9 \times P_{11}$ exhibited significant mean effect and positive significant additive effect for the character namely yield plant^{-1} and its important attributes namely number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, number of spikelets panicle^{-1}. These crosses recorded significant mean effect and favourable significant additive effect for several other characters like harvest index ($P_9 \times P_{11}$), 1000 grain weight ($P_4 \times P_3$ and $P_4 \times P_{10}$), height of plant ($P_7 \times P_6$), second uppermost internodal length ($P_4 \times P_6$ and $P_7 \times P_6$), number of days to harvest ($P_4 \times P_{10}$) and number of days to 50 per cent flowering ($P_4 \times P_3$ and $P_9 \times P_{11}$). The cross $P_4 \times P_8$ showed significant mean effect and significant positive additive effect for important yield components like number of tertiary branches panicle^{-1}, number of grains panicle^{-1}, number of spikelets panicle^{-1}, 1000 grain weight and number of panicles plant^{-1}. Hence among the 10 crosses studied the crosses $P_4 \times P_3$ (Mahsuri x Hraswa), $P_4 \times P_6$ (Mahsuri x Vytilla 3), $P_4 \times P_{10}$ (Mahsuri x IR60133-184-3-2-2), $P_7 \times P_6$ (Kachsiung sen Yu 338 x Vytilla 3), $P_9 \times P_{11}$ (IR62030-18-2-2 x PK3355-5-1-4) and $P_4 \times P_8$ (Mahsuri x IR36) (Plates 12A to 12 F) are the promising crosses for screening segregants and fixation of characters in promising lines. Among these crosses, the cross $P_9 \times P_{11}$ has favourable additive effect for harvest index which is the most important yield component. By exercising selection in the segregating generations of this cross, both grain yield and straw yield can be increased. For screening out a high yielding semidwarf plant type the crosses $P_7 \times P_6$ and $P_4 \times P_6$ are the best, since these crosses showed favourable additive effect and favourable additive x additive interaction effect for reduced plant stature. For high yielding varieties with short duration, selection may be exercised in the progenies of crosses $P_4 \times P_{10}$, $P_4 \times P_3$, and

Plate 12. F_1 crosses identified for screening out promising segregants from segregating generations based on generation mean analysis.



P_9 x P_{11} , as these crosses exhibited favourable additive effect for reduced flowering period and reduction in maturity period. The cross P_8 x P_1 recorded favourable mean effect and additive effect for 1000 grain weight, height of plant, second internodal length and maturity duration. The crosses P_3 x P_1, P_3 x P_6 and P_3 x P_{10} were found to possess favourable additive effect for harvest index, number of panicles plant^{-1} and for short stature.

In general it was observed that, both additive and non-additive gene effects play an important role in the inheritance of yield and 11 yield components studied, with predominance of dominance, additive x additive and dominance x dominance type of gene effects. Similar results were earlier reported by Khaleque *et al.* (1978) for yield, 1000 grain weight, number of spikelets panicle^{-1}, Sharma *et al.* (1986) for yield; Na darajan and Kumaravelu (1994) and Ram (1994) for yield, 1000 grain weight and number of grains panicle^{-1} and Chakraborty and Hazarika (1996) for yield and number of spikelets panicle^{-1}. Among the three types of digenic interactions, eventhough `i' and `l' types were predominant, most of the `l' type interactions were in the favourable direction. All the ten crosses recorded positive significant dominance x dominance (l) interaction effect for yield plant^{-1} and most of the yield components, which indicates the suitability of these 10 crosses for hybrid rice breeding. Among the 10 crosses the best crosses for hybrid rice breeding are P_4 x P_6, P_4 x P_8 and P_4 x P_{10} as these crosses exhibited significant positive dominance effect for the characters harvest index (P_4 x P_6 and P_4 x P_8), number of tertiary branches panicle^{-1} (P_4 x P_{10}) and reduced spikelet sterility (P_4 x P_8).

All the characters showed overdominance effect in almost all crosses which indicates the predominance of dominant gene action in the material.

The (h) and (l) effects showed opposite signs in all the crosses for the characters, namely, number of panicles plant^{-1}, number of spikelets panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight, second uppermost internodal length, height of plant at harvest, harvest index and yield plant^{-1}, which indicates the involvement of duplicate dominant type interaction. Duplicate type of interaction was also seen for the characters days to 50 per cent flowering (in 7 crosses), days to harvest (in 7 crosses), number of tertiary branches panicle^{-1} (in 9 crosses) and for spikelet sterility percentage (in 8 crosses). The (h) and (l) effects showed same direction for the characters days to 50 per cent flowering in three crosses (P_3 x P_6, P_4 x P_3, P_4 x P_6), days to harvest in three crosses (P_4 x P_3, P_4 x P_{10}, P_7 x P_6), number of tertiary branches panicle^{-1} in one cross (P_4 x P_8), and for spikelet sterility percentage in two crosses (P_3 x P_{10}, P_8 x P_1) which shows that there is involvement of complementary type gene interaction. Duplicate type epistasis was earlier reported by Khaleque *et al.* (1978) for yield, number of grains panicle^{-1}, 1000 grain weight, number of spikelets panicle^{-1}; Chauhan *et al.* (1993) for yield; Nadarajan and Kumaravelu (1994) for number of grains panicle^{-1} and 1000 grain weight; Ram (1994) for yield, number of grains panicle^{-1} and plant height; Chakraborty and Hazarika (1996) for yield, 1000 grain weight, number of panicles plant^{-1}, number of spikelets panicle^{-1} and plant height and Kumar and Mani (1998) for number of grains panicle^{-1} and 1000 grain weight. Chauhan *et al.* (1993) reported complementary type epistasis for the characters, number of grains panicle^{-1} and 1000 grain weight. Among the crosses which showed complementary type gene interaction, the crosses P_4 x P_3, P_4 x P_8 and P_4 x P_{10} also have additive effect in the favourable direction, for the characters, namely, number of days to 50 per cent flowering, number of tertiary branches panicle^{-1} and number of spikelets panicle^{-1}. This emphasises the importance of these crosses for screening out early flowering plants with panicles having increased number of tertiary branches and increased number of spikelets from the segregating populations.

Duplicate type interaction along with high and positive dominance effect were exhibited by the crosses P_4 x P_6 and P_4 x P_8 for harvest index, P_4 x P_{10} for number of tertiary branches panicle^{-1}, P_4 x P_8 for reduced spikelet sterility, P_7 x P_6 and P_9 x P_{11} for reduced flowering period. The duplicate type of epistasis, particularly in crosses showing high and positive dominance (h) effects may be exploited through heterosis breeding as advocated by Lin and Yuan (1980). Hence the crosses P_4 x P_6, P_4 x P_8, P_4 x P_{10}, P_7 x P_6 and P_9 x P_{11} can be utilized for heterosis breeding for the improvement of respective characters mentioned.

The scaling test for the character, number of tertiary branches panicle^{-1} in the cross P_4 x P_8 and for second upper most internodal length in the cross P_4 x P_{10} indicate the presence of nonallelic gene interaction. But none of the digenic interaction was found to be significant for these characters. It might so happen that three or more interacting genes might be present, which had reduced the values of i, j and l (Kaleque *et al.*, 1978) or may be due to the influence of the female parent P_4 (Mahsuri).

5.3.2 Inbreeding depression

Results of inbreeding depression indicated absence of reduction in vigour in the F_2 generation for yield and all other yield attributes in almost all the 10 crosses.

In all the crosses, except in P_7 x P_6, inbreeding depression was found to be negatively significant for yield plant^{-1}. This indicates absence of inbreeding depression in F_2 generations for yield plant^{-1}. Among the nine crosses which showed significant increase in yield in F_2 generation, the crosses P_3 x P_{10}, P_4 x P_3, P_3 x P_1 and P_3 x P_6 showed increased vigour for the characters, namely number of tertiary branches panicle^{-1}, number of spikelets panicle^{-1}, number of panicles plant^{-1}, number of grains panicle^{-1}, reduced second uppermost internodal length, reduced flowering period and reduced crop duration (P_3 x P_1 for 1000 grain weight also) in the F_2 generation. Similarly increased vigour shown by different crosses for different yield components were P_4 x P_8 for number of panicles plant^{-1}, reduced flowering period and reduced crop duration; P_4 x P_{10} for number of panicles plant^{-1}, 1000 grain weight, reduced flowering period and reduced crop duration; P_8 x P_1 for number of panicles plant^{-1}, number of grains panicle^{-1}, 1000 grain weight, reduced sterility, reduced flowering period and reduced crop duration; P_9 x P_{11} for harvest index, 1000 grain weight, reduced flowering period and reduced crop duration. So increased vigour in yield in F_2 generation of the nine crosses was due to the combined result of increased vigour of different yield components. The inbreeding depression of the cross P_7 x P_6 for yield was nonsignificant. These results reveal the presence of additive gene action for yield and 11 yield components. Hence there is scope for selection for increased yield in the subsequent generations of these 10 crosses.

Based on the mean yield performance in F_2 generation the order of preference of 10 crosses for exercising selection in the segregating generations for yield improvement are, P_4 x P_3 (30.9 g); P_4 x P_{10} (24.5 g); P_4 x P_6 (22.3 g); P_3 x P_{10} (21.9 g); P_3 x P_1 (20.8 g); P_8 x P_1 (20.6 g); P_4 x P_8 (19.8 g); P_7 x P_6 (16.9 g); P_3 x P_6 (15.3 g) and P_9 x P_{11} (13.6 g).

The crosses which showed significant inbreeding depression were P_3 x P_6 for harvest index; P_4 x P_6 for number of spikelets panicle^{-1} and number of grains panicle^{-1}; P_4 x P_8 for spikelet sterility percentage (for reduced sterility); P_3 x P_1, P_3 x P_6, P_3 x P_{10} and P_8 x P_1 for height of plant and second uppermost internodal length (for reduced height of plant and reduced second uppermost internodal length); P_4 x P_8 for height of plant and P_4 x P_3 and P_7 x P_6 for second uppermost internodal length. This suggests that there is presence of non-additive gene action for these characters.

Those hybrids that expressed high degree of heterosis and heterobeltiosis and significant inbreeding depression may be under the influence of non-additive or dominance gene interaction governing heterosis in F_1s.

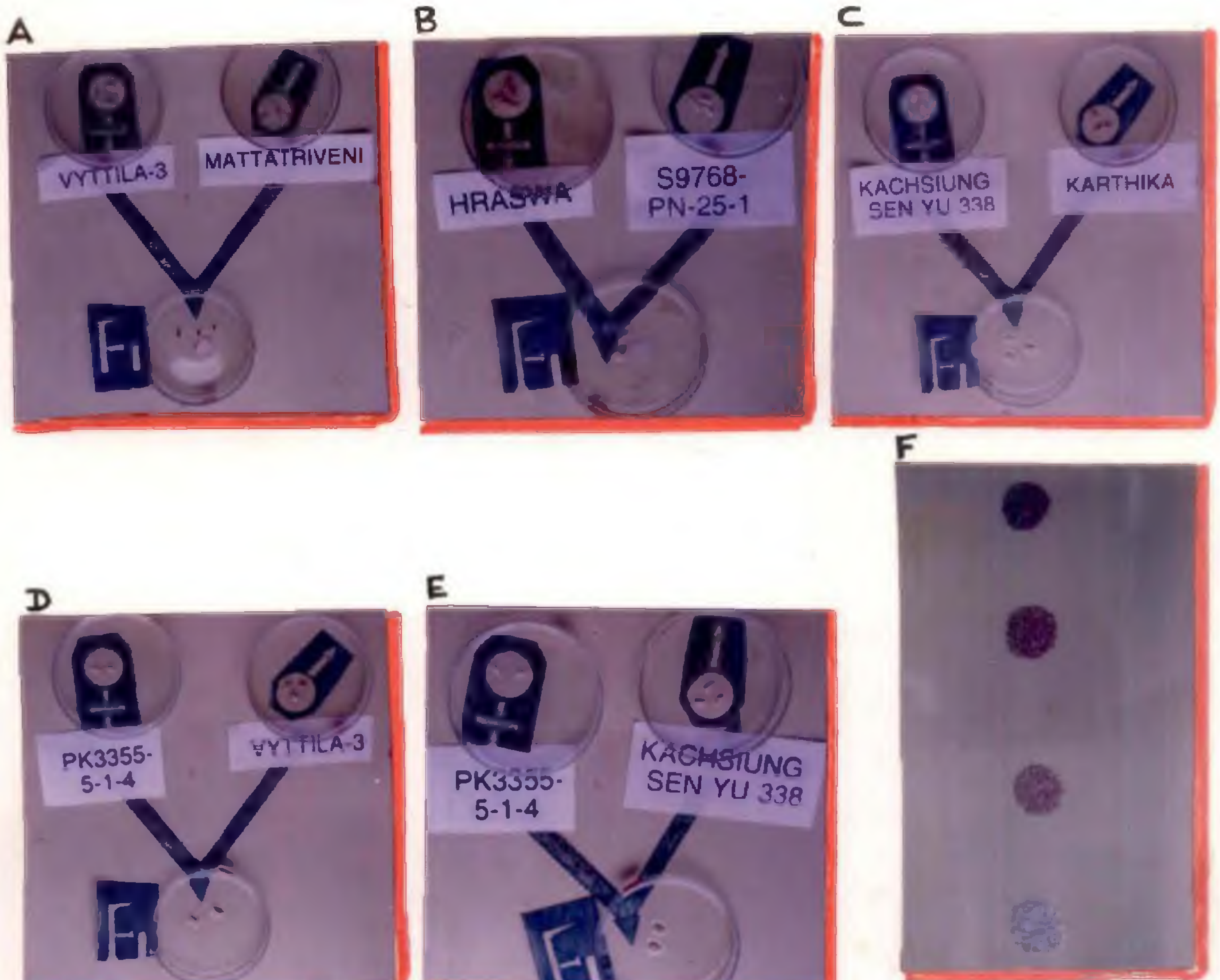
As the yield and yield components are found to be under the control of all the three types of gene actions namely, additive, dominance and epistasis, a breeding method, that could combine both fixable and non-fixable types of gene actions would be more desirable in rice improvement. Hence, intercrossing of early segregating generations derived from multiple crosses or reciprocal recurrent selection procedures seem to be the best suited method for improvement of rice.

5.3.3 Inheritance of kernel colour in rice

The inheritance pattern of kernel colour studied through chi-square test of goodness of fit revealed that, kernel colour in rice is a complex qualitative character. It apparently seems to be quantitative rather than qualitative in nature. Plates 14A to 14E illustrate the different pattern of inheritance of kernel colour. A varied spectrum of colour ranging from deep red, yellowish red, light red and white, was seen (Plate 14F). The segregation ratio for red colour and white colour suggests that, each red and white colour was separately controlled by two or more sets of genes. The probable dihybrid modified Mendelian ratios like 15:1 (duplicate gene action) and 13:3 (Inhibitory gene action) can apparently fit in the segregating populations with predominance of inhibitory type gene action. Recessive forms of genes controlling red colour is not only the factor for the production of white colour. The evolutionary process might have changed the recessive form of gene controlling red colour into dominant in behaviour. It seems that red colour is more primitive in nature compared to white. The possibility of cytoplasmic effect in controlling the kernel colour cannot

Plate 13. Plot view of experiment No. 3

Plate 14. pattern of inheritance of kernel colour in rice



Variability in kernel colour

be r uled out. The various degrees of red colour of kernel also leave the possibility of multi-allelic system of genes controlling the kernel colour. The red kernel colour can easily be fixed in the segregating generation by simple selection.

5.3.4 Evaluation of F_2 generations

Based on yield and other yield contributing characters, promising segregants were isolated from 22 F_2 generations. This include seven low variable lines in the F_2 generations (Plates 15A, 15B, 16, 17A to 17D) and 26 segregants from different cross combinations (Plate 18). The important characters of the early stabilised seven lines are given in Table 49. There were no promising segregants in the back cross populations. This may be due to the phenomenon of linkage drag, a common limitation to the use of wide crosses in breeding programmes. In the phenomenon of linkage drag the deleterious genes will be linked to useful allelles in to the elite recurring lines limiting the success of introgression procedures such as back cross.

The essential features of the new ideotype in rice proposed by IRRI (Singh, 1998) are:

1. Low tillering capacity with 3-4 panicles per plant when direct seeded
2. No unproductive tillers
3. 200-250 grains per panicle
4. 90-100 cm tall
5. Sturdy stem
6. Vigorous root system

7. Multiple diseases and insect resistance

8. 110-130 days growth duration

9. Harvest index 0.6

10. 13-15 tonnes ha^{-1} yield potential

In the present investigation, among the seven early stabilized crosses in the F_2, the cross combinations Karthika x Bhadra (Plate 15A) and PK3355-5-1-4 x Kachsiung Sen Yu 338 (Plate 15B) have the proposed ideotype features, for grains per panicle, harvest index, duration of crop and height of plant. Yield of these lines are 7.5 tonnes ha^{-1} and 10.5 tonnes ha^{-1} respectively, which can be increased to the proposed ideotype level of 13-15 tonnes ha^{-1} by growing in field at yield levels near the yield potential threshold. The increased tiller number of these lines could be due to the wider spacing adopted during transplanting of the crop. The proposed reduced tillering is for direct seeded crop. The two identified new ideotype rice cultures in the present investigation have the preferred quality characters namely intermediate amylose content, alkali spreading value and long bold size.

Apparent evaluation for pest resistance in the puncha season (January-April), during which F_2 generations were evaluated, revealed moderate resistance of Mattatriveni x Karthika, Mattatriveni x IR62030-18-2-2 and Hraswa x Mattatriveni to stem borer and thrips and telerance of Hraswa x IR60133-184-3-2-2, PK3355-5-1-4 x Kachsiung Sen Yu 338 and Kachsiung Sen Yu 338 x Mattatriveni to stem borer and thrips. But the line from Karthika x Bhadra was found to be susceptible to stem borer and thrips. Multiple resistance to other pests and diseases have to be throughly evaluated in the seven early stabilized lines.

The Taiwan variety, Kachsiung Sen Yu 338 with an yield potential of 3.8 tonnes ha^{-1} is a good variety in all aspects, except that the kernel is sticky on cooking (amylose content = 12.4%) and the kernel colour is white. Crossing this variety with Mattatriveni (Red rice of Kerala with amylose content of 25.8%), we were successful in transferring the nonsticky nature and red kernel colour of Mattatriveni to the line that was evolved, Kachsiung Sen Yu 338 x Mattatriveni (Plate 16). These two characters are the important quality characters prefered by Kerala people. This particular line is one of the early stabilized lines in the F_2 generations. This line gave an yield of 6.6 tonnes ha^{-1} with amylose content 24.7 per cent.

Plate 15 Early stabilized promising lines in the F_2 generations with most of the ideotype features

A

B

Plate 16 Early stabilized promising line in the F_2 generation with red kernel and which was non sticky on cooking (Developed from a Taiwan variety which was sticky on cooking and with white kernel)

Plate 17 Promising lines stabilized (low variability) in the F_2 generations

A

B

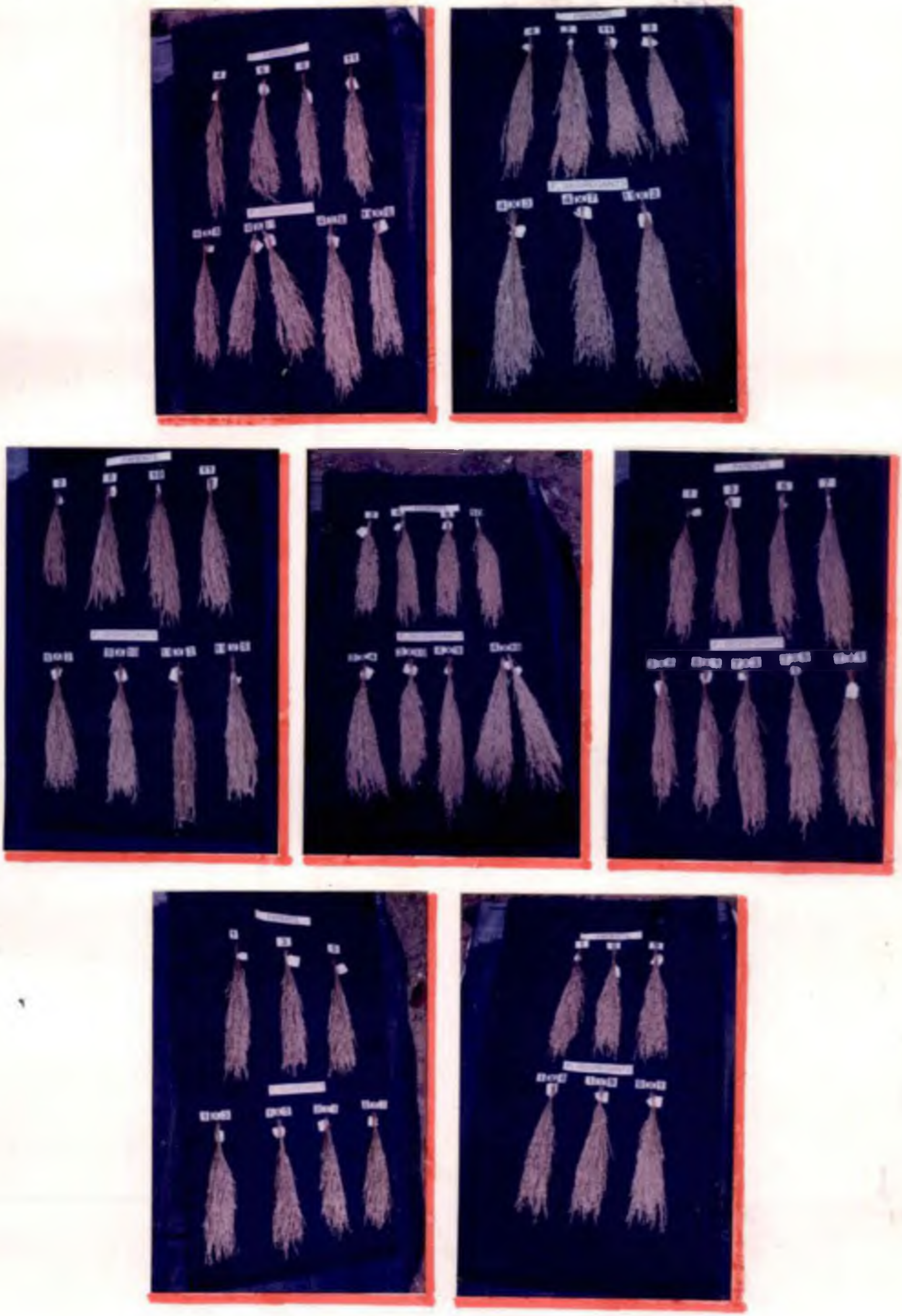
C

D

Plate 18 Promising F_2 segregants

Parental designation	Name
1	Mattatriveni
2	Bhadra
3	Hraswa
4	Mahsuri
5	Karthika
6	Vytilla 3
7	Kachsiung Sen Yu 338
8	IR36
9	IR62030-18-2-2
10	IR60133-184-3-2-2
11	PK3355-5-1-4

Plate 18 Promising F_2 segregants



Summary

SUMMARY

The present investigation of 'Genetic Analysis of High Yielding Rice Varieties of Diverse Origin' was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University during 1995-1998. Field trials were laid out at the Agricultural Research Station, Mannuthy of the Kerala Agricultural University.

The investigation was carried out with a view to understanding the mode of gene action of yield and yield contributing quantitative and qualitative characters, in high yielding varieties of diverse origin, so as to suggest appropriate breeding methodology. The ultimate objective was to isolate promising lines, from the segregating generations for developing varieties suitable to various climatic and soil conditions of Kerala. The experiment also was aimed at identification of alternative source of cytoplasmic male sterile system suitable to warm humid climatic conditions experienced in Kerala.

The materials consisted of 56 high yielding genotypes representing various eco-geographical conditions namely, Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Srilanka.

Initially the 56 genotypes were evaluated during 1996 May to 1997 September and grouped into nine genetically distant clusters. Observations were recorded

on 32 different quantitative and qualitative characters. Twelve genotypes representing the nine clusters were selected as parents for hybridization programme. These 12 parents were subjected to diallel crossing including reciprocals during 1996 November to 1997 March. F_1 generations were raised in randomised block design with two replications during 1997 May to 1998 September. F_1 generations were back crossed with both the parents. Observations on 18 characters were recorded in the F_1 generations. Six generations namely P_1, P_2, F_1, F_2, B_1C_1 and B_2C_1 of 10 crosses were sown during 1998 January to 1998 May in randomised block design with two replications. F_2 seeds of 12 more crosses were sown during this period in randomised block design. Observations were recorded on 12 characters. The data were subjected to statistical analysis.

The salient findings of the study are:

1. The characters namely, number of panicles m^{-2}, number of tertiary branches $panicle^{-1}$, yield $hectare^{-1}$, spikelet sterility percentage and alkali spreading value exhibited high broad sense heritability coupled with high expected genetic advance (EGA) and high genotypic coefficient of variation (GCV). The characters namely, height of plant at harvest, second upper most internodal length, length of flag leaf, ratio of vegetative phase to reproductive phase, number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake were found to have high broad sense heritability and high EGA coupled with moderate GCV. The character secondary branches $panicle^{-1}$ showed high

heritability, moderate EGA and moderate GCV. The characters grain length, grain breadth and kernel elongation ratio were found to have high heritability coupled with moderate EGA and low GCV.

2. While selecting genotypes for higher yield potential, emphasis should be given for moderate vegetative period, short period from panicle initiation to 50 per cent flowering and long ripening period.

3. The principal yield determining components identified are harvest index, number of tertiary branches panicle^{-1}, number of panicles m^{-2}, number of grains pa of spikelets panicle^{-1}, ratio of vegetative phase to reproductive phase, 1000 grain weight, number of days to 50 per cent flowering, number of days to harvest and spikelet sterility percentage.

4. Inter correlations among quantitative characters revealed the importance of increased panicle length, decreased second uppermost internodal length and decreased height of plant at harvest in enhancing yield potential. The inter correlations among the characters, number of grains panicle^{-1}, number of spikelets panicle^{-1}, leaf area plant^{-1} at maximum tillering stage, number of tertiary branches panicle^{-1} and panicle length were found to be positive and significant which indicates efficient source sink relationship. The second uppermost internodal length plays a major role as compared to the uppermost internodal length in determining the height of plant.

5. The absence of significant correlation between the important quality characters, namely, amylose content and alkali spreading value and grain yield ha^{-1} suggest that yield and quality characters can be recombined as desired.

6. Correlation between physico-chemical characters and cooking qualities suggest that longer grained types are better than wider grained ones for higher milling recovery. Hulling and milling recovery were not influenced by amylose content and alkali spreading value. High amylose type varieties will absorb more water with low gelatinization temperature and produce more volume of cooked material. Long grains have reduced amylose content compared to bold grains.

7. A selection model was formulated consisting of the characters namely, yield ha^{-1}, harvest index, number of days to harvest, number of tertiary branches $panicle^{-1}$, ratio of vegetative phase to reproductive phase and number of grains $panicle^{-1}$.

8. The 56 genotypes representing different eco-geographical regions were grouped into nine clusters based on genetic distance. There was no parallelism between geographical distribution and genetic diversity.

9. Combining ability studies showed that both additive and non-additive gene effects were important with predominance of non-additive gene action, for all

the characters except for 1000 grain weight, second uppermost internodal length and height of plant at harvest. For these three characters additive gene action was predominant.

10. The varieties Vytilla 3, Mahsuri, Mattatriveni and Karthika were identified as good general combiners.

11. In breeding programmes for combining earliness and short stature together, the varieties Mattatriveni and Hraswa can be utilized. Similarly, the variety Mahsuri can be recommended for incorporating both tallness and late maturity together.

12. Significant *sca* effects for yield and yield components were observed for the crosses evolved from all kinds of parental combinations namely, high x high, high x medium, medium x medium, high x low and low x low general combiners.

13. The genotypes Mahsuri, Karthika, Vytilla 3, Mattatriveni and IR62030-18-2-2 showed pronounced cytoplasmic effect on yield and various yield contributing characters.

14. The estimation of components of variation and genetic parameters using Hayman's approach revealed the presence of both additive and non-additive

gene effects in the inheritance of all the 18 characters with the predominance of non-additive gene action, except for 1000 grain weight, second uppermost internodal length and height of plant at harvest.

15. Heterosis analysis revealed that the extent of heterosis in rice was significant enough, to explore the prospects of commercial exploitation in warm tropical humid conditions. Three hybrids namely, Vytilla 3 x IR36, Vytilla 3 x IR60133-184-3-2 and PK3355-5-1-4 x Bhadra out yielded the check parent.

16. On the basis of *gca* effect of parents and *sca* effects of crosses, the crosses Vytilla 3 x Mattatriveni, Mahsuri x Vytilla 3 and Mahsuri x Mattatriveni were identified as suitable cross combinations for recombination breeding.

17. On the basis of *per se* performance, *sca* effect and heterosis, the hybrids Vytilla 3 x IR36, Vytilla 3 x IR60133-184-3-2, PK3355-5-1-4 x Bhadra, Vytilla 3 x Mattatriveni, Karthika x Bhadra, PK3355-5-1-4 x Karthika and PK3355-5-1-4 x IR62030-18-2-2 were identified for heterosis breeding.

18. There was no relationship between genetic diversity and heterosis. It was observed that hybrids can be formed from parents belonging to all types of divergent groups namely, high divergence, intermediate divergence and low divergence, with maximum number of superior hybrids derived from the combination of parents of intermediate divergent groups. It is suggested that

rice breeders, while selecting the parents for recombination breeding may stress on parents with intermediate genetic divergence rather than wide one. Parents for heterosis breeding can be selected from all the divergent groups.

19. The cytoplasm of Vytilla 3 (an improved saline tolerant variety of Kerala) was identified as an alternative source for cytoplasmic male sterility in rice, suitable to warm humid tropical climate experienced in Kerala. The varieties IR36 (International check) and Hraswa (Extra short duration high yielding rice variety recommended for cultivation in Kerala) are the proposed maintainer lines. Mattatriveni is the proposed restorer line for the proposed IR36`A' line and Hraswa `A' line.

20. The six parameter model analysis indicated that both additive and non-additive gene effects played an important role in the inheritance of yield and important yield components, with predominance of dominance, additive x additive and dominance x dominance type of gene effects. The nature of interaction was more of duplicate type.

21. Among the ten crosses which were selected for generation mean analysis, the crosses Mahsuri x Hraswa, Mahsuri x Vytilla 3, Mahsuri x IR60133-184-3-2, Kachsiung Sen Yu 338 x Vytilla 3, IR62030-18-2-2 x PK3355-5-1-4 and Mahsuri x IR36 were found to be the best crosses for screening out promising segregants and for fixation of characters in the promising lines.

22. In all the ten crosses absence of reduction in vigour in the F_2 generations for yield and all other yield attributes was observed.

23. Study of inheritance of kernel colour in rice revealed that it is a complex qualitative character. It apparently seems to be quantitative rather than qualitative in nature. Each red and white colour may be separately controlled by two or more sets of genes with predominance of inhibitory type gene interaction. There can be the possibility of multiallelic system of genes and cytoplasmic effect in controlling the kernel colour.

24. From $22F_2$ generations, seven early stabilized promising lines and 26 promising segregants were selected. The early stabilized lines from the crosses Karthia x Bhadra and PK3355-5-1-4 x Kachsiung Sen Yu338 were found to have most of the ideotype features proposed by IRRI with preferable cooking quality characters.

25. The nonsticky nature and red kernel colour, which are the preferable quality characters of Keralites, were successfully transferred to one of the early stabilized lines, namely Kachsiung Sen Yu338 x Mattatriveni, whose female parent was from Taiwan having white coloured kernel and was sticky on cooking.

The study revealed that there is ample scope for yield improvement in rice both through pedigree breeding and heterosis breeding. As yield and yield components were found to be under the control of all the three types of gene actions namely, additive, dominance and epistasis, a breeding method that could combine both fixable and non-fixable types of gene actions would be more desirable for yield improvement in rice. Hence, intercrossing of early segregating generations derived from multiple crosses seems to be the best suited method of breeding for yield improvement in rice.

The back cross seeds of sterile F_1 crosses and their F_3 seeds were handed over to the Department of Plant Breeding and Genetics for further studies in the direction of development of CMS lines. F_2 seeds of four cross combinations namely Vytilla 3 x Mattatriveni, Mattatriveni x Mahsuri, Vytilla 3 x Kachsiung Sen Yu 338 and IR36 x Mattatriveni were handed over to the same department for further genetic studies. The F_3 seeds of seven early stabilized promising crosses and 26 promising segregants were handed over to the Agricultural Research Station, Mannuthy, Kerala Agricultural University for further evaluation of segregants and for screening out elite types with high yield potential and preferable cooking qualities suited to Keralites and adaptable to various ecogeographical conditions of Kerala.

Future line of studies suggested

Efforts should be directed for the following future studies.

1. Conversion of the already obtained cytoplasmic male sterile F_1 crosses to fully sterile CMS lines by repeated back crossing with the respective recurrent parents.
2. Screening from the segregating populations of these cytoplasmic male sterile crosses for 100 per cent cytoplasmic male sterile lines.
3. Confirmation of the restoring ability of the proposed Mattatriveni `R' line and identification of other restorers.
4. Incorporation of the sterile cytoplasm of Vytilla 3 into other elite genotypes other than IR36 and Hraswa.
5. Screening for cytoplasmic male sterile system in other saline tolerant lines.
6. Screening of promising segregants selected, for high yield and quality with multiple resistance to pest and diseases, for developing varieties suited to various climatic and soil conditions of Kerala.

References

REFERENCES

Agrawal, K.B. and Sharma, R.K. 1987. Diallel analysis of duration in rice. *Indian J. Genet.* 47(1): 84-88

Allard, R.W. 1960. *Principles of Plant Breeding*. John Wiley and Sons, Inc. New York, p.89-98

Amirthadevarathinam, A. 1983a. Genetic variability, correlation and path analysis of yield components in upland rice. *Madras agric. J.* 70: 781-785

Amirthadevarathinam, A. 1983b. Combining ability and heterosis in dry and semi-dry paddy. *Madras agric. J.* 70: 233-237

Anandakumar, C.R. 1992. Variability and character association studies in upland rice. *Oryza*. 20: 11-13

Anandakumar, C.R. and Rangasamy, S.R.S. 1984. Combining ability of dwarf lines of indica rice. *Oryza*. 21: 218-224

Anandakumar, C.R. and Rangasamy, S.R.S. 1986. Heterosis and inbreeding depression in rice. *Oryza*. 23: 96-101

Anandakumar, C.R. and Subramanian, M. 1989. Genetic divergence in upland rice. *Int. Rice Res. Newsl.* 14(4): 6-7

*Angadi. S.P. 1976. Correlation studies and D^2 analysis in cowpea, (*Vigna sinensis* L. Savi) M.Sc. (Ag.). thesis, Tamil Nadu Agricultural University, Coimbatore.

Arumugachamy, S., Vivekanandan, P. and Subramanian, M. 1993. Character association and path coefficient analysis in ratoon rice. *Oryza*. **30**: 30-32

Arunachalam, V. 1989. Genetic basis of Plant Breeding. *Plant Breeding Theory and Practice* (Ed. Chopra, V.L.). Oxford and IBH Publishing Co. Ltd., New Delhi, p.324

Awan, M.A., Cheema, A.A. 1986. Relationship among test weight, plant height and height components in rice. *Pakist. J. agric. Res.* 7: 17-20

Azeez, M.H. and Shafi, M. 1966. *Quality in rice*. Tech. Bull. No. 13, *Dep. agric. Govt.* West Pakistan, p.50

Bai, N.R., Devika, R., Regina, A. and Joseph, C.A. 1992. Correlation of yield and yield components in medium duration rice cultivars. *Environment and Ecology*. **10**(2): 469-470

Bai, N.R., Regina, A., Devika, R. and Joseph, C.A. 1992. Genetic variability and association of characters in medium duration rice genotypes. *Oryza*.**29**: 19-22

Bansal, M.P., Panwar, D.V.S. and Naidu, M.R. 1990. Genetic divergence among the breeding lines of diverse crosses of rice. *Res. Development Reporter*. 7: 90-96

Banumathy, S. and Prasad, M.N. 1991. Studies of combining ability for development of new hybrids in rice. *Oryza*. **28**: 439-442

*Bao, G.L. 1989. Path analysis of main economic characters, selection index and panicle type in japonica rice. *Zhejiang agric. Sci*. 4: 160-162

Bhattacharyya, R.K. 1978. Estimates of genetic parameters of some quantitative characters in rice under stress soil (saline) conditions. *Oryza*. 15(2): 146-150

Bhattacharyya, R.K. 1980. The inter-relationship between grain yield attributes in salt tolerant rices grown in normal soil. *Oryza*. 17: 99-103

Bhattacharyya, R.K. 1981. Interrelationship between grain yield and some quantitative characters in rice adapted to saline soils. *Oryza*. 18: 147-149

Biswal, J. 1990. Genetic diversity of *Oryza nivara* and its allied taxa. *Oryza*. 27: 145-152

Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6^{th} int. Grassia. Cong*. 1: 277-283

Chakraborty, S. and Hazarika, M.H. 1994a. Estimation of various genetic parameters for yield and yield components of rice. *Oryza*. 31: 226-227

Chakraborty, S. and Hazarika, M.H. 1994b. Association analysis between grain yield and its components in rice. *Oryza*. 31: 263-265

Chakraborty, S.M.H., Hazarika, M.H. and Hazarika, G.W. 1994. Combining ability analysis in rice. *Oryza*. 31: 281-283

Chakraborty, S. and Hazarika, G.N. 1995. Inheritance of yield and yield traits in rice. *Oryza*. 32: 53-54

Chakraborty, S. and Hazarika, G.N. 1996. Gene action for some quantitative traits in rice. *Oryza*. 33: 136-137

Chatterjee, S.D., Chakraborty, R.C., Majumder, M.K. and Banerjee, S.P. 1978. Divergence in some rice strains in relation to low temperature tolerance. *Oryza*. 15:180-190

Chaubey, P.K. and Richharia, A.K. 1990. Genetic variability, correlations and path-coefficients in indica rices. *Indian J. Genet*. 53(4): 356-360

Chaudhury, D., Rao, M.J.B.K., Prasad, A.B. and Rao, A.V.S. 1980. Heritability and correlation in rice. *Oryza* 17: 194-199

Chauhan, J.S. 1996. Genotypic and phenotypic correlations between grain yield and other associated characters in very early duration elite breeding cultures of rice. *Oryza.* 33: 26-30

Chauhan, J.S. and Chauhan, V.S. 1995. Heterosis and inbreeding depression in rainfed rice. *Oryza* 32: 188-190

Chauhan, J.S., Chauhan, V.S. and Lodh, S.B. 1994. Studies on milling quality components of rainfed upland rice. *Oryza.* 31: 50-52

Chauhan, J.S., Chauhan, V.S. and Lodh, S.B. 1995. Comparative analysis of variability and correlations between quality components in traditional rainfed upland and low land rice. *Indian J. Genet.* 55(1):6-12

Chauhan, J.S., Chauhan, V.S., Sinha, P.K. and Prasad, K. 1989. Analysis of *in situ* variability for some panicle and grain characters in native germplasm of rice. *Oryza.* 26: 243-249

Chauhan, V.S., Chauhan, J.S. and Tandon, J.P. 1993. Genetic analysis of grain number, grain weight and grain yield in rice (*Oryza sativa* L.). *Indian J. Genet.* 53: 261-263

Chauhan, J.S., Chauhan, V.S. and Variar, M. 1993. Genetic variation and character association in rainfed upland rice. *Oryza.* 30: 116-119

Chauhan, J.S., Lopez, F.S.S. and Vergara, B.S. 1990. Heritability and genetic advance in early segregating populations of rice. *Oryza.* 27: 15-20

Chauhan, J.S. and Nanda, J.S. 1983. Inheritance of amylose content and its association with grain yield and yield contributing characters in rice. *Oryza.* 20: 81-85

Chauhan, V.S. and Singh, B.B. 1982. Heterosis and genetic variability in relation to genetic divergence in soybean. *Indian J. Genet. Plant Breed.* 42: 324-328

Darrah, L.L. and Hallaur, A.R. 1972. Genetic effects estimated from generation mean in four diallel sets of maize inbreds. *Crop Sci.* 12(19): 720-25

De, R.N. and Rao, A.V.S. 1987. Genetic divergence in rice under low land situation. *Crop Improv.* 14: 128-131

De, R.N. and Rao, A.V.S. 1988. Genetic variability and correlation studies in rice under semi-deep waterlogged situation. *Oryza.* 25: 360-364

De, R.N., Reddy, J.N., Rao, A.V.S. and Mohanty, K.K. 1992. Genetic divergence in early rice under two situations. *Indian J. Genet.* 52: 225-229

De, R.N., Seetharaman, R., Sinha, M.K. and Banerjee, S.P. 1988. Genetic divergence in rice. *Indian J. Genet.* 48: 189-194

Deosarkar, D.B., Misal, M.B. and Nerkar, Y.S. 1989. Variability and correlation studies for grain quality characters in breeding lines of rice. *J. Maharashtra agric. Univ.* 14(1): 124-125

Dhaliwal, T.S. and Sharma, H.L. 1990. Combining ability and maternal effects for agronomic and grain characters in rice. *Oryza.* 27: 122-128

Dhanraj, A., Jagadish, C.A. and Uprevijay. 1987. Heritability in segregating generation (F_2) of selected crosses in rice (*Oryza sativa* L.). *J. Res. APAU.* 15: 16-19

Dssawant. 1995. Character association and path coefficient analysis in rice (*Oryza sativa*). *Indian J. agric. Sci.* 65: 752-753

Ganesan, K., Manuel, W.W. and Sundaram, T. 1995. Analysis of yield and yield components in rice. *Int. Rice Res. Newsl.* 20: 1

Ganesan, K., Manuel, W.W., Vivekanandan, P. and Pillai, M.A. 1997. Combining ability, heterosis and inbreeding depression for quantitative traits in rice. *Oryza.* 34:13-18

Ganesan, K. Subramanian, M., manuel, W.W. and Sundaram, T. 1997. Genetic studies in F_2 and F_3 generations of rice. *Madras agric. J.* 84: 319-323

Ghorai, D.P. and Pande, K. 1982. Inheritance of yield and yield components and their association in a rice cross AC 1063 x AC 27. *Oryza.* 19: 185-187

Ghosh, A.K. and Govindaswami, S. 1972. Inheritance of starch iodine blue value and alkali digestion value in rice and their genetic association. *Riso.* 21: 423-432

Ghosh, P.K. and Hossain, M. 1986. Combining ability of indigenous exotic crosses of rice. *Exp. Genetics.* 2: 47-50

Ghosh, P.K. and Hossain, M. 1988. Genetic evaluation and regression analysis of yield and yield attributes in rice. *Oryza.* 25: 251-254

Gomathinayagam, P., Natarajan, S. and Subramanian, M. 1990. Genetic variability in drought tolerant genotypes of rice. *Oryza.* 27: 328-330

Gomathinayagam, P., Pappaiah, C.M. and Soundrapandian, G. 1988. Path coefficient analysis in upland varieties of rice. *Madras agric. J.* 75: 449-450

Govindaswami, S., Ghosh, A.K., Mahana, N.K. and Dash, A.B. 1973. Genetic variability and correlation studies on protein content and some quantitative characteristics of rice (*Oryza sativa* L.). *Oryza*. 10: 1-8

Grafius, J.E. 1959. Heterosis in barley. *Agron. J.* 51: 551-54

Gravois, K.A. and Mcnew, R.W. 1993. Genetic relationships among and selection for rice yield and yield components. *Crop Sci.* 33(2): 249-252

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci.* 9: 463-493

Hahn, W.S., Chae, Y.A. 1987. Estimating genetic parameters and efficiency analysis of the crossing among single, double, three way and back cross in rice (*Oryza sativa* L.) breeding. *Research Reports of the Rural Development Administration, Agricultural Engineering, Farm Management and Sericulture,* Korea Republic. 29(2): 36-57

Hanson, C.H., Robinson, H.F. and Comstock, R.E. 1956. Biometrical studies of yield in segregating populations of Korean Lespedeza, *Agron. J.* 48: 268-272

Hayman, B.I. 1954. The theory and analysis of diallel crosses. *Genetics*. 39: 789-809

Hayman, B.I. 1958. The separation of epistatic from additive and dominance variation in generation means. *Heredity*. 12: 371-390

Hazel, L.N. 1943. The genetic basis for construction of selection index. *Genet.* 28: 476-490

Heda, G.D. and Reddy, G.M. 1986. Studies on the inheritance of amylose content and gelatinisation temperature in rice.' (*Oryza sativa* L.). *Genetica agraria.* 40: 1-8

*Huang, C.W. and Li, M. 1990. The genetic analysis of amylose content of rice (*Oryza sativa* L.). *J. South China agric. Univ.* 13: 23-29

Hussain, A.A., Maurya, D.M. and Vaish, C.P. 1987. Studies on quality status of indigenous upland rice (*Oryza sativa*). *Indian J. Genet.* 47: 145-152

IRRI. 1995. Standard evaluation system for rice. IRRI, Manila, Philippines, p.44

IRRI. 1972. Annual report for 1971. Int. Rice. Res. Institute, Los Banos, Philippines, p.238

Jangale, R.D., Ugale, S.D. and Dumbre, A.D. 1987. A study of cause and effect relationship among quantitative traits in upland paddy. *J. Maharashtra agric. Univ.* 12(1): 31-34

Jenson, N.F. 1970. A diallel selective mating system for cereal breeding. *Crop Sci.* 10: 629-35

Jinks, J.L. and Hayman, B.I. 1953. The analysis of diallel crosses. *Maize Genetics Coop. Newsl.* 27: 48-54

Johanson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soybean. *Agron. J.* 47: 314-318

Joshi, A.B. 1979. Breeding methodology for autogamous crops. *Indian J. Genet. Plant Breed.* 39: 567-578

Jun, B.T. 1985. Studies on the inheritance of grain size and shape in rice (*Oryza sativa* L.). *Research Reports, Rural Development Administration,* Korea Republic, Crops. 27(2): 1-27

Kalaimani, S. and Sundaram, M.K. 1987a. Genetic analysis in rice (*Oryza sativa* L.). *Madras agric. J.* 74: 369-372

Kalaimani, S. and Sundaram, M.K. 1987b. Heterosis in rice(*Oryza sativa* L.). *Madras agric. J.* 74: 450-454

Kalaimani, S. and Sundaram, M.K. 1988. Combining ability for yield and yield components in rice. *Madras agric. J.* 75: 99-104

Katoch, A., Katoch, P.C. and Kaushik, R.P. 1993. Selection parameters among tall and semidwarf genotypes in rice. *Oryza.* 30: 106-110

Katre, N.B. and Jambhale, N.D. 1996. Combining ability for grain yield and related characters in rice. *Oryza.* 33: 21-25

Kaushik, A. and Patel, J.P. 1982. Relationship of characters contributing to yield in transplanted, short statured rice. *Indian J. agric. Sci.* 52: 750-753

Kaushik, R.P. and Sharma, K.D. 1988. Gene action and combining ability for yield and its component characters in rice under cold stress conditions. *Oryza.* 25: 1-9

Kaw, R.N. and Cruz, N.M.D. 1990. Genetic analysis of amylose content, gelatinization temperature and gel consistency in rice. *J. Genetics Pl. Breeding.* 44: 103-111

Kaw, R.N. and Cruz, N.M.D. 1991. Heterosis in physiochemical grain quality characters in intervarietal hybrids in rice. *Indian J. Genet.* 51: 51-58

Kempthorne, O. 1957. *An introduction to Genetic Statistics*. Newyork: John Wiley and Sons, Inc; London; Chapman & Hall Ltd.

Khalcque, M.A., Joarder, O.I., Eunus, A.M. and Islam, A.K.M.N. 1978. Nature of gene interaction in the inheritance of yield and yield components in some rice crosses. *Oryza*. 15: 157-172

Khush, G.S. 1984. IRRI breeding programme and its wide impact on increasing rice production. In the Gustafson (ed). *Gene manipulation in crop improvement*. Plenum Press. New York

Kihupi, A.N. and Doto, A.T. 1989. Genotypic and environmental variability in selected rice characters. *Oryza*. 26: 129-134

Kim, J.K. and Vergara, B.S. 1991. A low tillering ideotype of rice plant for increasing grain yield potential. *Korean J. Crop Sci.* 36: 134-142

Kotatah, K.C., Rao, P.C., Sreerama Reddy, N. and Sarma, Y.R.B. 1986. Mahalanobis's D^2 and metroglyph analysis in mid-duration genotypes of rice. *Indian J. agric. Sci.* 56: 151-160

Krishnayya, G.R., De, R.N., Mahana, N.K. and Bhattacharjee, D.P. 1991. Direct and indirect effects of some characters on grain yield in low land rice (*Oryza sativa* L.). *Oryza*. 28: 117-118

Kumar, M.D. and Mani, S.C. 1998. Genetic analysis of some polygenic traits in rice. *Oryza*. 35: 106-108

Kumar, C.R.A. and Subramanian, M. 1992. Genetic divergence studies in upland rice. *Oryza*. 29: 139-141

Kuo, Y.C. and Liu, C. 1986. Genetic studies on large kernel size of rice and inheritance of grain dimensions of brown rice. *J. agric. Res. China*. 35: 401-412

Kuo. Y.C., Liu, C., Chang. T.M. and Hsieh, S.C. 1988. Inheritance of quality and grain characteristics in indica rice. *Special publication* - Taichung District Agricultural Improvement Station. 13: 137-152

Lal, J.P., Richharia, A.K. and Agrawal, R.K. 1983. Coheritability, correlation and genetic parameters in semi-dwarf cultures of rice. *Oryza*. 20: 195-203

Liao, P.Y. and Liu, J.X. 1983. Multiple regression analysis of the characters influencing grain yield of rice. *Acta Agronomica Sinica*. 9(2): 117-122

Lin, S.C. and Yuan, L.P. 1980. Hybrid rice breeding in China. In Innovative Approaches to Rice Breeding, IRRI, Los Banos, Philippines, p.35-52

Little, R.R., Hilder, G.B. and Dawson, E.H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal chem*. 35: 111-126

Lokaprakash, R., Shivashankar, G., Mahadevappa, M., Shankaregowda, B.T. and Kulkarni, R.S. 1991. Combining ability for yield and its components in rice. *Oryza*. 28: 319-322

Lokaprakash, R., Shivashankar, G., Mahadevappa, M., Shankaregowda, B.T. and Kulkarni, R.S. 1992. Study on genetic variability, heritability and genetic advance in rice. *Indian J. Genet*. 52(4): 416-421

Lu, Z.T., Tang, S.C., Xun, Z.M., Ming, S.K. and Sheng, Z.D. 1988. Analysis of yield components in conventional and hybrid rice. *Zheijiang agric. Sci.* 4: 156-158

Madan, A. and Bhat, C.M. 1984. Cooking quality and sensory evaluation of high yielding varieties of rice. *Haryana agric. Univ. J. Res.* 14(1): 94-99

Maharajan, R.K., Rao, J.R., Sarma, Y.R.B. and Ghosh, A. 1987. Genetic divergence in rice. *Crop Improv*. 8: 85-89

Malik, S.S., Singh, H., Malik, C.V.S., Tonk, D.S. and Faroda, A.S. 1990. Relative performance of some medium duration rice genotypes in North Haryana. *Oryza*. 27:196-198

Mall, C.N. and Maurya, D.M. 1992. Genetic diversity in breeding lines of two crosses in rainfed lowland rice. *Oryza*. 29: 89-91

Mandal, R.K. and Saran, S. 1989. Hybrid rice breeding for grain characters. *Oryza*. 26: 91-93

Manuel, W.W. and Palanisamy, S. 1989. Line x Tester analysis of combining ability in rice. *Oryza*.26: 27-32

Manuel, W.W. and Prasad, M.N. 1992. Combining ability and heterosis in rice. *Oryza*. 29: 15-18

Manuel, W.W. and Rangaswamy, M. 1993. Correlation and path analysis in hybrid rice. *Oryza*. 30: 248-250

Mather, K. and Jinks, J.L. 1971. *Biometrical genetics*. Champman and Hall Ltd., London

Maurya, D.M. 1976. Heritability and genetic advance in rice. *Oryza*. 13: 97-100

Maurya, D.M., Singh, S.K. and Singh, R.S. 1986. Genetic variability in 48 low land rice cultivars of Uttar Pradesh, India. *Int. Rice Res. Newsl.* 11: 4-13

Mehetre, S.S., Mahajan, C.R., Patil, P.A., Lad, S.K. and Dhumal, P.M. 1994. Variability, heritability, correlation, path analysis and genetic divergence studies in upland rice. *Int. Rice Res. Newsl.* 19(1): 8-10

Mishra, S.K., Maurya, D.M. and Vishwakarma, D.N. 1993. Individual ranking method of simultaneous selection in rainfed rice (*Oryza sativa* L.). *Indian J. Genet.* 53(4): 424-426

Mishra, M. and Pandey, M.P. 1998. Heterosis breeding in rice for irrigated sub-humid tropics in north India. *Oryza.* 35(1): 8-14

Mohanty, K.K., De, R.N. and Srivastava, D.P. 1995. Mode of gene action for some important characters in rice. *Oryza.* 32: 5-9

Mohapatra, K.C. and Mohanty, H.K. 1986. Inheritance of some quantitative characters including heterosis in rice by combining ability analysis. *Rice genetics.* Int. Rice Res. Institute, Manila, p.579-591

Murai, M., Kinoshita, T. and Hirose, S. 1987. Diallel analysis of plant type in rice. Bulletin of the College of Agriculture and Veterinary Medicine, Nihon University. 44: 112-122

Murthy, N. and Kulkarni, R.S. 1996. Heterosis for physiological traits in rice. *Oryza.* 33: 100-102

Murthy, N., Shivashankar, G., Hittalamani, S. and Udaykumar, M. 1991. Association analysis among yield and some physiological traits in rice. *Oryza.* 28: 257-259

Murty, B.R. and Arunachalam, V. 1966. The nature of divergence in relation to breeding system in some crop plants. *Indian J. Genet.* 26: 89-98

Murty, P.S.S. and Murty, M.S. 1981. Influence of LAI at flowering on the productive efficiency of long duration rice cultures. *Oryza.* 18: 35-38

Nadarajan, N. and Kumaravelu, S. 1994. Genetic analysis in drought resistant rice (*Oryza sativa* L.) cultivars. *Oryza*. 31: 228-231

Nath, N. and Talukdar, P. 1997. Genetic variability and correlation studies in segregating populations of indegenous scented x high yielding non-scented crosses of rice. *Oryza*. 34: 91-93

Onate, L.U. and Del Mundo, H.M. 1966. Eating quality of some varieties of low land rice. *Philipp. agric.* 47: 208

Padmavathi, N., Mahadevappa, M. and Reddy, O.U.K. 1997. Combining ability and heterosis for grain yield and its related characters in rice. *Oryza*. 34: 107-111

Palaniswamy, K.M. and Kumarankutty, K. 1990. Effect of tiller height and flowering duration on panicle length in three rice varieties. *Oryza*. 27: 433-435

Pande, K. and Ghorai, D.P. 1987. Genetic divergence in rice. *Oryza*. 24: 353-357

Panse, V.G. 1957. Genetics of quantitative characters in relation to plant breeding. *Ind. J. Genet.* 17: 318-328

Panwar, D.V.S., Bansai, M.P. and Naidu, M.R. 1989. Correlation and path-coefficient analysis in advanced breeding lines of rice. *Oryza*. 26: 396-398

Panwar, D.V.S., Paroda, R.S. and Rana, R.S. 1985. Combining ability for grain yield and related characters in rice. *Indian J. agric. Sci.* 55: 443-448

Paramasivam, K., Giridharan, S., Soundararaj, A.P.M.K., Vivekanandan, P. and Parthasarathy, P. 1995. Combining ability of some varieties for grain quality traits in diallel mating system. *Int. Rice Res. Newsl.* 20(1): 6-7

Paramasivan, K.S. 1987. Study on correlation in long duration rice accessions. *Madras agric. J.* 74: 47-49

Paramasivan, K.S. 1988. Correlation studies in semi-dwarf and tall indica rice accessions. *Oryza.* 25: 307-309

Paramasivan, K.S. 1991. Correlation study in dwarf rice accessions. *Oryza.* **28**: 237-239

Paramasivan, K.S. and Rangasamy, S.R.S. 1987. Yield and yield components in high and low yielding F_1s and their F_2s in rice. *Oryza.* **24**: 206-214

Paramasivan, K.S. and Rangasamy, S.R.S. 1988a. Genetic analysis of yield and its components in rice. *Oryza.* 25: 111-119

Paramasivan, K.S. and Rangasamy, S.R.S. 1988b. Heterosis in hybrids of rice varieties. *Oryza.* 25: 396-401

Pathak, H.C. and Patel, M.S. 1989. Genetic variability, and character association in upland - rice. (*Oryza sativa* L.). *GAU Res. J.* 14(2): 34-41

Patil, P.A., Mahajan, C.R., Mehetre, S.S. and Hajare, D.N. 1993. Analysis of variability and heritability in upland rice. *Oryza.* **30**: 154-156

Patnaik, R.N., Pande, K., Ratho, S.N. and Jachuck, P.J. 1991. Heterosis in relation to gentic divergence and combining ability in rice. *Oryza.* 28: 455-458

Peng, J.Y. and Virmani, S.S. 1990a. Combining ability for yield and four related traits in relation to hybrid breeding in rice. *Oryza.* 27: 1-10

Peng, J.Y. and Virmani, S.S. 1990b. Heterosis in some inter-varietal crosses of rice. *Oryza.* **28**: 31-36

Peng, J.Y., Virmani, S.S. and Julfiquar, A.W. 1991. Relationship between heterosis and genetic divergence in rice. *Oryza.* 28: 129-133

Ponnuthurai, S. and Virmani, S.S. 1985. Yield depression in F_2 hybrids of rice *Oryza sativa* L. *Int. Rice Res. Newsl.* 10: 21

Prasad, G.S.V., Prasad, A.S.R., Sastry, M.V.S. and Srinivasan. 1988. Genetic relationship among yield components in rice (*Oryza sativa*). *Indian J. agric. Sci.* 58(6): 470-472

Prasad, S.K. and Singh, T.P. 1986. Heterosis in relation to genetic divergence in maize (*Zea mays* L.). *Euphytica.* 35: 919-924

Ram, T. 1994. Genetic of yield and its components in rice (*O. Sativa* L.). *Indian J. Genet.* 54: 149-154

Ram, T., Singh, J. and Singh, R.M. 1991. Genetic analysis of yield and components in rice. *Oryza.* 28:447-450

Ramalingam, J., Nadarajan, N., Rangaswamy, P. and Vanniarajan, C. 1994. Genetic variability for panicle characters in rice. *Oryza.* 31: 56-57

Ramalingam, J., Nadarajan, N.,Vanniarajan and Rangasamy, P. 1997. Combining ability studies involving CMS lines in rice. *Oryza.* 34: 4-7

Ramalingam, A., Sivasamy, N., Subramanian, S. and Koodalingam, K. 1995. Correlation and path analysis of rice grain yield under alkali stress conditions. *Int. Rice Res. Newsl.* 20(3):3-8

Rangaswamy, R. 1995. *A Text Book of Agricultural Statistics.* Wiley Eastern Limited, New Delhi, p.496

Rangel, P.H.N., Cruz, C.D., Vencovsky, R. Ferreira, R. and De, P. 1991. Selection of local lowland rice cultivars based on multivariate genetic divergence. *Revista Brasileira de Genetica.* 14: 437-453

Rao, C.R. 1952. *Advanced Statistical Methods in Biometrical Research.* John Wiley and Sons, New York

Rao, M.J.B. 1990. Relationship between grain yield and associated characters in high yielding tall-dwarf and semidwarf rice lines. *Oryza.* 27: 393-398

Rao, S.S. and Shrivastav, M.N. 1994. Genetic variation and correlation studies in rainfed upland rice. *Oryza.* 31: 288-291

Rao, S.B. and Vasudevamurthy, A.R. 1952. The amylose and amylopectin contents in rice and their influence on the cooking quality of cereals. *Proc. Indian agric. Sci.* p.70-80

Rather, A.G., Mir, G.N. and Raina, R.L. 1997. Cause and effect relationship of yield and other characters in rice. *Madras agric. J.* **84**: 311-313

Raut, V.M., Rao, V.S.P., Patil, V.P. and Deodikar, G.B. 1985. Genetic divergence in *Triticum durum. Indian J. Genet.* 45: 141-151

Reddy, C.R., Gopinath, M., Reddy, G.V., Satyanarayana, A. and Reddy, J.R. 1988. Heritability and Genetic Advance in Rice. *J. Res. APAU.* **18:** 51-53

Reddy, C.D.R. and Nerkar, Y.S. 1992. Studies on correlations and path coefficient in parental lines sensitive to iron chlorosis and F_2 populations (tolerant x sensitive) of rice. *Oryza.* 29: 204-207

Reddy, C.D.R. and Nerkar, Y.S. 1995. Heterosis and inbreeding depression in upland rice crosses. *Indian J. Genet.* 55: 94-97

Remina, L.K., Hazarika, M.H. and Talukdar, P. 1992. Performance of indigenous and improved rice genotypes of Assam during winter season. *Oryza.* 29: 288-292

Reuben, S.O.W.M. and Kisanga, J.R.L. 1989. Cause and effect relationships of yield and its components in advanced breeding lines of upland rice. *Oryza.* 26: 338-342

Rogbell, J.E. and Subbaraman, N. 1997. Line x Tester analysis for combining ability in saline rice cultivars. *Madras agric. J.* 84: 22-25

Rosamma, C.A., Elsy, C.R. and Potty, N.N. 1992. Cause and effect relationship of low yield of second crop rice in Kerala. *Oryza.* 29: 298-300

Roy, A. and Kar, M.K. 1992. Heritability and correlation studies in upland rice. *Oryza.* 29: 195-199

Roy, J.K. and Pani, D. 1994. Variation in panicle initiation period in indica rice varieties. *Oryza.* 31:188-191

Roy, A. and Panwar, D.V. 1993. Genetic divergence in rice. *Oryza.* 30: 197-201

Sadananda, A.R., Zaman, F.U. and Siddiq, E.A. 1987. Genetic variability for indices of major cooking and nutritive quality characters in rice (*Oryza sativa* L.) collections from northeast Indian hills. *Indian J.* Genet. 47: 249-255

Sadasivam, S. and Manickam, A. 1992. Determination of Amylose. *Biochemical Methods for agricultural sciences. Wiley Eastern Limited, New Delhi,* p.12-13

Sahai, V.N. and Chaudhary, R.C. 1991. A study of commercial exploitation of heterosis in rice. *Oryza.* 28:27-30

Sahai, V.N., Mandal, R.K., Chatterjee, S.K. and Chaudhary, R.C. 1986. Heterosis of grain quality characters in some hybrid rice. *Oryza.* 23: 182-184

Sarathe, M.L. and Perraju, P. 1990. Genetic divergence and hybrid performance in rice. *Oryza.* 27: 227-231

Sarathe, M.L. and Singh, S.P. 1986. Combining ability for yield and related characters in rice. *Oryza.* 23: 224-228

Sarathe, M.L., Singh, S.P. and Perraju, P. 1986. Heterosis and combining ability for quality characters in rice. *Indian J. agric. Sci.* 56: 749-753

Sarawgi, A.K. and Shrivastava, M.N. 1988. Heterosis in rice under irrigated and rainfed situations. *Oryza.* 25:10-15

Sarawgi, A.K. and Shrivastava, M.N. 1991. Parental diversity and its relationship with hybrid vigour in rice (*Oryza sativa*) under irrigated and rainfed conditions. *Ind. J. agric. Sci.* 61: 36-39

Sardana, S. and Borthakur, D.N. 1987. Combining ability for yield in rice. *Oryza.* 24: 14-18

Sardana, S. and Sasikumar, B. 1987. Genetic variability in cold tolerant genotypes of rice. *Oryza.* 24: 119-122

Sardana, S., Sasikumar, B. and Modak, D. 1989. Variability and path analysis in fixed cultures of rice. *Oryza.* 26: 250-251

Selvakumar,K.S.,Soundrapandian G. and Amirthadevarathinam, A. 1989. Genetic divergence for yield and yield components in cold tolerant rice. *Madras agric. J.* 76: 688-694

Shamsuddin, A.K.M. 1986. Analysis of genetic variation for panicle and grain characteristics in relation to grain yield in rice. *Pakist. J. Sci. Res.* 34(3/4): 75-78

Sharma, R.S. and Choubey, S.D. 1985. Correlation studies in upland rice. *Indian J. Agron.* 30: 87-88

Sharma, R.K. and Dubey, S.D. 1997. Variation and association among panicle traits in rice. *Oryza.* 34: 8-12

Sharma, R.K., Koranne, K.D. and Dube, S.D. 1996. Combining ability analysis for yield and yield components in rice. *Oryza.* 33: 18-20

Sharma, D.K., Shrivastava, M.N. and Shrivastava, P.S. 1986. Nature of gene interaction in the inheritance of grain yield, harvest index and their component characters in rice. *Indian J. agric. Sci.* 56: 397-403

Sharma, D.K. Shrivastava, M.N. and Tiwari, D.K. 1987. Line x Tester analysis for harvest index and related characters in rice (*Oryza sativa* L.). *Indian J. Genet.* 47: 211-218

Shouichi, Y., Douglasa, F., James, H.C. and Kwanchai. A.G. 1976. *Laboratory Manual for Physiological studies of Rice.* p.69-77

Singh, R.P. 1980. Association of grain yield and its components in F_1 and F_2 populations of rice. *Oryza.* 17: 200-204

Singh, R.S. 1981. Genetic divergence in indigenous varieties of rice grown in Mirzapur district, U.P., India. *Int. Rice Res. Newsl.* 6: 3-4

Singh, R.P. 1983. Studies on genetic variability in rice. *Madras agric. J.*70: 436-440

*Singh, S.P. 1984. Genetic architecture of grain yield in rice. *Genetica Iberica.* 36: 237-243

Singh, V.P. 1998. Physiological aspects of grain yield in rice. *Short course on physiological analysis of yield in crop plants.* Sponsored by Indian Council of Agricultural Research, Indian Agricultural Research Institute, New Delhi, p.156-165

Singh, R.B. and Bains, S.S. 1968. Genetic divergence for ginning out-turn and its components in upland cotton. *Indian J. Genet.* 20: 262-268

Singh, R.S., Chauhan, S.P. and Maurya, D.M. 1986. Genetic variability in 98 upland rice cultivars of India. *Int. Rice Res. Newsl.* 11(4): 9-10

Singh, Y.P., Kumar, A. and Chauhan, B.P.S. 1981. Genetic divergence in pearl millet. *Indian J. Genet. Plant Breed.* 41: 186-190

Singh, R.P., Rao, M.J.B.K. and Rao, S.K. 1984. Genetic evaluation of upland rice germplasm. *Oryza.* 21: 132-137

Singh, R.S. and Richharia, A.K. 1978. Combining ability for certain quantitative characters in rice. *Oryza.* 15: 34-38

Singh, R.S. and Richharia, A.K. 1980. Diallel analysis of grain yield and its components in rice. *Indian J. Agric. Sci.* 50: 1-5

Singh, N.B. and Singh, H.G. 1985. Heterosis and combining ability for kernel size in rice. *Indian J. Genet.* 45(2): 181-185

Singh, R. and Singh, A. 1991. Combining ability for harvest index and other related characters in rice. *Oryza.*28: 19-22

Singh, N.K., Singh, N.B., Jha, P.B. and Sharma, V.K. 1993. Combining ability and heterosis for some quality traits in rice. *Oryza.* 30: 159-161

Singh, S.K., Singh, R.S., Maurya, D.M. and Verma, O.P. 1987. Genetic divergence among lowland rice cultivars. *Indian J. Genet.* 47: 11-14

*Singh, S.P., Singh, H.N. and Rai, J.N. 1980. Multivariate analysis in relation to breeding systems in Okra *(Abelmoschus esculentus* (L) Moench). *Z. Pflanzonzenchtg.* 84: 57-62

Singh, S.P., Singh, H.G. and Singh, A.K. 1984. Hybrid vigour for yield and its components in rice. *Genetica Iberica*. 36: 53-59

Singh, S.P., Singh, R.R., Singh, R.P. and Singh, R.V. 1980a. Heterosis in rice. *Oryza*. 17: 109-113

Singh, S.P., Singh R.R., Singh, R.P. and Singh, R.V. 1980b. Combining ability in rice. *Oryza*. 17: 104-108

Sinha, M.K. and Banerjee, S.P. 1987. Path analysis of yield components in rice. *Kasetsart Journal, Natural Sciences*. 21(1): 86-92

Sonrexa, P. 1984. Genetic evaluation of some cultivars for quality traits in rice. (*Oryza sativa* L.). *Cereal Res. Communications*. 12: 89-96

Srivastava, D.P. 1981. Intermediate statured derivatives from two sources in rice. *Oryza*. 18: 39-43

Srivastava, D.P. and Roy, R.R. 1985. Inheritance of intermediate stature in rice. *Oryza*. 22: 97-101

Subramanian, S. and Rathnam, M. 1984a. Studies on combining ability for yield components in rice. *Madras agric. J.* 71: 424-430

Subramanian, S. and Rathinam, M. 1984b. Heterosis in rice. *Madras agric. J.* 71: 402-405

Swaminathan, M.S. 1989. Role of rice in global food security. *Oryza*. 26: 1-2

Swaminathan, M.S., Siddiq, E.A. and Sharma, S.D. 1972. Outlook for hybrid rice in India. In: Rice Breeding, IRRI, Laguna, Phillippines, p.609-613

Takita, T. 1986. Prospects of large grain rice for high yielding varieties. *Int. Rice Commission Newsl.* 35: 46-48

Thyagarajan, A. and Sivasubramanian, V. 1990. Study on cytoplasmic influence on economic traits in rice (*Oryza sativa* L.). *Oryza.* 27: 427-432

Tomar, J.B. 1987. Analysis of genetic components of generation mean for some quality characters in rice. *Oryza.* 24: 112-118

Tomar, J.B. and Nanda, J.S. 1981. Correlations between quality traits in rice. *Oryza* 19: 13-16

Tripathy, P. and Misra, R.N. 1986. Diallel analysis for plant height in dwarf and semidwarf rice. *Oryza.* 23: 27-31

Tripathy, P. and Misra, R.N. 1987. Combining ability for some of the quantitative characters in rice. *Oryza.* 24: 163-165

Verma, S.K. and Mani, S.C. 1997. Yield component analysis and its implications for early generation selection in rice. *Oryza.* 34: 102-106

Verma, V.S. and Mehta, R.K. 1970. Genetic divergence in Lucerma. *J. Maharastra agric. University.* 1: 23-8

Verma, Y.S., Singh, H. and Pandey, M.P. 1995. Combining ability fór yield and its components in rice. *Oryza.* 32: 1-5

Virmani, S.S., Raj, K.G., Casal, C., Dalmacio, R.D. and Aurin, P.A. 1985. Rice Genetics. IRRI, Manila, Philippines, p.635

Vivekanandan, P. and Giridharan, S. 1995. Heterosis for kernel characters in rice. *Int. Rice Res. Newsl.* 20: 1-7

Vivekanandan, P. and Giridharan, S. 1997. Combining ability for grain traits in rice. *Madras agric. J.* 84: 129-132

Vivekanandan, P. and Subramanian, S. 1993. Genetic divergence in rainfed rice. *Oryza.* 30: 60-62

Wada, S. 1991. The present position of yield and yield components for paddy rice in Hokkaido (z). *Agric. Hort.* 66: 405-408

Wright, S. 1923. The theory of path coefficients. *Genet.* 8: 239-355

Xiang, Z.M., Min, S.K., Shen, S.T., Qiu, H.B., Kong, F.L. and Wang, G.L. 1986. Analysis of the yield components of newly released indica varieties and future prospects. *Scientia Agricultura Sinica.* 6: 17-23

* Original was not seen

Appendices

Appendix i Mean performance of 56 high yielding rice varieties of diverse origin for different quantitative and qualitative characters

Sl. No.	Cultures	Source	Upper most internodal length (cm)	Second upper most internodal length (cm)	Orientation of leaf (in degree)	Length of flag leaf (cm)	Maximum width of falg leaf (cm)	Number of days to panicle initiation	Number of days to 50% flowering
1	AS 25370	INDIA	33.40	17.74	25.00	24.07	1.41	63.3	93.3
2	AT 85-2	SRILANKA	34.24	22.26	25.00	28.00	1.60	60.7	97.7
3	BR 4676 - 72 - 2- 4	BANGLADESH	33.96	18.63	22.67	26.27	1.19	66.3	102.3
4	BR4689-17-1-5	BANGLADESH	34.87	21.22	23.33	29.96	1.52	61.0	90.0
5	CCI 22 - 23 - 4 - 301	INDIA	35.93	19.25	27.00	27.96	1.35	63.0	101.0
6	CCI 38 - 11 - 6 F - 314	INDIA	33.90	19.75	21.00	29.36	1.41	60.7	102.7
7	CR 294 - 548	INDIA	30.93	19.05	14.00	27.59	1.31	66.0	105.0
8	HS INCHU 64	TAIWAN	34.10	20.24	22.00	30.08	1.39	59.3	97.3
9	IR53970 - 21 - 2 - 3 - 2	IRRI	34.14	13.75	22.67	29.68	1.35	64.7	89.7
10	IR54883 - 152 - 3 - 3	IRRI	36.40	14.43	21.67	28.34	1.25	63.0	90.0
11	IR54550 - 181 - 2 - 1 - 2 - 3	IRRI	38.19	15.73	24.67	33.24	1.32	67.3	102.3
12	IR56453 - 184 - 2 - 1 - 2	IRRI	34.11	16.72	18.67	27.20	1.30	57.3	90.3
13	IR59682 - 132 - 1 - 1 - 2	IRRI	34.61	16.93	17.00	27.46	1.24	70.0	103.0
14	IR60133 - 184 - 3 - 2 - 2	IRRI	35.23	15.86	23.67	21.13	1.41	58.3	102.3
15	IR60832 - 187 - 2 - 2 - 2	IRRI	35.56	17.30	22.00	37.18	1.57	58.0	90.0
16	IR61005 - 37 - 2 - 1 - 2	IRRI	32.21	16.36	17.67	25.59	1.34	63.0	102.0
17	IR62030 - 18 - 2 - 2	IRRI	34.55	16.88	19.00	26.18	1.39	61.0	90.0
18	IR62164 - 14 - 2 - 2 - 2 - 3	IRRI	38.29	17.47	58.00	28.24	1.35	58.0	90.0
19	KACHSIUNG SEN YU 338	TAIWAN	31.46	20.52	25.33	41.70	1.34	66.3	102.3
20	MR 123	MALAYSIA	36.34	14.94	15.00	24.43	1.29	66.3	102.3
21	PK2480 - 7 -31	PAKISTAN	32.33	18.75	19.00	25.12	1.23	66.0	98.0
22	PK2557 - 24 - 2 - 1	PAKISTAN	30.90	20.12	18.00	26.41	1.32	63.3	101.3
23	PK3355 - 5 - 1 - 4	PAKISTAN	27.20	15.79	23.00	21.73	1.33	64.7	102.3
24	RAVI (RP1664 - 1529 - 4254)	INDIA	35.62	19.51	20.00	24.88	1.57	63.7	89.7
25	RP 1670 - 1418 - 2205 - 1585	INDIA	32.87	17.09	20.00	23.53	1.14	60.3	93.3
26	S 972B - 22 - 1 - 3 - 1 - 1	INDONESIA	35.35	18.74	24.00	27.56	1.35	65.3	97.3
27	S 976B - PN - 25 - 1	INDONESIA	32.34	16.51	26.67	23.01	1.24	66.7	102.7
28	IR36(INT'L CHECK)	IRRI	34.92	18.39	19.67	27.31	1.29	60.0	90.0
29	IR50 (INT'L CHECK)	IRRI	36.62	16.81	24.67	31.56	1.29	61.3	90.3
30	AHALYA	INDIA	34.48	20.40	19.67	32.65	1.76	62.0	90.0
31	ANNAPURNA	INDIA	28.79	16.37	13.67	30.14	1.20	57.7	78.7
32	ARATHI	INDIA	26.03	17.72	19.00	21.48	1.32	66.3	103.3
33	ARUNA	INDIA	34.33	21.26	17.67	22.77	1.35	60.7	102.7
34	ASHA	INDIA	34.19	17.05	21.00	26.77	1.43	65.3	97.3
35	ATHIRA	INDIA	36.46	24.80	25.00	30.53	1.70	62.3	97.3
36	BHADRA	INDIA	30.43	18.17	19.00	24.68	1.31	62.7	105.7
37	BHAGYA	INDIA	36.36	21.02	20.67	33.21	1.34	56.7	88.7
38	HRASWA	INDIA	27.49	15.14	21.67	30.55	1.46	52.0	75.0
39	JAYA	INDIA	31.07	17.13	15.67	22.34	1.43	62.3	101.3
40	JAYANTHI	INDIA	35.28	19.74	18.67	29.94	1.31	65.0	102.0
41	JYOTHI	INDIA	34.54	20.33	22.67	27.24	1.40	58.7	94.7
42	KANCHANA	INDIA	31.41	18.12	19.00	25.44	1.26	64.3	95.3
43	KANAKAM	INDIA	36.74	20.95	16.00	25.91	1.44	63.7	105.7
44	KAIRALI	INDIA	30.40	18.56	14.667	23.01	1.23	65.0	90.0
45	KARTHIKA	INDIA	31.74	19.76	21.00	26.27	1.28	64.3	101.3
46	MAKAM	INDIA	28.23	18.17	10.67	23.52	1.30	65.0	107.0
47	MAHSURI	INDIA	38.58	25.36	25.33	36.50	1.36	68.3	116.3
48	MATTATRIVENI	INDIA	35.83	20.42	23.00	28.59	1.38	67.0	85.0
49	ONAM	INDIA	35.34	22.32	20.00	31.50	1.38	57.3	80.3
50	PAVIZHAM	INDIA	32.27	19.63	8.00	23.46	1.26	64.3	96.3
51	RANJINI	INDIA	29.04	18.53	0.00	23.77	1.27	66.0	101.0
52	REMYA	INDIA	34.48	17.61	9.00	27.02	1.16	65.3	106.3
53	SABARI	INDIA	29.18	17.77	15.00	22.94	1.20	64.7	101.7
54	VYTILLA 2	INDIA	35.71	32.00	22.00	31.87	1.34	64.3	102.3
55	VYTILLA 3	INDIA	34.76	27.70	26.00	35.49	1.32	69.3	97.3
56	VYTILLA 4	INDIA	33.34	27.05	25.67	29.66	1.44	63.7	101.7

(Contd.:............)

Appendix i (Contd....)

Sl. No.	Height of plant at harvest (cm)	Total number of tillers plant^{-1}	Number of panicle bearing tillers plant^{-1}	Leaf area plant^{-1} at maximum tillering stage(cm^2)	Number of days to harvest	Ratio of vegetative phase to reproductive phase	Number of panicles m^{-2}	Number of spikelets panicle^{-1}	Number of secondary branches panicle^{-1}	Number of tertiary branches panicle^{-1}
1	88.35	2.9	1.2	108.24	120.3	1.11	208.0	146.3	11.4	23.9
2	96.92	3.1	1.0	107.65	120.7	1.01	209.0	125.0	10.6	21.1
3	85.69	3.9	1.2	71.71	129.3	1.05	234.0	126.1	10.6	20.9
4	95.19	4.4	1.1	132.07	117.0	1.09	242.0	121.6	9.4	21.0
5	102.05	4.1	1.1	141.13	131.0	0.93	141.7	149.8	11.5	22.9
6	94.25	2.9	1.0	129.14	130.7	0.87	109.0	121.6	10.9	19.6
7	94.28	1.3	1.1	132.00	129.0	1.05	231.0	105.6	9.7	19.1
8	87.36	4.3	1.1	112.57	131.3	0.82	176.7	121.4	10.4	19.9
9	81.29	3.4	1.0	104.53	116.7	1.24	296.0	129.4	9.3	19.4
10	86.30	6.0	1.5	105.97	117.0	1.17	301.0	130.2	9.8	21.3
11	85.12	6.1	1.0	90.91	129.3	1.02	240.0	126.3	10.1	16.8
12	88.68	3.9	1.5	141.64	117.3	0.96	294.7	155.8	9.3	20.1
13	85.31	6.2	1.1	95.17	130.0	1.17	303.0	110.3	11.3	18.3
14	88.91	3.3	1.3	90.19	129.3	0.82	290.0	115.1	9.7	19.3
15	90.28	4.3	1.3	138.98	117.0	0.98	265.0	155.7	10.1	28.3
16	82.85	3.8	1.6	117.76	129.0	0.95	242.7	127.8	11.9	20.4
17	87.75	2.9	1.2	99.61	117.0	1.09	273.7	139.1	10.4	26.1
18	94.13	3.4	1.5	118.58	117.0	0.98	227.7	149.0	11.0	29.4
19	90.15	5.7	1.1	144.18	129.3	1.05	179.0	176.6	12.2	25.3
20	83.55	3.9	1.0	116.78	129.3	1.05	207.3	128.2	11.3	20.0
21	85.15	5.9	1.4	102.97	130.0	1.03	236.0	107.0	10.3	14.2
22	92.98	4.1	1.5	95.15	129.3	0.96	227.7	91.5	9.1	11.5
23	77.68	6.0	1.0	111.60	129.7	0.98	133.0	100.5	10.7	13.2
24	95.06	7.5	1.1	107.04	116.7	1.20	277.7	105.9	10.1	21.2
25	81.97	4.6	1.0	113.49	120.3	1.01	292.7	104.8	8.8	14.9
26	85.70	3.0	1.2	108.31	129.3	1.02	272.0	135.6	10.8	21.2
27	87.55	1.6	1.2	106.41	129.7	1.06	250.7	137.2	10.5	21.9
28	78.58	3.7	1.4	83.84	117.0	1.05	336.7	98.7	8.6	18.7
29	86.68	5.4	1.1	116.99	117.3	1.10	290.0	142.7	10.4	24.3
30	92.64	3.7	1.2	146.09	117.0	1.13	274.0	117.0	9.2	19.1
31	84.98	5.9	1.5	104.44	105.7	1.20	310.3	96.9	8.6	11.6
32	93.65	2.2	1.3	95.83	132.3	1.00	317.0	121.7	12.3	21.3
33	101.20	2.4	1.2	122.70	131.7	0.86	236.0	170.2	12.8	30.4
34	82.68	4.1	1.3	97.21	129.3	1.02	170.7	97.6	9.9	12.7
35	116.65	3.3	1.1	108.36	129.3	0.93	220.0	127.1	12.7	20.9
36	88.65	3.5	1.1	76.05	141.7	0.79	309.0	110.0	9.9	15.4
37	91.51	6.4	1.6	133.23	115.7	0.96	277.0	108.0	9.5	20.5
38	67.04	6.4	1.9	46.78	100.0	1.08	259.3	95.3	8.7	9.7
39	85.34	2.2	1.0	87.61	130.3	0.92	173.3	109.6	9.6	17.7
40	92.78	2.6	1.1	109.36	129.0	1.02	200.7	148.2	11.3	25.6
41	89.46	4.0	1.0	88.92	120.7	0.95	290.0	108.3	9.8	15.3
42	83.86	5.0	1.6	107.16	129.3	0.99	246.0	122.9	10.1	22.1
43	100.72	2.1	1.1	105.21	141.7	0.81	176.7	180.4	14.2	33.8
44	87.09	3.2	1.0	77.55	117.0	1.25	282.7	103.1	9.2	16.9
45	96.51	1.8	1.2	104.60	130.3	0.97	193.7	131.6	12.2	19.7
46	91.75	3.1	1.3	92.69	132.0	0.97	225.7	146.2	11.3	29.1
47	136.80	4.3	1.0	135.97	142.3	0.92	198.7	157.5	13.6	25.5
48	90.76	3.3	1.6	122.49	117.0	1.34	236.7	163.2	11.6	24.9
49	89.62	5.5	1.5	115.08	107.3	1.15	247.7	112.2	9.1	16.6
50	89.59	2.8	1.3	82.86	130.3	0.97	221.0	139.7	12.1	20.8
51	90.33	2.3	1.1	100.22	133.0	0.99	211.0	133.9	9.9	23.3
52	102.75	2.2	1.1	105.16	142.3	0.85	240.7	152.4	12.7	25.1
53	83.88	3.1	1.0	95.91	130.7	0.98	167.0	81.8	9.5	11.6
54	159.95	1.6	1.0	111.78	129.3	0.99	172.0	84.3	9.5	10.8
55	148.60	1.7	1.0	131.97	129.3	1.16	217.0	101.9	10.4	14.2
56	144.00	2.9	1.0	116.97	128.7	0.98	175.7	74.7	9.4	7.6

(Contd..............)

Appendix i (Contd....)

Sl. No.	Length of panicle (cm)	Spikelet sterility percentage	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Number of grains panicle^{-1}	1000 grain weight (g)	Yield kg ha^{-1}	Harvest index	Hulling Percentage
1	22.45	3.78	8.98	3.22	2.80	139.9	29.77	4033.20	0.42	77.10
2	20.71	6.88	9.26	3.18	2.91	116.7	32.11	2745.57	0.33	76.10
3	23.69	9.45	8.43	2.56	3.30	114.1	27.20	2530.17	0.22	77.50
4	21.45	7.22	9.19	3.12	2.94	112.9	27.18	3542.35	0.32	69.10
5	24.10	7.16	8.51	2.88	2.96	139.5	32.48	1066.17	0.12	74.30
6	22.99	6.40	9.04	2.82	3.20	113.7	35.50	523.24	0.07	75.30
7	24.00	6.37	9.86	3.18	3.10	98.9	37.30	2854.24	0.23	75.20
8	18.35	4.76	7.35	3.76	1.95	116.1	32.89	1168.47	0.17	78.00
9	23.35	6.53	9.61	2.79	3.45	117.3	26.52	3491.11	0.39	75.50
10	24.00	7.67	9.61	2.59	3.72	119.9	24.88	3864.17	0.26	74.30
11	22.80	5.62	9.53	2.61	3.74	119.1	34.73	2530.42	0.26	71.13
12	23.61	8.22	10.06	2.79	3.61	144.0	25.43	2959.63	0.32	74.80
13	23.71	8.67	9.56	2.66	3.59	100.6	30.95	3023.38	0.24	69.20
14	24.68	8.29	10.11	2.64	3.85	106.1	33.67	3099.83	0.29	77.50
15	25.74	8.21	10.00	2.60	3.85	142.2	28.39	3324.09	0.38	77.60
16	23.47	6.37	9.82	2.84	3.46	120.6	31.95	2402.19	0.23	75.50
17	24.76	6.12	9.60	2.62	3.65	131.1	23.89	6109.29	0.44	75.70
18	25.07	9.39	9.71	2.68	3.64	136.1	29.64	2683.55	0.34	75.80
19	25.02	6.15	8.81	3.45	2.56	166.0	38.85	3016.99	0.30	68.90
20	22.49	6.85	10.01	2.61	3.84	119.3	32.25	3309.22	0.37	72.40
21	22.54	6.80	10.10	2.73	3.70	99.5	24.53	2532.31	0.25	76.60
22	23.46	7.76	10.08	2.70	3.73	84.9	41.47	1771.11	0.21	75.90
23	21.52	2.99	9.81	3.09	3.23	97.6	30.50	1390.82	0.23	78.20
24	22.36	14.82	8.85	3.22	2.75	91.0	28.53	2807.99	0.22	73.80
25	21.31	9.95	9.61	2.66	3.62	94.3	31.04	3123.97	0.39	75.40
26	23.05	4.52	9.15	2.60	3.51	129.7	24.24	3074.37	0.30	77.50
27	22.62	3.54	9.48	2.76	3.44	132.7	28.61	4337.60	0.45	77.20
28	22.20	8.10	9.22	2.66	3.48	98.2	25.91	3790.94	0.38	76.20
29	24.78	7.98	9.29	2.57	3.61	131.7	23.52	4120.11	0.36	72.60
30	21.48	5.36	7.93	3.26	2.45	111.0	27.07	3405.66	0.27	77.70
31	21.27	15.76	8.59	3.21	2.68	83.0	26.73	2416.37	0.35	75.80
32	22.02	5.60	9.17	3.27	2.80	114.9	39.93	3158.47	0.27	72.60
33	23.71	10.27	8.35	3.27	2.56	152.0	32.18	2137.74	0.20	74.60
34	22.61	11.68	8.78	3.26	2.70	85.3	39.24	1674.54	0.14	78.20
35	23.40	5.09	8.56	3.08	2.77	120.9	35.01	3454.62	0.25	71.80
36	20.37	4.20	7.80	3.25	2.41	105.0	23.30	2777.93	0.23	77.50
37	22.65	6.93	8.82	3.29	2.69	100.7	32.15	2460.57	0.21	79.60
38	20.21	15.86	8.64	3.33	2.59	80.0	28.02	716.28	0.29	71.70
39	22.89	7.70	9.20	3.17	2.90	101.8	35.68	2117.82	0.23	78.30
40	26.81	7.42	8.77	2.99	2.94	136.6	30.99	3465.09	0.31	67.30
41	20.84	9.01	9.73	3.13	3.11	98.8	29.26	3324.31	0.30	76.00
42	20.60	8.07	8.91	3.11	2.87	113.2	34.49	2250.02	0.20	71.50
43	24.02	10.04	8.49	3.24	2.63	161.5	33.60	2295.31	0.20	78.90
44	19.37	13.65	8.41	3.00	2.64	88.8	23.23	2584.69	0.29	77.80
45	22.13	7.82	9.83	3.22	2.65	121.7	32.53	4332.39	0.45	76.50
46	22.45	1.78	8.59	3.39	2.54	143.7	37.88	2730.60	0.26	77.20
47	23.96	15.00	7.97	2.75	2.91	134.2	41.63	728.16	0.04	75.90
48	24.39	7.18	8.55	3.26	2.62	151.3	28.89	6319.54	0.42	71.70
49	22.55	6.07	8.66	3.31	2.62	105.0	50.14	2651.60	0.30	76.40
50	20.47	5.57	7.72	3.22	2.40	132.0	26.01	3248.97	0.28	74.90
51	21.39	4.75	8.51	3.14	2.72	126.9	29.02	2515.99	0.23	70.40
52	24.03	12.49	9.35	3.15	2.98	133.9	31.53	1976.23	0.14	72.30
53	21.52	10.81	9.88	3.46	2.87	73.7	42.76	1886.14	0.26	72.70
54	25.31	9.84	9.09	3.63	2.53	76.9	32.19	1631.79	0.21	77.20
55	27.05	5.35	8.84	3.55	2.48	96.4	43.03	2437.70	0.21	76.60
56	23.02	4.94	9.16	3.48	2.63	71.2	40.79	1986.36	0.21	75.10

(Contd..............)

Appendix i (Contd....)

Sl. No.	Milling Percentage	Amylose content (%)	Kernal elongation ratio	Volume Expansion Ratio	Water uptake	Alkali spreading value	Presence of awn(score)	Colour of grain(score)	Presence of pubescence(score)	Colour of kernel
1	71.80	24.34	1.38	2.35	0.47	2.3	0.00	0.00	3.00	R
2	51.10	36.80	1.48	3.17	0.96	4.7	1.00	1.00	3.00	R
3	72.80	21.94	1.44	2.97	0.71	2.0	0.00	1.00	3.00	W
4	52.30	26.35	1.20	2.58	0.61	4.3	0.00	1.00	3.00	W
5	53.70	29.49	1.46	2.50	0.62	4.7	0.00	1.00	3.00	W
6	55.70	31.20	1.16	2.71	0.59	5.7	0.00	0.00	1.00	R
7	51.70	29.25	1.11	2.14	0.45	5.7	0.00	1.00	1.00	W
8	66.30	26.57	1.60	2.78	0.57	3.3	0.00	0.00	4.00	W
9	71.67	20.74	1.13	2.07	0.55	2.0	0.00	1.00	3.00	W
10	73.70	23.05	1.30	2.35	0.59	5.3	0.00	0.00	3.00	W
11	68.10	27.26	1.20	2.80	0.58	2.0	1.00	0.00	3.00	W
12	59.50	29.68	1.37	2.66	0.64	5.3	0.00	1.00	3.00	W
13	66.50	28.10	1.20	2.70	0.56	6.3	0.00	1.00	3.00	W
14	62.40	26.82	1.23	1.93	0.50	2.7	0.00	1 00	3.00	W
15	69.40	27.42	1.30	2.75	0.68	2.0	0.00	0.00	3.00	W
16	66.40	26.90	1.37	2.75	0.70	6.0	0.00	0.00	3.00	W
17	75.10	29.70	1.33	2.76	0.58	5.0	0.00	0.00	3.00	W
18	71.67	26.30	1.18	2.05	0.38	3.7	0.00	1.00	3.00	W
19	57.80	19.04	1.13	2.31	0.66	3.0	0.00	1.00	3.00	W
20	68.70	19.46	1.45	2.33	0.39	1.0	0.00	0.00	3.00	W
21	75.80	30.00	1.36	2.06	0.51	5.0	1.00	0.00	3.00	W
22	72.50	24.12	1 17	2.40	0.56	2.3	1.00	1.00	3.00	W
23	67.70	31.03	1.29	1.93	0.49	5.3	0.00	0.00	3.00	W
24	72.67	24.99	1.26	2.20	0.57	4.0	0.00	1.00	3.00	W
25	71.10	20.15	1.24	2.17	0.53	3.7	0.00	1.00	3.00	W
26	60.30	32.47	1.22	2.61	0.63	1.0	0.00	1.00	4.00	W
27	76.30	24.87	1.24	2.15	0.50	4.7	0.00	0.00	3.00	W
28	75.40	30.52	1.21	2.08	0.42	1.0	1.00	1.00	3.00	W
29	71.80	32.56	1.21	2.74	0.65	5.3	0.00	1.00	1.00	W
30	72.90	31.07	1.21	2.07	0.41	6.3	0.00	2.00	4.00	R
31	58.90	25.71	1.31	2.32	0.50	5.7	1.00	3.00	3.00	R
32	63.30	25.87	1.23	2.32	0.65	1.3	0.00	3.00	3.00	R
33	76.90	27.26	1.21	2.48	0.47	4.3	0.00	4.00	3.00	R
34	69.30	23.05	1.23	1.87	0.50	3.7	1.00	0.00	3.00	R
35	51.70	25.27	1.31	2.60	0.58	3.7	0.00	2.00	3.00	R
36	68.10	25.06	1.23	2.74	0.66	4.3	0.00	1.00	3.00	R
37	60.40	29.17	1.24	2.50	0.64	6.0	0.00	0.00	3.00	R
38	69.10	29.37	1.13	2.85	0.69	7.0	0.00	0.00	4.00	R
39	67.50	23.77	1.22	2.04	0.42	2.0	0.00	1.00	3.00	W
40	57.80	23.52	1.33	2.34	0.60	2.7	0.00	0.00	3.00	W
41	64.20	25.67	1.20	2.38	0.57	4.7	0.00	3.00	4.00	R
42	64.90	29.01	1.32	2.59	0.61	4.3	0.00	0.00	3.00	R
43	69.30	29.45	1.23	2.42	0.59	4.3	0.00	0.00	3.00	R
44	50.10	22.14	1.15	2.22	0.55	2.7	0.00	0.00	3.00	R
45	60.40	31.40	1.24	2.75	0.66	7.0	1.00	0.00	3.00	R
46	57.10	29.11	1.26	2.00	0.49	3.3	0.00	2.00	3.00	R
47	71.30	23.64	1.23	2.75	0.54	4.3	0.00	1.00	3.00	W
48	63.10	30.44	1.32	2.17	0.55	1.0	0.00	0.00	3.00	R
49	69.70	28.91	1.21	2.53	0.54	3.0	0.00	0.00	3.00	R
50	65.30	29.45	1.31	2.63	0.56	3.3	0.00	0.00	3.00	R
51	51.90	22.65	1.26	2.45	0.51	5.0	0.00	2.00	3.00	R
52	68.20	26.47	1.22	2.32	0 51	4.0	0.00	4.00	3.09	R
53	68.60	25.99	1.50	2.48	0.60	6.0	7.00	0.00	3.00	R
54	52.20	31.07	1.20	2.33	0.47	2.3	9 00	2.00	3.00	R
55	70.70	30.28	1.36	2.55	0.59	3.3	7.00	0.00	3.00	R
56	71.10	30.70	1.45	2.52	0.57	2.3	9.00	2.00	3.00	R

R = Red W = White

Appendix ii Ranking of 96 rice hybrids based on selection index

Rank	Cross	Selection index	Rank	Cross	Selection index	Rank	Cross	Selection index
1	P_{11} x P_3	3821.40	33	P_{11} x P_9	2471.60	65	P_7 x P_2	1976.10
2	P_4 x P_9	3707.10	34	P_7 x P_{11}	2468.40	66	P_{12} x P_6	1922.90
3	P_5 x P_4	3459.80	35	P_{12} x P_5	2465.50	67	P_1 x P_{11}	1915.20
4	P_4 x P_{11}	3431.00	36	P_6 x P_7	2452.80	68	P_2 x P_{12}	1884.30
5	P_4 x P_7	3425.10	37	P_3 x P_6	2404.60	69	P_9 x P_5	1817.10
6	P_4 x P_1	3169.90	38	P_5 x P_1	2391.70	70	P_1 x P_3	1814.30
7	P_4 x P_6	3114.5	39	P_9 x P_{12}	2370.90	71	P_2 x P_3	1814.10
8	P_4 x P_5	3079.60	40	P_3 x P_9	2360.30	72	P_{10} x P_1	1805.00
9	P_{11} x P_5	3062.30	41	P_9 x P_{11}	2355.30	73	P_{12} x P_9	1795.60
10	P_8 x P_1	3053.80	42	P_8 x P_5	2349.30	74	P_8 x P_4	1791.50
11	P_4 x P_{10}	3022.70	43	P_1 x P_2	2323.00	75	P_{12} x P_2	1761.60
12	P_5 x P_6	3011.10	44	P_1 x P_9	2310.00	76	P_{11} x P_6	1760.60
13	P_{11} x P_2	2964.40	45	P_9 x P_1	2294.10	77	P_2 x P_{10}	1738.10
14	P_7 x P_1	2957.10	46	P_7 x P_3	2287.90	78	P_9 x P_6	1735.40
15	P_1 x P_4	2891.00	47	P_3 x P_2	2282.60	79	P_{12} x P_3	1717.20
16	P_4 x P_2	2734.60	48	P_{12} x P_{10}	2267.50	80	P_{10} x P_{11}	1703.80
17	P_5 x P_2	2729.60	49	P_6 x P_1	2256.60	81	P_6 x P_5	1699.20
18	P_3 x P_{10}	2709.40	50	P_1 x P_8	2247.50	82	P_5 x P_3	1675.90
19	P_4 x P_3	2676.50	51	P_9 x P_7	2215.20	83	P_7 x P_5	1643.70
20	P_9 x P_{10}	2653.20	52	P_3 x P_{12}	2206.00	84	P_6 x P_9	1624.60
21	P_1 x P_5	2652.00	53	P_6 x P_{10}	2173.20	85	P_{12} x P_4	1582.80
22	P_4 x P_8	2636.50	54	P_1 x P_7	2134.20	86	P_{11} x P_1	1564.50
23	P_5 x P_9	2629.90	55	P_8 x P_6	2129.20	87	P_6 x P_8	1561.80
24	P_5 x P_8	2615.50	56	P_6 x P_4	2127.80	88	P_{10} x P_2	1514.90
25	P_7 x P_6	2594.90	57	P_8 x P_3	2122.40	89	P_1 x P_{12}	1476.10
26	P_1 x P_6	2582.90	58	P_9 x P_8	2105.80	90	P_3 x P_7	1453.10
27	P_4 x P_{12}	2571.10	59	P_{10} x P_3	2070.10	91	P_{12} x P_7	1438.20
28	P_{11} x P_7	2571.10	60	P_{11} x P_{10}	2058.80	92	P_{10} x P_7	1419.90
29	P_3 x P_1	2527.20	61	P_{10} x P_4	2054.40	93	P_2 x P_6	1375.80
30	P_8 x P_{12}	2524.30	62	P_{12} x P_1	2029.20	94	P_9 x P_4	1365.30
31	P_5 x P_{11}	2512.20	63	P_7 x P_8	2014.10	95	P_{10} x P_8	1234.50
32	P_5 x P_{10}	2481.80	64	P_{11} x P_8	1988.60	96	P_6 x P_3	1002.00

Appendix iii Estimates of relative heterosis (di) and heterobeltiosis(dii) along with parental divergence for seventeen characters of 96 rice hybrids

Cross	Parental diversity D² value	Number of days to 50 % flowering			Number of days to harvest			Ratio of vegetative phase to reproductive phase		
		Mean	di	dii	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7	8	9	10	11
$P_1 \times P_4$	1484.20	87.00	-5.43 *	-16.75 **	115.00	-4.96 *	-12.88	1.40	30.23 *	23.35 *
$P_1 \times P_5$	523.45	85.50	2.09	-2.84 **	124.00	5.53 *	-0.80 **	1.16	-3.53	-8.66
$P_1 \times P_6$	1664.38	89.50	9.82 **	7.19 **	128.50	16.55 **	16.29 **	1.25	5.02	0.00
$P_1 \times P_9$	441.84	85.00	4.62	2.41 *	124.00	10.96 **	9.25 **	1.10	-4.14	-5.17
$P_4 \times P_1$	1484.20	117.00	27.17 **	11.96 **	150.00	23.97 **	13.64 **	1.11	3.26	-2.20
$P_4 \times P_5$	661.37	117.00	21.56 **	11.96 **	150.00	16.73 **	13.64 **	1.11	-2.84	-12.60
$P_4 \times P_6$	1020.39	100.00	6.38 **	-4.31 **	131.00	8.04	-0.76	1.26	11.01	0.40
$P_4 \times P_9$	1437.84	116.50	24.27 **	11.48 **	137.50	12.02 **	4.17 **	1.43	31.95 **	23.71 *
$P_5 \times P_1$	523.45	114.50	36.72 **	30.11 **	145.00	23.40 **	16.00 **	1.12	-7.28	-12.20
$P_5 \times P_4$	661.37	106.50	10.65 **	1.91 **	145.00	12.84 **	16.00 **	1.22	6.35	-4.33
$P_5 \times P_6$	1293.15	114.50	33.53 **	30.11 **	145.00	23.14 **	16.00 **	1.57	23.96 *	23.23 *
$P_5 \times P_9$	560.65	121.50	42.11 **	38.07 **	150.00	25.79 **	20.00 **	1.25	3.29	-1.18
$P_6 \times P_1$	1664.38	91.50	12.27 **	9.58 **	134.00	21.54 **	21.27 **	0.96	-19.67	-23.51 *
$P_6 \times P_4$	1020.30	88.50	-5.85 **	-15.31 **	120.00	-1.03	-9.09 **	1.09	-3.96	-13.15
$P_6 \times P_5$	1293.15	92.50	7.87 **	5.11 **	139.00	18.05 **	11.20 **	0.94	-25.15 *	-25.59 *
$P_6 \times P_9$	2057.10	101.50	21.92 **	21.56 **	134.00	19.64 **	18.06 **	0.90	-25.47 *	-28.29
$P_9 \times P_1$	441.84	97.50	20.00 **	17.47 **	134.00	19.91 **	18.06 **	1.11	-3.27	-4.31
$P_9 \times P_4$	1437.84	112.50	20.00 **	7.66 **	150.00	22.20 **	13.64 **	0.99	-9.43	-15.09
$P_9 \times P_5$	560.65	110.00	28.65 **	25.00 **	151.00	26.62 **	20.80 **	0.91	-25.10 *	-28.35 **
$P_9 \times P_6$	2057.10	85.50	2.70	2.40	126.00	12.50 **	11.01 **	1.15	-4.35	-7.97
$P_4 \times P_{11}$	867.57	105.00	11.70	25.75 **	125.00	-1.19	3.31	1.66	63.14 **	62.75 **
$P_4 \times P_{10}$	903.65	119.50	26.79 **	42.26 **	147.50	19.92 **	29.39 **	1.29	16.55	7.98
$P_4 \times P_7$	903.65	123.00	30.85 **	47.31 **	150.00	18.58 **	23.97 **	1.31	25.18	21.96
$P_4 \times P_8$	1437.84	96.50	2.66	15.57 *	134.00	8.94 *	17.54 **	1.08	-1.60	-8.12
$P_4 \times P_3$	1894.73	110.50	27.01 **	58.99 **	133.50	12.18 **	25.94 **	1.40	50.54 **	37.93 **
$P_{11} \times P_6$	1685.37	88.50	5.99	5.99	135.00	16.63 **	22.17 **	1.10	-3.74	-12.75
$P_{11} \times P_{10}$	458.98	94.00	12.24	12.57	135.00	14.89 **	18.42 **	1.02	-7.69	-14.29
$P_{11} \times P_7$	458.98	85.50	2.40	2.40	128.00	5.79	5.79	1.12	6.70	4.21
$P_{11} \times P_8$	366.43	109.50	31.14 **	31.14 **	145.00	23.40 **	27.19 **	0.93	-15.07	-20.51
$P_{11} \times P_3$	935.01	133.50	74.51 **	92.09 **	145.00	27.75 **	36.79 **	1.71	83.91 **	68.14 **
$P_{11} \times P_1$	574.08	96.50	18.40 **	21.38 **	150.00	29.87 **	36.36 **	0.87	-19.72	-23.79
$P_6 \times P_{10}$	1554.91	87.00	3.88	4.19	134.00	19.38 **	21.27 **	0.89	-27.20 *	-29.08 *
$P_6 \times P_7$	1554.91	84.50	1.20	1.20	116.00	0.22	4.98	1.17	0.65	-6.77
$P_6 \times P_8$	2057.10	86.50	3.59	3.59	134.00	19.38 **	21.27 **	0.93	-23.71	-26.29
$P_6 \times P_3$	2017.45	92.00	20.26 **	32.37 **	154.00	42.26 **	45.28 **	0.77	-26.67	-38.65 **
$P_{10} \times P_7$	456.10	119.00	42.09 **	42.51 **	163.00	38.72 **	42.98 **	0.99	-12.39	16.81
$P_{10} \times P_8$	611.02	113.00	34.93 **	35.33 **	163.00	42.98 **	42.98 **	0.85	-27.97 *	-28.57 *
$P_{10} \times P_3$	1003.58	97.50	27.04 **	40.29 **	128.00	16.36 **	20.75 **	1.23	20.88	3.36
$P_{10} \times P_1$	819.81	107.00	30.89 **	34.59 **	145.00	29.46 **	31.82 **	0.91	-21.72	-23.53
$P_7 \times P_8$	611.02	111.50	33.53 **	33.53 **	138.00	17.45 **	21.05 **	1.14	1.79	-2.56
$P_7 \times P_3$	1003.58	106.50	39.22 **	53.24 **	139.00	22.47 **	31.13 **	0.98	1.83	-8.88
$P_7 \times P_1$	819.81	89.50	9.82	12.58	119.00	3.03	8.18	1.53	39.23 **	35.24 **
$P_8 \times P_3$	586.22	98.00	28.10 **	41.01 **	132.00	20.00 **	24.53 **	1.17	16.13	0.00
$P_8 \times P_1$	441.84	88.50	8.59	11.32	117.00	4.46	6.36	1.51	31.45 **	29.49 *
$P_3 \times P_1$	456.00	86.50	16.11 *	24.46 **	122.00	12.96 **	15.09 **	1.28	29.29 *	12.78

(Contd...)

Appendix iii (Contd....)

1	2	3	4	5	6	7	8	9	10	11
P_{12} x P_1	574.08	102.50	20.94 **	28.93 **	142.00	26.79 **	29.09 **	1.14	-4.00	-8.06
P_{12} x P_2	767.47	96.00	1.86	6.67 **	142.00	18.83 **	24.56 **	0.94	-27.86 **	-31.52 **
P_{12} x P_6	1685.37	101.00	16.43 **	20.96 **	126.00	12.25 **	14.03 **	1.00	-19.84 *	-20.32 *
P_3 x P_2	1280.04	87.00	3.57	25.18 **	127.00	9.96 **	19.81 **	1.19	6.97	-13.77
P_3 x P_6	2017.45	83.50	9.15 **	20.14 **	121.00	11.78 **	14.15 **	1.18	12.38	-5.98
P_5 x P_2	384.96	100.50	7.77 **	14.20 **	139.00	11.20 **	11.20 **	1.12	-15.09	-18.48 *
P_7 x P_2	805.20	91.50	0.55	9.58 **	139.00	13.01 **	14.88 **	0.87	-29.39 **	-37.32 **
P_7 x P_6	1554.91	99.50	19.16 **	19.16 **	139.00	20.09 **	25.79 **	1.09	-6.24	-13.15
P_{11} x P_2	767.47	109.50	20.33 **	31.14 **	145.00	17.89 **	19.83 **	0.98	-18.75	-29.35 **
P_4 x P_2	628.74	122.00	20.20 **	23.86 **	150.00	16.73 **	20.00 **	1.24	3.55	-10.14
P_1 x P_2	941.95	84.00	-5.62	5.66	124.00	5.53	12.73 **	1.00	-20.63 *	-27.54 **
P_1 x P_3	456.00	84.50	13.42 *	21.58 **	128.00	18.52 **	20.75 **	1.00	0.50	-11.50
P_1 x P_7	819.81	90.00	10.43 *	13.21 *	122.50	6.06	11.36 **	1.06	-4.07	-7.02
P_1 x P_8	441.84	83.50	2.45	5.03	118.50	5.80	7.73 *	1.14	-1.30	-2.56
P_1 x P_{11}	574.08	90.00	10.43 *	13.21 **	121.00	4.76	10.00 **	1.09	0.93	-4.39
P_1 x P_{12}	574.08	97.00	14.45 **	22.01 **	139.00	24.11 **	26.36 **	1.00	-15.97	-19.35
P_2 x P_3	574.08	91.50	8.93	31.65 **	134.00	16.02 **	26.42 **	0.93	-16.59	-32.61 **
P_2 x P_6	1455.29	95.00	4.40	13.77 **	134.00	13.56 **	20.72 **	1.03	-21.97 *	-25.36 *
P_2 x P_{10}	805.20	98.00	7.40	16.67 **	137.00	14.64 **	20.18 **	1.08	-15.95	-21.74 *
P_2 x P_{12}	767.47	116.00	23.08 **	28.89 **	163.00	36.40 **	42.98 **	0.92	-29.77 **	-33.33 **
P_3 x P_7	1003.58	69.50	-9.15	0.00	105.00	-7.49 *	-0.94	0.86	-10.42	-19.63
P_3 x P_9	586.22	92.00	20.66 **	32.37 **	116.00	5.94	9.43 *	1.27	26.37 *	9.48
P_3 x P_{10}	1003.58	86.50	12.70 *	24.46 **	116.00	5.45	9.43 *	1.43	40.20 **	20.17
P_3 x P_{12}	935.01	88.50	10.97 *	27.34 **	126.00	14.55 **	18.87 **	1.30	24.40 *	4.84
P_4 x P_{12}	867.57	113.50	16.71 **	26.11 **	148.50	20.73 **	30.26 **	1.04	-7.96	-16.13
P_5 x P_3	840.74	87.50	11.11 *	25.90 **	139.00	20.35 **	31.13 **	1.00	-5.66	-21.26
P_5 x P_8	560.65	109.50	27.70 **	31.14 **	150.00	25.52 **	31.58 **	1.24	1.64	-2.36
P_5 x P_{10}	457.45	101.50	18.02 **	20.83 **	145.00	21.34 **	27.19 **	1.06	-13.82	-16.54
P_5 x P_{11}	341.84	104.50	21.87 **	25.15 **	139.00	13.01 **	14.88 **	1.28	11.79	0.79
P_7 x P_5	457.45	102.00	18.95 **	22.16 **	141.00	14.63 **	16.53 **	0.84	-28.21 **	-33.86 **
P_7 x P_{11}	458.98	97.50	16.77 **	16.77 **	134.00	10.74 **	10.74 **	1.11	6.22	3.74
P_8 x P_4	1437.84	94.00	0.00	12.57 **	141.00	14.63 **	23.68 **	0.91	-16.89	-22.22
P_8 x P_5	560.65	110.00	28.28 **	31.74 **	140.00	17.15 **	22.81 **	1.05	-13.93	-17.32
P_8 x P_6	2057.10	90.00	7.78	7.78	125.00	11.11 **	12.61 **	1.02	-16.05	-19.05
P_8 x P_{12}	366.43	97.00	11.82 **	16.17 **	129.00	13.16 **	13.16 **	1.19	-1.24	-4.03
P_9 x P_7	611.02	97.50	17.12 **	17.47 **	125.00	6.84 *	10.13 **	1.29	15.70	11.21
P_9 x P_8	189.98	95.50	14.71 **	15.06 **	139.00	22.20 **	22.47 **	1.01	-13.30	-13.68
P_9 x P_{10}	611.02	95.50	14.37 **	15.06 **	127.00	11.65 **	11.89 **	1.17	-0.43	-1.68
P_9 x P_{11}	366.43	91.50	9.90 *	10.24 *	125.00	6.61 *	10.13 **	1.07	-1.83	-7.76
P_9 x P_{12}	366.43	93.50	8.09	12.65 **	125.00	9.89 **	10.13 **	1.14	-5.00	-8.06
P_{10} x P_2	805.20	95.00	4.11	13.10 **	157.50	31.80 **	38.16 **	0.79	-38.52 **	-42.75 **
P_{10} x P_4	903.65	99.00	5.04	17.86 **	151.00	22.76 **	32.46 **	0.92	-16.74	-22.69
P_{10} x P_{11}	458.98	104.00	24.18 **	24.55 **	145.00	23.40 **	27.19 **	0.84	-24.32 *	-29.41 *
P_{11} x P_5	341.84	98.00	14.29 **	17.37 **	129.00	4.88	6.61	1.23	7.42	-3.15
P_{11} x P_9	366.43	108.00	29.73 **	30.12 **	143.00	21.96 **	25.99 **	0.96	-11.93	-17.24
P_{12} x P_3	935.01	94.50	18.50 **	35.97 **	139.00	26.36 **	31.13 **	0.95	-9.09	-23.39 *
P_{12} x P_4	867.57	97.00	-0.26	7.78	150.00	21.95 **	31.58 **	0.88	-22.12	-29.03 *
P_{12} x P_5	341.84	125.50	41.01 **	42.61 **	150.00	25.52 **	31.58 **	1.26	0.40	-0.79
P_{12} x P_7	458.98	101.50	17.00 **	21.56 **	150.00	27.66 **	31.58 **	0.73	-36.80 **	-41.13 **
P_{12} x P_9	366.43	101.50	17.34 **	22.29 **	145.00	27.47 **	27.75 **	0.78	-35.00 **	-37.10 **
P_{12} x P_{10}	458.98	89.00	2.30	5.95	137.00	20.18 **	20.18 **	1.08	-11.11	-12.90

(Contd...)

Appendix iii (Contd...)

Cross	Number of panicles m^{-2}			Number of spikelets $panicle^{-1}$			Number of tertiary branches $panicle^{-1}$		
	Mean	di	dii	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7	8	9	10
$P_1 \times P_4$	62.50	-3.10	-24.24	114.15	-34.98 **	-54.06 **	16.80	-31.57 *	-49.09 **
$P_1 \times P_5$	66.50	32.66	24.53	136.25	25.11	18.25	24.60	24.40	4.90
$P_1 \times P_6$	99.00	121.23 *	112.90 *	111.50	3.79	-0.67	16.50	-9.84	-19.51
$P_1 \times P_9$	90.50	76.59	61.61	134.75	26.94	22.84	25.25	46.38 *	37.23 *
$P_4 \times P_1$	41.50	-35.66	-49.70	288.35	64.26 **	16.04	52.70	114.66 **	59.70 **
$P_4 \times P_5$	115.50	70.48 *	40.00	275.50	51.50 **	10.87	48.00	70.06 **	45.45 **
$P_4 \times P_6$	66.00	5.18	-20.00	237.75	31.81 **	-4.33	47.25	76.64 **	43.18 **
$P_4 \times P_9$	82.50	19.13	0.00	284.00	58.57 **	14.29	47.00	82.88 **	42.42 **
$P_5 \times P_1$	99.00	98.99 *	86.79 *	130.00	19.38	12.85	15.90	-19.66 **	-32.20 *
$P_5 \times P_4$	132.00	94.83 **	60.00 *	296.50	63.05 **	19.32	34.75	23.15 *	5.30
$P_5 \times P_6$	132.00	175.00 **	149.06 **	262.50	130.82 **	127.86 **	42.50	93.40 **	81.24 **
$P_5 \times P_9$	99.00	81.65 *	76.79 *	145.00	28.95	25.87	22.10	5.62	-5.76
$P_6 \times P_1$	181.50	305.59 **	290.32 **	125.50	16.83	11.80	19.50	6.56	-4.88
$P_6 \times P_4$	165.00	162.95 **	100.00 **	84.50	-53.15 **	-66.00 **	12.50	-53.27 **	-62.12 **
$P_6 \times P_5$	150.50	213.54 **	183.96 **	76.00	-33.17 *	-34.03 *	12.20	-44.48 **	-47.97 **
$P_6 \times P_9$	66.00	33.33	17.86	48.00	-56.75 **	-57.24 *	3.10	-84.06 **	-84.88 **
$P_9 \times P_1$	57.50	12.20	2.68	91.25	-14.04	-16.82	11.50	-33.33	-37.50 *
$P_9 \times P_4$	99.00	42.96	20.00	36.00	-79.90 **	-85.51 **	3.75	-85.41 **	-88.64 **
$P_9 \times P_5$	48.00	-11.93	-14.29	79.50	-29.30	-30.99 *	10.65	-49.10 **	-54.58 **
$P_9 \times P_6$	132.00	166.67 **	135.71 **	29.00	-73.87 **	-74.16 **	2.50	-87.15 **	-87.80 **
$P_4 \times P_{11}$	99.00	11.24	3.66	164.00	-9.94	-34.00 **	27.50	8.48	-16.67
$P_4 \times P_{10}$	58.00	-21.89	-29.70	204.80	16.93	-17.61 *	37.00	48.30 **	12.12
$P_4 \times P_7$	66.00	-21.66	-23.26	284.50	40.67 **	14.49	52.00	79.31 **	57.58 **
$P_4 \times P_8$	66.00	-11.11	-20.00	172.00	-1.43	-39.78 **	25.25	2.85	-23.48 *
$P_4 \times P_3$	62.50	-18.57	-24.24	125.50	-31.38 **	-49.50 **	20.00	-19.68	-39.39 **
$P_{11} \times P_6$	610.50	781.59 **	539.27 **	143.50	25.90	24.03	24.25	26.96	18.29
$P_{11} \times P_{10}$	165.00	104.33 **	72.77 **	121.00	11.32	4.58	17.95	3.76	1.41
$P_{11} \times P_7$	99.00	9.09	3.66	163.50	20.35	4.81	31.00	45.20 **	24.00
$P_{11} \times P_8$	66.00	-18.27	-30.89	100.50	-7.03	-13.14	13.75	-18.64	-22.32
$P_{11} \times P_3$	99.00	18.92	3.66	218.00	87.12 **	85.85 **	34.00	97.10 **	92.09 **
$P_{11} \times P_1$	132.00	85.92 **	38.22	112.00	2.61	-3.20	9.25	-45.27 **	-47.74 **
$P_6 \times P_{10}$	465.50	754.13 **	605.30 **	141.00	31.81	25.61	21.50	14.97	4.88
$P_6 \times P_7$	297.00	360.47 **	245.35 **	104.50	-22.09	-33.01 *	18.75	-17.58	-25.00
$P_6 \times P_8$	957.00	1655.96 **	1350.00 **	183.50	72.50 **	63.47 **	24.25	32.51	18.29
$P_6 \times P_3$	752.50	1220.18 **	959.86 **	84.00	-26.81	-28.39	12.75	-31.64	-37.80
$P_{10} \times P_7$	132.00	73.68 **	53.49 *	104.50	-18.90	-33.01 *	20.00	-4.53	-20.00
$P_{10} \times P_8$	120.50	82.58 **	82.58 **	146.80	45.15 *	44.30 *	23.70	43.64 *	40.24
$P_{10} \times P_3$	99.00	44.53	39.44	41.00	-62.56 **	-65.05 **	5.10	-69.73 **	-69.82 **
$P_{10} \times P_1$	74.50	32.44	12.88	120.50	17.96	17.45	19.50	18.18	15.38
$P_7 \times P_8$	66.00	-13.16	-23.26	57.00	-55.56 **	-63.46 **	9.95	-51.58 **	-60.20 **
$P_7 \times P_3$	66.00	-15.92	-23.26	135.50	-0.84	-13.14	23.60	12.92	-5.60
$P_7 \times P_1$	92.50	39.62	7.56	109.60	-15.24	-29.74 *	25.50	24.09	2.00
$P_8 \times P_3$	95.50	39.42	34.51	62.50	-42.61 *	-46.72 *	8.50	-48.33 *	-49.40 *
$P_8 \times P_1$	206.50	267.11 **	212.88 **	125.50	23.58	22.32	22.00	36.65	36.65
$P_3 \times P_1$	117.50	100.00 **	-65.49 **	85.30	-22.46	-27.32	11.90	-27.66	-29.17

(Contd...)

Appendix iii (Contd....)

1	2	3	4	5	6	7	8	9	10
P_{12} x P_1	66.00	17.33	0.00	71.00	-41.91 **	-49.95 **	9.50	-48.79 **	-54.76 **
P_{12} x P_2	66.00	-14.84	-25.84 *	73.50	-37.90 *	-48.18 **	9.00	-53.37 **	-57.14 **
P_{12} x P_6	66.00	21.10	0.00	64.00	-49.63 **	-54.88 **	8.50	-59.04 **	-59.52 **
P_3 x P_2	165.00	106.25 **	132.39 **	84.05	-20.76	-28.35	7.50	-56.40 **	-57.39 **
P_3 x P_6	168.50	195.61 **	137.32 **	74.00	-35.53 *	-36.91 *	9.75	-47.72 **	-52.44 **
P_5 x P_2	165.00	132.39 **	85.39 **	193.00	83.77 **	67.53 **	31.50	53.47 **	34.33
P_7 x P_2	165.00	88.57 **	85.39 **	111.00	-11.50	-28.85	18.60	-12.68	-25.60
P_7 x P_6	165.00	155.81 **	91.86 **	174.00	29.73 *	11.54	29.50	29.67 *	18.00
P_{11} x P_2	165.00	78.86 **	72.77 **	290.00	175.47 **	150.65 **	45.00	154.96 **	154.24 **
P_4 x P_2	66.00	-23.03 *	-25.84 *	173.25	0.92	-30.28 **	31.35	23.91	-5.00
P_1 x P_2	165.00	143.54 **	85.39 **	133.50	35.22 **	30.12 **	20.00	18.69	13.64
P_1 x P_3	156.50	166.38 **	120.42 **	34.25	-68.85 **	-70.80 **	3.25	-80.24 **	-80.65 **
P_1 x P_7	74.50	66.48	-13.37	74.50	-42.38 **	-52.24 **	10.25	-50.12 **	-59.00 **
P_1 x P_8	66.00	3.53	-18.52	93.50	-7.93	-8.87	14.75	-8.39	-8.39
P_1 x P_{11}	99.00	39.44	3.66	59.25	-45.72 **	-48.79 **	8.25	-51.18 **	-53.39 **
P_1 x P_{12}	66.00	17.33	0.00	39.50	-67.68 **	-72.15 **	5.00	-73.05 **	-76.19 **
P_2 x P_3	297.00	271.25 **	233.71 **	130.00	22.55	10.83	22.75	32.27	29.26
P_2 x P_6	355.00	437.88 **	298.88 **	125.50	21.20	11.80	22.10	16.01	7.80
P_2 x P_{10}	425.50	449.03 **	378.09 **	104.00	5.83	2.26	16.00	-7.25	-9.09
P_2 x P_{12}	280.50	261.94 **	215.17 **	105.00	-11.28	-25.98 *	14.00	-27.46	-33.33 *
P_3 x P_7	165.00	110.19 **	91.86 **	56.50	-58.65 **	-63.78 **	4.50	-78.47 **	-82.00 **
P_3 x P_9	132.00	107.87 **	85.92 **	52.00	-54.19 **	-55.67 **	16.90	-9.09	-13.04
P_3 x P_{10}	128.50	87.59 **	80.99 **	84.00	-23.29	-28.39 **	11.75	-30.27	-30.47
P_3 x P_{12}	165.00	148.12 **	132.39 **	80.50	-37.87 **	-43.25 **	13.50	-28.57	-35.71 *
P_4 x P_{12}	57.50	-22.56	-30.30	214.00	9.65	-13.88	37.80	40.00 **	14.55
P_5 x P_3	388.00	525.81 **	446.48 **	153.50	32.04 **	30.86 **	29.50	46.58 **	25.80
P_5 x P_8	180.00	168.66 **	122.22 **	182.50	69.22 **	58.42 **	30.00	51.71 **	27.93
P_5 x P_{10}	99.00	66.39	50.00	151.50	39.70 **	31.51 **	23.90	18.46	1.92
P_5 x P_{11}	99.00	33.33	3.66	130.00	12.60	12.36	20.50	-0.36	-12.58
P_7 x P_5	66.00	-5.04	-23.26	91.00	-32.89 **	-41.67 **	22.00	-9.18	-12.00
P_7 x P_{11}	115.50	27.27	20.94	156.00	14.83 **	0.00	26.00	21.78	4.00
P_8 x P_4	165.00	101.83 **	100.00 **	86.00	-50.72 **	-65.39 **	16.50	-32.79	-50.00 **
P_8 x P_5	99.00	47.76	22.22	139.50	29.35 **	21.09	24.00	21.37	2.35
P_8 x P_6	165.00	166.13 **	103.70 **	103.00	-3.17	-8.24	19.00	3.83	-7.32
P_8 x P_{12}	165.00	124.49 **	103.70 **	117.00	-3.45	-17.52	17.90	-3.50	-14.76
P_9 x P_7	33.00	-53.52	-61.63 **	29.25	-77.98 **	-81.25 **	4.50	-79.26 **	-82.00 **
P_9 x P_8	52.50	-23.36	-35.19	128.00	21.79	16.68	21.00	21.74	14.13
P_9 x P_{10}	153.50	151.64 **	132.58 **	154.75	46.40 **	41.07 **	23.40	32.58	27.17
P_9 x P_{11}	132.50	75.50 **	38.74 *	129.25	14.69	11.71	21.50	19.11	16.85
P_9 x P_{12}	66.00	8.20	0.00	100.00	-20.49	-29.50 *	15.00	-23.86	-28.57
P_{10} x P_2	302.00	289.68 **	239.33 **	89.00	-9.44	-12.49	14.50	-15.94	-17.61
P_{10} x P_4	82.50	11.11	0.00	113.50	-35.18 **	-54.33 **	15.00	-39.88 **	-54.55 **
P_{10} x P_{11}	112.50	40.54	17.80	96.50	-11.22	-16.59	13.35	-22.83	-24.58
P_{11} x P_5	132.00	77.78 **	38.22 *	231.00	100.09 **	99.65 **	38.50	87.12 **	64.18 **
P_{11} x P_9	227.50	200.33 **	138.22 **	179.00	58.83 **	54.71 **	25.00	38.50 *	35.87 *
P_{12} x P_3	110.50	61.31	55.63 *	60.75	-53.12 **	-57.17 **	7.25	-61.64 **	-65.48 **
P_{12} x P_4	115.50	55.56	40.00 *	116.00	-40.57 **	-53.32 **	9.60	-64.44 **	-70.91 **
P_{12} x P_5	66.00	10.92	0.00	109.00	-15.19	-23.16 *	13.75	-38.13 **	-41.36 **
P_{12} x P_7	66.00	-13.16	-23.26	68.50	-54.00 **	-56.09 **	5.50	-76.09 **	-78.00 **
P_{12} x P_9	132.00	116.39 **	100.00 **	113.50	-9.76	-19.99	17.90	-9.14	-14.76
P_{12} x P_{10}	165.00	150.00 **	150.00 **	116.00	-4.74	-18.22	18.00	-5.01	-14.29

(Contd...)

Appendix iii (Contd...)

Cross	Number of grains panicle^{-1}			Spikelet sterility percentage			Harvest index		
	Mean	di	dii	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7	8	9	10
P_1 x P_4	101.35	-34.82 **	-56.60 **	11.20	-25.83	96.49	0.58	55.59 **	-15.36 **
P_1 x P_5	122.75	29.28	9.21	10.15	-24.68	314.29	0.65	16.36 **	-6.04
P_1 x P_6	110.50	21.80	6.30	0.90	-94.36 **	-87.84	0.44	-36.70 **	-38.11 **
P_1 x P_9	123.75	33.78 *	15.12	8.15	-38.84	279.07	0.33	-47.46 **	-51.53 **
P_4 x P_1	278.50	79.10 **	19.27 *	3.40	-77.48 *	-40.35	0.41	9.57	-40.39 **
P_4 x P_5	258.00	49.18 **	10.49	6.35	55.83	159.18	0.42	75.78 **	0.47
P_4 x P_6	213.25	26.39	-8.67	10.10	54.20	77.19	0.47	21.10 **	-34.35 **
P_4 x P_9	268.50	57.48 **	14.99	5.20	32.48	141.86	0.46	44.15 **	-20.41 **
P_5 x P_1	121.80	28.28	8.36	6.30	-53.25	157.14	0.43	-21.77 **	-36.83 **
P_5 x P_4	278.50	61.03 **	19.27 *	6.10	49.69	148.98	0.45	85.92 **	6.27
P_5 x P_6	246.00	127.41 **	118.86 **	6.25	26.90	155.10	0.47	-17.13 **	-34.21 **
P_5 x P_9	128.00	16.42	13.88	11.70	408.70 **	444.19	0.46	-7.48	-20.07 **
P_6 x P_1	112.00	23.45	7.74	10.70	-32.92	44.59	0.61	-12.66 **	-14.60 **
P_6 x P_4	70.60	-58.16 **	-69.76 **	16.45	151.15	188.60	0.45	16.74 **	-36.72 **
P_6 x P_5	55.00	-49.16 **	-51.07 **	27.85	465.48 **	1036.73 **	0.38	-33.07 **	-46.87 **
P_6 x P_9	47.50	-55.07 **	-55.81 **	1.05	-78.01	-51.16	0.37	-43.52 **	-48.96 **
P_9 x P_1	83.25	-10.00	-22.56	8.80	-33.96	309.30	0.57	-10.77 **	-17.69 **
P_9 x P_4	32.10	-81.17 **	-86.25 **	10.80	175.16	402.33	0.06	-80.97 **	-89.49 **
P_9 x P_5	64.15	-41.66 **	-42.93 *	19.35	741.36 **	800.00 **	0.55	9.47 *	-5.43
P_9 x P_6	25.10	-76.26 **	-76.65 **	13.20	176.44	513.95	0.17	-74.14 **	-76.63 **
P_4 x P_{11}	158.00	-8.42	-32.33 **	3.40	-26.88	-5.56	0.40	41.93 **	-20.61 **
P_4 x P_{10}	197.75	19.49	-15.31	3.45	-29.95	-16.87	0.43	79.06 **	2.52
P_4 x P_7	270.00	43.81 **	15.63	5.15	-30.17	-9.65	0.42	61.20 **	-8.74
P_4 x P_8	168.50	2.53	-27.84 **	2.05	-62.56	-60.95	0.47	49.96 **	-16.96 *
P_4 x P_3	109.75	-35.90 **	-53.00 **	12.65	93.87	121.93	0.33	-32.79 **	-64.18 **
P_{11} x P_6	56.25	-47.80 **	-49.57 *	60.80	1005.45 **	1588.89 **	0.22	-65.00 **	-70.10 **
P_{11} x P_{10}	83.50	-20.11	-25.15	31.00	700.00 **	761.11 **	0.48	3.62	-5.79
P_{11} x P_7	147.50	16.35	3.87	9.80	54.94	172.22	0.49	0.31	-4.81
P_{11} x P_8	94.50	-8.59	-15.28	5.95	34.46	65.28	0.49	-9.00	-13.32
P_{11} x P_3	207.50	88.21 **	86.02 **	5.40	-1.37	50.00	0.49	-30.67 **	-46.07 **
P_{11} x P_1	49.60	-47.53 **	-55.54 **	55.40	294.31 **	1438.89 **	0.43	-28.46 **	-37.70 **
P_6 x P_{10}	117.75	16.90	13.28	16.50	185.71 *	297.59 *	0.61	6.69	-15.72 **
P_6 x P_7	91.75	-25.39	-11.74	12.20	48.33	64.86	0.56	-4.97	-22.25 **
P_6 x P_8	43.50	-56.31 **	-58.15 **	76.30	1106.32 **	1353.33 **	0.38	-41.26 **	-47.64 **
P_6 x P_3	17.50	-83.56 **	-83.94 **	79.15	973.22 **	976.87 **	0.19	-76.53 **	-79.06 **
P_{10} x P_7	30.50	-74.53 **	-78.52 **	69.50	953.03 **	1574.70 **	0.26	-40.08 **	-42.73 **
P_{10} x P_8	115.35	19.72	18.31	21.45	356.38 **	416.87 **	0.40	-18.57 *	-29.13 **
P_{10} x P_3	35.10	-66.00 **	-67.78 **	14.35	149.57 *	245.78 *	0.38	-42.80 **	-58.40 **
P_{10} x P_1	89.50	2.29	-8.21	25.80	80.10	521.69 **	0.37	-32.88 **	-46.07 **
P_7 x P_8	50.80	-57.17 **	-64.23 **	10.85	51.75	106.67	0.42	-17.88 *	-25.58 **
P_7 x P_3	129.10	2.89	-9.08	4.70	-42.68	-36.05	0.54	-21.57 **	-41.22 **
P_7 x P_1	96.40	-12.16	-32.11 *	12.15	-27.57	34.25	0.51	-11.40	-26.20 **
P_8 x P_3	52.00	-49.06 **	-52.27 *	16.60	163.49 *	216.19 *	0.46	-37.84 **	-49.84 **
P_8 x P_1	106.25	23.05	11.61	14.80	-0.50	181.90 *	0.56	-10.96	-19.00 **
P_3 x P_1	79.25	-14.99	-27.26	7.10	-55.42	3.40	0.52	-34.60 **	-42.80 **

(Contd...)

Appendix iii (Contd....)

1	2	3	4	5	6	7	8	9	10
P_{12} x P_1	47.50	-52.38 **	-61.07 **	33.25	75.00 *	146.30 *	0.47	-28.66 **	-31.08 **
P_{12} x P_2	59.50	-44.18 **	-51.23 **	19.30	122.48	401.30 *	0.42	-24.71 **	-35.05 **
P_{12} x P_6	51.90	-54.06 **	-57.46 **	18.90	80.86	155.41	0.52	-23.94 **	-28.09 **
P_3 x P_2	73.50	-26.56	-32.54 *	12.55	124.11	225.97	0.43	-37.89 **	-53.22 **
P_3 x P_6	61.50	-42.23 **	-43.55 **	11.50	123.73	124.49	0.68	-16.75 **	-25.74 **
P_5 x P_2	177.30	74.29 **	57.95 **	8.10	157.14	230.61	0.46	4.17	-0.54
P_7 x P_2	102.00	-12.52	-28.17	8.10	25.58	110.39	0.54	17.68 **	18.58 *
P_7 x P_6	153.00	24.42	7.75	10.45	27.05	41.22	0.54	-7.69	-24.48 **
P_{11} x P_2	270.50	166.83 **	142.49 **	7.00	87.92	94.44	0.41	-16.84 **	-20.51 **
P_4 x P_2	165.75	2.09	-29.01 **	4.35	-8.90	12.99	0.38	45.71 **	-17.65 *
P_1 x P_2	122.75	45.52 **	34.59 *	8.05	-43.21	1.09	0.51	-11.28	-25.62 **
P_1 x P_3	27.75	-70.23 **	-74.53 **	19.45	22.14	164.63	0.55	-31.80 **	-40.35 **
P_1 x P_7	72.25	-34.17 **	-49.12 **	3.95	-76.45 *	-56.35	0.50	-11.97	-26.64 **
P_1 x P_8	76.35	-11.58	-19.80	18.25	22.69	247.62 *	0.48	-22.72 **	-29.69 **
P_1 x P_{11}	57.75	-38.91 **	-48.23 **	2.60	-81.49 *	-27.78	0.28	-52.51 **	-58.66 **
P_1 x P_{12}	36.50	-63.41 **	-70.08 **	1.75	-90.79 **	-87.04	0.11	-84.02 **	-84.57 **
P_2 x P_3	87.75	-12.32	-19.46	24.25	333.04 **	529.87 **	0.35	-49.78 **	-62.16 **
P_2 x P_6	15.00	-84.63 **	-85.57 **	87.60	1457.33 **	2175.32 **	0.17	-70.95 **	-76.08 **
P_2 x P_{10}	28.50	-69.79 **	-70.77 **	72.55	1713.75 **	1784.42 **	0.40	-9.07	-13.76
P_2 x P_{12}	94.00	-11.82	-22.95	10.15	17.00	163.64	0.43	-22.17 **	-32.81 **
P_3 x P_7	46.10	-63.26 **	-67.54 **	18.40	124.39 **	150.34	0.16	-76.87 **	-82.66 **
P_3 x P_9	44.10	-59.25 **	-59.52 **	15.15	218.95 **	604.65 **	0.62	-17.70 **	-32.82 **
P_3 x P_{10}	77.25	-25.16	-29.10 *	7.90	37.39	90.36	0.46	-30.73 **	-49.62 **
P_3 x P_{12}	75.50	-34.62 **	-38.11 **	6.25	-40.05	-14.97	0.15	-80.60 **	-83.53 **
P_4 x P_{12}	196.00	10.27	-16.06	7.85	-18.23	37.72	0.37	4.29	-42.97 **
P_5 x P_3	47.00	-57.53 **	-58.19 **	69.35	1315.31 **	2730.61 **	0.40	-39.66 **	-55.94 **
P_5 x P_8	152.00	46.44 **	35.23 *	16.10	318.18 **	557.14 **	0.34	-30.36 **	-39.08 **
P_5 x P_{10}	135.50	29.11 *	20.55	10.55	219.70 **	330.61 **	0.60	28.25 **	41.47 **
P_5 x P_{11}	111.50	-0.42	-0.80	14.50	379.34 **	491.84 **	0.36	-22.88 **	-29.47 **
P_7 x P_5	69.55	-45.32 **	-51.02 **	23.55	309.57 **	861.22 **	0.47	6.59	2.40
P_7 x P_{11}	134.50	6.09	-5.28	13.85	118.97 **	284.72	0.46	-5.07	-9.82
P_8 x P_4	78.50	-52.24 **	-66.38 **	8.60	57.08	63.81	0.41	31.30 **	-27.35 **
P_8 x P_5	129.00	24.28	14.77	7.50	94.81 **	206.12	0.49	-91.37 **	-13.32
P_8 x P_6	95.50	-4.09	-8.13	7.10	12.25	35.24	0.45	-30.11 **	-37.69 **
P_8 x P_{12}	111.10	2.30	-8.93	5.00	-46.67	-4.76	0.50	-17.21 **	-22.19 **
P_9 x P_7	23.00	-81.56 **	-83.80 **	22.20	296.43 **	932.56 **	0.53	1.93	-8.79
P_9 x P_8	110.00	8.53	2.33	14.05	279.73 **	553.49	0.39	-31.23 **	-32.24 **
P_9 x P_{10}	142.55	39.07 **	32.60 *	7.70	144.44 **	258.14	0.48	-4.71	-18.10 *
P_9 x P_{11}	123.75	12.99	10.94	4.30	49.57	100.00	0.44	-19.56 **	-24.48 **
P_9 x P_{12}	90.50	-21.13	-25.82 *	9.50	21.41	341.86	0.54	1.80	-15.94 *
P_{10} x P_2	60.25	-36.14 **	-38.21 **	32.30	707.50 **	738.96 **	0.48	7.71	2.15
P_{10} x P_4	105.00	-36.56 **	-55.03 **	7.40	50.25	78.31	0.54	126.83 **	29.74 **
P_{10} x P_{11}	87.85	-15.95	-21.25	9.35	141.29 **	159.72	0.37	-20.95 **	-28.09 **
P_{11} x P_5	211.50	88.88 **	88.17 **	18.05	496.69 **	636.73 *	0.43	-8.27	-16.11
P_{11} x P_9	156.45	42.84 **	40.25 **	12.60	338.26 **	486.05	0.60	9.27	2.59
P_{12} x P_3	46.50	-59.73 **	-61.89 **	23.80	128.30 **	223.81 *	0.44	-43.10 **	-51.69 **
P_{12} x P_4	39.00	-72.43 **	-79.01 **	26.85	179.69 **	371.05 **	0.43	22.29 **	-33.13 **
P_{12} x P_5	95.10	-18.86	-22.05	12.75	59.87	420.41	0.47	-11.11	-26.25 **
P_{12} x P_7	56.40	-57.27 **	-60.28 **	17.10	51.66	88.95	0.45	-17.49 **	-29.22 **
P_{12} x P_9	107.25	-6.54	-12.09	5.50	-29.71	155.81	0.46	-25.08 **	-28.59 **
P_{12} x P_{10}	106.50	-2.96	-12.70	9.15	3.68	120.48	0.46	-12.58	-27.81 **

(Contd...)

Appendix iii (Contd...)

Cross	1000 grain weight (g)			Second upper most internodal length (cm)			Height of plant at harvest (cm)		
	Mean	di	dii	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7	8	9	10
P_1 x P_4	22.50	-4.66	-12.11 *	15.10	-26.34 **	-6.50	75.50	-25.50 **	-2.08
P_1 x P_5	24.15	-11.78 *	-17.15 **	18.80	9.46 *	16.41 **	76.15	-9.61	-1.23
P_1 x P_6	20.20	-34.09 **	-43.42 **	10.75	-47.43 **	-33.44 **	70.90	-26.18 **	-8.04
P_1 x P_9	23.20	-7.48	-9.37	18.50	21.91 **	30.28 **	83.00	8.07	8.50
P_4 x P_1	17.10	-27.54 **	-33.20 **	24.00	17.07 **	48.61 **	125.85	24.11 **	63.23 **
P_4 x P_5	15.50	-38.92 **	-46.83 **	26.00	20.79 **	42.86 **	132.50	22.06 **	44.97 **
P_4 x P_6	22.35	-21.99 **	-37.39 **	27.00	8.87 *	9.09 *	130.15	8.60	13.65 *
P_4 x P_9	16.95	-26.54 **	-30.96 **	23.75	21.64 **	67.25 **	123.15	21.81 **	60.98 **
P_5 x P_1	23.30	-14.89 **	-20.07 **	14.10	-17.90 *	-12.69 *	72.80	-13.59	-5.58
P_5 x P_4	24.70	-2.66	-15.27 **	22.90	6.39	25.82 **	85.65	-21.10 **	-6.29
P_5 x P_6	25.65	-20.89 **	-28.15 **	19.00	-11.53 **	4.40	93.90	-9.01	2.74
P_5 x P_9	24.90	-7.26	-14.58 **	9.25	12.65 **	28.52 **	84.05	0.12	9.87
P_6 x P_1	28.60	-6.69	-19.89 **	30.25	47.92 **	87.31 **	121.00	25.98 **	56.94 **
P_6 x P_4	25.45	-11.17 *	-28.71 **	20.10	-18.95 **	-18.79 **	106.05	-11.88	-7.78
P_6 x P_5	27.55	-15.03 **	-22.83 **	27.10	26.19 **	48.90 **	137.00	32.75 **	49.89 **
P_6 x P_9	31.15	3.40	-12.75 **	27.65	41.98 **	94.72 **	97.05	1.36	26.86 **
P_9 x P_1	18.60	-25.82 **	-27.34 **	11.15	-26.52 **	-21.48 **	55.05	-28.32 **	-28.04 **
P_9 x P_4	18.50	-19.83 **	-24.64 **	7.15	-63.38 **	-49.65 **	45.00	-55.49 **	-41.18 **
P_9 x P_5	22.75	-15.27 **	-21.96 **	9.15	-43.52 **	-35.56 **	58.90	-29.84 **	-23.01 **
P_9 x P_6	20.00	-33.61 **	-43.98 **	9.25	-52.50 **	-34.86 **	51.05	-46.68 **	-33.27 **
P_4 x P_{11}	21.00	-9.19	-14.81 *	25.10	21.11 **	51.20 **	102.50	-0.87	26.39 **
P_4 x P_{10}	17.60	-27.05 **	-33.96 **	23.00	23.16 **	84.00 **	113.25	10.70	43.54 **
P_4 x P_7	18.75	-27.40 **	-37.60 **	21.80	4.18	28.24 **	109.50	8.04	42.21 **
P_4 x P_8	17.75	-22.66 **	-26.95 **	24.90	30.71 **	87.92 **	91.90	-3.97	39.88 **
P_4 x P_3	20.05	-23.11 **	-34.37 **	21.10	4.98	37.46 **	93.50	-5.79	28.43 **
P_{11} x P_6	27.70	-8.20	-22.41 **	32.05	55.02 **	93.07 **	146.10	49.01 **	80.15 **
P_{11} x P_{10}	22.65	-11.70 *	-15.01 **	14.20	-2.41	13.60	70.90	-11.37	-10.14
P_{11} x P_7	23.40	-14.44 **	-22.13 **	19.10	13.69 **	15.06 *	83.90	6.14	8.96
P_{11} x P_8	24.50	0.10	-0.61	12.75	-14.59 **	-3.77	66.00	-10.08	0.46
P_{11} x P_3	26.25	-4.89	-14.08 **	17.25	7.98	12.38	92.50	20.21 **	27.06 **
P_{11} x P_1	24.25	-3.48	-5.27	20.85	27.33 **	29.10 **	47.50	-39.95 **	-38.39 **
P_6 x P_{10}	26.30	-15.64 **	-26.33 **	24.15	29.66 **	93.20 **	120.05	23.83 **	52.15 **
P_6 x P_7	30.20	-8.14	-15.41 **	18.10	-13.29 **	6.47	122.90	28.02 **	59.61 **
P_6 x P_8	24.70	-17.67 **	-30.81 **	27.75	46.05 **	109.43 **	121.95	34.98 **	85.62 **
P_6 x P_3	28.25	-14.72 **	-20.87 **	20.95	4.49	36.48 **	100.10	6.60	37.50 **
P_{10} x P_7	24.30	-14.29 **	-8.82 **	15.50	5.02	24.00 **	74.50	-4.43	-3.25
P_{10} x P_8	25.80	1.28	-3.19	17.30	34.37 **	38.40 **	87.80	21.44 **	33.64 **
P_{10} x P_3	22.30	-22.03 **	-27.00 **	8.25	-40.75 **	-34.00 **	46.25	-39.02 **	-36.47 **
P_{10} x P_1	22.00	-15.79 **	-17.45 **	14.25	-0.52	14.00	79.25	1.60	2.79
P_7 x P_8	25.10	-7.64	-16.47 **	15.15	0.17	-10.88	60.10	-15.77	-8.52
P_7 x P_3	25.70	-15.18 **	-15.88 **	7.30	-54.87 **	-52.44 **	86.05	14.89	18.20 *
P_7 x P_1	25.35	-8.89	-15.64 **	16.85	1.66	4.33	71.75	-6.88	-6.82
P_8 x P_3	21.85	-20.33 **	-28.48 **	9.55	-33.22 **	-27.92 **	50.25	-27.44 **	-23.52 **
P_8 x P_1	21.25	-14.83 **	-16.99 **	12.90	-12.24 *	-2.64	73.75	3.29	12.25
P_3 x P_1	25.00	-10.95 *	-18.17 **	13.45	-14.60 **	-12.38	60.90	-18.75 *	-16.35

(Contd...)

Appendix iii (Contd....)

1	2	3	4	5	6	7	8	9	10
P_{12} x P_1	19.10	-24.73 **	-25.39 **	21.75	32.42 **	34.67 **	55.75	-29.21 **	-27.69 **
P_{12} x P_2	22.60	-9.33 **	-10.14 **	12.20	-27.70 **	-26.95 **	64.50	-19.83 **	-19.78 **
P_{12} x P_6	17.65	-41.99 **	-50.56 **	8.75	-57.78 **	-47.00 **	57.10	-41.56 **	-28.98 **
P_3 x P_2	27.40	-0.81	-10.31 **	12.10	-25.31 **	-21.17 **	63.10	-17.68 **	-13.32 *
P_3 x P_6	26.80	-19.09 **	-24.93 **	10.20	-49.13 **	-33.55 **	61.65	-34.35 **	-15.32 **
P_5 x P_2	23.75	-11.79 **	-18.52 **	19.10	8.37	12.02	96.80	12.62 **	20.25 **
P_7 x P_2	24.60	-10.14 **	-18.14 **	13.05	-23.35 **	-23.24 **	73.05	-7.24	-5.13
P_7 x P_6	25.05	-23.80 **	-29.83 **	20.25	-2.99	19.12 **	84.50	-11.98 **	9.74
P_{11} x P_2	24.70	0.10	0.00	19.85	17.98 **	19.58 **	97.05	20.11 **	20.56 **
P_4 x P_2	16.25	-29.81 **	-34.21 **	22.25	6.21	30.50 **	115.00	11.54 **	42.86 **
P_1 x P_2	25.30	0.60	-1.17	12.55	-24.40 **	-22.29 **	84.10	6.73	9.08
P_1 x P_3	17.65	-37.13 **	-42.23 **	10.60	-32.70 **	-30.94 **	58.40	-22.08 **	-19.78 *
P_1 x P_7	24.60	-11.59 **	-18.14 **	14.85	-10.41 *	-8.05	67.75	-12.07	-12.01
P_1 x P_8	22.70	-9.02	-11.33 *	12.60	-14.29 **	-4.91	66.00	-7.56	0.46
P_1 x P_{11}	20.10	-20.00 **	-21.48 **	10.90	-33.44 **	-32.51 **	53.75	-32.01 **	-30.29 **
P_1 x P_{12}	22.30	-12.12 *	-12.89 *	11.65	-29.07 **	-27.86 **	49.00	-37.78 **	-36.45 **
P_2 x P_3	22.35	-19.10 **	-26.84 **	16.10	-0.62	4.89	73.95	-3.52	1.58
P_2 x P_6	24.80	-17.88 **	-30.53 **	14.75	-29.43 **	-13.49 *	101.50	3.84	26.09 **
P_2 x P_{10}	23.60	-8.08	-11.44 *	14.05	-4.91	12.40	75.00	-5.60	-4.94
P_2 x P_{12}	21.75	-12.74 **	-13.52 *	17.50	3.70	4.79	78.00	-3.05	-2.99
P_3 x P_7	24.00	-20.79 **	-21.44 **	10.20	-36.94 **	-33.55 **	58.05	-22.50 **	-20.26 *
P_3 x P_9	19.70	-28.49 **	-35.52 **	17.75	20.14 **	15.64 **	63.05	-15.54 *	-13.39
P_3 x P_{10}	28.35	-0.87	-7.20	13.40	-3.77	7.20	70.90	-6.53	-10.14
P_3 x P_{12}	28.90	3.77	-5.40	13.90	-13.26 **	-9.45	66.50	-13.19	-8.65
P_4 x P_{12}	19.00	-18.72 **	-24.45 **	24.60	18.41 **	47.31 **	122.00	18.39 **	51.74 **
P_5 x P_3	26.50	-11.22 **	-13.26 **	22.05	31.45 **	43.65 **	81.15	-1.16	11.47
P_5 x P_8	24.45	-8.51	-16.12 **	16.50	4.93	24.53 **	81.50	3.76	24.05 *
P_5 x P_{10}	22.65	-18.82 **	-22.30 **	14.20	-7.49	13.60	80.90	-4.99	2.53
P_5 x P_{11}	23.10	-14.13 **	-20.75 **	17.00	-2.30	2.41	63.50	-26.33 **	-21.60 **
P_7 x P_5	26.95	-8.95	-10.32 *	13.05	-25.85 **	-23.24 **	86.75	3.03	12.66
P_7 x P_{11}	26.50	-3.11	-11.81 *	20.00	19.05 **	20.48 **	91.50	15.82 *	18.83 *
P_8 x P_4	21.75	-5.23	-10.49	11.15	-41.47 **	-15.85 **	58.50	-38.87 **	-10.96
P_8 x P_5	28.20	5.52	-3.26	18.90	20.19 **	42.64 **	80.90	2.99	23.14 *
P_8 x P_6	20.10	-33.00 **	-43.70 **	13.80	-27.37 **	4.15	73.50	-18.65 **	11.87
P_8 x P_{12}	25.25	2.12	0.40	13.75	-8.18	3.77	74.90	2.53	14.00
P_9 x P_7	17.60	-35.53 **	-41.43 **	6.75	-56.73 **	-52.46 **	37.00	-51.79 **	-51.63 **
P_9 x P_8	18.20	-25.49 **	-25.87 **	13.00	-5.28	-1.89	65.00	-8.58	-1.07
P_9 x P_{10}	19.15	-25.20 **	-28.14 **	15.60	16.85 **	24.80 **	75.50	-2.83	-1.31
P_9 x P_{11}	20.05	-18.50 **	-18.66 **	15.50	0.65	9.15	70.50	-10.48	-7.84
P_9 x P_{12}	19.60	-21.13 **	-22.07 **	16.05	3.88	13.03	77.00	-1.85	0.65
P_{10} x P_2	24.45	-4.77	-8.26	16.00	8.29	28.00 **	69.50	-12.80	-11.91
P_{10} x P_4	22.60	-6.32	-15.20 **	12.45	-33.33 **	-40.00 **	80.50	-21.31 **	2.03
P_{10} x P_{11}	21.55	-15.98 **	-19.14 **	14.65	68.73 **	17.20 **	74.10	-7.32	-6.08
P_{11} x P_5	25.35	-5.76	-13.04 **	19.25	10.63 *	15.96 **	98.00	13.69 *	20.99 *
P_{11} x P_9	23.45	-4.67	-4.87	17.15	11.36 *	20.77 **	87.80	11.49	14.77
P_{12} x P_3	26.05	-6.46	-14.73 **	7.30	-54.45 **	-52.44 **	22.00	-71.28 **	-69.78 **
P_{12} x P_4	21.35	-8.66	-15.11 **	20.30	-2.29	21.56 **	64.00	-37.89 **	-20.40 *
P_{12} x P_5	23.65	-12.89 **	-18.87 **	15.95	-8.60	-4.49	84.35	-1.80	4.91
P_{12} x P_7	23.15	-16.12 **	-22.96 **	13.35	-20.77 **	-20.06 **	63.15	-19.76 **	-17.99 *
P_{12} x P_9	25.10	1.01	-0.20	14.15	-8.41	-0.35	75.10	-4.27	-1.83
P_{12} x P_{10}	25.70	-0.77	-3.56	13.50	-7.53	8.00	71.50	-10.23	-9.38

(Contd...)

Appendix iii (Contd...)

Cross	Leaf area plant^{-1} at maximum tillering stage (cm^2)			Length of panicle (cm)			L/B ratio of grain		
	Mean	di	dii	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7	8	9	10
P_1 x P_4	217.70	-7.16	-29.35	22.40	-10.67 **	-18.55 **	2.63	-9.23 *	-16.64 **
P_1 x P_5	319.80	200.56 **	515.59 **	22.30	-3.98	-6.30	2.55	-10.86 *	-17.10 **
P_1 x P_6	193.65	30.40	20.39	22.10	-9.98 **	-16.45 **	2.45	-7.63	-8.07 **
P_1 x P_9	277.95	23.74	-3.62	23.95	7.64 *	5.74	2.53	-19.04 **	-29.92 **
P_4 x P_1	390.15	66.38 **	26.61	25.40	1.30	-7.64 **	3.11	7.33	-1.43
P_4 x P_5	602.50	234.63 **	95.52 **	25.85	0.78	-6.00 *	3.20	2.81	1.43
P_4 x P_6	609.40	174.32 **	97.76 **	26.70	-1.02	-2.91	2.88	-1.03	-8.72
P_4 x P_9	589.85	97.75 **	91.42 **	26.20	6.18 *	-4.73	3.08	-8.94 *	-14.68 **
P_5 x P_1	644.00	505.26 **	300.37 **	21.05	-9.36 **	-11.55 **	3.82	33.80 **	24.43 **
P_5 x P_4	693.95	285.42 **	125.20 *	25.05	-2.34	-8.91 **	3.32	6.67	5.23
P_5 x P_6	712.10	657.15 **	423.03 **	26.35	4.88	-0.38	2.50	-12.82 **	-18.57 **
P_5 x P_9	812.20	377.27 **	181.62 **	23.35	2.30	-1.89	2.97	-11.08	-17.73
P_6 x P_1	884.96	495.94 **	450.18 **	28.25	15.07 **	6.81 *	2.53	-4.43	-4.88
P_6 x P_4	331.55	49.25 *	7.59	27.25	1.02	-0.91	2.55	-12.37 **	-19.18 **
P_6 x P_5	114.75	22.01	120.89 **	20.05	-20.20 **	-24.20 **	2.41	-15.78 **	-21.34 **
P_6 x P_9	202.15	-4.77	-29.91	20.40	-15.53 **	-22.87 **	2.26	-27.97 **	-37.40 **
P_9 x P_1	97.90	-56.42 *	-66.05 **	20.25	-8.99 **	-10.60 **	3.42	9.60 *	-5.12
P_9 x P_4	28.20	-90.55 **	-90.22 **	15.10	-38.80 **	-45.09 **	2.65	-21.66 **	-26.59 **
P_9 x P_5	70.85	-58.37	-75.43 **	20.90	-8.43 *	-12.18 **	3.47	4.04	-3.74
P_9 x P_6	44.05	-79.25 **	-84.73 **	10.55	-56.31 **	-60.11 **	3.30	5.18	-8.59
P_4 x P_{11}	539.45	126.83 **	75.06 **	22.00	-13.13 **	-20.00 **	2.82	-17.21 **	-22.77 **
P_4 x P_{10}	638.85	145.38 **	107.32 **	22.40	-13.76 **	-18.55 **	3.20	-7.98 **	-15.79 **
P_4 x P_7	282.50	46.45 *	-8.32	25.70	-3.47	-6.55	2.90	0.43	-7.92 *
P_4 x P_8	261.25	33.44	-15.22	24.15	0.31	-12.18 **	2.84	-16.29 **	-21.76 **
P_4 x P_3	187.80	-30.79	-39.06 *	21.45	-13.07 **	-22.00 **	3.05	2.78	-3.17
P_{11} x P_6	1262.00	731.22 **	653.43 **	28.35	14.31 **	7.18	2.80	-11.25 **	-23.18 **
P_{11} x P_{10}	703.50	269.98 **	230.77 **	22.60	-5.04	-7.57	3.00	-19.41 **	-21.05 **
P_{11} x P_7	515.70	320.72 **	207.88 **	24.25	-0.82	-5.83	2.30	-26.69 **	-36.90 **
P_{11} x P_8	320.40	155.40 **	91.28 **	22.70	3.65	-1.94	3.57	-1.86	-2.06
P_{11} x P_3	481.55	139.55 **	105.31 **	28.80	28.00 **	24.41 **	2.91	-9.71 **	-20.30 **
P_{11} x P_1	137.00	-16.55	-18.21	19.10	-16.59 **	-17.49 **	3.04	-3.26	-16.60
P_6 x P_{10}	911.40	422.74 **	328.79 **	29.50	15.91 **	11.53 *	2.76	-14.62 **	-27.37 **
P_6 x P_7	614.65	474.98 **	351.45 **	26.10	0.00	-1.32	2.39	-9.73 **	-10.32 *
P_6 x P_8	1921.00	1649.94 **	1310.94 **	29.40	24.84 **	11.15 *	2.75	-12.63 **	-24.24 **
P_6 x P_3	629.65	239.71 **	168.45 **	25.45	5.38	-3.78	2.42	-11.27 **	-13.26 **
P_{10} x P_7	381.20	162.72 **	79.35 **	25.15	0.20	-2.33	3.40	5.75	-10.53 **
P_{10} x P_8	64.35	-56.51	-69.72 **	26.10	15.74 **	6.75	3.54	-4.71	-6.84 *
P_{10} x P_3	36.20	-83.81 **	-84.57 **	18.45	-20.30 **	-24.54 **	3.64	10.47 **	-4.21
P_{10} x P_1	243.65	30.50	14.63	24.00	1.91	-1.84	3.82	18.63 **	2.36
P_7 x P_8	86.35	7.23	11.20	22.70	-2.16	-11.84 *	2.50	-20.13 **	-31.13 **
P_7 x P_3	407.75	161.21 **	73.84 **	26.55	11.55 *	3.11	2.65	-2.21	-5.02
P_7 x P_1	266.55	123.52 **	65.71	23.15	-4.34	-10.10	2.61	-0.95	-1.14
P_8 x P_3	120.45	-24.23	-48.65	18.35	-13.65 *	-16.02 **	3.45	7.48 *	-4.96
P_8 x P_1	1011.75	728.45 **	529.00 **	20.90	-3.46	7.73	3.58	14.19 **	-1.38
P_3 x P_1	527.10	166.62 **	124.73 **	18.90	-15.06 **	-16.56 **	2.39	-11.97 **	-14.34 **

(Contd...)

Appendix iii (Contd....)

1	2	3	4	5	6	7	8	9	10
P_{12} x P_1	73.40	-54.33	-54.37	19.45	-14.32 **	-14.51 *	3.23	7.04 *	-4.86
P_{12} x P_2	78.15	-52.49	-53.58	18.00	-15.19 **	-20.88 **	3.34	12.48 **	-1.77
P_{12} x P_6	107.25	-27.72	-33.22	21.40	-13.01 **	-19.09 **	3.55	17.16 **	4.57
P_3 x P_2	200.85	-0.30	-14.37	18.90	-9.03	-13.50 *	3.36	26.20 **	20.43 **
P_3 x P_6	695.85	275.42 **	196.67 **	18.65	-22.77 **	-29.49 **	2.86	4.67	2.33
P_5 x P_2	1283.25	1065.00 **	662.25 **	23.65	8.74	-0.63	2.92	4.19	-4.89
P_7 x P_2	569.30	362.85 **	238.16 *	24.95	9.79	-3.11	2.68	3.97	2.09
P_7 x P_6	542.65	407.62 **	298.57 **	28.30	8.43	6.99	2.68	1.23	0.56
P_{11} x P_2	2942.05	1652.00 **	1647.58 **	29.30	36.76 **	26.57 **	3.56	15.21 **	-2.33
P_4 x P_2	245.00	2.83	-20.49	20.55	-12.92 *	-25.27 **	3.11	9.31 *	-1.43
P_1 x P_2	639.20	287.98 **	279.69 **	25.05	18.30 **	10.60 *	2.47	-4.63	-6.44
P_1 x P_3	86.35	-56.36	-63.18 *	19.45	-12.58 **	-14.13 **	2.59	-4.60	-7.17
P_1 x P_7	154.80	29.65	-3.94	20.95	-13.43 **	-18.64 **	2.61	-0.95	-1.14
P_1 x P_8	157.27	28.62	-2.41	21.35	-1.39	-5.74	2.51	-19.94 **	-30.85 **
P_1 x P_{11}	66.20	-59.71	-60.48	18.35	-19.87 **	-20.73 **	2.69	-14.47 **	-26.30 **
P_1 x P_{12}	50.35	-68.70	-68.76	15.20	-33.04 **	-33.19 **	2.58	-14.57 **	-24.12 **
P_2 x P_3	741.45	268.06 **	216.12 **	22.35	7.58	2.29	2.47	-7.32	-11.47 **
P_2 x P_6	726.90	377.44 **	331.78 **	23.65	2.49	-10.59 *	2.55	-2.11	-4.49
P_2 x P_{10}	309.65	62.59	45.68	23.10	4.64	-5.52	2.41	-23.97 **	-36.58 **
P_2 x P_{12}	309.75	88.33 *	83.99 *	18.40	-13.31 **	-19.12 **	2.41	-18.86 **	-29.12 **
P_3 x P_7	160.85	3.04	-31.42	15.25	-35.92 **	-40.78 **	2.67	-1.48	-4.30
P_3 x P_9	135.35	-48.24	-53.07	18.05	-17.39 **	-17.39 **	2.64	-17.50 **	-26.87 **
P_3 x P_{10}	486.55	100.00 **	107.44 **	21.00	-9.29 *	-14.11 **	2.79	-15.33 **	-26.58 **
P_3 x P_{12}	207.25	4.90	-11.64	20.20	-9.42 *	-11.21 *	2.65	-14.38 **	-22.06 **
P_4 x P_{12}	386.35	64.84	25.38	24.40	-2.89	-11.27 **	3.21	-2.13	-5.59
P_5 x P_3	1630.85	964.18 **	595.31 **	24.25	6.24	1.89	2.21	-24.57 **	-28.01 **
P_5 x P_8	701.25	936.20 **	740.83 **	25.05	12.71 **	5.25	3.36	0.30	-7.44
P_5 x P_{10}	216.90	64.01	2.05	25.10	4.04	2.66	3.40	-1.02	-10.53 **
P_5 x P_{11}	381.80	247.96 **	127.94 **	23.10	-1.60	-2.94	3.14	-6.55	-13.97 **
P_7 x P_5	363.75	461.34 **	368.45 **	24.10	-2.72	-6.41	2.71	-4.91	-11.73 **
P_7 x P_{11}	468.15	281.93 **	179.49 **	27.10	10.84 **	5.24	2.66	-15.29 **	-27.12 **
P_8 x P_4	124.10	-36.61	-59.73	20.70	-14.02 **	-24.73 **	3.61	6.33	-0.55
P_8 x P_5	119.45	76.51	43.23	23.45	5.51	-1.47	2.89	-13.73 **	-20.39 **
P_8 x P_6	431.00	292.62 **	216.56 **	23.00	-2.34	-13.04 **	3.72	18.10 **	2.48
P_8 x P_{12}	202.15	65.70	25.87	23.15	6.68	1.76	3.65	3.84	0.55
P_9 x P_7	24.05	-86.86 **	-91.66 **	15.10	-36.55 **	-41.36 **	3.39	8.65 **	-6.09
P_9 x P_8	125.75	-32.36	-56.40	22.80	7.29	4.35	3.60	-0.55	-0.83
P_9 x P_{10}	357.05	42.55	23.80	24.10	4.10	-1.43	3.54	-4.45	-6.84
P_9 x P_{11}	441.78	93.81 **	53.18 *	23.05	2.44	-0.43	3.40	-6.34	-6.85
P_9 x P_{12}	107.45	-52.14	-62.74 **	23.00	3.14	1.10	3.46	-1.28	-4.16
P_{10} x P_2	246.80	29.59	16.11	22.55	2.15	-7.77	3.20	1.03	-15.79 **
P_{10} x P_4	140.35	-46.09	-54.45 *	24.10	-7.22	-12.36 **	3.54	1.72	-6.84
P_{10} x P_{11}	463.60	143.97 **	118.11 **	22.60	-5.04	-7.57	3.70	-0.67	-2.63
P_{11} x P_5	1030.05	838.76 **	514.96 **	26.30	12.03 **	10.50 *	3.46	2.98	-5.21
P_{11} x P_9	2000.65	777.67 **	593.71 **	26.10	16.00 **	12.74 **	3.64	0.28	-0.27
P_{12} x P_3	101.95	-48.40	-56.53	18.50	-17.04 **	-18.68 **	3.47	12.12 **	2.06
P_{12} x P_4	65.70	-71.97 **	-78.68 **	20.60	-18.01 **	-25.09 **	2.72	-17.07 **	-20.00 **
P_{12} x P_5	462.50	335.19 **	187.98 **	22.25	-4.40	-6.50	2.89	-10.66 **	-15.00 **
P_{12} x P_7	102.80	-13.70	-35.99	19.65	-18.97 **	-23.69 **	3.41	13.10 **	0.29
P_{12} x P_9	224.00	-22.27	-22.33	21.00	-5.83	-7.69	2.93	-16.41 **	-18.84 **
P_{12} x P_{10}	217.35	16.49	2.26	23.90	1.27	-2.25	3.00	-16.67 **	-21.05 **

(Contd...)

Appendix iii (Contd...)

Cross	Amylose content(%)			Yield $plant^{-1}$(g)		
	Mean	di	dii	Mean	di	dii
1	2	3	4	5	6	7
P_1 x P_4	23.70	-5.47 *	-8.30 **	3.62	-65.09 **	-70.94 **
P_1 x P_5	19.94	-19.32 **	-22.85 **	5.30	-6.32	-35.91
P_1 x P_6	20.40	-16.79 **	-21.09 **	3.99	-32.86	-51.75 *
P_1 x P_9	21.44	-5.72 *	-17.02 **	5.68	-11.00	-31.26
P_4 x P_1	26.48	5.61 *	2.46	4.60	-55.58 **	-63.02 **
P_4 x P_5	23.97	0.09	-1.38	13.90	79.59 **	11.78
P_4 x P_6	20.06	-15.49 **	-17.45 **	7.78	-3.15	-37.50 **
P_4 x P_9	24.83	12.98 **	2.16	6.93	-18.26	-44.33 **
P_5 x P_1	21.78	-11.86 **	-15.71 **	4.64	-17.98	-43.89 **
P_5 x P_4	21.15	-11.68 **	-12.98 **	7.91	2.23	-36.37 **
P_5 x P_6	22.50	-3.76	-4.60	11.93	258.11 **	229.88 **
P_5 x P_9	20.17	-6.69 *	-14.48 **	6.57	74.17 **	45.95 **
P_6 x P_1	21.22	-13.42 **	-17.90 **	17.26	190.53 **	108.77 **
P_6 x P_4	22.08	-6.96 *	-9.12 **	6.30	-21.58	-49.40 **
P_6 x P_5	20.69	-11.48 **	-12.25 **	2.84	-14.71	-21.44
P_6 x P_9	18.93	-11.58 **	-18.32 **	1.91	-52.83	-57.49
P_9 x P_1	15.40	-32.29 **	-40.41 **	2.36	-63.05 **	-71.46 **
P_9 x P_4	13.41	-38.99 **	-44.84 **	0.13	-98.47 **	-98.95 **
P_9 x P_5	18.33	-15.20 **	-22.28 **	1.15	-69.54 **	-74.47 **
P_9 x P_6	12.06	-43.67 **	-47.96 **	0.34	-91.75 **	-92.56 **
P_4 x P_{11}	21.41	-12.16 **	-12.43 **	7.70	-23.34	-38.10
P_4 x P_{10}	21.17	-6.32	-12.90 **	4.73	-46.32 *	-61.94 **
P_4 x P_7	23.70	29.31 **	-2.47	4.40	-63.03 **	-64.63 **
P_4 x P_8	18.82	-20.93 **	-22.57 **	4.16	-54.08 *	-66.56 **
P_4 x P_3	20.61	-8.29 *	-15.16 **	2.29	-82.93 **	-84.09 **
P_{11} x P_6	23.44	-1.56	-4.13	10.01	77.63 **	30.78
P_{11} x P_{10}	17.60	-22.36 **	-28.02 **	6.12	-4.75	-20.00
P_{11} x P_7	20.17	9.60 *	-17.51 **	8.65	-8.94	-23.81
P_{11} x P_8	19.34	-18.96 **	-20.88 **	2.75	-58.66 **	-63.99 **
P_{11} x P_3	12.86	-42.98 **	-47.40 **	10.82	-1.86	-24.84
P_{11} x P_1	17.58	-30.09 **	-31.98 **	1.20	-84.92 **	-85.49 **
P_6 x P_{10}	19.08	-13.39 **	-17.67 **	23.43	431.59 **	350.58 **
P_6 x P_7	22.24	25.16 **	-4.06	12.24	63.54 **	7.79
P_6 x P_8	22.99	-1.04	-1.29	25.90	457.29 **	355.99 **
P_6 x P_3	16.31	-25.60 **	-29.64 **	6.51	-27.69	-54.76 **
P_{10} x P_7	12.11	-27.11 **	-41.99 **	2.57	-68.90 **	-77.33 **
P_{10} x P_8	14.18	-35.80 **	-39.12 **	4.76	-12.50	-16.20
P_{10} x P_3	13.46	-35.19 **	-35.55 **	1.20	-87.75 **	-91.66 **
P_{10} x P_1	17.81	-23.80 **	-31.11 **	3.16	-53.01	-61.73 *
P_7 x P_8	7.06	-60.39 **	-69.69 **	1.73	-79.75 **	-84.82 **
P_7 x P_3	9.73	-41.05 **	-52.89 **	4.31	-66.52 **	-70.05 **
P_7 x P_1	9.61	-49.66 **	-62.80 **	4.67	-52.42 *	-58.89 **
P_8 x P_3	18.26	-16.92 **	-21.62 **	0.96	-90.43 **	-93.33 **
P_8 x P_1	23.55	-4.14	-8.88 *	12.18	74.62 *	47.28
P_3 x P_1	19.80	-14.86 **	-23.41 **	5.23	-53.80 **	-63.62 **

(Contd...)

Appendix iv Generation mean of 10 crosses for 12 characters

Crosses	Generations	Number of days to 50 % flowering	Number of days to harvest	Number of panicles $plant^{-1}$	Number of spikelets $panicle^{-1}$	Number of tertiary branches $panicle^{-1}$	Number of grains $panicle^{-1}$	Spikelets sterility percentage	1000 grain weight (g)	Second uppermost internodal length (cm)	Height of plant (cm)	Harvest index	Yield $plant^{-1}$ (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
$P_3 \times P_1$	P_1	72.00	103.00	2.03	106.25	13.25	94.00	11.60	29.28	21.43	69.92	0.60	2.18
	P_2	82.50	114.00	1.40	132.80	20.47	109.80	24.50	27.75	18.25	83.80	0.55	8.27
	F_1	86.50	122.00	3.55	85.25	11.90	79.25	7.10	25.00	13.45	60.90	0.52	5.24
	F_2	80.00	106.50	11.55	120.00	22.29	113.00	6.05	26.68	18.75	82.90	0.60	20.77
	B_1C_1	80.50	115.00	5.45	86.70	11.67	56.75	39.60	25.65	11.10	60.89	0.39	2.98
	B_2C_1	89.00	116.00	3.45	95.80	11.10	95.90	0.80	24.25	13.39	66.90	0.49	4.69
$P_3 \times P_6$	P_1	72.00	103.00	2.03	106.25	13.20	94.00	11.60	29.28	21.43	69.92	0.60	2.18
	P_2	90.50	120.00	1.15	107.95	17.00	100.20	6.40	39.31	25.88	131.50	0.47	3.62
	F_1	83.50	121.00	5.10	74.00	9.75	61.50	16.50	26.80	10.20	61.65	0.68	11.22
	F_2	68.00	108.00	14.00	93.30	15.80	90.25	3.60	27.30	13.89	68.10	0.60	15.34
	B_1C_1	72.00	109.00	4.00	87.15	12.50	78.65	0.10	25.85	13.45	64.65	0.53	4.39
	B_2C_1	73.00	121.00	4.40	78.00	14.00	25.00	67.95	19.20	20.08	68.50	0.54	3.01
$P_3 \times P_{10}$	P_1	72.00	103.00	2.03	106.25	13.25	94.00	11.60	29.28	21.43	69.92	0.60	2.18
	P_2	93.50	122.00	1.63	108.00	18.10	101.75	6.20	30.18	14.13	83.91	0.35	5.20
	F_1	86.50	116.50	3.90	84.00	11.75	77.25	7.90	28.35	13.40	70.90	0.46	6.74
	F_2	76.00	109.50	14.71	123.20	22.42	119.65	2.95	28.05	15.91	82.68	0.60	21.85
	B_1C_1	90.00	116.00	3.10	56.00	5.00	53.15	4.80	25.00	9.55	52.75	0.53	2.39
	B_2C_1	90.00	116.00	2.40	64.20	7.90	57.80	5.20	23.20	10.47	51.67	0.54	1.62
$P_4 \times P_3$	P_1	110.50	137.00	1.80	203.00	29.25	183.85	10.40	31.62	25.02	130.50	0.05	12.44
	P_2	72.00	103.00	2.03	106.25	13.25	87.80	11.60	29.16	21.43	69.92	0.60	2.18
	F_1	110.50	140.50	1.90	123.45	20.00	109.75	12.65	20.05	21.10	93.50	0.33	2.29
	F_2	84.00	114.00	14.85	181.02	32.75	176.75	2.75	23.58	22.70	102.25	0.56	30.85
	B_1C_1	81.00	121.00	3.60	184.00	29.55	162.15	11.60	13.70	25.44	108.30	0.43	5.80
	B_2C_1	88.00	121.00	4.75	132.00	20.25	104.90	23.30	23.10	17.45	85.65	0.44	6.31

(contd........)

Appendix iv (Contd.........)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
$P_4 \times P_6$	P_1	110.50	137.00	1.80	203.00	29.38	183.85	10.40	31.62	25.02	131.70	0.05	12.44
	P_2	90.50	120.00	1.15	107.95	17.00	100.20	6.40	39.31	25.88	131.50	0.47	3.62
	F_1	100.00	131.00	2.00	225.95	47.25	213.25	10.10	22.35	27.00	130.70	0.47	7.78
	F_2	83.00	118.00	13.25	169.09	34.21	154.90	7.65	26.92	25.33	112.60	0.46	22.30
	B_1C_1	95.50	130.00	2.70	172.75	28.69	137.70	19.60	21.30	26.05	109.55	0.42	3.97
	B_2C_1	81.00	121.00	3.70	136.70	30.43	119.40	12.75	20.80	19.78	76.70	0.69	5.81
$P_4 \times P_8$	P_1	110.50	137.00	1.70	203.00	29.25	183.85	10.40	31.62	25.02	130.80	0.05	12.44
	P_2	87.00	115.50	1.95	99.60	17.40	96.70	6.70	25.11	15.83	72.25	0.47	5.68
	F_1	96.50	134.00	2.00	172.00	25.25	168.50	2.05	17.75	24.90	91.90	0.46	4.16
	F_2	90.00	123.00	13.60	176.55	31.78	161.45	8.40	19.36	24.36	112.25	0.44	19.78
	B_1C_1	93.00	121.00	5.00	143.00	31.00	133.00	8.65	15.60	21.50	85.00	0.42	4.69
	B_2C_1	84.00	121.00	4.00	178.00	25.33	167.65	4.80	18.20	20.50	94.30	0.56	5.75
$P_4 \times P_{10}$	P_1	110.50	137.00	1.70	203.00	29.25	183.85	10.40	31.62	25.02	130.80	0.05	12.44
	P_2	93.50	122.00	1.63	108.00	18.10	101.75	6.20	30.18	14.13	83.91	0.35	5.20
	F_1	119.50	147.50	1.75	199.25	37.00	197.75	3.45	17.60	23.00	113.25	0.43	4.74
	F_2	87.50	123.00	13.53	214.23	40.10	212.05	0.95	20.18	24.28	123.24	0.39	24.48
	B_1C_1	96.00	124.50	3.10	148.90	24.50	130.70	17.70	17.65	25.81	98.60	0.41	5.11
	B_2C_1	105.50	137.00	2.70	243.30	51.67	235.00	3.70	14.70	21.60	130.30	0.24	4.90
$P_7 \times P_6$	P_1	92.50	125.00	1.90	166.50	25.40	154.00	7.55	34.35	18.86	81.05	0.38	11.36
	P_2	90.50	120.00	1.15	107.95	17.00	100.20	6.40	39.31	26.48	131.50	0.47	3.62
	F_1	99.50	139.00	4.75	174.00	29.50	153.00	10.45	25.05	20.25	84.50	0.54	11.32
	F_2	124.00	124.00	8.15	176.80	33.55	169.55	4.85	25.97	21.25	98.06	0.52	16.92
	B_1C_1	89.50	121.00	2.60	113.10	15.55	108.30	4.90	22.50	17.01	71.28	0.39	4.44
	B_2C_1	88.00	121.00	2.30	107.90	15.90	103.90	3.80	21.50	18.76	74.15	0.46	3.26
$P_8 \times P_1$	P_1	87.00	115.50	1.95	99.60	17.40	96.70	6.70	25.11	15.83	72.00	0.47	5.68
	P_2	82.50	114.00	1.45	133.00	20.50	109.80	19.95	27.75	18.25	84.00	0.55	8.27
	F_1	88.50	117.00	6.25	125.50	22.00	106.25	14.80	21.25	12.90	73.75	0.56	12.18
	F_2	83.50	117.00	12.36	133.07	23.38	131.80	1.05	23.49	18.43	88.21	0.60	20.59
	B_1C_1	88.00	116.00	4.00	128.20	21.20	123.20	3.75	18.00	15.78	76.80	0.43	5.76
	B_2C_1	84.00	121.00	3.38	99.25	14.75	95.00	3.60	20.60	14.04	73.25	0.56	4.12
$P_9 \times P_{11}$	P_1	86.50	115.50	1.50	138.25	22.38	119.35	6.10	24.23	15.80	82.28	0.51	4.51
	P_2	93.00	125.50	2.00	108.11	15.43	104.55	3.25	27.58	16.05	79.27	0.37	7.65
	F_1	91.50	125.00	4.00	129.25	21.50	123.75	4.30	20.05	16.10	70.50	0.44	4.77
	F_2	88.50	117.00	9.85	128.73	22.59	128.55	0.11	21.36	15.80	81.54	0.61	13.60
	B_1C_1	85.50	120.50	6.15	125.35	15.80	100.50	3.40	16.80	11.65	60.00	0.46	3.95
	B_2C_1	89.00	121.00	4.60	126.60	17.60	114.60	23.20	18.60	14.78	63.00	0.40	4.74

GENETIC ANALYSIS OF HIGH YIELDING RICE VARIETIES OF DIVERSE ORIGIN

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

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ABSTRACT

The research project Genetic Analysis of High Yielding Rice Varieties of Diverse Origin' was carried out in the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period 1995-'98. The major objectives of the study were to understand the genetic architecture of high yielding rice varieties of diverse origin so as to evolve appropriate breeding methodology, to isolate promising lines having the new ideotype concepts from the segregating generations and to identify alternative source of cytoplasmic male sterile system suitable to warm humid climatic conditions experienced in Kerala.

The study, about components of heritable variation revealed that the characters, number of panicles m^{-2}, number of tertiary branches $panicle^{-1}$, yield ha^{-1}, spikelet sterility percentage and alkali spreading value exhibited high broad sense heritability coupled with high expected genetic advance and high genotypic coefficient of variation. High broad sense heritability and high expected genetic advance coupled with moderate genotypic coefficient of variation were manifested by the characters, namely, height of plant at harvest, second uppermost internodal length, length of flag leaf, ratio of vegetative phase to reproductive phase, number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake.

Correlation studies revealed that the principal yield determining components in rice are harvest index, number of tertiary branches panicle^{-1} number of panicles m^{-2}, number of grains panicle^{-1} number of spikelets panicle^{-1}, ratio of vegetative phase to reproductive phase, 1000 grain weight, number of days to 50 per cent flowering, number of days to harvest and spikelet sterility percentage. While selecting genotypes for higher yield potential, emphasis should be given for comparatively long vegetative period, short period from panicle initiation to 50 per cent flowering and long ripening period.

A selection model was formulated consisting of the characters, namely, yield ha^{-1}, harvest index, number of days to harvest, number of tertiary branches panicle^{-1}, ratio of vegetative phase to reproductive phase and number of grains panicle^{-1}.

Cluster analysis revealed that there was no parallelism between geographical distribution and genetic diversity. The 56 genotypes representing different eco-geographical regions were grouped into nine clusters based on genetic distances.

Combining ability studies showed that both additive and non-additive gene effects were important, with predominance of non-additive gene action, for all the characters except for 1000 grain weight, second uppermost internodal length and height of plant at harvest.

The varieties Vytilla3, Mahsuri, Mattatriveni and Karthika were identified as good general combiners.

The varieties Mahsuri, Karthika, Vytilla 3, Mattatriveni and IR62030-18-2-2 showed pronounced cytoplasmic effect on yield and various yield contributing characters.

The crosses Vytilla 3 x Mattatriveni, Mahsuri x Vytilla-3 and Mahsuri x Mattatriveni are recommended for recombination breeding. The crosses Vytilla 3 x IR36, Vytiila 3 x IR60133-184-3-2, PK3355-5-1-4 x Bhadra, Vytilla 3 x Mattatriveni, Karthika x Bhadra, PK3355-5-1-4 x Karthika and PK3355-5-1-4 x IR62030-18-2-2 are recommended for heterosis breeding.

The cytoplasm of Vytilla 3 (an improved saline tolerant variety of Kerala) was identified as an alternative source for cytoplasmic male sterility in rice, suitable to warm humid tropical climate, experienced in Kerala. The varieties IR36 (international check) and Hraswa (extra short duration high yielding variety of Kerala) are the proposed maintainer lines. Mattatriveni is the proposed restorer line for the proposed IR36 `A' line and Hraswa `A' line.

The generation mean analysis using six parameter model revealed that both additive and non-additive gene effects played an important role in the inheritance of yield and important yield components, with predominance of dominance, additive x additive and dominance x dominance type of gene effects.

Results of inbreeding depression indicated absence of reduction in vigour in the F_2 generations for yield and all other yield attributes.

Investigation on pattern of inheritance of kernel colour revealed that kernel colour in rice is a complex qualitative character. Each red and white colour may be separately controlled by two or more sets of genes having both inhibitory and duplicate type of gene interactions with predominance of inhibitory type gene interaction.

From $22F_2$ generations, seven early stabilized promising lines and 26 promising segregants were selected. Two early stabilized lines were found to possess most of the ideotype features proposed by IRRI with preferable cooking quality characters. Their further evaluation and multiplication are being carried out at the Agricultural Research Station, Mannuthy, Kerala Agricultural University.

By hybridization, it was possible to successfully transfer the non sticky nature and red kernel colour of Mattatriveni to a high yielding Taiwan variety whose kernel is white and sticky on cooking.

The gene action studies revealed that there is ample scope for yield improvement in rice both through pedigree breeding and heterosis breeding. As yield and yield components were found to be under the control of all the three types of gene actions namely, additive, dominance and epistasis, intercrossing of early segregating generations derived from multiple crosses seems to be the best suited method of breeding for yield improvement in rice.

Future line of studies suggested

1. Conversion of the already obtained cytoplasmic male sterile F_1 crosses to fully sterile CMS lines by repeated back crossing with the respective recurrent parents.
2. Screening from the segregating populations of these cytoplasmic male sterile crosses for 100 per cent cytoplasmic male sterile lines.
3. Confirmation of the restoring ability of the proposed Mattatriveni 'R' line and identification of other restorers.
4. Incorporation of the sterile cytoplasm of Vytilla 3 into other elite genotypes other than IR36 and Hraswa.
5. Screening for cytoplasmic male sterile system in other saline tolerant lines.
6. Screening of promising segregants selected, for high yield and quality with multiple resistance to pest and diseases, for developing varieties suited to various climatic and soil conditions of Kerala.