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GENOTYPE X ENVIRONMENT INTERACTION IN COMMERCIAL RICE (*Oryza sativa* L.) HYBRIDS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Genotype x environment interaction in commercial rice (*Oryza sativa* L.) hybrids "** is a bonafide record of research work done by me during the course of research and that the 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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CERTIFICATE

Certified that this thesis entitled **"Genotype x environment interaction in commercial rice (*Oryza sativa* L.) hybrids"** is a record of work done independently by **Somanagoudra. S. Chandrashekhar** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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DEDICATED TO,

HUNDREDS OF INDIAN FARMERS WHO ENDED THEIR LIVES DUE TO AGRARIAN CRISIS

&

MY BELOVED PARENTS

INTRODUCTION

1. INTRODUCTION

Rice is an important staple food crop that meets the dietary energy requirements of more than half of the humanity. Owing to large influence of rice on human nutrition and the fight against hunger all over the world, United Nations has declared the year, 2004 as the International Year of Rice. Over 90% of the rice is produced and consumed in Asia alone. Rice occupies pivotal place in India's food and livelihood security system, providing 43 % of calorie requirement of more than 70% of Indian population. Rice occupies the largest area among all the crops grown in India, having an area of 43 million hectares with a production of 78 million tonnes. The country has to produce around 135-140 million tonnes of rice by 2020 to meet food requirements of its burgeoning population. The target has to be achieved in the backdrop of plateuing yield trends of high yielding varieties and declining resource base of land, labour and water (Khush, 2001).

Hybrid rice is a practically feasible and readily adoptable genetic option to increase the rice production, as has been amply demonstrated in the People's Republic of China. (Vijaykumar *et al.*, 2002). Recognising the importance of hybrid rice technology to step up the rice productivity and rice production, Indian Council of Agricultural Research, New Delhi initiated a network project on hybrid rice in 1989. The project was further strengthened with the assistance from UNDP/FAO since September 1991. As a result of sustained efforts over a decade, both public and private sector were able to release 17 hybrids (13 from public sector and four from private sector) for commercial cultivation in India.

Rice forms the staple food of the people of Kerala and contributes significantly to its economy and culture. At present rice is grown in an area of 3.2 lakh ha with a production of 7.2 lakh tonnes, 25 % less than the total requirement. The decline in area under rice and productivity has contributed to this deficit (Peter and Balachandran, 2004). The yield advantage of 20-30 %, of hybrids over high yielding varieties can be harnessed to step up productivity and thus help in bridging the gap between availability and requirement of rice. In Kerala research is being carried out at Regional Agricultural Research Station, Pattambi, to evolve rice hybrids suitable for Kerala. As a result of sustained efforts one hybrid viz., KAURH-2 had been developed and is under evaluation (Remabai *et al.*, 2002).

The performance of varieties is greatly influenced by the genotype (G), the environment (E) and the genotype x environment (G x E) interaction. G x E interaction is the differential genotypic expression across environments and largely affects the stable performance of the genotypes. Genotype x environment interaction reduces association between phenotypic and genotypic values and cause genotypes from one environment to perform poorly in another, forcing plant breeder to examine genotypic adaptation.

One of the prerequisites in any breeding programme is the assessment of genotypes over locations, to assess their performance in a given environment and their stability. Analysis of multilocation data can help to dissect the G X E interaction into different components for assessing the genetic worth of genotypes for specific environments.

Present study involves testing of different commercial rice hybrids for their adaptability in different agroclimatic regions of central zone of Kerala. The hybrids were tested in different climatic situations in farmers' fields in target environments, so that the time gap for adoption and large scale cultivation of hybrid rice can be reduced.

The present study was undertaken with the following objectives:

1. To assess the magnitude of genotype x environment interaction of rice hybrids over locations in central zone of Kerala.

2. To assess the stability of the rice hybrids over different environments in central zone of Kerala.

3. To assess the cooking and milling quality characteristics of rice hybrids.

4. To assess the magnitude of standard heterosis and inbreeding depression in rice hybrids.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Hybrid rice has a yield advantage of about 20 to 30% over the best commercial rice varieties. The technology was first commercialised in China in 1976. Recognizing the potential of hybrid rice to sustain self-sufficiency in rice production, India launched a national network program in 1989 to develop and adopt the technology on large scale. As a result of sustained efforts to popularize hybrid rice, it now occupies an estimated area of 2,00,000 hectares. Intensive development and evaluation of hybrids during the last decade has led to the release of 17 hybrids, developed by both public and private sector institutions, for commercial cultivation in India. A brief review of the literature on various aspects related to genotype x environment interaction of rice hybrids is presented under the following heads.

1. Mean performance and genetic variability
2. Heritability, Genetic advance and Genetic gain
3. Phenotypic and genotypic correlation
4. Path analysis
5. Milling and cooking quality
6. Genotype x environment interaction
7. Heterosis and inbreeding depression

2.1 MEAN PERFORMANCE AND GENETIC VARIABILITY

Genetic variability in a crop is the basic requirement for its further genetic improvement. The critical assessment of nature and magnitude of variability is one of the important pre-requisites in formulating effective breeding methods.

Kumar (1992) reported high variability estimates for plant height, tiller number, boot leaf length and yield plant^{-1} from the analysis of upland rice. Genotypic coefficient of variation of these characters showed close resemblance with phenotypic coefficient of variation, which suggested the effectiveness of selection of these traits. Variability in *indica* rice varieties was assessed by Chaubey and Richcharia (1993). They observed highest variability for spikelets panicle^{-1} and lowest for panicle length.

Analysis of yield components in rice by Chaubey and Singh (1994) identified wide range of variation for all the traits that offered scope of selection for development of desirable types. The higher estimates of phenotypic coefficient of variation in comparison to genotypic coefficient of variation for all traits studied suggested the influence of environmental factors on the traits. Govindarasu *et al.* (1995) evaluated high density grain characters in rice. Results indicated that grain density, grains panicle^{-1} and 1000 grain weight recorded high estimates of genotypic coefficient of variation while low values were recorded by number of spikelets and high density grain. Highest value of genotypic and phenotypic coefficient of variation was observed for high density grain numbers panicle^{-1}. The extent of genetic variation for 11 characters in 99 rice genotypes was assessed by Roy *et al.* (1995). Bacterial blight severity expressed the highest genotypic coefficient of variation followed by panicles plant^{-1}, grains panicle^{-1} and spikelets panicle^{-1}. The low estimates of variability was observed in hulling and milling per cent while moderate values were showed by yield plant^{-1}, days to 50 % flowering and 1000 grain weight.

Ganesan *et al.* (1996) reported high values of genotypic coefficient of variation for panicles plant^{-1}, grains panicle^{-1}, grain yield plant^{-1}, dry matter production and harvest index from the study of F_2 population derived from early and extra early cultivars. The low amount of genetic variability observed for days to panicle emergence might be due to involvement of early and extra early maturing parents. Murthy *et al.* (1997) analysed the variability in morphophysiological traits in 49 rice genotypes. Phenotypic and genotypic coefficient of variation were high for grain yield, total dry matter, leaf area at 45 days and leaf area at harvest.

Muker *et al.* (1998) studied the quality and milling characters in 50 rice varieties. The coefficient of variability was highest for kernel elongation ratio followed by kernel length-width ratio, length after cooking and kernel length. For hulling and milling recovery, very low magnitude of variability was observed which indicated lack of heritable variation for these traits. The estimates of genetic parameters from the analysis of genetic variability in rice quality traits by Vivekanandan and Giridharan (1998) revealed that kernel length after cooking, kernel length and kernel length-breadth ratio showed maximum phenotypic and genotypic variations, whereas linear elongation ratio, breadth wise expansion ratio and elongation index recorded the minimum. Kernel length-breadth ratio showed the highest phenotypic and genotypic coefficient of variations.

The estimates of mean squares in 65 rice hybrids, developed by crossing two cytoplasmically male sterile lines viz., IR58025A and PMS10A, were highly significant for all the nine characters indicating the presence of wide variation in the material (Vishwakarma *et al.*, 1999).

Variability for five characters in salt tolerant rice genotypes was estimated by Balan *et al.* (1999). The analysis of variance showed highly significant differences among genotypes for all the characters studied. Higher genotypic coefficient of variation was observed for grain yield followed by harvest index and straw yield. The difference between genotypic and phenotypic variability was minimum for days to maturity followed by days to 50 % flowering, suggesting that these characters were the least affected by environment. Rice genotypes evaluated by Kaw *et al.* (1999) for genetic variability and character association under three cold stressed environments revealed high genotypic variation for fertility per cent, fertile spikelets number panicle^{-1} and low for flowering duration and panicle length at all locations.

Seetharamiah *et al.* (1999) evaluated ten rice hybrids at Bapatla, Andhara Pradesh and found that the mean grain yield ha^{-1} in hybrids ranged from 3.99 to 5.654 tons ha^{-1}. Sarawagi *et al.* (2000) observed high variability in sterile spikelets panicle^{-1}, sterility percent, fertile spikelets panicle^{-1} and grain yield from the study of low land rice genotypes.

Data on genetic variability studied by Thakur *et al.* (2000) in segregating population of rice revealed that, grains panicle^{-1} had maximum variance followed by panicle weight and biological yield indicating the higher influences of environments on expression of these characters. Genetic variability for yield and its components was worked out by Yadav (2000) in 15 rice genotypes for two successive years. High genotypic and phenotypic coefficient of variation was observed for grain yield plant^{-1}, total grains plant^{-1} and total grains panicle^{-1}.

Shivani and Ramareddy (2000a) evaluated 10 rice hybrids and reported that analysis of variance indicated the existence of considerable genetic variability. Moderate to high genotypic and phenotypic coefficient of variation was recorded for plant height, productive tillers plant^{-1}, 1000 grain weight, grain yield plant^{-1} and harvest index.

Bala (2001) conducted a critical study of saline and alkaline rice genotypes. The genotypic coefficient of variation ranged from 9.93 for plant height to 41.16 for grain yield. Minimum difference between phenotypic and genotypic coefficient of variation was observed for days to 50 % flowering, which suggested that the trait was least affected by environment.

Variability assessed in 15 rice varieties by Satyavathi *et al.* (2001) revealed moderate to high coefficient of variation for plant height, number of grains panicle^{-1}, spikelet sterility, amylose content, gel consistency, kernel elongation ratio, 1000 grain weight and yield plant^{-1}. Shanthi and Singh (2001) analysed induced mutants of Mahsuri rice. They emphasized the importance of panicle weight, panicle length, 1000 grain weight and number of grains panicle^{-1} in selection programme as revealed by their low difference between phenotypic and genotypic coefficient of variation.

Pradhan and Das (2001) evaluated 11 rice hybrids and reported the presence of considerable variability among genotypes. Shirame and Muley (2003) studied variability in three rice hybrids and one variety and found that maximum coefficient of variation was observed for grain yield (31.15%). Plant height, length of panicle and test weight had shown very less coefficient of variation.

Elsy *et al.* (2002) conducted a preliminary trial to evaluate the performance of commercial rice hybrids in Palakkad, Kerala and reported that NSD-2 had recorded the maximum grain yield of 8.0 t ha^{-1} followed by PA-6201 with a yield of 7.0 t ha^{-1}. Local check variety (Aishwarya) recorded 4.8 t ha^{-1}.

Mishra *et al.* (2002) reported than mean grain yield ha^{-1} ranged from 6.02 tons for KRH-1 to as high as 7.86 tons ha^{-1} for PHB-71.

Raju *et al*, (2004) evaluated F_2 generations of 21 crosses and found that phenotypic coefficient of variation (PCV) and genotypic coefficients of variation (GCV) were high for productive tillers $plant^{-1}$ and 1000 grain weight. PCV was higher than GCV for all characters and difference between these two observed to be low for grain quality characters, which indicated less influence of environment on them.

Pushpam *et al.* (2004) evaluated 40 rice hybrids and reported that, four hybrids namely TNRH-53, HR-1, UPHR-1528 and MRP-5951 recorded a yield of more than seven t ha^{-1}.

In a study involving 11 entries which included both public and private sector released hybrids, conducted by Rajeshwari *et al.* (2004), it was found that yield of some experimental rice hybrids exceeded yield of check hybrid (5755 kg ha^{-1}).

Ramesh *et al.* (2004) evaluated the hybrid PHB-71 along with check variety ADT-39 in Kancheepuram district of Tamil Nadu. They found that PHB-71 had recorded superior performance at different places and registered an average record yield of 5508 kg ha^{-1}.

2.2 HERITABILITY AND GENETIC ADVANCE

The heritability estimates, which involves the breeding value of genotypes, serves as an effective tool in predicting the performance of genotypes in subsequent generations, and to decide appropriate weightage for improving particular character or breeding method to be followed as per objectives.

Vishwakarma (1989) reported that estimates of broad sense heritability were high for grains $panicle^{-1}$ in parents, primary bulk and worst populations in F_4, for plant height in secondary bulk and for test weight in best population in F_4. Heritability was moderate for grain yield and low for number of tillers. Genetic advance was high in grains panicle^{-1} and medium to low in grain yield, test weight and number of tillers. The expected genetic advance was estimated for all traits.

Heritability was moderately high only for days to heading and grain yield plant^{-1} in AC517 X Cross 1 and heritabilities of all other characters were low (Sahu and Sahu, 1990). Reddy and Nerkar (1991) studied six yield related traits in the parental, F_1, F_2 and backcross generations from four high yielding *indica* rice crosses grown at Parbhani during *Kharif*, 1986 and reported that narrow sense heritability estimates were high for number of effective tillers plant^{-1} and 1000 grain weight and moderate for the other characters, including grain yield.

Chauhan *et al.* (1992) conducted genetic analysis of quality parameters in rainfed upland *indica* rice varieties. Results indicated high heritability estimates for kernel breadth and low values for water uptake. Genetic advance values were lowest for hulling and milling recovery.

Lokprakash (1992) reported that in general, heritability showed an increasing trend from F_2 to F_3, while variances and genetic advances were reduced. Among the eight characters studied, panicle weight, 1000 seed weight and number of fertile spikelets panicle^{-1} recorded high heritability coupled with moderate to high genetic advance, indicating that they were governed by additive gene action and thus offer greater scope for further improvement through selection.

Roy and Kar (1992) tested 34 elite breeding lines of rice for heritability of characters. High heritability was observed for days to 50 % flowering and panicle number plant^{-1}, biological yield and harvest index while plant height exhibited moderately high heritability. High heritability with high genetic advance was found in 1000 grain weight and plant height.

Chaubey and Singh (1994) observed high heritability for all the traits studied in yield component analysis in rice, highest for total number of spikelets followed by grain yield plant^{-1}, 100 grain weight and lowest for panicle length. The genetic advance as per cent of mean was highest for grain yield plant^{-1} while lowest for plant height. High heritability with genetic advance was observed for total number of spikelets, grain yield plant^{-1} and panicle weight.

Ganesan *et al.* (1996) studied the heritability in F_2 populations, derived from early and extra early rice cultivars. Panicles plant^{-1}, grains panicle^{-1}, grain yield plant^{-1}, dry matter production and harvest index recorded high heritability and genetic advance in F_1 and F_2 generations of crosses. Based on genetic parameters, ADT 36 x AS 89011, ASD 16 x Kalyani 11 and IR 50 x Heera, were identified as best crosses.

Thakur *et al.* (1998) reported that high heritability coupled with high genetic advance was observed for grain yield, biological yield, panicle weight and number of tillers plant^{-1}.

Quality traits in rice were evaluated by Vivekanandan and Giridharan (1998). They identified high heritability for all the characters studied. The genetic advance was highest for kernel length breadth ratio and lowest for linear elongation ratio and breadth wise expansion ratio. High heritability and genetic advance were shown by kernel length breadth ratio.

In a study comprising ten hybrids and two varieties of rice, high heritability and genetic advance was observed for number of spikelets panicle^{-1}, grain yield plant $^{-1}$ and leaf area. Productive tillers plant^{-1}, panicle length and 1000 grain weight recorded high heritability with low genetic advance and moderate genetic gain (Shivani and Ramareddy, 2000a). Thakur *et al.* (2000) concluded from the genetic parameters of F_2 population and the parents, that Anupama and IR 50 had high heritability and genetic advance values for biological yield and grain yield panicle^{-1}.

Shanthi and Singh (2001) identified high estimates of heritability for the characters studied in induced mutants of Mahsuri rice except for grain yield plant^{-1} and number of tillers plant^{-1}. Number of grains panicle^{-1} had the maximum estimate of genetic advance whereas minimum value was shown by number of tillers plant^{-1}.

2.3 GENOTYPIC AND PHENOTYPIC CORRELATIONS

Correlations provide useful information to plant breeders for developing selection schemes as it reveals the strength of relationship among the group of characters. Correlation between various characters helps in simultaneous selection of these characters. Genotypic correlations higher than phenotypic correlations indicate the inherent association between the traits and thereby the importance of these correlations in selection.

Singh (1980) reported that in rice, grain yield plant^{-1} was positively correlated with number of productive tillers, grain weight and number of fertile grains panicle^{-1} in both the F_1 and F_2 population. Path coefficient analysis revealed that number of fertile tillers, grain weight and number of fertile grains panicle^{-1} in F_1 and F_2 and grain number panicle^{-1} in F_2 had considerable positive direct effects on grain yield plant^{-1}. Hong (1984) identified a positive correlation between yield and number of effective tillers, grain number panicle^{-1} and panicle number. Selection for harvest index would be effective due to its high coefficient of genotypic variation, heritability and genetic advance (Roi and Smetanin, 1984).

Paramasivan *et al.* (1988) conducted the analysis of yield and its components in rice and found significant positive association of yield with plant height, tiller number, panicle length, grain number and grain weight. Manuel and Palanisamy (1989) observed significant positive correlation of grain yield with days to 50% flowering, plant height, flag leaf area, panicles plant^{-1}, panicle length and number of grains panicle^{-1} from the evaluation of fifteen hybrids and their parents.

In a multilocation trial conducted by Lin *et al.* (1989) using Shanyou 63, correlation analysis showed that total number of spikelets ha^{-1} is closely correlated with number of productive panicles ha^{-1} and had most effect on grain yield.

Cai *et al.* (1989) reported that grain yield was positively correlated with panicle numbers, floret number panicle^{-1}, fertile florets and 1000 grain weight. Biological yield and dry matter production before and after heading had very significant positive effects on grain yield.

Sampath (1989) evaluated 14 intervarietal hybrids and their parents and observed that yield was correlated significantly with 1000 grain weight, panicle length and number of grains panicle^{-1} in the parents but not in the hybrids, in which yield was correlated with the number of primary and secondary branches panicle^{-1}, number of days to panicle emergence and tiller number.

Roy and Kar (1992) assessed the phenotypic and genotypic correlations among 11 metric characters in 29 early maturing upland rice genotypes. Yield plant^{-1} and harvest index exhibited positive association with plot yield. Negative significant association of days to flowering and plant height with plot yield was observed. Association analysis carried out by Vanniarajan (1996) revealed that the selection based on filled grains panicle^{-1} in MS 37A x IR 50 and 1000 grain weight in Zhen Shan 97A X IR 50 will improve the selection efficiency since they had high positive correlation as well as direct effect on yield. However, in Erjiunan 1A X IR 50, there was no association among the characters studied.

Fourty five hybrids along with ten parents were evaluated and results showed a significant positive correlation with genetic distance. When separate analyses were performed for the three subsets, yield potential and its heterosis showed significant positive correlations with genetic distance for the 15 *indica x indica* crosses and the six *japonica* x *japonica* crosses; however, yield potential and its heterosis were not correlated with genetic distance for the 22 *indica x japonica* crosses (Xiao, 1996).

Information on yield correlations derived from data on several yield components in the hybrid varieties Shanyou 669 and Shanyou Douxil revealed that, panicle number in the first and ratoon crop had the most effect on yield (Liang, 1997). Correlation studies by Thakur *et al.* (1998) indicated grain yield was positively associated with biological yield, number of tillers plant^{-1}, harvest index, plant height and panicle weight.

Ganesan *et al.* (1998) observed significant and positive relationship of number of productive tillers, harvest index and dry matter production with single plant yield in F_2 and F_3 generations of tall and semidwarf crosses of rice. Number of grains panicle^{-1} showed significant correlation with panicle length, harvest index and dry matter production.

Kennedy and Rangasamy (1998) evaluated hybrids derived from three CMS lines and cold tolerant testers and reported that the direction of phenotypic and genotypic correlation coefficients was the same, but their magnitude varied. Generally, genotypic correlation coefficients were higher than the corresponding phenotypic ones. It was concluded that simultaneous selection for traits such as days to 50 % flowering (early), productive tillers, spikelet sterility, harvest index and 1000 grain weight may serve to increase grain yield. Mavarkar *et al.* (1999) found that panicle length, number of spikelets panicle^{-1} and percentage of filled spikelets, as well as their mutual interactions had significant and positive effects on grain yield of hybrid rice.

Association analysis carried out for eight quantitative traits in rice (*Oryza sativa L.,*) utilizing 24 hybrids and 11 parents showed that productive tillers plant^{-1} was the principal character responsible for grain yield followed by 1000 grain weight, days to 50 % flowering, plant height and harvest index as they had positive and significant association with yield (Sathya, 1999). Prabhagaran *et al.* (1999) evaluated hybrid rice and reported that correlation studies with weather parameters showed significant relationship with selected parameters.

Meenakshi *et al.* (1999) worked out the genotypic and phenotypic correlations for yield and physiological characters in rainfed rice. Productive tillers plant^{-1}, grains panicle^{-1}, dry matter production and harvest index were positively correlated with grain yield. Nehru *et al.* (2000) reported that the number of productive tillers directly correlated with grain yield. Hybrids had profuse tillering compared with varieties, and thus improved yields.

Genotypic correlation coefficients were in general higher than that of corresponding phenotypic ones. Grain yield showed positive significant correlation with plant height, days to 50 % flowering at genotypic level and number of spikelets panicle^{-1}, yield and harvesting index at both genotypic and phenotypic level (Shivani and Ramareddy, 2000b).

The genotypic and phenotypic correlations among yield components of 35 rice hybrids showed that, at the genotypic level plant yield was positively and significantly correlated with productive tillers plant^{-1}, however, at genotypic and phenotypic levels, it was significantly and positively correlated with leaf area index, total dry matter accumulation and harvest index. The yield components and physiological traits were interrelated: 1000 grain weight with total dry matter accumulation and harvest index; leaf area index with total dry matter accumulation and filled grain ear^{-1} with leaf area index and total dry matter accumulation. Leaf area index and 1000 grain weight also exhibited a high indirect effect on yield through total dry matter accumulation (Durai, 2001).

Bhave *et al.* (2002) observed a positive association of grain yield with mean performance of hybrid for tillers plant^{-1} and productive tillers plant^{-1}, while genetic distance showed significant negative association with plant height, panicle length and grain panicle^{-1}. Zhou *et al.* (2002) reported that a significant negative correlation was found between eating quality and amylose content, chalky grain percentage and chalkiness. Of the 20 factors related to plant morphology, only plant height and leaf angle were two most important factors, which were highly correlated with grain yield (Pan *et al.*, 2003).

In a field experiment conducted with 21 rice hybrids, it was observed that grain yield had significant correlation with productive tillers plant^{-1}, 1000 grain weight, panicle length and harvest index (Raju *et al.*, 2003). Grain yield exhibited a very strong positive correlation with harvest index and also significantly correlated with dry matter hill^{-1}, productive tillers plant^{-1} and grains panicle^{-1} (Shirame and Muley, 2003). Lio (2003) observed in *indica* hybrid combinations, derived from B and R lines, the correlations between 1000 grain weight and chalky rice rate were positively significant.

Estimation of correlations in 20 selected rice genotypes by Khedikar *et al.* (2004) revealed that genotypic correlation was slightly higher than respective phenotypic correlations for most of characters. High phenotypic and genotypic correlations for head rice recovery and grain yield plant^{-1} was shown by productive tillers plant^{-1} and for grain yield plant^{-1} by spikelet density.

Raju *et al.* (2004) studied simple correlation coefficients in 21 crosses and found that plant height, productive tillers plant^{-1} and 1000 grain weight had significant correlation with grain yield plant^{-1}.

2.4 PATH COEFFICIENT ANALYSIS

Path coefficient is a standardised partial regression coefficient and as such measures the direct influence of one variable upon another and permits the *separation of correlation coefficient into components of direct and indirect effects* (Dewey and Lu, 1959).

Lu *et al.* (1988) reported that, 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}. Paramasivan and Rangasamy (1988) suggested that the selection for grain yield could be efficient if it is based on plant height, tiller number, panicle length, grain number panicle^{-1} and grain weight as these characters fulfilled both the requirements of genotypes association with yield and path coefficient analysis.

Analysis of upland rice by Kumar (1992) revealed that maximum direct effect on grain yield was by panicle length followed by plant height and tiller number. Rajarathinam and Raja (1992) inferred from the results of correlation and path analysis of 40 genotypes of rice that plant height, number of productive tillers and grain number panicle^{-1}showed both positive correlation and direct effects on yield.

Path coefficients on quantiative characters in 80 *indica* rice varieties were studied by Chaubey and Richharia (1993). They found that panicle weight showed the highest direct effect on grain yield. It was also emphasised that direct effect of panicle length was negative and very low, but indirect effect of this trait through panicle weight was as high as its genotypic correlation with grain yield.

Gravois and McNew (1992) conducted the genetic analysis of yield and yield components in rice and identified positive direct effects for both panicle number and panicle weight on rice yield, with panicle weight exhibiting larger direct effects on yield than panicle number.

Chaubey and Singh (1994) reported that number of ear bearing tillers exerted maximum direct effect on grain yield plant^{-1} followed by plant height and 100 grain weight. Path coefficient analysis in early rice varieties revealed grains panicle^{-1} as the most important character because of its higher positive direct effect followed by productive tillers and panicle weight (Sundaram and Palaniswamy, 1994).

Path analysis indicated that among the six characters that affected grain weight plant^{-1} in the F_1, number of filled grains plant^{-1} had the greatest effect, followed by number of panicles plant^{-1}, grain: straw ratio, percentage seed set, ear length and growth period (Feng *et al.*, 1995). Roy *et al.* (1995) concluded that grains panicle^{-1}, spikelets panicle^{-1} and bacterial blight severity were the most important characters contributing to yield from the study of casual relationship in rice.

Murthy *et al.* (1997) analysed the physiological productive and chemical parameters on the yield of ratoon rice crop. They indicated that total regenerated tillers, panicle number, nitrogen percentage, total carbohydrate percentage, and non reducing sugar percentage were the major characters exerting a major direct influence on the productivity of ratoon rice crop.

Correlation and path analysis of yield components in F_2 and F_3 generations of tall x dwarf rice crosses were undertaken by Ganesan *et al.* (1998). Dry matter production and harvest index exhibited positive direct effect on grain yield in both the generations.

Vivekanandan and Giridharan (1998) studied the genetic variability and character association for kernel and cooking quality traits in rice. Linear elongation ratio and breadth wise expansion ratio showed the maximum direct effect whereas moderate direct effect was indicated by kernel length breadth ratio.

Bagali *et al.* (1999) reported that panicle weight exerted maximum positive direct effect, followed by number of grains panicle^{-1} and harvest index on grain yield plant^{-1}. Panicle weight showed high positive indirect effect through harvest index and number of grains.

Path coefficients for five characters in salt tolerant genotypes were estimated by Balan *et al.* (1999). Days to 50 % flowering recorded the highest positive direct effect on seed yield followed by harvest index. Path coefficient analysis by Kaw *et al.* (1999) indicated that fertile spikelet number had the highest positive influence and panicle length a negative influence, both directly and indirectly, upon fertility.

Meenakshi *et al.* (1999) evaluated the path coefficients for yield and physiological characters in rainfed rice. The result indicated dry matter production as the most important character because of its higher positive direct effect, followed by harvest index. Sarawagi *et al.* (2000) reported a greater contribution of harvest index, fertile spikelets panicle^{-1}, biological yield and plant height to grain yield from the character association studies in rainfed lowland rice genotypes.

Shivani and Ramareddy (2000b) found that plant height had negative direct effect on grain yield plant^{-1}, while days to 50 % flowering had showed positive direct effect on yield and positive indirect effect via productive tillers plant^{-1}, yield and harvest index. Grains panicle^{-1} has direct positive significant correlation with grain yield.

Results of path coefficient analysis in saline and alkaline rice genotypes carried out by Bala (2001) showed that, grain yield m^{-2} exerted the maximum direct positive effect on plot yield, followed by panicle length, plant height, and days to 50 % flowering. Data on path coefficient analysis of Kavitha and Reddi (2001) revealed that the characters, filled grains panicle^{-1}, dry matter production plant^{-1} and harvest index exhibited a high positive direct effect coupled with positive significant correlation with grain yield plant^{-1}.

Satyavathi *et al.* (2001) analysed the genetic parameters in 15 rice varieties under different spacings. Number of productive tillers plant^{-1}, number of grains panicle^{-1}, length breadth ratio and 1000 grain weight were found to be the main contributes to grain yield.

Janardhanam *et al.* (2001) reported that plant height, spikelets panicle^{-1} and number of grains panicle^{-1}, as the most important characters that modify expression of single plant yield, based on direct and indirect effects from path analysis. Raju *et al.* (2003) observed that, days to 50 % flowering had high direct positive effect on yield while harvest index had low direct effect.

Path coefficient analysis in 20 scented rice genotypes by Khedikar *et al.* (2004) revealed that the test weight had the high positive direst effect in grain yield plant^{-1}, followed by productive tillers plant^{-1}, days to 50 % flowering and spikelet density. Days to 50 % flowering had indirect positive effect on grain yield via spikelet density, productive tillers plant^{-1} and panicle length.

In a study conducted by Raju *et al.* (2004), it was observed that positive direct effect on grain yield were exhibited by plant height, 1000 grain weight and filled grain panicle^{-1}.

2.5 COOKING AND MILLING QUALITY

Rice grain quality is usually determined according to preparations for which grains are used and it is region specific. Acceptance of variety by consumers is determined by grain milling quality, appearance, size, shape of kernel, cooking and eating qualities and aroma of cooked rice.

Hybrid rice developed in China had a yield advantage of more than 20 per cent over conventional pure line varieties. However, when Chinese rice hybrids introduced in other countries were rejected due to their poor grain quality (Virmani and Zaman, 1998). Thus higher yield of hybrid rice by itself would not make hybrid rice technology acceptable. Rice hybrids must have also acceptable grain quality before rice farmers would accept them. Only limited efforts have been made to improve the grain quality of hybrid rice (Khush *et al.* 1987).

Zhang *et al.* (1990) evaluated 12 late *hsien* rice hybrids (LHH) and seven late *keng* hybrids and concluded that the quality of most materials tested was inferior, and that head rice percentage, amylose content and gel consistency for *hsien* genotypes and gel consistency and gelatinization temperature for late keng genotypes. Amylose content ranged from17.93 to 21.33 %, head rice percentage was more than 59 %, low to intermediate gelatinisation temperature and flaky gel consistency.

Bong and Singh (1993) evaluated three rice hybrids and reported that amylose content was as high as 36 % in hybrid V20 x Improved Sabarmati, gelatisation temperature ranged from 2.9 to 5.7 and kernel elongation ratio from 1.8-2.0.

Rani (1998) tested 27 hybrids for their physiochemical properties and reported that IR58025A/IR34686 exhibited a high volume expansion ratio (5.3) and six hybrids showed a high head rice recovery (60.3-63.9%). Eleven hybrids were in the most desirable amylose content range (20-25%) in India.

Khush *et al.* (1998) studied grain quality of several rice hybrids and compared with that of respective parental lines possessing diverse grain quality characteristics. They concluded that the genetic heterozygosity of hybrids did not affect the grain quality as long as one of the parents was not of poor in grain quality.

Fifty four varieties of rice were evaluated for milling and quality characteristics by Muker *et al.* (1998). Kernel elongation ratio ranged from 1.21-2.02, hulling percentage from 74.9-81.54, milling percentage from 66.63-74.63 and head rice recovery from 57.19-73.50.

Ma *et al.* (2002) studied 18 hybrids derived from nine CMS and three restorers and reported that the value of gelatinization temperature and amylose content of hybrid rice were in between that of both parents.

Eleven grain quality characters were studied in 63 hybrids and found that the mean values of F_1 hybrids were significantly lower than those of their mid-parent values in all characters except milled rice length and amylose content, and significantly higher than those of their lower parents in all characters except for brown rice, milled rice and gel consistency (Lio *et al.*, 2003)

2.6 STABILITY (GENOTYPE X ENVIRONMENT INTERACTION) ANALYSIS

One of the major objectives in any plant breeding programme is the selection of genotypes that are consistently high yielding over a range of environments. This selection is often inefficient due to genotype x environment interactions and the failure of genotypes to have the same relative performance in different environment. Therefore the interrelationship of inherent effect and environmental influence has been studied.

Young and Virmani (1990) evaluated 140 rice hybrids with parents over six environments created by three levels of fertilizers applied in three different fields over two seasons. Selected hybrids showed yield advantage over parents and also better performance across environments.

Stability parameters for 16 hybrid combinations were studied by Manuel and Rangaswamy (1994). A X TNAU 88013 and V20A X TNAU 88013 were identified as most stable and consistent for grain yield.

Courtois (1996) reported that genotype X environment (GXE) interaction represented the major component of the variability for yield (54% of the total sum of squares) followed by site effect (42%) and genotype effect (4%). Partitioning of G X E sum of squares by traditional stability regression analysis only explained 11% of the interaction while the first two axes of the AMMI model accounted for 65%.

Among the 30 rice hybrids, derived from the crosses of five CMS lines with six restorers, only hybrid IR62829A X Vajram was stable over all environments. Three other hybrids were found suitable for specific environments (Lavanya, 1997). Partitioning of genotype x environment interactions could be attributed to both genotype x environment interaction (linear) and pooled deviation (nonlinear) but the later was more important when they evaluated 30 genotypes of rice over locations (Ajmer *et al.* 1997).

Reddy *et al.* (1998) conducted a critical study of G x E interaction for grain yield in lowland rice cutlivars. Among the significant linear and non linear components of G x E interaction observed, linear component was found to be predominant and this helped in predicting the performance of the genotypes across environments.

Mishra and Mahapatra (1998) reported that, rice genotypes exhibited significant difference for grain yield and their both linear and non-linear components of variation were highly significant in stability analysis. Genotype x environment interaction showed variation in their magnitude indicating differential response of some of the genotypes.

The yield potential of two rice hybrids (ASRH-1 and ASRH-2) along with four high yielding varieties was evaluated during dry and wet seasons. High number panicles per hill and spikelets panicle^{-1} were observed in hybrids compared to varieties. ASRH –1 hybrid was found stable (Manuel *et al.*, 1999).

Experiments by Kandhoa and Panwar (1999) indicated that in the partitioning of GxE interactions, the linear components were significant for hulling percentage, grain length and breadth, where as nonlinear components were important for milling percentage and amylose content when 52 genotypes of rice were evaluated for their stability characters. Xihong *et al.* (1999) studied 12 *indica* rice cultivars in South China and showed that location had greatest effect on yield stability and variance.

Hegde and Vidyachandra (1998) observed significant G x E interactions for yield and its components, but none of the five hybrids and four controls evaluated showed stability for yield over the environments studied. Medium duration hybrid IR58025A X KMR3 (KRH-2) was the best performer at all locations except at one location.

Lohithaswa *et al.,* (1999) studied 15 genotypes (11 hybrids and four checks) and revealed significant G x E interaction for all the seven character considered for stability analysis. The variance due to genotype x season (linear) was significant for all the traits. Nonlinear component was found to be significant for all the characters.

Results of trials conducted at 12 locations in the wet season (WS) and six locations in the dry season (DS) showed average WS grain yield of the hybrids increased from 4.5 t ha^{-1} in 1991 to 5.5 t ha^{-1} in 1995. For the DS, the increase was from 5.0-to 6.0 t ha^{-1}. During the same period, the percentage of widely adapted hybrids in the WS increased from 0.0 to 17.0%, and similarly in the DS, it increased from 1.75 to 17.0%. The results indicated that hybrids have a yield advantage over high yielding varieties such as Jaya (Ahmed, 1999a)

Ahmed (1999b) observed that the stability of rice hybrids for grain yield was comparable with that of the best inbred control variety, Jaya. The hybrids IR58025A/IR34686 and IR58025A/IR29723 showed better yield stability over seasons than Jaya.

Vijaykumar *et al.* (2001) analysed the pattern of G X E interaction for grain yield involving 16 hybrids and two inbred checks and reported that there existed a significant G X E interaction that influenced relative ranking of hybrids across locations.

Estimates of stability parameters showed that, hybrids were unstable over the environments for both fertility restoration and grain yield, with the exception of PRH 3. A linear (predictable) response was shown by nearly all hybrids for all characters, as revealed by a significant genotype x environment interaction (linear) variance, though part of the variation was unpredictable in nature as shown by significant pooled deviation values. These results indicated the specificity of the hybrids to various environmental conditions (Sarkar *et al.*, 2003).

Stability analysis for days to 50 per cent flowering, number of spikelets panicle^{-1}, spikelet fertility and yield ha^{-1} was carried out in 12 released rice hybrids by Deshpande (2003) at five locations in Maharashtra, India, during *kharif* 1999. There was significant variation among the genotypes for all the characters. The component environment + (genotype x environment) was highly significant for all the characters. This was contributed by highly significant effect of environment (linear) and genotype x environment (linear) components. The non-linear component of the interaction was not significant for yield. However, the 50 % flowering, spikelets panicle^{-1} and spikelet fertility characters of the genotypes possessed significant non-linear component of the interaction of genotype x environment.

2.7 HETEROSIS AND INBREEDING DEPRESSION

The biological phenomenon in which an F_1 hybrid of two genetically dissimilar parents shows increased vigour over parents is referred to as heterosis. Superiority of F_1 over commercial variety is referred to as standard heterosis. The term heterosis was first coined by Shull (1908) and commonly standard heterosis is more important in plant breeding.

In rice, heterosis was first observed by Jones (1926), who noticed some F_1 hybrids with more culms and higher yield than parents. Ponnuthurai (1985) evaluated four F_2's along with their F_1's and noted that yield depression in the F_2 ranged from 14 to 21% and was significant in all hybrids and highest yield depression in the F_2 occurred in IET3257/IR2797, the same combination also showed highest yield heterosis in the F_1.

Anandakumar and Sreeranagasamy (1986) reported that out of 21 hybrids, eight hybrids showed inbreeding depression for all the characters studied. Culture 25337 X TKM 6 mutant 2 showed inbreeding depression for panicle length alone. Three crosses viz., TKM 6 mutantl X TKM 6, TKM 6 mutantl X IR 8, TKM 6 mutant 2 x culture 4372 and culture 25337 X TKM 6 mutant 6 did not show inbreeding depression for any of the characters studied.

Standard heterosis for productive tillers plant^{-1} varied from –46.8 to 16.21 per cent while for 1000 grain weight it varied from –33.45 to 6.33 per cent. Standard heterosis for grain yield plant^{-1}ranged from –56.6 to –2.84 per cent. None of the hybrids showed standard heterosis for yield (Kalaimani and Kadambavanasundaran, 1987).

Rangaswamy and Natarajamurthy (1988) reported that straw yield showed standard heterosis of up to 134% while standard heterosis for grain yield reached a maximum of only 8%, but all combinations had high standard heterosis for tiller number.

Most of the crosses with significant standard heterosis for yield were found to show heterosis for more than one component (Sharma and Mani, 1990). Heterosis in yield was mostly due to simultaneous heterosis for yielding components like panicles plant^{-1}, grains panicle^{-1}, panicle length and grain weight.

Standard heterosis percentage varied from –59 to 34 for grain yield, -40 to 58 for dry matter, -36 to 20 for harvest index -27 to 19 for days to flowering and -21 to 27 for plant height.

The performance of 57 F_1 hybrids and 43 inbreds of growth period durations ranging from 110 to 138 days were evaluated during 1988 by Blanco (1990). Biomass production increased with growth period and heterosis was observed for both biomass and grain yield. F_1 hybrids showed almost 10% advantage in biomass and harvest index and 20% increase in grain yield over the inbred lines. F_1 hybrids and inbreds with growth periods of 125-129 days had the highest grain yields.

Information on heterosis derived from data on five agronomic and yield related traits in five F_1 hybrids and their parents revealed that, only one hybrid failed to show heterosis over its pollen parent. V20A X IR54, IR46829A X IR54 and IR46830A X IR54 exhibited the highest heterosis over the respective male parent and the standard CR44-35 (Mandal, 1990).

Reddy *et al.* (1991) studied eight crosses and reported that inbreeding depression was negative in all crosses except Prabhavati X Punjab1 and Prabhavati X RPA5929. Grain yield and number of effective tillers plant^{-1} gave the highest average values for heterosis and inbreeding depression (Reddy and Nerkar, 1991).

Ram (1992) evaluated 45 F_1 and 42 F_2's and found that, out of 45 crosses 31 showed significant inbreeding depression for plant height, 42 for tillers plant^{-1}, 31 for grains panicle^{-1}, 41 for 1000 grain weight and 42 for grain yield. The expression of heterosis varied with the cross, so also with characters (Lokpraksh *et al.*, 1992). To know potentiality of hybrids magnitude and direction of heterosis are important.

Ramalingam (1994) evaluated 25 hybrids and found significantly high heterosis for production of tillers in all crosses except IR58025A X IR 24, IR58025A X ARC11353, IR62829A X IR24, IR62829A X IR29723 and IR62829A X ARC11353. Heterosis for ear length, filled grains ear^{-1}, 1000 grain weight and grain yield were also expressed. IR58025A X IR54742 and IR58025A X IR29723 had heterotic expression for all the economic traits studied.

Zhang *et al.* (1995) found that, of the eight characters studied, only three characters showed standard heterosis while relative heterosis was observed in all characters. Standard heterosis for grain yield ranged from –36.8 to 33.6 per cent with a mean of –2.4 per cent. Reddy and Nerkar (1995) observed highly significant and positive heterosis for grain yield over mid parent and better parent in four hybrids and, invariably followed by inbreeding depression in F_2. Such high grain yield heterosis was due to additive heterotic effect of one or more component traits.

Yolanda (1996) developed 36 hybrids utilising three cytoplasmically male sterile lines (V20A, IR58055A and IR62829A) and twelve testers. Of these, IR62829A X CO37 showed significant positive heterosis for panicles plant^{-1} and grain yield plant^{-1}. Ganesan and Rangasamy (1996) evaluated ten crosses involving three Wild Abortive (WA) sources and reported that inbreeding depression was significant in five of the ten crosses and was highest in the cross IR 62829A X White Ponni and lowest in IR 58025 A X C 20.

Mishra *et al.* (1998) evaluated four hybrids and reported that a high magnitude of heterosis was noted for grain yield, biological yield and panicle weight in IR36 X MW10 followed by Tuljapur 1 X ARC 10372 and MW10 X IR25588-7-3-1.

Standard heterosis over HKR126 (standard check) evaluated in 22 rice hybrids was significant for all the four traits studied. It was both negative and positive for grain yield plant^{-1} (-0.57 to 54.75 %), panicles plant^{-1} (-14.84 to 89.14 %) and grains panicle^{-1} (-16.04 to 43.28%), and negative for 1000 grain weight (-34.55 to -5.82%). Six hybrids showed positive and significant standard heterosis for all traits except 1000 grain weight (Panwar and Dhaka, 1998).

Seetharamiah *et al.* (1999) evaluated ten rice hybrids and observed that, plant height and panicle length did not play significant role in expression of heterosis. Negative heterosis was observed for test weight ranging from –45.6 to –28.2 per cent while hybrid MTUHR 2003 exhibited highest standard heterosis of 157.4 per cent for grain yield.

In a study made to assess the nature and extent of heterosis, heterobeltiosis and standard heterosis for yield and its components in a line x tester design, the hybrids IR 62829A X IR 50, IR 62829A X AS 90043 and IR 58025A X AS 89090 were adjudged best for exploitation of heterosis based on standard heterosis pertaining to grain yield plant^{-1}. The two former cross combinations showed significant standard heterosis for productive tillers plant^{-1} in addition to heterosis for grain yield (Sathya, 1999).

Singh and Haque (1999) reported that inbreeding depression was negligible for the traits like days to 50 % flowering, plant height and panicle length and test weight in 14 hybrids tested. Biolological yield, grain yield and seed setting percentage suffered considerably from inbreeding depression in F_2 generation.

In 65 rice hybrids, developed by crossing two cytoplasmically male sterile lines, viz., IR58025A and PMS10, the cross IR58025A X NDRK 5042 showed the highest heterosis for grain yield plant^{-1} i.e. 108.8% (Vishwakarma, 1999). Magnitude of inbreeding depression was most favourable for plant height, least for 1000 grain weight, moderate for filled spikelets panicle^{-1} and high for grain yield plant^{-1} (Tiwari and Sarathe, 2000).

Annaduari and Nandarajan (2001) evaluated 35 rice hybrids and reported that with respect to productive tillers plant^{-1}, none of the hybrids showed positive standard heterosis while 12 hybrids showed positive standard heterosis for grains panicle^{-1}, six for 1000 grain weight and nine for grain yield plant^{-1}.

Standard heterosis in 32 rice hybrid were studied by Bhave *et al.* (2002) and they observed standard heterosis ranging from –9.18 to 26.41 per cent for plant height, -58.5 to 80.43 per cent for productive tillers plant^{-1}, -21.86 to 14.24 per cent for days to 50 per cent flowering, -45.97 to 5.96 per cent for test weight, -85.7 to –2.17 per cent for harvest index and –84.96 to 132.32 per cent for grain yield plant^{-1}.

Banumathy *et al.* (2003) evaluated 100 rice hybrids and reported that top yielding hybrids viz., IR 70364A X TNAU 80030, IR 70364A X IR 65515-47-2-1-19 and IR 58025A X TNAU 94301 exhibited significant standard heterosis over CORH 2 and ADTRH-1, while IR 69616A x TNAU 841434 and IR 58025A X IR 6551547-2-1-19 manifested significant standard heterosis over ADTRH-1.

High standard heterosis for productive tillers and 1000 grain weight also resulted in increased grain yield in some cross combinations

Twenty five aromatic rice hybrids developed by line x tester mating design were evaluated for standard heterosis over standard variety Pusa Basmati 1. The study revealed that heterosis for grain yield was mainly because of simultaneous manifestation of heterosis for tiller number, grains panicle^{-1} and test weight (Krishnaveni and Shobharani, 2003).

Rathika *et al.* (2004) found that the hybrid RP6784-690-39-14 X Rp-825-24-7 expressed significant standard heterosis for all the seven characters studied.

In an experiment conducted using all the public and private rice hybrids by Rajeswari *et al.,* 2004 it was revealed that five hybrids recorded higher yield than check ADT-46 (5560 kg ha^{-1}) and another four hybrids higher yield than hybrid check KRH-2 (5755 kg ha^{-1}).

Standard heterosis for 64 rice hybrids estimated over two hybrids viz., CORH-2 and ADTRH-1 by Sundar and Thiyagarajan (2004) revealed that 37 hybrids recorded negative standard heterosis over CORH-2 for days to 50 % flowering and ten hybrids showed significant positive heterosis over CORH-2 while 15 hybrids recorded significant positive standard heterosis for productive tillers plant^{-1}.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken in the the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period 2003-2004. Field experiments related to the investigation were laid out in farmers' fields of Mullakkara (Thrissur), Mathur (Southern Palakkad.) and Chittoor (Eastern Palakkad). The general climatic features of Thrissur and Palakkad districts are given in Appendix I.

3.1 MATERIALS

Seven selected rice hybrids released for commercial cultivation in India along with two local check varieties constituted the material for study.

Table 1. Details of rice genotypes used for the experiment

Sl. No.	Name of genotype	Parentage	Duration (Days)	Target state
1	ADTRH-1	IR58025A x IR 66	115-120	Tamil Nadu
2	CORH-2	IR58025A x C20 R	120-125	Tamil Nadu
3	KRH-2	IR58025A x KMR3	130-135	Karnataka
4	DRRH-1	IR58025A x IR 40750	125-130	Andhra Pradesh
5	PHB-71*	Not known	130-035	Haryana, Uttar Pradesh, Maharasthra, Tamil Nadu
6	PA-6201*	Not known	125-130	North and Eastern India
7	NSD-2	IR58025A x NDR 3026	125-130	Uttar Pradesh
8	Local check	-	-	Kerala
9	Jyothy (Standard check)	PTB 10 x IR 8	115-120	Kerala

*Released by private sector and parentage not revealed.

Seeds of rice hybrids were obtained from Directorate of Rice Research, Hyderabad.

3.2 METHODS

3.2.1 Experiment 1

Seven selected rice hybrids along with a standard variety and a local popular variety were compared in a yield trial. The experiments were conducted in different ecological situations of central zone of Kerala viz., Mullakkara (Thrissur), Mathur (Kuzhalmannam) and Kalluttiyal (Chittoor) during *kharif*, 2003 (Plate 1).

The genotypes were raised according to the package of practices (Appendix II) recommended by Directorate of Rice Research, Hyderabad (Ahmed *et al.*, 2003) in a Randomized Block Design with three replications at each environment. Plot size was 9 m^2 with a spacing of 20cm x 15cm. The data were recorded from 10 randomly selected plants in each plot and mean was worked out. Observations were taken based on the Standard Evaluation System of Rice (IRRI, 1995).

Observations recorded.

1. Days to 50 % flowering

Numbers of days were taken from date of germination to 50 % flowering stage within a plot.

2. Height of plant at harvest

Height of plant was measured at the time of harvest. This was taken in centimeters from ground level to the tip of the panicle.

3. Number of productive tillers

Number of productive tillers in a hill was recorded prior to harvest and observations were recorded from 10 hills $plot^{-1}$.

4. Number of days to physiological maturity

Number of days from germination to grain ripening (when 85% of grains were matured) were recorded.

5. Benefit cost ratio.

The benefit to cost ratio was calculated as per the following formula

$$\text{BC ratio} = \frac{\text{Total gross returns}}{\text{Cost of cultivation}}$$

The components of cost of cultivation at each location are given in Appendix III.

6. Number of grains panicle^{-1}

Number of grains from ten panicles collected from each plot was counted and the mean was worked out.

7. Density of grain

Volume of known weight of grains was measured by the displacement of water using a measuring cylinder and density was calculated as weight by volume.

8. Harvest index

Harvest index was calculated by dividing grain yield by total yield.

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Total yield}}$$

PLATE 1. PLOT VIEW OF EXPERIMENTS AT MULLAKKARA, MATHUR AND CHITTOOR (*Kharif*, 2003).

9. Productivity day^{-1}

Productivity day^{-1} was calculated by dividing the grain yield by number of days to physiological maturity and expressed in grams.

$$\text{Productivity day}^{-1}\ (g) = \frac{\text{Grain yield ha}^{-1}}{\text{Number of days to physiological maturity}}$$

10. Productivity $plant^{-1}$

Grain yield from one square meter area of each plot was taken and divided by the number of plants per square meter and recorded weight in grams, at 14 % moisture level.

11. 1000 grain weight

Weight of 1000 fully filled, ripened grains taken at random from each plot, was recorded in grams, at 14 % moisture level.

12. Grain yield ha^{-1}

The plants from each plot were harvested excluding border rows and the grain yield was expressed in kg ha^{-1} at 14 % moisture level.

13. Straw yield ha^{-1}

The plants from each plot were harvested excluding border rows and the straw yield was recorded in kg ha^{-1} at 14% moisture level.

14. Milling percentage

One kg of parboiled paddy samples were milled for 30 seconds and milling percentage calculated as follows,

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

15. Head rice recovery

Five grams of rice per milled sample (parboiled) was used to study head rice recovery and was calculated as follows,

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of total rice taken}} \times 100$$

16. Cooking qualities

Cooking qualities such as amylose content, alkali spreading value, volume expansion ratio and kernel elongation ratio were studied, using the following procedures.

a) Amylose content

100 mg parboiled milled rice was powdered. In this sample, one ml of distilled ethanol was added. 10.0 ml of I N NaOH was added to this and it was kept overnight. The volume was made upto 100 ml. 2.5 ml of the extracts was taken and added 20.0 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 1.0 ml of iodine reagent was added and made upto 50 ml and the colour developed was read at 590 nm using spectrometer. 0.2, 0.4, 0.6, 0.8 and 1.0 ml of standard amylose solution was taken and developed colour as in 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 (Sadasivam and Manickam, 1992).

Absorbance corresponds to 2.5 ml of the test solution = X mg amylose

$$100 \text{ ml extract} = \frac{X}{2.5} \times 100 \text{ mg/100 ml amylose} = \text{\% amylose}$$

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

b) Alkali spreading value

Ten milled rice kernels were placed in 10.0 ml of 1.7 per cent KOH in petri plate. 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 after incubation based on the following numerical scale (IRRI, 1995).

Code	**Akali Digestion**	**Gelatinization Temperature**
1. Not affected but chalky	Low	High
2. Swollen	Low	High
3. Swollen with collar incomplete or narrow	Low or intermediate	High or intermediate
4. Swollen with collar complete and wide	Intermediate	Intermediate
5. Split or segmented with collar complete and wide	Intermediate	Intermediate
6. Dispersed merging with collar	High	High
7. Completely dispersed and cleared	High	High

c) Volume expansion ratio

The volume of raw rice as well as cooked rice was determined by water displacement method using a measuring cylinder (Onate and Delmundo, 1966) and volume expansion ratio was calculated as

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

d) Kernel elongation ratio

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

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

3.2.2 Experiment 2

Seven hybrids and their corresponding F_2's along with one standard variety and one popular local variety were compared in a yield trial during *rabi*, 2003 at Kalluttiyal, Palakkad Dst. The observations on days to 50 per cent flowering, plant height, number of days to physiological maturity, grain yield ha^{-1}, productivity $plant^{-1}$, amylose content, milling percentage, kernel elongation ratio, volume expansion ratio, alkali spreading value and head rice recovery were recorded as in experiment 1.

3.3 STATISTICAL ANALYSIS

The data obtained from three locations viz., Mullakkara (location 1), Mathur (location 2) and Kalluttiyal (location 3) were subjected to locationwise analysis of variance and stability analysis.

3.3.1 Estimation of genetic parameters

The variance components were estimated as suggested by Singh and Choudhary (1985).

3.3.1(a) Phenotypic variance

Phenotypic variance (Vp) = Vg + Ve

where (Vg) = Genotypic variance

(Ve) = Environmental variance

3.3.1(b) Genotypic variance

$$\text{Genotypic variance (Vg)} = \frac{VT - VE}{N}$$

where VT = Mean sum of squares due to treatments

VE = Mean sum of squares due to error

N = Number of replications

Environmental variance (Ve) = VE

Where, VE = Mean sum of squares due to error

3.3.1(c) Phenotypic and genotypic coefficients of variation

The phenotypic and genotypic coefficients of variation were calculated by the formula suggested by Burton and Devane (1953).

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

where Vp = Phenotypic variance

$\bar{X}$ = Mean of the character under study

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{Vg}}{\bar{X}} \times 100$$

where Vg = Genotypic variance

$\bar{X}$ = Mean of the character under study

The estimates of PCV and GCV were classified as

High	-	>20 per cent
Moderate	-	10-20 per cent
Low	-	<10 per cent

3.3.1(d) Heritability

Heritability in the broad sense was estimated by following the formula suggested by Burton and Devane (1953).

$$\text{Heritability (H)} = \frac{Vg}{Vp} \times 100$$

where Vg = Genotypic variance

Vp = Phenotypic variance

The heritability was categorised as

High	-	60-100 per cent
Moderate	-	30-60 per cent
Low	-	< 30 per cent

3.3.1(e) Expected genetic advance

The expected genetic advance of the cultures was measured by the formula suggested by Lush (1949) and Johnson *et al.* (1955a) at five per cent selection intensity using the constant K as 2.06 given by Allard (1960).

$$\text{Expected genetic advance (GA)} = \frac{Vg}{\sqrt{Vp}} \times K$$

where Vg = Genotypic variance

Vp = Phenotypic variance

K = Selection differential

Genetic gain (Genetic advance as percentage of mean)

Genetic advance (GA) calculated in the above method was used for estimation of genetic gain.

$$\text{Genetic gain (GG)} = \frac{GA}{\bar{X}} \times 100$$

X = Mean of the character under study

Genetic gain was categorised as

High	- >20 per cent
Moderate	-10-20 per cent
Low	-<10 per cent

3.3.1(f) Phenotypic and genotypic correlation coefficients

The phenotypic and genotypic covariances were worked out in the same way as the variances were calculated. Mean product expectations of the covariance analyses are analogous to the mean square expectation of the analyses of variance. The different covariance estimates were calculated by the method suggested by Fisher (1954) using the statistical package SPAR 1.

Phenotypic covariance between two characters 1 and 2 (CoVp12) = CoVg12 + CoVe12

Where,

CoVg12 = Genotypic covariance between characters 1 and 2 and

CoVe12 = Environmental covariance between characters 1 and 2

Genotypic covariance between two characters 1 and 2 is as follows,

$$CoVg12 = \frac{Mt12 - Me12}{N}$$

Where,

Mt12 = Mean sum of product due to treatment between characters 1 and 2

Me12 = Mean sum of product due to error between characters 1 and 2

N = Number of replications

The phenotypic and genotypic correlation coefficients among the various characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955b).

Phenotypic correlation coefficient between two characters 1 and 2.

$$(r_p12) = \frac{CoVp12}{\sqrt{Vp1\ Vp2}}$$

where,

CoVp12 = phenotypic covariance between characters 1 and 2

Vp1 = Phenotypic variance of character 1

Vp2 = Phenotypic variance of character 2

Genotypic correlation coefficient between two characters 1 and 2.

$$(r_g12) = \frac{CoVg12}{\sqrt{Vg1\ Vg2}}$$

where

CoVg12 = Genotypic covariance between characters 1 and 2

Vg1 = Genotypic variance of character 1

Vg2 = Genotypic variance of character 2

3.3.1(g) Path analysis

Path analysis was carried out by methods by Singh and Chaudhary (1985).

3.3.1(h) Stability analysis

The model of Eberhart and Russel (1966) was used for stability analysis. According to Eberhart and Russel (1966), a desired variety should have high mean than grand mean, unit regression coefficient (b = 1) and least mean square deviation from linear regression ($S^2d = 0$). Breese (1969) and Paroda *et al.* (1973) stated that regression coefficient is a measure of response to varying environments and the mean square deviation from linear regression is a true measure of stability, the genotypes with the least deviation being the most stable. For carrying out various statistical analysis, the software package SPAR 1 was used.

3.3.1(i) Standard heterosis.

Magnitude of standard heterosis for all the hybrids was estimated over standard variety as given below

$$\text{Standard heterosis (\%)} = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

Where,

$\overline{SV}$-Mean value of standard variety (Jyothy)

$\overline{F_1}$- Mean value of hybrid

TEST OF SIGNIFICANCE OF HETEROSIS

Signifcance of estimates of heterosis was tested at error degrees of freedom as suggested by Turner (1952)

$$\text{'t' for standard heterosis} = \frac{\bar{F}_1 - \bar{SV}}{\sqrt{\frac{Me \times 2}{r}}}$$

where,

$\bar{SV}$-Mean value of standard variety (Jyothy)

Me-Error variance

r- Number of replications

3.3.1(j) Inbreeding depression

Inbreeding depression (ID) in F_2 generation over F_1 generation was estimated by using the following formula (Kempthorne, 1957).

$$ID (\%) = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_1} \times 100$$

Where,

$\bar{F}_1$- Mean value of hybrid

$\bar{F}_2$- Mean value of hybrid

RESULTS

4. RESULTS

The analysis of genotype x environment interaction in seven rice hybrids along with two check varieties was carried out for all the three locations viz., Mullakkara (Thrissur), Mathur (Southern Palakkad) and Chittoor (Eastern Palakkad), during *kharif* 2003.

4.1 MEAN PERFORMANCE AND VARIABILITY

4.1.1 Mean performance

The mean performance of genotypes at each location was analysed for significant difference using Duncan's Multiple Range Test and the results are presented in Tables 2, 3, 4 and 5. In general the hybrids had recorded more number of days to 50 per cent flowering, more days to physiological maturity, more grain yield ha^{-1}, more number of grains $panicle^{-1}$ and more plant height than check varieties.

At Mullakkara, Thrissur (Table 2) CORH-2 recorded significantly high mean values for number of grains $panicle^{-1}$ (211.1). KRH-2, with 103 days to 50 per cent flowering had significantly high mean values for grain yield ha^{-1} (7148.13 kg) and productivity $plant^{-1}$ (21.66 g). PA-6201 recorded highest productive tillers $plant^{-1}$ (10.27). Local variety (Aishwarya-PTb-52) and Jyothy exhibited high mean value for head rice recovery. Local variety had and significantly low plant height (84.07 cm). Lowest number of days to 50 per cent flowering was recorded by Jyothy (84.67). All the hybrids and check varieties performed uniformly for harvest index and grain density. Significantly high productivity day^{-1} was recorded by KRH-2 and NSD-2 (53.74g and 53.63g respectively). 1000 grain weight was significantly high for KRH-2 (26.27g), local check variety (25.67g) and Jyothy (25.02g).

Mean performance analysis by hybrids and check varieties at Mathur (Table 3) indicated that CORH-2 had a significantly high mean value for amylose content (34.29 %). DRRH-1 had significantly high mean value for alkali spreading value (5.133). Local check variety (Sulochana) had recorded significantly low mean values for plant height (86.53 cm). Head rice recovery was significantly high for Sulochana (83.62 %) and Jyothy (84.5%). Days to 50 per cent flowering were low for Jyothy (90.67). With regard to grain yield ha^{-1}, KRH-2, PHB-71, PA-6201 and NSD-2 were on par with each other and were significantly superior over other genotypes.

At Chittoor (Table 4), ADTRH-1 had significantly high mean value for number of grains $panicle^{-1}$ (239.8). Density of grain were high for KRH-2, local variety and Jyothy. KRH-2 and DRRH-1 recorded significantly high mean values (11.87 and 10.93 respectively) for productive tillers $plant^{-1}$. DRRH-1 exhibited significant superiority for amylose content (29.17). The mean grain yield ha^{-1} of hybrids was 6390.6kg whereas it was 5882.5 kg for check varieties. ADTRH-1, KRH-2, PA-6201 and NSD-2 were on par with each other for grain yield ha^{-1}. Days to 50 per cent flowering were low for local check variety (87.33) and Jyothy (88.33). PA-6201 recorded high mean value of 5.30 for alkali spreading value. Local check variety (white Ponni) had low mean value of 87.27 and 111.0 for the characters, plant height and number of days to physiological maturity and high mean values for harvest index (0.543). Jyothy had significantly high mean value for 1000 grain weight (27.35 g). Head rice recovery was high for the hybrids PHB-71, PA-6201 and NSD-2.

At Chittoor during *rabi*, 2003 the performance of hybrids and their corresponding F_2 population was tested and compared with check varieties. Significantly low plant height (87.60 cm) was noticed in hybrid ADTRH-1 (F_1). Significanly high mean grain yield ha^{-1} was recorded by F_1 generations of KRH-2 (8005.5 kg), DRRH-1 (7489 kg) and PHB-71 (7547.8 kg) and NSD-2 (7784.5 kg). Standard check variety Jyothy and local check variety (Ponni) recorded lowest (118) number of days to physiological maturity. Productivity $plant^{-1}$ was observed to be higher in case of KRH-2 (F_1), DRRH-1 (F_1), PHB-71 (F_1) and NSD-2 (F_1). Amylose content was found to be intermediate in most of genotypes. Milling percentage was high for Jyothy (68.75), NSD-2–F_1 (68.25), local variety and KRH-2- F_1 (65). NSD-2 (F_1), local variety and Jyothy had highest volume

Table 2. Mean performance of rice hybrids and check varieties for different quantitative characters at Mullakkara, Thrissur (*kharif*, 2003).

Sl. No.	Genotypes	Characters								
		Days to 50% flowering	Productive tillers plant^{-1}	Plant height (cm)	Grain yield ha^{-1} (kg)	Straw yield ha^{-1} (kg)	Harvest index	Number of days to physiological maturity	Productivity day^{-1} (g)	Productivity plant^{-1} (g)
1	ADTRH-1	96.67^{c}	9.533^{ab}	91.20^{c}	5685.17^{c}	5279.67^{b}	0.5167^{a}	122.30^{e}	46.47^{b}	17.23^{c}
2	CORH-2	99.67^{b}	7.833^{bc}	91.87^{bc}	5370.63^{d}	5138.67^{bc}	0.5100^{a}	124.70^{de}	43.07^{c}	16.27^{d}
3	KRH-2	103.00^{a}	7.800^{bc}	101.20^{a}	7148.13^{a}	6770.33^{a}	0.5133^{a}	133.00^{a}	53.74^{a}	21.66^{a}
4	DRRH-1	102.70^{a}	7.467^{c}	94.40^{bc}	4925.93^{e}	4981.67^{bc}	0.4967^{a}	127.70^{cd}	38.58^{de}	14.93^{e}
5	PHB-71	102.30^{a}	7.800^{bc}	100.30^{a}	5833.33^{c}	5537.33^{b}	0.5133^{a}	131.30^{ab}	44.42^{bc}	17.68^{c}
6	PA-6201	102.70^{a}	10.27^{a}	92.73^{bc}	4518.53^{f}	4870.67^{bc}	0.4833^{a}	128.30^{bc}	35.21^{f}	13.69^{f}
7	NSD-2	104.30^{a}	7.000^{c}	97.00^{ab}	6722.23^{b}	6555.67^{a}	0.5067^{a}	125.30^{cde}	53.63^{a}	20.37^{b}
8	Local variety	88.33^{d}	7.867^{bc}	84.07^{d}	4203.70^{g}	4352.0^{c}	0.4933^{a}	111.70^{g}	37.66^{e}	12.74^{g}
9	Jyothy	84.67^{e}	8.000^{bc}	90.20^{c}	4685.20^{ef}	4685.670^{bc}	0.5033^{a}	115.70^{f}	40.52^{d}	14.20^{ef}
	Mean of hybrids	101.62	8.24	95.53	5743.43	5590.71	0.51	127.51	45.02	17.40
	Mean of check varieties	86.5	7.95	87.15	4444.5	4519	0.5	113.7	39.1	13.45

Cont.....

Table 2. Mean performance of rice hybrids and check varieties for different quantitative characters at Mullakkara, Thrissur (*kharif*, 2003).

Sl. No.	Genotypes	Characters								
		Number of grains panicle^{-1}	1000 grain weight (g)	Density of grain (gms/m^3)	Head rice recovery (%)	Milling percentage	Amylose content (%)	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
1	ADTRH-1	191.30^b	24.37^{abc}	0.8300^a	69.18^e	61.47^a	23.25^{bc}	1.473^{ab}	5.753^a	3.767^{bc}
2	CORH-2	211.10^a	22.63^{bcd}	1.083^a	78.45^{cd}	57.77^b	27.42^a	1.310^{bc}	5.227^c	4.600^a
3	KRH-2	143.50^d	26.27^a	0.9867^a	78.31^d	57.22^c	26.18^{ab}	1.563^a	5.493^b	2.400^e
4	DRRH-1	178.20^c	24.47^{abc}	1.067^a	66.45^e	53.23^d	22.74^{bc}	1.257^c	5.103^c	4.400^a
5	PHB-71	130.30^e	20.22^d	1.050^a	75.22^d	51.70^e	23.39^{bc}	1.473^{ab}	5.680^{ab}	2.967^d
6	PA-6201	151.40^d	21.31^d	1.060^a	82.45^{bc}	50.83^f	22.13^c	1.300^{bc}	5.107^c	3.367^{cd}
7	NSD-2	146.50^d	21.99^{cd}	1.063^a	76.40^d	46.18^g	23.34^{bc}	1.243^c	5.143^c	3.933^b
8	Local variety	105.10^f	25.67^a	0.8300^a	86.70^a	61.23^a	25.05^{abc}	1.360^{abc}	4.753^d	4.533^a
9	Jyothy	103.60^f	25.02^{ab}	0.9133^a	85.13^{ab}	61.35^a	17.20^d	1.520^a	5.557^b	4.167^{ab}
	Mean of hybrids	164.61	23.04	1.02	75.21	54.06	24.06	1.37	5.36	3.63
	Mean of check varieties	104.35	25.35	0.85	85.9	61.3	21.15	1.14	5.15	4.35

Table 3. Mean performance of rice hybrids and check varieties for different quantitative characters at Mathur (*kharif*, 2003)

Sl. No.	Genotypes	Characters								
		Days to 50 % flowering	Productive tillers plant^{-1}	Plant height (cm)	Grain yield ha^{-1} (kg)	Straw yield ha^{-1} (kg)	Harvest index	Number of days to physiological maturity	Productivity day^{-1} (g)	Productivity plant^{-1} (g)
1	ADTRH-1	99.67^{bc}	12.73^{a}	103.80^{de}	4706.67^{c}	5210.67^{e}	0.4533^{a}	125.30^{b}	37.57^{d}	14.26^{c}
2	CORH-2	100.70^{b}	11.67^{ab}	107.10^{cd}	5792.67^{b}	5844.00^{cd}	0.4967^{a}	127.30^{ab}	45.51^{b}	17.55^{b}
3	KRH-2	105.70^{a}	13.27^{a}	126.40^{a}	6942.00^{a}	7062.33^{a}	0.4900^{a}	127.30^{ab}	54.51^{a}	21.04^{a}
4	DRRH-1	103.30^{ab}	11.73^{ab}	104.30^{de}	5775.67^{b}	6312.67^{bc}	0.4567^{a}	129.70^{a}	44.57^{b}	17.50^{b}
5	PHB-71	100.00^{bc}	12.73^{a}	112.30^{b}	6694.67^{a}	7490.00^{a}	0.4467^{a}	126.70^{ab}	52.85^{a}	20.29^{a}
6	PA-6201	105.30^{a}	11.33^{ab}	111.20^{bc}	6513.67^{a}	6458.67^{b}	0.5033^{a}	125.00^{b}	52.10^{a}	19.74^{a}
7	NSD-2	96.00^{cd}	12.47^{a}	110.2^{bc}	6468.33^{a}	7104.67^{a}	0.4567^{a}	121.00^{c}	53.44^{a}	19.60^{a}
8	Local variety	92.67^{de}	10.20^{b}	86.53^{f}	4857.33^{c}	5354.33^{de}	0.4567^{a}	115.00^{d}	42.23^{bc}	14.72^{c}
9	Jyothy	90.67^{e}	12.60^{a}	102.10^{e}	4428.67^{c}	5000.33^{e}	0.4467^{a}	112.70^{d}	39.32^{cd}	13.42^{c}
	Mean of hybrids	101.52	12.28	110.76	6127.86	6497.71	0.47	126.04	48.65	18.57
	Mean of check varieties	91.67	11.40	94.32	4643.00	5177.00	0.45	113.85	40.78	14.07

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Table 3. Mean performance of rice hybrids and check varieties for different quantitative characters at Mathur (*kharif*, 2003)

Sl. No.	Genotypes	Characters								
		Number of grains panicle^{-1}	1000 grain weight (g)	Density of grain (gms/m^{3})	Head rice recovery (%)	Milling percentage	Amylose content (%)	Kernel elonga tion ratio	Volume expansion ratio	Alkali spreading value
1	ADTRH-1	221.7^{a}	23.03^{b}	0.7567^{c}	66.40^{f}	65.02^{a}	20.14^{cd}	1.397^{b}	5.793^{a}	3.633^{c}
2	CORH-2	209.7^{abc}	23.10^{b}	0.7833^{c}	75.32^{c}	59.48^{cd}	34.29^{a}	1.403^{b}	5.543^{abc}	4.267^{b}
3	KRH-2	199.1^{c}	26.11^{a}	1.0200^{a}	79.40^{b}	61.17^{bc}	27.17^{b}	1.433^{ab}	5.253^{c}	4.567^{b}
4	DRRH-1	199.9^{c}	22.84^{b}	0.9300^{b}	71.41^{cde}	57.34^{de}	26.42^{b}	1.410^{b}	5.770^{ab}	5.133^{a}
5	PHB-71	206.7^{bc}	22.84^{b}	1.0800^{a}	73.55^{cd}	56.67^{e}	19.97^{cd}	1.600^{a}	5.533^{abc}	3.267^{d}
6	PA-6201	216.6^{ab}	22.74^{b}	1.0070^{ab}	69.68^{def}	52.32^{f}	22.07^{c}	1.443^{ab}	5.507^{abc}	3.600^{cd}
7	NSD-2	183.4^{d}	25.83^{a}	0.7900^{c}	68.27^{ef}	49.43^{g}	20.47^{cd}	1.527^{ab}	5.210^{cd}	3.300^{cd}
8	Local variety	136.7^{e}	28.41^{a}	0.8167^{c}	83.62^{a}	63.55^{ab}	22.45^{c}	1.400^{b}	4.850^{d}	3.600^{cd}
9	Jyothy	130.7^{e}	27.90^{a}	0.8167^{c}	84.44^{a}	63.04^{ab}	19.06^{d}	1.550^{ab}	5.377^{bc}	3.567^{cd}
	Mean of hybrids	205.30	23.78	0.91	72.00	57.35	24.36	1.46	5.52	3.97
	Mean of check varieties	133.70	28.16	0.82	84.03	63.30	20.76	1.48	5.11	3.58

Table 4. Mean performance of rice hybrids and check varieties for different quantitative characters at Chittoor (*kharif*, 2003).

Sl. No.	Genotypes	Characters								
		Days to 50% flowering	Productive tillers plant^{-1}	Plant height (cm)	Grain yield ha^{-1} (kg)	Straw yield ha^{-1} (kg)	Harvest index	Number of days to physiological maturity	Productivity day^{-1} (g)	Productivity plant^{-1} (g)
1	ADTRH-1	95.67^{d}	10.60^{bc}	108.30^{c}	7045.67^{ab}	6667.67^{ab}	0.5200^{d}	128.00^{b}	55.03^{ab}	21.35^{ab}
2	CORH-2	97.33^{d}	9.967^{bc}	108.60^{c}	5277.33^{f}	6721.00^{ab}	0.4633^{f}	129.70^{b}	40.71^{e}	15.99^{f}
3	KRH-2	98.00^{cd}	11.87^{a}	120.80^{a}	6703.67^{abc}	6851.33^{ab}	0.5267^{c}	134.30^{a}	49.89^{bc}	20.31^{abc}
4	DRRH-1	102.30^{ab}	10.93^{ab}	109.70^{c}	5591.67^{ef}	6419.33^{ab}	0.4800^{e}	129.70^{b}	43.14^{de}	16.95^{ef}
5	PHB-71	101.30^{b}	9.800^{bc}	115.20^{b}	6362.33^{bcd}	6258.670^{b}	0.4800^{e}	133.00^{a}	47.83^{cd}	19.28^{bcd}
6	PA-6201	100.00^{bc}	10.33^{bc}	114.0^{b}	6649.67^{abc}	7006.67^{ab}	0.5233^{cd}	129.00^{b}	51.57^{abc}	20.15^{abc}
7	NSD-2	104.00^{a}	9.567^{c}	110.10^{c}	7103.0^{a}	8419.33^{b}	0.5367^{b}	127.30^{b}	55.78^{a}	21.52^{a}
8	Local variety	87.33^{e}	7.467^{d}	87.27^{e}	5761.0^{def}	7292.00^{a}	0.5433^{a}	111.00^{d}	51.93^{abc}	17.46^{def}
9	Jyothy	88.33^{e}	10.47^{bc}	93.40^{d}	6003.67^{cde}	6974.00^{ab}	0.5367^{b}	117.30^{c}	51.18^{abc}	18.19^{cde}
	Mean of hybrids	99.8	10.4	112.4	6390.6	6906.3	0.5	130.1	49.1	19.4
	Mean of check varieties	87.8	9.0	90.3	5882.5	7133.0	0.5	114.2	51.6	17.8

Cont.....

Table 4. Mean performance of rice hybrids and check varieties for different quantitative characters at Chittoor (*kharif*, 2003).

Sl. No.	Genotypes	Characters								
		Number of grains $panicle^{-1}$	1000 grain weight (g)	Density of grain (g/m^3)	Head rice recovery (%)	Milling percentage	Amylose content (%)	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
1	ADTRH-1	239.80^{a}	21.10^{e}	0.8633^{b}	77.62^{cd}	63.97^{a}	20.37^{cd}	1.353^{d}	5.890^{ab}	4.100^{c}
2	CORH-2	211.90^{b}	23.32^{cd}	0.7333^{c}	67.67^{e}	60.00^{abc}	26.67^{b}	1.420^{bcd}	5.083^{c}	3.600^{c}
3	KRH-2	188.30^{c}	25.69^{b}	0.9700^{a}	79.68^{bc}	58.05^{bcd}	26.81^{b}	1.520^{ab}	5.763^{ab}	3.933^{c}
4	DRRH-1	193.50^{c}	24.22^{bcd}	0.8667^{b}	74.74^{d}	55.23^{d}	29.17^{a}	1.497^{abc}	5.073^{c}	4.667^{b}
5	PHB-71	220.50^{b}	23.05^{d}	0.6967^{c}	82.20^{ab}	50.30^{e}	20.96^{c}	1.570^{a}	5.950^{ab}	3.733^{c}
6	PA-6201	209.50^{b}	19.97^{e}	0.6733^{c}	81.12^{abc}	55.98^{cd}	21.30^{c}	1.353^{d}	6.150^{a}	5.300^{a}
7	NSD-2	195.90^{c}	24.90^{bc}	0.7567^{c}	80.84^{abc}	49.48^{e}	19.47^{cd}	1.383^{cd}	5.610^{abc}	2.500^{d}
8	Local variety	124.30^{d}	25.23^{b}	0.9500^{ab}	75.49^{d}	64.28^{a}	26.40^{b}	1.467^{abcd}	5.567^{abc}	2.567^{d}
9	Jyothy	129.20^{d}	27.35^{a}	0.8867^{ab}	84.56^{a}	62.00^{ab}	18.46^{d}	1.353^{d}	5.463^{bc}	3.633^{c}
	Mean of hybrids	208.5	23.2	0.8	77.7	56.1	23.5	1.4	5.6	4.0
	Mean of check varieties	126.8	26.3	0.9	80.0	63.1	22.4	1.4	5.5	3.1

Table 5. Mean performance of genotypes at Chittoor (*rabi*, 2003)

Genotypes	Characters										
	Plant height (cm)	Days to 50% flowering	Grain yield ha^{-1} (kg)	Number of days to physiological maturity	Productivity plant^{-1} (g)	Head rice recovery (%)	Milling percentage	Amylose content (%)	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
ADTRH-1 F$_1$	87.60^{f}	104.50^{ab}	5755.0^{e}	126.50^{cde}	17.44^{e}	75.18^{ef}	48.15^{g}	26.22^{a}	1.410^{ab}	5.245^{bcde}	3.650^{f}
ADTRH-1 F$_2$	102.40^{cd}	99.00^{cde}	5054.5^{f}	122.00^{f}	15.32^{f}	71.81^{fghi}	44.30^{h}	21.24^{def}	1.270^{bc}	4.930^{def}	3.150^{g}
CORH-2 F$_1$	95.30^{e}	105.50^{ab}	7268.0^{b}	130.00^{ab}	22.02^{b}	79.90^{bc}	57.38^{e}	20.71^{defg}	1.580^{a}	5.140^{bcde}	4.650^{cd}
CORH-2 F$_2$	97.90^{de}	101.50^{bcd}	6419.5^{cd}	122.00^{f}	19.45^{cd}	74.04^{efg}	52.90^{f}	18.60^{g}	1.535^{a}	4.785^{ef}	2.750^{g}
KRH-2 F$_1$	120.50^{b}	102.00^{abcd}	8005.5^{a}	125.50^{de}	24.26^{a}	75.50^{de}	65.00^{ab}	25.08^{ab}	1.565^{a}	5.330^{abcd}	3.650^{f}
KRH-2 F$_2$	127.30^{a}	103.50^{abc}	6235.0^{cde}	130.50^{a}	18.90^{cde}	72.00^{fgh}	60.00^{de}	20.85^{defg}	1.580^{a}	5.055^{cde}	5.600^{a}
DRRH-1 F$_1$	94.30^{e}	99.50^{cde}	7489.0^{ab}	124.00^{ef}	22.69^{ab}	81.38^{ab}	64.25^{bc}	22.89^{bcd}	1.430^{ab}	5.230^{bcde}	5.550^{a}
DRRH-1 F$_2$	95.10^{e}	105.50^{ab}	6493.0^{c}	129.00^{abc}	19.67^{c}	76.81^{cde}	58.00^{e}	19.95^{efg}	1.235^{bc}	4.955^{def}	4.250^{de}
PHB-71 F$_1$	108.30^{c}	106.50^{a}	7547.5^{ab}	130.50^{a}	22.88^{ab}	78.68^{bcd}	57.75^{e}	25.00^{ab}	1.505^{a}	5.170^{bcde}	5.500^{a}
PHB-71 F$_2$	118.90^{b}	97.50^{de}	6124.5^{cde}	122.00^{f}	18.56^{cde}	71.15^{ghi}	48.50^{g}	20.45^{defg}	1.285^{bc}	4.845^{ef}	4.000^{ef}
PA-6201 F$_1$	95.00^{e}	99.50^{cde}	7361.5^{b}	127.00^{bcde}	22.31^{b}	70.57^{ghi}	63.75^{bcd}	24.14^{abc}	1.575^{a}	4.570^{ef}	4.450^{cde}
PA-6201 F$_2$	104.70^{cd}	103.00^{abc}	6476.5^{c}	127.50^{abcd}	19.63^{c}	68.30^{i}	57.00^{e}	20.45^{defg}	1.505^{a}	4.195^{g}	5.150^{ab}
NSD-2 F$_1$	103.30^{cd}	102.00^{abcd}	7784.5^{ab}	124.00^{ef}	23.59^{ab}	83.90^{a}	68.25^{a}	22.45^{cd}	1.520^{a}	5.750^{a}	5.400^{a}
NSD-2 F$_2$	98.00^{de}	102.00^{abcd}	5829.0^{e}	128.00^{abcd}	17.66^{e}	80.85^{ab}	60.75^{cde}	18.95^{fg}	1.205^{c}	5.140^{bcde}	4.850^{bc}
Local variety	115.80^{b}	92.50^{f}	5903.0^{de}	118.00^{g}	17.89^{de}	68.50^{hi}	67.50^{ab}	22.25^{cde}	1.425^{ab}	5.555^{ab}	5.200^{ab}
Jyothy	92.70^{ef}	95.00^{ef}	5894.5^{de}	118.00^{g}	17.86^{de}	83.49^{a}	68.75^{a}	19.06^{fg}	1.405^{ab}	5.490^{abc}	5.250^{ab}
Mean (F$_1$)	100.61	102.79	7316.14	126.79	22.17	77.87	60.65	23.78	1.51	5.21	4.69
Mean (F$_2$)	106.33	101.71	6090.57	125.86	18.46	73.57	54.49	20.07	1.37	4.84	4.25
Mean varieties	104.25	93.75	5899.00	118.00	17.88	76.00	68.13	20.66	1.42	5.52	5.23

expansion ratio of 5.750, 5.555 and 5.490 respectively. Alkali spreading value of genotypes was found be intermediate ranging from 2.750 to 5.600. In general for grain yield ha^{-1} the F_1 generations recorded higher mean yields than corresponding F_2 generation (Table 5).

4.1.2 Variability

The extent of genetic variability with respect to different quantitative characters in seven hybrids and two check varieties were estimated for three locations viz., Mullakkara, Mathur, Chittoor during *kharif, 2003* and in Chittoor during *rabi*, 2003. The abstract of analysis of variance and variability of different characters are given in Table 6.

At Mullakkara nine genotypes showed significant difference for all the yield attributing characters except productive tillers plant^{-1}, harvest index and number of days to physiological maturity. At Mathur, except for productive tillers plant^{-1}, harvest index and kernel elongation ratio, all other characters showed significant difference.

Results of analysis of variance revealed a highly significant difference among the nine genotypes for all the characters studied at Chittoor (*kharif*, 2003). The characters included days to 50 per cent flowering, productive tillers plant^{-1}, plant height, grain yield ha^{-1}, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity day^{-1}, productivity plant^{-1}, number of grains panicle^{-1}, 1000 grain weight, density of grain, milling percentage, amylose content, kernel elongation ratio, volume expansion ratio, alkali spreading value and head rice recovery.

Analysis of variance (Table 7) revealed highly significant difference among 16 genotypes (seven F_1 and their corresponding F_2 generations and two check varieties) for all the characters studied at Chittoor during *rabi*, 2003. The characters included plant height, days to 50 per cent flowering, grain yield ha^{-1}, number of days to physiological maturity, productivity plant^{-1}, milling percentage,

Table 6. Analysis of variance for grain yield and associated characters in nine rice genotypes at three locations in Kerala (*kharif*, 2003).

Characters	Mean sum of squares								
	Genotype df = 8	Replication df = 2	Error df = 16	Genotype df = 8	Replication df = 2	Error df = 16	Genotype df = 8	Replication df = 2	Error df = 16
	Mullakkara			Mathur			Chittoor		
X_1	150.98**	0.594	2.009	84.41**	2.11	5.15	103.68**	0.481	2.06
X_2	3.23	1.005	1.111	2.65	1.041	1.25	4.342**	0.081	0.4853
X_3	84.87**	2.9	8.75	335.09**	43.17**	5.731	337.36**	11.54	4.55
X_4	2996635**	700016**	29167	2634650**	27156.27	98977.42	127924.1.7**	10184.1	144871.3
X_5	200940**	33814	198145	2462046**	76883.8	82004.4	1022932**	80026.7	242581.33
X_6	0.000365	0.0042	0.00031	0.0004898	0.000027	0.00016	0.00061*	0.000161	0.000134
X_7	1469.15	23.11**	3.19	104.5**	0	5.125	171.39**	13.338*	2.161
X_8	132.28**	0.095	1.943	126.27**	1.21	6.11	76.31**	4.37	8.25
X_9	27.5**	0.636	0.2672	24.18**	0.248	0.909	11.736**	0.09445	1.332
X_{10}	4066.71**	20.31	40.89	3358.69**	70.17	55.49	4624.9**	317.81*	54.81
X_{11}	13.10*	3.624	2.25	16.25**	3.988	1.905	15.866**	3.341*	0.868
X_{12}	0.0321**	0.0112	0.0042	0.0443**	0.00915	0.00162	0.0360**	0.0101*	0.00257
X_{13}	137.47**	9.87	5.4	129.063**	3.896	5.319	76.77**	12.95	4.48
X_{14}	89.512**	0.484	3.78	83.12**	16.15**	2.377	89.19**	0.967	5.99
X_{15}	25.21**	0.465	1.06	75.77**	1.54	1.74	46.45**	1.31	1.334
X_{16}	0.043*	0.00914	0.019	0.0174	0.00985	0.0076	0.01993*	0.0034	0.00364
X_{17}	0.3212*	0.1426	0.062	0.2609*	0.0635	0.0454	0.4115*	0.1777	0.1074
X_{18}	1.671**	0.1782	0.6648	1.208**	0.0182	0.0339	2.395**	0.01147	0.0769

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

X_1 –Days to 50% flowering, X_2 – Productive tillers plant^{-1}, X_3 – Plant height, X_4 – Grain yield ha^{-1}, X_5 – Straw yield ha^{-1}, X_6 – Harvest index, X_7 –Number of days to physiological maturity, X_8 – Productivity day^{-1}, X_9 – Productivity plant^{-1}, X_{10} – Number of grains panicle^{-1}, X_{11} –1000 grain weight, X_{12} – Density of grain, X_{13} – Head rice recovery, X_{14} - Milling percentage, X_{15} - Amylose content, X_{16} - Kernel elongation ratio, X_{17} - Volume expansion ratio, X_{18} - Alkali spreading value.

Table 7. Analysis of variance for grain yield and associated characters for location Chittoor during *rabi*, 2003

Character	Mean sum of squares		
	Genotype df = 15	Replication df = 1	Error df = 15
X_1	266.04**	2.53	8.48
X_2	29.99**	12.50	3.77
X_3	1492241.1**	16486	57796.3
X_4	33.19**	26.28**	2.015
X_5	13.71**	1.52	0.531
X_6	53.34**	7.35	2.25
X_7	111.1**	2.85	2.86
X_8	11.07**	0.115	1.04
X_9	0.0332**	0.0061	0.0069
X_{10}	0.293**	0.014	0.039
X_{11}	1.64**	0.0079	0.046

*- Significant at 5% level

**- Significant at 5% level

where,

- X_1- Plant height (cm)
- X_2- Days to 50 % flowering
- X_3- Grain yield ha^{-1} (kg)
- X_4- Number of days to physiological maturity
- X_5- Productivity $plant^{-1}$ (g)
- X_6- Head rice recovery (%)
- X_7- Milling percentage
- X_8- Amylose content (%)
- X_9- Kernel elongation ratio
- X_{10}- Volume expansion ratio
- X_{11}- Alkali spreading value

amylose content, kernel elongation ratio, volume expansion ratio, alkali spreading value and head rice recovery.

Variability parameters like range, mean, Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) computed for characters in all the locations are presented in Tables 8-11.

Among the three locations, Mullakkara (Table 8) recorded the highest mean values for harvest index (0.504) and density of grain (0.987 g/m^3). The experiment conducted at Mathur (Table 9) recorded high mean values for days to 50 per cent flowering (99.33), productive tillers plant^{-1} (12.08), 1000 grain weight (24.76 g), milling percentage (58.67), amylose content (23.56%), kernel elongation ratio (1.463) and alkali spreading value (3.89).

Plant height (107.47 cm), grain yield ha^{-1} (6277.56 kg), straw yield ha^{-1} (6746.48 kg), number of days to physiological maturity (126.59), productivity day^{-1} (49.67 g), productivity plant^{-1} (19.02 g), number of grains panicle^{-1} (190.34), volume expansion ratio (5.62) and head rice recovery (78.21 %) had the highest mean values at Chittoor (Table 10).

The mean values recorded for different characters at Chittoor (*rabi*, 2003) are presented in Table 11. Plant height (103.57 cm), days to 50 per cent flowering (101.19), grain yield ha^{-1} (6602.53 kg), number of days to physiological maturity (125.28), productivity plant^{-1} (20.01 g), milling percentage (58.89), amylose content (21.77%), kernel elongation ratio (1.44), volume expansion ratio (5.09), alkali spreading value (4.57) and head rice recovery (75.75 %) were recorded in this experiment.

Phenotypic and genotypic coefficients of variation were estimated for all the yield attributing characters at all the four locations. At Mullakkara, characters like plant height, productive tillers plant^{-1}, grain yield ha^{-1}, straw yield ha^{-1}, harvest index, productivity plant^{-1}, milling percentage and kernel elongation ratio expressed the highest PCV and GCV. At Mathur, 1000 grain weight, amylose content and head rice recovery exhibited highest values of PCV and the same trend was exhibited by GCV also.

Table 8. Variability parameters of nine rice genotypes at Mullakkara, Thrissur (*kharif*, 2003).

Sl.No.	Characters	Range	Mean	PCV	GCV
1	Days to 50 % flowering	84.67-104.33	98.26 ± 1.16	7.32	7.17
2	Productive tillers plant^{-1}	7.00-10.27	8.17 ± 0.86	16.5	10.29
3	Plant height (cm)	84.07-101.2	93.66 ± 2.42	6.24	5.38
4	Grain yield ha^{-1} (kg)	4203.70-7148.13	5454.76 ± 139.4	18.5	18.23
5	Straw yield ha^{-1} (kg)	4352-6770.33	5352.41 ± 363.44	16.73	14.52
6	Harvest index	0.48-0.52	0.504 ± 0.014	3.58	0.87
7	Number of days to physiological maturity	111.67-133	124.44 ± 1.46	5.74	5.56
8	Productivity day^{-1} (g)	3766-53.74	43.70 ± 1.13	15.42	15.08
9	Productivity plant^{-1} (g)	12.74-21.66	16.53 ± 0.42	18.51	18.24
10	Number of grains panicle^{-1}	103.6-211.13	151.23 ± 5.22	24.59	24.22
11	1000 grain weight (g)	20.22-26.27	23.55 ± 1.22	10.28	8.08
12	Density of grain (g/m^3)	0.83-1.08	0.987 ± 0.05	11.76	9.77
13	Head rice recovery (%)	66.48-86.70	77.59 ± 1.9	9.06	8.55
14	Milling percentage	46.18-61.47	55.67 ± 1.59	10.22	9.60
15	Amylose content (%)	17.20-27.42	23.42 ± 0.84	12.88	12.11
16	Kernel elongation ratio	1.24-1.56	1.39 ± 0.09	10.77	7.37
17	Volume expansion ratio	4.75-5.75	5.31 ± 0.20	7.25	5.53
18	Alkali spreading value	2.40-4.60	3.80 ± 0.21	20.61	19.46

Table 9. Variability parameters of nine rice genotypes at Mathur (*kharif*, 2003).

Sl. No.	Characters	Range	Mean	PCV	GCV
1	Days to 50 % flowering	90.67-105.67	99.33 ± 1.85	5.66	5.17
2	Productive tillers plant^{-1}	10.20-13.27	12.08 ± 0.91	10.85	5.65
3	Plant height (cm)	86.53-126.4	107.09 ± 1.96	10.04	9.78
4	Grain yield ha^{-1} (kg)	4428.67-6942	5797.74 ± 256.86	16.76	15.86
5	Straw yield ha^{-1} (kg)	5000.33-7490	6204.19 ± 233.83	15.08	14.36
6	Harvest index	0.47-0.50	0.483 ± 0.01	3.4	2.18
7	Number of days to physiological maturity	112.67-129.67	123.33 ± 1.85	5.01	4.67
8	Productivity day^{-1} (g)	37.57-54.51	46.9 ± 2.01	14.49	13.49
9	Productivity plant^{-1} (g)	13.42-21.04	17.57 ± 0.78	16.76	15.85
10	Number of grains panicle^{-1}	130.73-221.73	189.42 ± 6.08	17.95	17.52
11	1000 grain weight (g)	22.74-28.41	24.76 ± 1.13	10.45	8.84
12	Density of grain (g/m^3)	0.76-1.08	0.8889 ± 0.033	14.16	13.42
13	Head rice recovery (%)	66.40-84.43	74.68 ± 1.88	9.14	8.6
14	Milling percentage	49.43-65.02	58.67 ± 1.26	9.22	8.84
15	Amylose content (%)	19.06-34.29	23.56 ± 1.08	21.40	20.65
16	Kernel elongation ratio	1.40-1.60	1.463 ± 0.07	7.12	3.91
17	Volume expansion ratio	4.85-5.79	5.443 ± 0.17	6.31	4.94
18	Alkali spreading value	3.27-5.13	3.89 ± 0.15	16.80	16.11

Table 10. Variability parameters of nine rice genotypes at Chittoor (*kharif*, 2003).

Sl. No.	Characters	Range	Mean	PCV	GCV
1	Days to 50 % flowering	88.33-104	97.15 ± 1.11	6.17	5.99
2	Productive tillers plant^{-1}	7.47-11.87	10.11 ± 0.569	13.16	11.21
3	Plant height (cm)	87.27-120.8	107.47 ± 1.74	10.00	9.8
4	Grain yield ha^{-1} (kg)	5277.33-7103	6277.56 ± 310.78	11.52	9.8
5	Straw yield ha^{-1} (kg)	5866.67-7506.67	6746.48 ± 402.14	10.51	7.56
6	Harvest index	0.46-0.50	0.4815 ± 0.0095	3.55	2.61
7	Number of days to physiological maturity	111-134.33	126.59 ± 1.2	6.05	5.93
8	Productivity day^{-1} (g)	40.71-55.78	49.67 ± 1.24	11.20	9.59
9	Productivity plant^{-1} (g)	15.99-21.52	19.02 ± 0.94	11.52	9.79
10	Number of grains panicle^{-1}	124.33-239.8	190.34 ± 6.04	20.87	20.51
11	1000 grain weight (g)	19.97-27.35	23.87 ± 0.76	10.15	9.37
12	Density of grain (g/m^3)	0.70-0.97	0.8219 ± 0.41	14.26	12.85
13	Head rice recovery (%)	67.67-82.2	78.21 ± 1.73	6.83	6.28
14	Milling percentage	49.48-64.28	57.7 ± 1.99	10.06	9.13
15	Amylose content (%)	18.46-29.17	23.29 ± 0.94	17.37	16.65
16	Kernel elongation ratio	1.35-1.57	1.44 ± 0.49	6.64	5.14
17	Volume expansion ratio	5.07-6.15	5.62 ± 0.27	8.14	5.67
18	Alkali spreading value	2.50-4.67	3.782 ± 0.23	24.38	23.25

Table 11. Variability parameters of nine rice genotypes at Chittoor (*rabi* 2003).

Sl. No.	Characters	Range	Mean	PCV	GCV
1	Plant height (cm)	87.60-127.30	103.57 ± 2.91	11.31	10.96
2	Days to 50 % flowering	92.50-106.50	101.19 ± 1.94	4.06	3.58
3	Grain yield ha^{-1} (kg)	5054.5-8005.5	6602.53 ± 240.41	13.33	12.83
4	Number of days to physiological maturity	118-130.50	125.28 ± 1.42	3.35	3.15
5	Productivity $plant^{-1}$ (g)	15.32-24.26	20.01 ± 0.73	13.34	12.83
6	Head rice recovery (%)	68.30-83.90	75.75 ± 1.5	6.96	6.67
7	Milling percentage	44.30-68.75	58.89 ± 1.69	12.82	12.49
8	Amylose content (%)	18.60-26.22	21.77 ± 1.02	11.30	10.29
9	Kernel elongation ratio	1.20-1.58	1.44 ± 0.08	9.84	7.98
10.	Volume expansion ratio	4.19-5.75	5.09 ± 0.20	8	7
11	Alkali spreading value	2.75-5.60	4.57 ± 0.21	20.12	19.57

Number of days to physiological maturity, volume expansion ratio and alkali spreading value had the highest values for both PCV and GCV while plant height, harvest index, number of grains panicle^{-1} and 1000 grain weight exhibited highest values for GCV at Chittoor.

In Chittoor (*rabi*, 2003) alkali spreading value recorded highest for both PCV and GCV, while number of days to physiological maturity recorded lowest value for both PCV and GCV.

4.2 HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN

Genetic parameters like heritability, genetic advance and genetic gain estimated for yield attributes at Mullakkara, Mathur, Chittoor and Chittoor (*rabi*, 2003) are presented in Tables 12, 13, 14 and 15.

At Mullakkara, high estimates (>60 %) of heritability were noticed for six characters viz., days to 50 per cent flowering, grain yield ha^{-1}, productivity day^{-1}, productivity plant^{-1}, number of grains panicle^{-1} and head rice recovery. Heritability percentage was lowest (6.0) for harvest index and highest (97.1) for grain yield and productivity day^{-1}. Highest genetic advance of 2019.25 was observed in the case of grain yield. Genetic gain was zero for harvest index whereas it was 49.16 for number of grains panicle^{-1} (Table 12). High heritability coupled with high genetic gain (>20 %) was exhibited by days to 50 per cent flowering, grain yield ha^{-1}, productivity day^{-1}, productivity plant^{-1}and number of grains panicle^{-1}.

At Mathur, high estimates of heritability were noticed for six characters, viz., straw yield ha^{-1}, density of grain, milling percentage, amylose content, volume expansion ratio and alkali spreading value. Maximum heritability of 93.2 per cent was noticed for amylose content and the minimum of 27.1 per cent, in the case productive tillers plant^{-1}. Genetic advance expressed as percentage of mean was maximum (1791.88) for grain yield and lowest (0.01) for harvest index (Table 13). High estimates of heritability coupled with high genetic advance and genetic gain were observed in case of density of grain, straw yield ha^{-1} and

Table 12. Estimation of genetic parameters for grain yield and associated characters in nine rice genotypes at Mullakkara, Thrissur (*kharif*, 2003).

Sl. No.	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1	Days to 50 % flowering	96.1	14.23	14.48
2	Productive tillers $plant^{-1}$	38.9	1.08	13.22
3	Plant height (cm)	74.3	8.95	9.56
4	Grain yield ha^{-1} (kg)	97.1	2019.25	37.02
5	Straw yield ha^{-1} (kg)	75.3	1388.9	25.95
6	Harvest index	6.0	0.00	0.00
7	Number of days to physiological maturity	93.7	13.81	11.10
8	Productivity day^{-1} (g)	95.7	13.28	30.39
9	Productivity $plant^{-1}$ (g)	97.1	6.12	37.02
10	Number of grains $panicle^{-1}$	97.0	74.34	49.16
11	1000 grain weight (g)	61.7	3.08	13.08
12	Density of grain (g/m^3)	69.0	0.16	16.21
13	Head rice recovery (%)	89.1	12.9	16.63
14	Milling percentage	88.3	10.35	18.59
15	Amylose content (%)	88.4	5.49	23.44
16	Kernel elongation ratio	46.9	0.14	10.07
17	Volume expansion ratio	58.2	0.46	8.66
18	Alkali spreading value	89.1	1.43	37.63

Table 13. Estimation of genetic parameters for grain yield and associated characters in nine rice genotypes at Mathur (*kharif,* 2003).

Sl. No.	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1	Days to 50 % flowering	83.7	9.69	9.76
2	Productive tillers plant^{-1}	27.1	0.73	6.04
3	Plant height (cm)	95.0	21.04	19.65
4	Grain yield ha^{-1} (kg)	89.5	1791.88	30.91
5	Straw yield ha^{-1} (kg)	90.6	1746.77	28.15
6	Harvest index	40.9	0.01	2.07
7	Number of days to physiological maturity	86.6	11.03	8.94
8	Productivity day^{-1} (g)	86.8	12.14	25.88
9	Productivity plant^{-1} (g)	89.5	5.43	30.90
10	Number of grains panicle^{-1}	95.2	66.69	35.21
11	1000 grain weight (g)	71.5	3.81	15.39
12	Density of grain (g/m^3)	89.8	0.23	25.87
13	Head rice recovery (%)	88.6	12.45	16.67
14	Milling percentage	91.9	10.24	17.45
15	Amylose content (%)	93.2	9.68	41.09
16	Kernel elongation ratio	30.1	0.06	4.10
17	Volume expansion ratio	61.3	0.43	7.90
18	Alkali spreading value	92.0	1.24	31.88

Table 14. Estimation of genetic parameters for grain yield and associated characters in nine rice genotypes at Chittoor (*kharif*, 2003).

Sl.No.	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1	Days to 50 % flowering	94.3	11.64	11.98
2	Productive tillers plant^{-1}	72.6	1.99	19.68
3	Plant height (cm)	96.1	21.27	19.79
4	Grain yield ha^{-1} (kg)	72.3	1077.08	17.16
5	Straw yield ha^{-1} (kg)	51.7	755.78	11.20
6	Harvest index	54.1	0.02	4.15
7	Number of days to physiological maturity	96.3	15.18	11.99
8	Productivity day^{-1} (g)	73.3	8.40	16.91
9	Productivity plant^{-1} (g)	72.2	3.26	17.14
10	Number of grains panicle^{-1}	96.5	78.99	41.50
11	1000 grain weight (g)	85.2	4.25	17.80
12	Density of grain (g/m^3)	81.3	0.20	24.33
13	Head rice recovery (%)	84.3	9.29	11.88
14	Milling percentage	82.2	9.84	17.05
15	Amylose content (%)	91.9	7.66	32.89
16	Kernel elongation ratio	59.9	0.12	8.33
17	Volume expansion ratio	48.6	0.46	8.19
18	Alkali spreading value	91.0	1.73	45.74

Table 15. Estimation of genetic parameters for grain yield and associated characters in nine rice genotypes at Chittoor (*rabi,* 2003).

Sl.No.	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1	Plant height (cm)	93.8	22.64	21.86
2	Days to 50 % flowering	77.7	6.57	6.49
3	Grain yield ha^{-1} (kg)	92.5	1678.28	25.42
4	Number of days to physiological maturity	88.6	7.65	6.11
5	Productivity $plant^{-1}$ (g)	92.5	5.09	25.44
6	Head rice recovery (%)	91.9	9.98	13.17
7	Milling percentage	95.0	14.77	25.08
8	Amylose content (%)	82.9	4.20	19.29
9	Kernel elongation ratio	65.8	0.19	13.19
10	Volume expansion ratio	76.5	0.64	12.57
11	Alkali spreading value	94.6	1.79	39.17

amylose content. Genetic gain was maximum for amylose content (41.09) while harvest index exhibited lowest genetic gain (2.07).

At Chittoor (*kharif*, 2003) most of the yield attributing characters showed high heritability (Table 14). Heritability values were highest in case of number of grains panicle^{-1}(96.5) and lowest in case of volume expansion ratio (48.6). Highest genetic gain was observed in case of alkali spreading value (45.74) and lowest of 4.15 was recorded in case of harvest index. High heritability along with high genetic gain was noticed in case of plant height, number of days to physiological maturity and 1000 grain weight. Genetic advance value was 0.02 for harvest index and 1077.08 in case of grain yield.

At Chittoor (*rabi*, 2003) in the case of F_1 and F_2 generations, most of the yield attributing characters showed high heritability values (Table 15). Highest heritability value of 95.0 was observed for milling percentage while lowest value of 65.8 in case of kernel elongation ratio. Genetic gain was 6.11 for number of days to physiological maturity and 39.17 for alkali spreading value. Grain yield recorded the highest value of 1678.28 while kernel elongation ratio recorded lowest of 0.19 in case of genetic advance.

4.3 PHENOTYPIC AND GENOTYPIC CORRELATIONS

The genotypic and phenotypic correlation among yield and yield attributes had been worked out for each location and results are presented below.

At Mullakkara, significant positive genotypic correlation of grain yield was observed with days to 50 per cent flowering, plant height, straw yield, harvest index, number of days to physiological maturity, productivity day $^{-1}$, productivity plant^{-1} and volume expansion ratio (Table 16). Alkali spreading value exhibited significant negative correlation with grain yield (-0.625).

Days to 50 per cent flowering, plant height, straw yield, number of days to physiological maturity and productivity day $^{-1}$ had significant positive phenotypic correlation with yield, whereas alkali spreading value, (-0.597) had significant negative phenotypic correlation with grain yield.

Table 16. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice genotypes at Mullakkara, Thrissur (*kharif*, 2003).

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**1.000**	-0.020	0.794**	0.591**	0.678**	0.331	0.900**	0.402	0.591**	0.529*
2	Productive tillers plant^{-1} (X_2)	-0.035	**1.000**	-0.443	-0.415	-0.383	-1.223**	0.494*	-0.494*	-0.415	0.236
3	Plant height (X_3)	0.673**	-0.040	**1.000**	0.857**	0.917**	1.237**	0.966**	0.685**	0.857**	0.153
4	Grain yield ha^{-1} (X_4)	0.574*	-0.313	0.721**	**1.000**	1.018**	1.814**	0.635**	0.965**	1.000**	0.194
5	Straw yield ha^{-1} (X_5)	0.585*	-0.319	0.676**	0.918**	**1.000**	2.138**	0.684**	0.971**	1.018**	0.125
6	Harvest index (X_6)	0.068	-0.083	0.252	0.407	0.016	**1.000**	0.759**	1.885**	1.814**	0.781**
7	Number of days to physiological maturity (X_7)	0.883**	0.001	0.808**	0.613**	0.616**	0.104	**1.000**	0.414	0.635**	0.398
8	Productivity day^{-1} (X_8)	0.380	-0.364	0.569*	0.962**	0.862**	0.449	0.377	**1.000**	0.966**	0.114
9	Productivity plant^{-1} (X_9)	0.574*	-0.313	0.721**	1.000	0.918**	0.407	0.613**	0.962**	**1.000**	0.194
10	Number of grains panicle^{-1} (X_{10})	0.514*	0.115	0.102	0.196	0.143	0.132	0.384	0.117	0.196	**1.000**
11	1000 grain weight (X_{11})	-0.396	0.029	-0.279	-0.028	-0.022	-0.020	-0.316	0.054	-0.028	-0.155
12	Density of grain (X_{12})	0.689**	-0.151	0.528*	0.230	0-236	0.013	0.639**	0.062	0.230	0.281
13	Milling percentage (X_{13})	-0.713**	0.167	-0.532*	-0.349	0.432	0.112	-0.564*	-0.231	-0.349	-0.075
14	Amylose content (X_{14})	0.461	-0.104	0.118	0.345	0.280	0.167	0.289	0.296	0.345	0.455
1s	Kernel elongation ratio (X_{15})	-0.270	-0.055	0.161	0.276	0.235	0.151	0.054	0.292	0.276	-0.249
16	Volume expansion ratio (X_{16})	0.032	0.089	0.410	0.378	0.209	0.497*	0.281	0.354	0.378	0.097
17	Alkali spreading value (X_{17})	-0.426	-0.128	-0.673**	-0.597**	-0.604**	-0.101	-0.642**	-0.469*	-0.597**	0.167
18	Head rice recovery (X_{18})	-0.541*	0.072	-0.377	0.341	-0.273	-0.213	-0.459	-0.260	-0.341	-0.640**

* Significant at 5% level

** Significant at 1% level

Contd....

Table 16. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice genotypes at Mullakkara, Thrissur (*kharif,* 2003).

Sl.No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
1	Days to 50 % flowering (X_1)	-0.576*	0.774**	-0.794**	0.481*	-0.430	0.060	-0.476*	-0.588**
2	Productive tillers plant^{-1} (X_2)	-0.353	-0.321	0.196	-0.228	0.302	0.262	-0.272	0.081
3	Plant height (X_3)	-0.376	0.649**	-0.609**	0.146	0.274	0.556*	-0.819**	-0.449
4	Grain yield ha^{-1} (X_4)	-0.035	0.287	-0.350	0.381	0.269	0.489*	-0.625**	-0.358
5	Straw yield ha^{-1} (X_5)	-0.093	0.426	-0.500*	0.369	0.113	0.401	-0.658**	-0.298
6	Harvest index (X_6)	0.296	-0.468*	0.493*	0.639**	1.896**	1.753**	-0.911**	-1.081**
7	Number of days to physiological maturity (X_7)	-0.486*	0.740**	-0.612**	0.328	0.011	0.409	-0.739**	-0.536*
8	Productivity day^{-1} (X_8)	0.100	0.097	-0.220	0.326	0.293	0.449	-0.475*	-0.259
9	Productivity plant^{-1} (X_9)	-0.035	0.287	-0.350	0.380	0.269	0.489*	-0.625**	-0.358
10	Number of grains panicle^{-1} (X_{10})	-0.194	0.397	-0.074	0.510	-0.429	0.157	0.181	-0.670**
11	1000 grain weight (X_{11})	**1.000**	-0.769**	0.760**	0.018	0.555*	-0.095	0.102	0.107
12	Density of grain (X_{12})	-0.435	**1.000**	-0.857**	0.174	-0.671**	-0.118	-0.181	-0.292
13	Milling percentage (X_{13})	0.613**	-0.664**	**1.000**	-0.050	0.740**	0.192	0.264	0.247
14	Amylose content (X_{14})	0.002	0.202	-0.025	**1.000**	-0.206	-0.307	-0.087	-0.170
15	Kernel elongation ratio (X_{15})	0.200	-0.292	0.360	-0.141	**1.000**	0.953**	-0.649**	0.195
16	Volume expansion ratio (X_{16})	-0.123	-0.095	0.167	-0.172	0.471*	**1.000**	-0.581*	-0.410
17	Alkali spreading value (X_{17})	0.169	-0.070	0.220	-0.098	-0.490*	-0.437	**1.000**	0.052
18	Head rice recovery (X_{18})	0.133	-0.166	0.238	-0.131	0.135	-0.274	0.074	**1.000**

* Significant at 5% level

** Significant at 1% level

Table 17. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice genotypes at Mathur (*kharif*, 2003).

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**1.000**	0.316	0.726**	0.718**	0.566**	0.827**	0.937**	0.544*	0.718**	0.868**
2	Productive tillers plant^{-1} (X_2)	0.132	**1.000**	1.024**	0.375	0.448	-0.178	00.352	0.320	0.375	0.411
3	Plant height (X_3)	0.619**	0.540*	**1.000**	0.804**	0.716**	0.579*	0.621**	0.738**	0.804**	0.586*
4	Grain yield ha^{-1} (X_4)	0.652**	0.226	0.731**	**1.000**	0.962**	0.555*	0.635**	0.971**	1.000**	0.548*
5	Straw yield ha^{-1} (X_5)	0.478*	0.305	0.671**	0.928**	**1.000**	0.305	0.568*	0.949**	0.962**	0.455
6	Harvest index (X_6)	0.573*	-0.155	0.331	0.470*	0.114	**1.000**	0.512*	0.485*	0.555**	0.537*
7	Number of days to physiological maturity (X_7)	0.830**	0.231	0.535*	0.584*	0.498*	0.380	**1.000**	0.433	0.635**	0.918**
8	Productivity day^{-1} (X_8)	0.488*	0.182	0.668**	0.967**	0.912**	0.421	0.360	**1.000**	0.971**	0.361
9	Productivity plant^{-1} (X_9)	0.652**	0.226	0.731**	1.000**	0.928**	0.471*	0.584*	0.967**	**1.000**	0.548*
10	Number of grains panicle^{-1} (X_{10})	0.798**	0.237	0.540*	0.535*	0.443	0.357	0.888**	0.342	0.535*	**1.000**
11	1000 grain weight (X_{11})	-0.660**	-0.180	-0.300	-0.311	-0.229	-0.291	-0.762*	-0.123	-0.311	-0.816**
12	Density of grain (X_{12})	0.564*	0.149	0.548*	0.683**	0.681**	0.191	0.371	0.654**	0.683**	0.308
13	Milling percentage (X_{13})	-0.242	0.009	-0.349	-0.645**	-0.670**	-0.178	-0.246	-0.677**	-0.644**	-0.294
14	Amylose content (X_{14})	0.383	-0.115	0.186	0.184	0.015	0.450	0.481*	0.061	0.184	0.293
1s	Kernel elongation ratio (X_{15})	-0.257	0.100	0.164	0.093	0.200	-0.220	-0.197	0.171	0.094	-0.223
16	Volume expansion ratio (X_{16})	0.412	0.168	0.233	0.040	-0.004	0.116	0.517*	-0.116	0.040	0.573*
17	Alkali spreading value (X_{17})	0.461	-0.041	0.197	0.112	0.020	0.279	0.502*	-0.035	0.112	0.224
18	Head rice recovery (X_{18})	-0.479*	-0.162	-0.275	-0.319	-0.338	-0.062	-0.545*	-0.212	-0.319	-0.765**

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

contd...

Table 17. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice genotypes at Mathur (*kharif*, 2003).

Sl.No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
1	Days to 50 % flowering (X_1)	-0.748**	0.617**	-0.322	0.478*	-0.429	0.543*	0.567*	-0.509*
2	Productive tillers plant^{-1} (X_2)	-0.140	0.299	0.001	-0.228	1.060**	0.666**	0.044	-0.270
3	Plant height (X_3)	-0.379	0.585*	-0.354	0.207	0.313	0.301	0.229	-0.273
4	Grain yield ha^{-1} (X_4)	-0.430	0.731**	-0.713**	0.259	0.379	-0.018	0.127	-0.333
5	Straw yield ha^{-1} (X_5)	-0.400	0.719**	-0.709**	0.057	0.668**	-0.002	0.011	-0.341
6	Harvest index (X_6)	-0.291	0.357	-0.352	0.810**	-0.855**	-0.079	0.489*	-0.134
7	Number of days to physiological maturity (X_7)	-0.901**	0.482*	-0.273	0.526*	-0.350	0.741**	0.566*	-0.660**
8	Productivity day^{-1} (X_8)	-0.227	0.690**	-0.761**	0.134	0.540*	-0.252	-0.036	-0.204
9	Productivity plant^{-1} (X_9)	-0.430	0.731**	-0.713**	0.259	0.379	-0.018	0.127	-0.333
10	Number of grains panicle^{-1} (X_{10})	-0.973**	0.328	-0.315	0.321	-0.240	0.780**	0.225	-0.818**
11	1000 grain weight (X_{11})	**1.000**	-0.351	0.362	-0.274	0.197	-0.970**	-0.255	0.832**
12	Density of grain (X_{12})	-0.243	**1.000**	-0.319	-0.041	0.506*	0.085	0.140	0.023
13	Milling percentage (X_{13})	0.268	-0.268	**1.000**	0.063	-0.481*	-0.020	0.171	0.527*
14	Amylose content (X_{14})	-0.246	-0.068	0.052	**1.000**	-0.801**	0.154	0.704**	0.065
15	Kernel elongation ratio (X_{15})	0.044	0.184	-0.251	-0.332	**1.000**	-0.219	-0.735**	0.020
16	Volume expansion ratio (X_{16})	-0.655**	0.110	-0.015	0.068	0.050	**1.000**	0.360	-0.696**
17	Alkali spreading value (X_{17})	-0.160	0.126	0.157	0.657**	-0.433	0.267	**1.000**	0.049
18	Head rice recovery (X_{18})	0.683**	-0.045	0.506*	0.105	0.172	-0.528*	0.053	**1.000**

* Significant at 5% level

** Significant at 1% level

Table 18. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice cultures at Chittoor (*kharif, 2003*)

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**1.000**	0.437	0.842**	0.366	0.764**	-0.530*	0.839**	-0.158	0.366	0.739**
2	Productive tillers plant^{-1} (X_2)	0.378	**1.000**	0.738**	0.300	0.540*	-0.261	0.772**	-0.188	0.330	0.471*
3	Plant height (X_3)	0.801**	0.642**	**1.000**	0.442	0.832**	-0.453	0.990**	-0.180	0.442	0.795**
4	Grain yield ha^{-1} (X_4)	0.264	0.181	0.383	**1.000**	0.856**	0.646**	0.310	0.803**	1.000**	0.415
5	Straw yield ha^{-1} (X_5)	0.487*	0.272	0.602**	0.833**	**1.000**	0.164	0.786**	0.362	0.856**	0.904**
6	Harvest index (X_6)	-0.352	-0.129	-0.314	0.374	-0.192	**1.000**	-0.635**	1.043**	0.646**	-0.592**
7	Number of days to physiological maturity (X_7)	0.808**	0.639**	0.955**	0.284	0.569**	-0.430	**1.000**	-0.317	0.310	0.841**
8	Productivity day^{-1} (X_8)	-0.177	-0.173	-0.136	0.850**	0.528*	0.608**	-0.263	**1.000**	0.803**	-0.113
9	Productivity plant^{-1} (X_9)	0.264	0.181	0.383	1.000**	0.833**	0.347	0.284	0.850**	**1.000**	0.415
10	Number of grains panicle^{-1} (X_{10})	0.718**	0.380	0.762**	0.332	0.639**	-0.451	0.807**	-0.107	0.332	**1.000**
11	1000 grain weight (X_{11})	-0.376	-0.009	-0.382	-0.274	-0.413	0.153	-0.405	-0.055	-0.274	-0.702**
12	Density of grain (X_{12})	-0.518*	0.010	-0.344	-0.115	-0.389	0.394	-0.372	0.088	-0.115	-0.530*
13	Milling percentage (X_{13})	-0.770**	-0.214	-0.551*	-0.290	-0.435	0.219	-0.535*	0.001	-0.290	-0.333
14	Amylose content (X_{14})	0.028	0.018	0.074	-0.488*	-0.333	-0.390	0.098	-0.541*	-0.487*	-0.092
15	Kernel elongation ratio (X_{15})	0.186	0.020	0.211	-0.159	-0.022	-0.283	0.278	-0.312	-0.159	0.016
16	Volume expansion ratio (X_{16})	0.082	0.108	0.190	0.498*	0.347	0.335	0.124	0.428	0.498*	0.245
17	Alkali spreading value (X_{17})	0.310	0.568**	0.468*	0.010	0.148	-0.175	0.465	-0.247	0.010	0.437
18	Head rice recovery (X_{18})	-0.007	0.103	0.047	0.541*	0.334	0.450	-0.062	0.577*	0.541*	-0.155

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

Contd...

Table 18. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice cultures at Chittoor (*kharif, 2003*)

Sl no	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
1	Days to 50 % flowering (X_1)	-0.427	-0.602**	-0.884**	0.059	0.268	0.093	0.302	-0.023
2	Productive tillers plant^{-1} (X_2)	-0.092	0.081	-0.118	0.053	0.024	-0.030	0.664**	0.217
3	Plant height (X_3)	-0.452	-0.412	-0.625**	0.077	0.362	0.398	0.496*	0.054
4	Grain yield ha^{-1} (X_4)	-0.285	-0.072	-0.291*	-0.686**	-0.332	0.985**	0.013	0.670**
5	Straw yield ha^{-1} (X_5)	-0.608**	-0.355	-0.532*	-0.550*	0.008	0.947**	0.275	0.416
6	Harvest index (X_6)	0.353	0.303	0.259	-0.609**	-0.698**	0.571*	-0.366	0.751**
7	Number of days to physiological maturity (X_7)	-0.421	-0.436	-0.596**	0.110	0.352	0.209	0.504*	-0.039
8	Productivity day^{-1} (X_8)	-0.019	0.201	0.079	-0.753**	-0.544*	0.857**	-0.307	0.692**
9	Productivity plant^{-1} (X_9)	-0.285	-0.072	-0.291	-0.686**	-0.332	0.985**	0.013	0.669**
10	Number of grains panicle^{-1} (X_{10})	-0.790**	-0.585**	-0.405	-0.075	0.040	0.318	0.444	-0.197
11	1000 grain weight (X_{11})	**1.000**	0.663**	0.111	0.116	0.252	-0.584*	-0.610**	0.185
12	Density of grain (X_{12})	0.527*	**1.000**	0.609**	0.384	0.182	-0.241	-0.296	-0.002
13	Milling percentage (X_{13})	0.065	0.568*	**1.000**	0.178	-0.355	-0.112	-0.023	-0.333
14	Amylose content (X_{14})	0.095	0.354	0.137	**1.000**	0.561*	-0.633**	0.120	-0.746**
15	Kernel elongation ratio (X_{15})	0.168	0.104	-0.347	0.518*	**1.000**	-0.264	-0.085	-0.097
16	Volume expansion ratio (X_{16})	-0.382	-0.264	-0.202	-0.474*	0.090	**1.000**	0.250	0.786**
17	Alkali spreading value (X_{17})	-0.532	-0.220	-0.023	0.094	-0.072	0.212	**1.000**	0.062
18	Head rice recovery (X_{18})	0.132	-0.037	-0.239	-0.653**	-0.100	0.466	0.051	**1.000**

*- Significant at 5% level

**- Significant at 1% level

Table 19. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice genotypes at Chittoor (*rabi,* 2003).

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
1	Plant height (X_1)	**1.000**	-0.142	0.081	0.024	0.081	0.070	0.087	0.238	0.026	0.170	-0.450
2	Days to 50 % flowering (X_2)	-0.152	**1.000**	0.374	0.938**	0.374	0.246	-0.323	0.273	-0.261	-0.046	0.238
3	Grain yield ha^{-1} (X_3)	0.083	0.338	**1.000**	0.370	1.000	0.484*	0.518*	0.729**	0.169	0.298	0.376
4	Number of days to physiological maturity (X_4)	0.004	0.857**	0.343	**1.000**	0.370	0.190	-0.154	0.269	-0.349	0.213	0.084
5	Productivity plant^{-1} (X_5)	0.083	0.339	1.000	0.343	**1.000**	0.484*	0.518	0.729**	0.161	0.298	0.375
6	Amylose content (X_6)	0.029	0.167	0.396	0.228	0.396	**1.000**	0.034	0.423	0.323	0.042	-0.069
7	Milling percentage (X_7)	0.068	-0.253	0.502*	-0.132	0.502*	0.043	**1.000**	0.403	0.538*	0.660**	0.402
8	Kernel elongation ratio (X_8)	0.181	0.147	0.547*	0.181	0.547*	0.302	0.302	**1.000**	-0.070	0.242	-0.087
9	Volume expansion ratio (X_9)	0.064	-0.204	0.139	-0.300	0.138	0.129	0.433	0.019	**1.000**	0.321	0.666**
10	Alkali spreading value (X_{10})	0.142	-0.033	0.286	0.171	0.286	0.020	0.644**	0.147	0.244	**1.000**	0.320
11	Head rice recovery (X_{11})	-0.423	0.192	0.310	0.041	0.309	-0.069	0.376	-0.059	0.564**	0.298	**1.000**

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

At Mathur (Table 17), significant positive genotypic correlation of grain yield was observed with days to 50 per cent flowering, plant height, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity day $^{-1}$, productivity $plant^{-1}$, number of grains $panicle^{-1}$ and density of grain. Milling percentage exhibited high significant negative correlation (-0.713) with grain yield.

Significant positive phenotypic correlation of grain yield was observed with straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity day $^{-1}$, productivity $plant^{-1}$, number of grains panicle $^{-1}$ and density of grain. Milling percentage exhibited high significant negative correlation (-0.645) with yield.

At Chittoor (*kharif*, 2003) grain yield had significant positive correlation with straw yield, harvest index, productivity day^{-1}, productivity $plant^{-1}$, volume expansion ratio and head rice recovery (Table 18). Amylose content exhibited significant negative correlation (-0.686) with grain yield. Straw yield, productivity day $^{-1}$ and volume expansion ratio had significant positive phenotypic correlation with grain yield.

At Chittoor in the case of F_1 and F_2 generations (*rabi*, 2003) productivity $plant^{-1}$ and kernel elongation ratio (0.729) alone had positive significant correlation with grain yield. None of the characters studied had significant phenotypic correlation with grain yield (Table 19).

4.4 PATH ANALYSIS

Path analysis was carried out to measure the direct and indirect contribution of various independent characters on the dependent character, yield.

At Mullakkara (Table 20) the estimates of path coefficients for 14 component characters indicated that, maximum positive direct effect on grain yield was shown by straw yield (0.706) followed by days to 50 per cent flowering (0.673) while number of days to physiological maturity had maximum negative direct effect (-0.620).

Table 20. Direct and indirect effect of 14 characters on grain yield at Mullakkara, Thrissur (*kharif*, 2003)

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**0.673**	0.002	0.284	0.478	-0.558	0.053	-0.013	-0.104	-0.057	0.023
2	Productive tillers plant^{-1} (X_2)	0.014	**-0.086**	-0.158	-0.270	-0.031	0.024	-0.008	0.043	0.014	-0.011
3	Plant height (X_3)	0.535	0.038	**0.357**	0.647 -	-0.599	0.015	-0.009	-0.087	-0.044	0.007
4	Straw yield ha^{-1} (X_4)	0.456	0.033	0.327	**0.706**	-0.424	0.013	-0.002	-0.057	-0.036	0.017
5	Number of days to physiological maturity (X_5)	0.606	-0.004	0.345	0.483	**-0.620**	0.040	-0.011	-0.099	-0.044	0.015
6	Number of grains panicle^{-1} (X_6)	0.356	-0.020	0.055	0.088	-0.246	**0.100**	-0.005	-0.053	-0.005	0.024
7	1000 grain weight (X_7)	0.387	0.030	-0.134	-0.065	0.301	-0.019	**0.023**	0.103	0.055	0.001
8	Density of grain (X_8)	0.521	0.027	0.232	0.300	-0.459	0.040	-0.018	**-0.134**	-0.061	0.008
9	Milling percentage (X_9)	0.534	-0.017	-0.218	-0.353	0.380	-0.007	0.018	0.115	**0.072**	-0.002
10	Amylose content (X_{10})	0.324	0.020	0.052	0.261	-0.203	0.051	0.000	-0.023	-0.004	**0.047**
11	Kernel elongation ratio (X_{11})	0.289	-0.026	0.098	0.080	-0.007	-0.043	0.013	0.090	0.053	-0.010
12	Volume expansion ratio (X_{12})	0.041	-0.022	0.198	0.283	-0.254	0.016	-0.002	0.016	0.014	-0.014
13	Alkali spreading value (X_{13})	0.320	0.023	-0.292	-0.464	0.458	0.018	0.002	0.024	0.019	-0.004
14	Head rice recovery (X_{14})	0.396	-0.007	-0.160	-0.211	0.333	-0.067	0.003	0.039	0.018	-0.008

Contd....

Table 20. Direct and indirect effect of 14 characters on grain yield at Mullakkara, Thrissur (*kharif*, 2003)

Sl. No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	RG
1	Days to 50 % flowering (X_1)	-0.040	0.016	-0.056	-0.109	0.592
2	Productive tillers plant^{-1} (X_2)	0.028	0.071	-0.032	0.015	-0.387
3	Plant height (X_3)	0.026	0.151	-0.097	-0.083	0.21
4	Straw yield ha^{-1} (X_4)	0.011	0.109	-0.078	-0.055	1.02
5	Number of days to physiological maturity (X_5)	0.001	0.111	-0.088	-0.099	0.636
6	Number of grains panicle^{-1} (X_6)	-0.040	0.043	0.021	-0.124	0.247
7	1000 grain weight (X_7)	0.052	-0.026	0.012	0.020	0.74
8	Density of grain (X_8)	-0.063	-0.032	-0.021	-0.054	0.286
9	Milling percentage (X_9)	0.069	0.052	0.031	0.046	0.72
10	Amylose content (X_{10})	-0.019	-0.083	-0.010	-0.032	0.381
11	Kernel elongation ratio (X_{11})	**0.093**	0.258	-0.077	0.036	0.847
12	Volume expansion ratio (X_{12})	0.089	**0.271**	-0.069	-0.076	0.491
13	Alkali spreading value (X_{13})	-0.060	-0.157	**0.119**	0.010	0.016
14	Head rice recovery (X_{14})	0.018	-0.111	0.006	**0.185**	0.434

Table 21. Direct and indirect effect of 14 characters on grain yield at Mathur (*Kharif*, 2003).

Sl. No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	RG
1	Days to 50 % flowering (X_1)	0.029	0.014	-0.086	-0.174	0.718
2	Productive tillers plant^{-1} (X_2)	-0.072	0.017	-0.007	-0.092	0.375
3	Plant height (X_3)	-0.021	0.008	-0.035	-0.093	0.805
4	Straw yield ha^{-1} (X_4)	-0.045	0.000	-0.002	-0.116	0.961
5	Number of days to physiological maturity(X_5)	0.024	0.019	-0.086	-0.225	0.636
6	Number of grains panicle^{-1} (X_6)	0.016	0.019	-0.034	-0.279	0.549
7	1000 grain weight (X_7)	-0.013	-0.024	0.039	0.284	0.281
8	Density of grain (X_8)	-0.034	0.002	-0.021	0.008	0.732
9	Milling percentage (X_9)	0.032	0.000	-0.026	0.180	-0.406
10	Amylose content (X_{10})	0.054	0.004	-0.107	0.022	0.259
11	Kernel elongation ratio (X_{11})	**-0.067**	-0.005	0.112	0.007	0.789
12	Volume expansion ratio (X_{12})	0.015	**0.025**	-0.055	-0.237	-0.017
13	Alkali spreading value (X_{13})	0.050	0.009	**-0.153**	0.017	0.127
14	Head rice recovery (X_{14})	-0.001	-0.017	-0.008	**0.341**	0.152

Table 21. Direct and indirect effect of 14 characters on grain yield at Mathur (*kharif*, 2003).

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**0.476**	-0.012	0.065	0.465	-0.111	0.135	-0.037	-0.115	0.062	0.007
2	Productive tillers plant^{-1} (X_2)	0.150	**-0.037**	0.092	0.368	-0.042	0.064	-0.007	-0.056	0.000	-0.003
3	Plant height (X_3)	0.346	-0.038	**0.090**	0.588	-0.074	0.091	-0.019	-0.109	0.068	0.003
4	Straw yield ha^{-1} (X_4)	0.270	-0.017	0.064	**0.821**	-0.068	0.070	-0.020	-0.134	0.137	0.001
5	Number of days to physiological maturity(X_5)	0.446	-0.013	0.056	0.466	**-0.119**	0.142	-0.045	-0.090	0.053	0.008
6	Number of grains panicle^{-1} (X_6)	0.413	-0.015	0.053	0.373	-0.109	**0.155**	-0.048	-0.061	0.061	0.005
7	1000 grain weight (X_7)	0.356	0.005	-0.034	-0.328	0.107	-0.151	**0.049**	0.065	-0.070	-0.004
8	Density of grain (X_8)	0.294	-0.011	0.053	0.590	-0.057	0.051	-0.017	**-0.186**	0.061	-0.001
9	Milling percentage (X_9)	0.153	0.000	-0.032	-0.582	0.033	-0.049	0.018	0.059	**-0.193**	0.001
10	Amylose content (X_{10})	0.228	0.008	0.019	0.047	-0.063	0.050	-0.014	0.008	-0.012	**0.015**
11	Kernel elongation ratio (X_{11})	0.204	-0.040	0.028	0.548	0.042	-0.037	0.010	-0.094	0.093	-0.012
12	Volume expansion ratio (X_{12})	0.259	-0.025	0.027	-0.001	-0.088	0.121	-0.048	-0.016	0.004	0.002
13	Alkali spreading value (X_{13})	0.270	-0.002	0.021	0.009	-0.067	0.035	-0.013	-0.026	-0.033	0.010
14	Head rice recovery (X_{14})	0.242	0.010	-0.024	-0.279	0.079	-0.127	0.041	-0.004	-0.102	0.001

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Table 22. Direct and indirect effect of 14 characters on grain yield at Chittoor (*kharif*, 2003)

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Days to 50 % flowering (X_1)	**0.644**	0.072	0.441	0.609	-0.261	-0.739	0.134	-0.166	-0.223	-0.020
2	Productive tillers plant^{-1} (X_2)	0.282	**0.164**	0.387	0.430	-0.240	-0.471	0.029	0.022	-0.030	-0.018
3	Plant height (X_3)	0.542	0.121	**0.524**	0.662	-0.308	-0.795	0.142	-0.114	-0.157	-0.027
4	Straw yield ha^{-1} (X_4)	0.492	0.089	0.436	**0.796**	-0.244	-0.905	0.192	-0.098	-0.134	0.189
5	Number of days to physiological maturity (X_5)	0.540	0.127	0.519	0.626	**-0.311**	-0.841	0.133	-0.121	-0.150	-0.038
6	Number of grains panicle^{-1} (X_6)	0.476	0.077	0.417	0.720	-0.261	**-1.000**	0.249	-0.162	-0.102	0.026
7	1000 grain weight (X_7)	0.275	-0.015	-0.237	-0.484	0.131	0.791	**-0.315**	0.183	0.028	-0.040
8	Density of grain (X_8)	0.388	0.013	-0.216	-0.282	0.136	0.585	-0.209	**0.276**	0.153	-0.132
9	Milling percentage (X_9)	0.569	-0.019	-0.328	-0.423	0.185	0.405	-0.035	0.168	**0.252**	-0.061
10	Amylose content (X_{10})	0.038	0.009	0.041	-0.438	-0.034	0.075	-0.036	0.106	0.045	**-0.344**
11	Kernel elongation ratio (X_{11})	0.173	0.004	0.190	0.006	-0.109	-0.040	-0.079	0.050	-0.089	-0.193
12	Volume expansion ratio (X_{12})	0.060	-0.005	0.209	0.754	-0.065	-0.319	0.184	-0.067	-0.028	0.218
13	Alkali spreading value (X_{13})	0.194	0.109	0.260	0.219	-0.157	-0.444	0.192	-0.082	-0.006	-0.041
14	Head rice recovery (X_{14})	0.015	0.036	0.029	0.332	0.012	0.197	-0.058	-0.001	-0.084	0.257

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Table 22. Direct and indirect effect of 14 characters on grain yield at Chittoor (*kharif*, 2003)

Sl. No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	RG
1	Days to 50 % flowering (X_1)	-0.062	0.021	-0.089	0.005	0.366
2	Productive tillers plant^{-1} (X_2)	-0.005	-0.007	-0.196	-0.047	0.3
3	Plant height (X_3)	-0.083	0.091	-0.146	-0.012	0.44
4	Straw yield ha^{-1} (X_4)	-0.002	0.216	-0.081	-0.091	0.855
5	Number of days to physiological maturity (X_5)	-0.081	0.048	-0.148	0.008	0.311
6	Number of grains panicle^{-1} (X_6)	-0.009	0.073	-0.131	0.043	0.416
7	1000 grain weight (X_7)	-0.058	-0.134	0.180	-0.040	0.265
8	Density of grain (X_8)	-0.042	-0.055	0.087	0.001	0.703
9	Milling percentage (X_9)	0.081	-0.026	0.007	0.072	0.847
10	Amylose content (X_{10})	-0.129	-0.145	-0.035	0.162	-0.685
11	Kernel elongation ratio (X_{11})	**-0.229**	-0.060	0.025	0.021	-0.33
12	Volume expansion ratio (X_{12})	0.061	**0.229**	-0.074	-0.171	0.986
13	Alkali spreading value (X_{13})	0.020	0.057	**-0.295**	-0.014	0.012
14	Head rice recovery (X_{14})	0.022	0.180	-0.018	**-0.218**	0.701

Table 23. Direct and indirect effect of nine characters on grain yield at Chittoor (*rabi,* 2003).

Sl. No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Rg
1	Plant height (X_1)	**6.678**	-0.562	0.083	-0.612	-0.188	1.077	0.414	0.162	6.386	13.438
2	Days to 50 % flowering (X_2)	0.949	**3.950**	3.302	-2.150	0.698	1.234	-4.182	-0.044	-3.383	0.374
3	Number of days to physiological maturity (X_3)	-0.157	3.706	**3.520**	-1.660	0.333	1.217	-5.602	0.204	-1.189	0.372
4	Amylose content (X_4)	-0.469	0.973	0.670	**-8.725**	-0.073	1.912	5.179	0.040	0.978	0.485
5	Milling percentage (X_5)	-0.582	-1.277	-0.543	-0.296	**-2.159**	1.819	8.632	0.630	-5.706	0.518
6	Kernel elongation ratio (X_6)	-1.592	1.079	0.948	-3.692	-0.869	**4.518**	-1.126	0.231	1.233	0.73
7	Volume expansion ratio (X_7)	-0.172	-1.030	-1.230	-2.818	-1.162	-0.317	**16.034**	0.307	-9.449	0.163
8	Alkali spreading value (X_8)	-1.133	-0.183	0.750	-0.370	-1.425	1.093	5.147	**0.955**	-4.537	0.297
9	Head rice recovery (X_9)	3.006	0.942	0.295	0.601	-0.868	-0.393	10.677	0.305	**-14.190**	0.375

Days to 50 per cent flowering exhibited high indirect effect on grain yield through plant height, straw yield, number of days to physiological maturity, density of grain and milling percentage (Table 20). Days to 50 per cent flowering, plant height, straw yield ha^{-1} and 1000 grain weight exerted high negative indirect effect on grain yield through number of days to physiological maturity.

At Mathur (Table 21), among the component characters involved, straw yield had high direct effect (0.821) on grain yield followed by days to 50 per cent flowering (0.476).

Productive tillers plant^{-1}, plant height, number of days to physiological maturity, number of grains panicle^{-1}, 1000 grain weight, milling percentage, kernel elongation ratio and head rice recovery had high indirect effect on grain yield through days to 50 per cent flowering, head rice recovery and straw yield. Straw yield ha^{-1} had high indirect effect on grain yield through days to 50 per cent flowering. Straw yield and head rice recovery had high negative indirect effect through milling percentage (Table 21).

At Chittoor, straw yield (0.796) followed by days to 50 per cent flowering (0.644) had high direct positive effect on grain yield among 14 component characters involved in path analysis (Table 22).

Analysis of indirect effects of yield contributing characters showed that, productive tillers plant^{-1}, 1000 grain weight, grain density, milling percentage, kernel elongation ratio, volume expansion ratio and alkali spreading value had high indirect effect on grain yield through straw yield, days to 50 per cent flowering, productive tillers plant^{-1} and number of days to physiological maturity. Days to 50 per cent flowering, plant height, straw yield ha^{-1} and number of grains panicle^{-1} and density of grain had indirect effect through milling percentage (Table 22).

During *rabi*, volume expansion ratio exhibited maximum positive direct effect (16.034) on grain yield followed by plant height (6.678) and kernel elongation ratio (4.518) at Chittoor (Table 23).

Head rice recovery had high positive indirect effect (10.677) on grain yield through volume expansion ratio, while volume expansion ratio exhibited high negative indirect effect (-9.449) on grain yield through head rice recovery. Head rice recovery exhibited the highest negative direct effect (-14.19) on grain yield. All the yield component characters exhibited high indirect effect on grain yield through volume expansion ratio and head rice recovery.

4.5 GENOTYPE X ENVIRONMENT INTERACTION

4.5.1 Pooled ANOVA

The analysis of variance of genotypes in relation to the environment was carried out using seven hybrids and two check varieties at Mullakkara, Mathur and Chittoor. Pooled analyses of variance for 18 characters in nine genotypes are shown in Table 24.

It was found that, days to 50 per cent flowering, plant height, grain yield ha^{-1}, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity $plant^{-1}$, number of grains $panicle^{-1}$, 1000 grain weight, milling percentage, amylose content and head rice recovery showed significant difference among genotypes tested. With respect to variance due to environment, productive tillers $plant^{-1}$, plant height, grain yield ha^{-1}, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity $plant^{-1}$, number of grains $panicle^{-1}$, density of grain, milling percentage and alkali spreading value showed significant difference. Genotype x environment (G X E) component was found significant for days to 50 per cent flowering, plant height, grain yield ha^{-1}, productivity day^{-1}, productivity $plant^{-1}$, number of grains $panicle^{-1}$, density of grain, amylose content, kernel elongation ratio and alkali spreading value. G X E (linear) was significant for days to 50 per cent flowering and number of grains panicle $^{-1}$ indicating that the significant difference among genotypes for these characters was due to linear response to environments.

Table 24. Pooled analysis of variance for yield and yield attributing characters at three locations during *kharif*, 2003.

Sl. No.	Characters	Mean sum of squares of					
		Genotypes	Environments	G x E	ENV (linear)	G x E (linear)	Pooled deviation
1	Days to 50 % flowering	98.06**	10.74	7.48**	21.49*	10.68*	3.81**
2	Productive tillers plant^{-1}	1.74	34.35**	0.834	68.7*	1.094	0.509
3	Plant height (cm)	218.47**	557.19**	16.98**	111.32**	23.21	9.569**
4	Grain yield ha^{-1} (kg)	1501687*	1537159.7*	400911.1**	3074530.5*	357127.2	395261**
5	Straw yield ha^{-1} (kg)	1350870**	4444630.6**	240296.5	8889155.4**	194286.6	254506.3**
6	Harvest index	0.000089**	0.00146*	0.000199	0.00292**	0.000196	0.00018*
7	Number of days to harvest	130.75**	24.72*	5.09	49.41**	5.11	4.496**
8	Productivity day^{-1} (g)	55.38	80.36	28.12**	160.72*	24.24	28.44**
9	Productivity plant^{-1} (g)	13.78*	14.12*	3.68**	28.23*	3.28	3.63**
10	Number of grains panicle^{-1}	3540.99**	4482.48**	2378.71**	8965.31**	412.59**	566.097**
11	1000 grain weight (g)	11.6**	3.52	1.74	7.04	1.61	1.66**
12	Density of grain (g/m^3)	0.00913	0.06212*	0.0142**	0.1242**	0.01763	0.00952**
13	Head rice recovery (%)	65.6*	32.11	24.42**	64.18	24.45	21.68**
14	Milling percentage	82.98**	21.18**	2.143	42.33**	0.3979	3.458**
15	Amylose content (%)	37.24**	0.165	5.45*	0.333	5.24	5.03**
16	Kernel elongation ratio	0.0124	0.0125	0.00721	0.0250	0.00839	0.00537*
17	Volume expansion ratio	0.166	0.212	0.0825	0.424*	0.0956	0.0316*
18	Alkali spreading value	0.636	0.0270*	0.565**	0.541	0.251	0.783**

* Significant at 5% level

** Significant at 1% level

4.5.2 Stability for yield and yield contributing characters

The significance of G X E interaction indicated the importance for estimating the stability parameters. The stability parameters like mean, regression coefficient and mean square deviation for each character are presented in Table 25.

4.5.2.1 Days to 50 per cent flowering

Stability parameters for this character revealed that the standard check Jyothy had lowest number of days for 50 per cent flowering (87.89) with regression coefficient of 1.04 and mean square deviation of 14.68. Among hybrids, ADTRH-1 recorded mean value of 97.33 with regression coefficient 1.82 and mean deviation of –0.31.

4.5.2.2 Productive tillers plant^{-1}

The hybrid KRH-2 had the maximum mean value of 10.98 with regression coefficient of 1.40 and mean square deviation of 0.91. DRRH-1 had a mean of 10.04 productive tillers plant^{-1} with a regression coefficient of 1.09 and a low mean square deviation of 0.90. The check variety Jyothy had a mean of 10.36 with a regression coefficient of 1.10 and mean square deviation of –0.29.

4.5.2.3 Plant height

The hybrid ADTRH-1 recorded lowest mean plant height (101.09 cm) among hybrids with regression coefficient of 1.09 and mean deviation of 6.11. CORH-2 had a mean value of 102.5 cm with regression coefficient of 1.17 and mean deviation of –1.56. Check variety Jyothy had mean value of 95.22 cm with regression coefficient of 0.54 and mean deviation of 37.23.

Table 25. Analysis of G x E interaction in rice hybrids in 18 characters at three locations (*kharif*, 2003).

Genotypes	Days to 50 % flowering			Productive tillers plant^{-1}			Plant height		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
ADTRH–1	97.33	1.82	-0.31	10.96	0.82	-0.14	101.09	1.09	6.11
CORH–2	99.22	1.53	-0.75	9.82	0.98	-0.28	102.5	1.17	-1.56
KRH-2	102.22	3.51	-0.21	10.98	1.40	0.91	116.13	1.63	17.17
DRRH-1	102.78	0.46	-1.01	10.04	1.09	0.90	102.78	0.93	10.65
PHB-71	101.22	-0.60	0.85	10.11	1.26	-0.18	109.27	0.99	0.99
PA-6201	102.67	2.44	-1.02	10.64	0.27	-0.17	105.98	1.46	0.41
NSD–2	101.44	-3.64	11.88	9.68	1.40	-0.30	105.76	0.96	-2.00
LOCAL VARIETY	89.44	-0.60	0.85	8.51	0.60	1.30	85.96	0.21	-1.90
JYOTHY	87.89	1.04	14.68	10.36	1.18	-0.29	95.22	0.54	37.23

Genotypes	Grain yield ha^{-1}			Straw yield ha^{-1}			Harvest index		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
ADTRH–1	5812.5	1.86	1547768.38	5599	1.45	1282563	0.49	1.72	0
CORH–2	5480.21	-0.17	110009.48	5747.22	0.81	-57796.52	0.49	1.50	0
KRH-2	6931.27	-0.54	-30050.65	6946.44	0.18	-43800	0.50	1.00	0
DRRH-1	5431.09	0.73	185984.17	5904.56	1.08	76268.1	0.48	1.16	0
PHB-71	6296.78	0.56	240938.47	6773.22	1.35	450238.69	0.48	2.04	0
PA-6201	5893.96	2.44	778884.88	6101.22	1.54	1997.66	0.49	-0.58	0
NSD–2	6764.52	0.52	82144.01	6969.56	0.51	-47701.27	0.49	0.95	0
LOCAL VARIETY	4940.68	1.89	-30291.62	5191	1.09	-54210.87	0.49	0.35	0
JYOTHY	5039.18	1.71	398960.78	5277	0.99	160266.84	0.49	0.86	0

Contd..

Table 25. Analysis of G x E interaction in rice hybrids in 18 characters at three locations (*kharif*, 2003).

Genotypes	Number of days to harvest			Productivity day^{-1}			Productivity plant^{-1}		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
ADTRH–1	125.22	1.06	8.98	46.36	1.33	119.19	17.61	1.86	14.21
CORH–2	127.22	0.93	6.56	43.10	-0.37	7.30	16.61	-0.17	1.01
KRH-2	131.56	1.94	5.77	52.71	-0.362	3.52	21.00	-0.54	-0.28
DRRH-1	129	0.13	1.42	42.10	0.79	6.55	16.46	0.73	1.71
PHB-71	130.33	1.79	2.89	48.37	0.62	27.22	19.08	0.56	2.21
PA-6201	127.44	1.10	1.34	46.29	2.80	42.11	17.86	2.44	7.16
NSD–2	124.56	1.81	1.88	54.29	0.35	-0.61	20.50	0.52	0.76
LOCAL VARIETY	112.56	-1.10	1.34	43.94	2.36	4.46	14.97	1.89	-0.28
JYOTHY	115.22	1.34	0.12	43.68	1.73	29.95	15.27	1.71	3.66

Genotypes	Number of grains panicle^{-1}			1000 grain weight			Density of grain		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
ADTRH–1	217.62	1.03	129.82	22.83	-0.41	4.70	0.82	-0.13	0
CORH–2	210.93	-0.01	-14.38	23.01	0.25	-0.36	0.87	2.19	0
KRH-2	176.99	1.29	55.61	26.02	0.00	-0.38	0.99	0.07	0
DRRH-1	190.53	0.48	7.09	23.84	-1.39	-0.54	0.95	1.22	0
PHB-71	185.84	2.16	52.98	22.03	1.66	2.27	0.94	1.96	0.04
PA-6201	192.51	1.59	19.72	21.34	1.60	1.28	0.91	2.21	0.02
NSD–2	175.29	1.14	49.48	24.24	2.73	1.64	0.87	1.92	0
LOCAL VARIETY	122.04	0.65	67.79	26.44	2.55	0.29	0.87	-0.66	0
JYOTHY	121.18	0.68	-14.44	26.76	2.01	0.96	0.87	0.22	0

Contd.

Table 25. Analysis of G x E interaction in rice hybrids in 18 characters at three locations (*kharif*, 2003).

Genotypes	Head rice recovery			Milling percentage			Amylose content		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
ADTRH–1	71.07	2.48	22.67	63.48	1.19	-1.35	21.29	-0.95	5.91
CORH–2	73.81	-1.15	50.40	59.08	0.65	0.62	29.46	28.12	5.56
KRH-2	79.73	-0.06	-0.66	58.81	1.18	0.82	26.72	1.35	-0.03
DRRH-1	70.87	0.12	32.99	55.27	1.31	-0.96	26.11	-9.94	16.71
PHB-71	76.99	1.86	15.72	52.89	1.29	13.17	21.44	-3.74	5.24
PA-6201	77.75	3.59	4.86	53.04	0.81	9.64	21.83	2.81	-0.32
NSD–2	75.17	3.31	1.18	48.37	1.16	-0.58	21.09	3.57	7.14
LOCAL VARIETY	81.94	-1.25	54.22	63.02	0.88	0.05	24.64	-14.54	-0.22
JYOTHY	84.70	0.10	-1.48	62.13	0.53	-1.19	18.24	2.28	1.16

	Kernel elongation ratio			Volume expansion ratio			Alkali spreading value		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
	1.41	-1.20	0	5.81	0.46	-0.02	3.82	-3.45	0.02
	1.38	1.38	0	5.28	-0.67	0.07	4.16	2.67	0.46
	1.51	-1.68	0	5.50	1.07	0.05	3.63	13.25	1.41
	1.39	2.41	0.01	5.32	-0.47	0.28	4.73	6.04	0.04
	1.55	1.76	0	5.72	1.02	0.02	3.32	-1.58	0.26
	1.37	1.86	0	5.59	3.43	-0.02	4.09	-9.47	1.67
	1.38	3.76	0	5.32	1.60	-0.02	3.24	2.20	0.98
	1.41	0.73	0	5.06	2.79	0.00	3.57	2.34	1.88
	1.47	-0.01	0.02	5.47	-0.23	-0.01	3.71	-3.00	0.14

4.5.2.4 Grain yield ha^{-1}

Mean grain yield was maximum (6931.27 kg) for KRH-2 with a regression coefficient of –0.54 and deviation of –30050.65. Hybrid NSD-2 gave a mean value of 6764.52 with a regression coefficient of 0.52. Standard check Jyothy had a mean value of 5039.18 and regression coefficient of 1.71.

4.5.2.5 Straw yield ha^{-1}

Hybrid NSD-2 recorded maximum straw yield (6969.56 kg) with a regression coefficient of 0.51 and mean square deviation of –47701.27. The hybrid PA-6201 had a mean value of 6101.22 with regression coefficient of 1.54 and low mean square deviation of 1997.66.

4.5.2.6 Harvest index

The hybrid KRH-2 recorded mean value of 0.50 with regression coefficient unity and zero mean square deviation. All the genotypes had recorded zero mean square deviation and regression coefficient near unity.

4.5.2.7 Number of days to physiological maturity

Among hybrids, NSD- 2 had recorded lowest number of days to physiological maturity (124.56) among hybrids with a regression coefficient of 1.81 and mean square deviation of 1.88. PA-6201 recorded a regression coefficient near unity (1.08) and low mean square deviation (1.34).

4.5.2.8 Productivity day^{-1}

Productivity day^{-1} was highest (54.29 g) for hybrid NSD- 2 followed by KRH-2 (52.71g). The corresponding regression coefficients were 0.35 and –0.36 respectively.

4.5.2.9 Productivity plant^{-1}

Among the genotypes KRH-2 recorded the highest mean productivity plant^{-1} (21.00 g) with a regression coefficient of -0.54 and deviation of –0.28. Hybrid NSD-2 had a mean value of 20.5 g with regression coefficient of 0.52 and deviation 0.76. Jyothy had a mean value of 15.27 g with regression coefficient of 1.71 and 3.66 mean square deviation.

4.5.2.10 Number of grains panicle^{-1}

Maximum number of grains panicle^{-1} (217.62) was observed for the hybrid ADTRH-1 with a regression coefficient of 1.03. The hybrid DRRH-1 recorded lowest mean square deviation of 7.09.

4.5.2.11 1000 Grain weight

The standard check variety Jyothy ranked first with respect to 1000 grain weight (26.76 g) followed by local check variety (26.44 g). The corresponding regression coefficients were 2.01, 2.55 respectively with a mean square deviation of 0.96 for both.

4.5.2.12 Density of grain

The mean density of grain was maximum for KRH-2 (0.99) with regression coefficient of 0.07 and mean square deviation of 0. The hybrid PHB-71

Table 26. Standard heterosis (%) of hybrids at Mullakkara, Thrissur (*kharif*, 2003).

Hybrids	Days to 50% flowering	Productive tillers plant^{-1}	Plant height	Number of days to physiological maturity	Grain yield ha^{-1}	Straw yield ha^{-1}	Harvest index	Productivity day^{-1}	Productivity plant^{-1}
ADTRH-1	14.173**	19.16	1.11	5.70**	21.34**	12.7*	2.66	14.68**	21.34**
CORH-2	17.716**	-2.09	1.85	7.78**	14.64**	9.7**	1.33	6.29	14.58**
KRH-2	21.649**	-2.50	12.20**	14.95**	52.57**	44.5**	1.99	32.63**	52.54**
DRRH-1	21.294**	-6.66	4.66	10.37**	5.14	6.3	-1.31	-4.79	5.14
PHB-71	20.822**	-2.50	11.20**	13.48**	24.50**	18.2*	1.99	9.62*	24.51**
PA-6201	21.294**	28.38*	2.80	10.89**	-3.54	3.9	-3.97	-13.10	-3.59
NSD-2	23.184**	-12.50	7.54	8.30**	43.48**	39.9**	0.68	32.35**	43.45**

*- Significant at 5% level
**- Significant at 5% level

Contd…..

Table 26. Standard heterosis (%) of hybrids at Mullakkara, Thrissur (*kharif,* 2003).

Hybrids	Number of grains panicle^{-1}	1000 grain weight	Density of grain	Head rice recovery	Milling percentage	Amylose content	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
ADTRH-1	84.65**	-2.60	-9.12	-18.74	0.20	10.34**	-3.09	3.53	-9.60
CORH-2	103.76**	-9.55	18.58*	-7.85	-5.84	9.46**	-13.82	-5.94	10.39
KRH-2	38.51**	5.00	8.04	-8.01	-6.73	4.51**	2.83	-1.15	-42.40
DRRH-1	72.01**	-2.20	16.83*	-21.94	-13.24	-9.22**	-17.30	-8.17	5.59
PHB-71	25.77**	-19.18	14.97*	-11.64	-15.73	-6.63**	-3.09	2.21	-28.80
PA-6201	46.14**	-14.83	16.06*	-3.15	-17.15	-11.66**	-14.47	-8.10	-19.20
NSD-2	41.41**	-12.11	16.39*	-10.25	-24.73	-6.83**	-18.22	-7.45	-5.62

*- Significant at 5% level

**- Significant at 5% level

had a mean value of 0.95 regression coefficient of 0.88 and a low mean square deviation of 0.05.

4.5.2.13 Head rice recovery

Standard check Jyothy had the highest mean value of 84.70 per cent with regression coefficient of 0.10 and mean square deviation of –1.48. The hybrid PHB-71 has a mean value of 76.99 per cent with regression coefficient of 1.86 and mean deviation of 15.72.

4.5.2.14 Milling percentage

The highest mean for this character was observed in hybrid ADTRH-1 (63.48) followed by local check variety (63.02). The local check variety had a regression coefficient of 0.88 and low (0.05) mean square deviation.

4.5.2.15 Amylose content

The hybrid CORH-2 showed the highest mean value of 29.46 with a regression coefficient of 28.12 and a mean square deviation of 5.56. KRH-2 had recorded second best mean of 26.72 with a regression coefficient 1.35 and low deviation of –0.05.

4.5.2.16 Kernel elongation ratio

Highest kernel elongation ratio was observed in PHB-71 (1.55) followed by KRH-2 (1.51). The hybrid CORH-2 had recorded a regression coefficient of 1.38 and zero mean deviation.

4.5.2.17 Volume expansion ratio

Mean volume expansion ratio was maximum (5.72) with 1.02 regression coefficient and low mean square deviation of 0.02 in case of PHB-71. KRH-2 recorded a mean value of 5.50 with regression coefficient of 1.07 and low deviation of 0.05.

4.5.2.18 Alkali spreading value

Among the nine genotypes tested, DRRH-1 had recorded highest mean of 4.73 with regression coefficient 6.04 and low mean square deviation of 0.04. ADTRH-1 had a mean value of 3.82 and had lowest mean square deviation of 0.02. Standard check variety Jyothy also recorded a low mean square deviation of 0.14.

Genotype x environment interaction showed that, ADTRH-1 was stable for days to 50 per cent flowering, number of grains panicle^{-1}, number of days to physiological maturity and milling percentage whereas CORH-2 was the stable hybrid for traits like kernel elongation ratio and alkali spreading value. KRH-2 was stable for harvest index and amylose content, whereas DRRH-1 for productive tillers plant^{-1}, straw yield ha^{-1}, productivity plant^{-1} and density of grain. The performance of PHB-71 was stable for plant height, volume expansion ratio and head rice recovery, while PA-6201 was stable for 1000 grain weight. NSD-2 had recorded stable performance for grain yield ha^{-1} and productivity day^{-1}. The hybrids ADTRH-1 and DRRH-1 showed stability for maximum characters in the central zone of Kerala.

4.6 HETEROSIS AND INBREEDING DEPRESSION

Exploitation of hybrid vigour needs a sound knowledge on the extent of heterosis. To know the potential of hybrids over ruling varieties, the magnitude and direction of heterosis are important. In the present study location wise

Table 27. Standard heterosis (%) of hybrids at Mathur (*Kharif*, 2003).

Hybrids	Days to 50% flowering	Productive tillers plant^{-1}	Plant height	Grain yield ha^{-1}	Straw yield ha^{-1}	Harvest index	Number of days to physiological maturity	Productivity day^{-1}	Productivity plant^{-1}
ADTRH-1	9.60**	12.73	1.67	6.28**	4.22	1.478	11.18	-4.45	6.26
CORH-2	10.73**	11.67	4.90*	30.80**	16.88**	11.193	12.95**	15.74*	30.77**
KRH-2	16.25**	13.27	23.80**	56.74**	41.24**	9.693	12.95**	38.63**	56.78**
DRRH-1	13.60**	11.73	2.15	30.41**	26.26**	2.239	15.08**	13.35*	30.40**
PHB-71	9.96**	12.73	9.99**	51.16**	49.8**	0.000	12.42**	34.41**	51.19**
PA-6201	15.80**	11.33	8.91**	47.08**	29.18**	12.671	10.91**	32.50**	47.09**
NSD-2	5.55**	12.47	7.93**	46.04**	42.1**	2.239	7.36**	35.91**	46.05**

*- Significant at 5% level
**- Significant at 5% level

Contd…

Table 27. Standard heterosis (%) of hybrids at Mathur (*kharif*, 2003).

Hybrids	Number of grains panicle^{-1}	1000 grain weight	Density of grain	Head rice recovery	Milling percentage	Amylose content	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
ADTRH-1	69.63**	-17.46	-7.35	-21.36	3.14	5.67	-9.87	7.74*	1.85
CORH-2	60.44**	-17.20	-4.09	-10.80	-5.65	79.91**	-9.48	3.09	19.62**
KRH-2	52.33**	-6.42	24.89**	-5.97	-2.97	42.55**	-7.55	-2.31	28.03**
DRRH-1	52.95**	-18.14	13.87*	-15.43	-9.04	38.61**	-9.03	7.31*	43.90**
PHB-71	58.15**	-18.14	32.24**	-12.90	-10.10	4.77	3.23	2.90	-8.41
PA-6201	65.72**	-18.49	23.30**	-17.48	-17.01	15.79*	-6.90	2.42	0.93
NSD-2	40.32**	-7.42	-3.27	-19.15	-21.59	7.40	-1.48	-3.11	-7.49

*- Significant at 5% level
**- Significant at 5% level

Table 28. Standard heterosis (%) of hybrids at Chittoor (*Kharif*, 2003)

Hybrids	Days to 50% flowering	Productive tillers $plant^{-1}$	Plant height	Grain yield ha^{-1}	Straw yield ha^{-1}	Harvest index	Number of days to physiological maturity	Productivity day^{-1}	Productivity $plant^{-1}$
ADTRH-1	8.31**	1.24	15.95**	17.36**	-4.39	-3.11	9.12**	7.52	17.37**
CORH-2	10.19**	-4.80	16.27**	-12.11	-3.63	-13.68	10.57**	-20.46	-12.09
KRH-2	10.95**	13.37*	29.34**	11.66**	-1.76	-1.86	14.49**	-2.52	11.65
DRRH-1	15.82**	4.39	17.45**	-6.86	-7.95	-10.56	10.57**	-15.71	-6.82
PHB-71	14.68**	-6.40	23.34**	5.96**	-10.25	-10.56	13.38**	-6.55	5.99
PA-6201	13.21**	-1.34	22.06**	10.76	0.47*	-2.50	9.97**	0.76	10.78**
NSD-2	17.74**	-8.62	17.88**	18.30**	20.72	0.00	8.53**	8.99	18.31

** - Significant at 5% level

*- Significant at 1% level

Table 28. Standard heterosis (%) of hybrids at Chittoor (*kharif*, 2003)

Hybrids	Number of grains panicle^{-1}	1000 grain weight	Density of grain	Head rice recovery	Milling percentage	Amylose content	Kernel elongation ratio	Volume expansion ratio	Alkali spreading value
ADTRH-1	85.60**	-22.85	-2.64	-8.21	3.18	10.35	0	7.82	12.85
CORH-2	64.01**	-14.73	-17.30	-19.97	-3.23	44.47**	5.0	-6.96	-0.91
KRH-2	45.74**	-6.07	9.39	-5.77	-6.37	45.23**	12.3*	5.49	8.26
DRRH-1	49.77**	-11.44	-2.26	-11.61	-10.92	58.02**	10.6*	-7.14	28.46*
PHB-71	70.67**	-15.72	-21.43	-2.79	-18.87	13.54	16.0*	8.91	2.75
PA-6201	62.15**	-26.98	-24.07	-4.07	-9.71	15.38*	0.0	12.58*	45.88**
NSD-2	51.63**	-8.96	-14.66	-4.40	-20.19	5.47	2.2	2.69	-31.19

** - Significant at 5% level

*- Significant at 1% level

Table 29. Standard heterosis (SH %) and inbreeding depression (ID %) in rice hybrids at Chittoor (*rabi*, 2003)

Genotype	Plant height $^{-1}$		Days to 50% flowering		Grain yield ha^{-1}		Amylose content		Number of days to physiological maturity	
	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)
ADTRH-1	-14.45	-5.50	5.56*	10.00	13.87	-2.37*	23.45	37.57*	3.69*	7.20*
CORH-2	-2.66	2.80	3.94*	11.05	13.23*	23.30*	11.34*	8.66*	6.56*	10.17*
KRH-2	27.78*	29.99*	-1.45*	7.37	28.39*	35.80*	20.29*	31.58*	-3.83*	6.36
DRRH-1	-11.94	2.59	-5.69	4.74	15.34*	27.05*	14.74*	20.09*	-3.88*	5.08
PHB-71	-8.92*	16.83	8.45*	12.11*	123.23*	28.04*	22.25*	31.16*	6.97*	10.59*
PA-6201	-9.26	2.48	-3.40	4.74	13.66*	24.89	18.04*	26.65*	-0.39*	7.63
NSD-2	5.41*	11.438	0.00	7.37	33.55*	32.06*	18.47*	17.79*	-3.13*	5.08

Grain yield plant^{-1}		Milling percentage		Kernel elongation ratio		Volume expansion ratio		Head rice recovery		Alkali spreading value	
SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)	SH (%)	ID (%)
13.84	-2.35*	8.69	-29.96*	9.93	0.71	13.70	-30.48*	4.69	-9.95*	-30.48	15.87*
13.21*	23.29*	8.47	-16.54*	2.53*	12.86	40.86	-11.43*	7.91	-4.30*	-11.43*	69.09*
28.36*	35.83*	8.33	-5.45*	-0.64	12.14	-53.42	-30.48	4.86	-9.57*	-30.48*	-34.82*
15.35*	27.04*	10.78	-6.55*	13.29	2.14*	23.42	5.71*	5.95	-2.53*	5.71	30.59*
23.28*	28.11*	19.07	-16.00*	14.67	7.14*	27.27	4.76*	10.58	-5.76*	4.76*	37.50*
13.71*	24.92*	11.84	-7.27*	5.06*	12.86	-15.73	-15.24	3.32	-15.47	-15.24	-13.59
33.580*	32.08*	12.35	-0.73*	21.05	8.57*	10.19	2.86*	3.77	0.49	2.86	11.34*

** - Significant at 5% level

* - Significant at 1% level

standard heterosis was calculated using Jyothy as standard check variety. Inbreeding depression was also estimated as per cent increase or decrease of F_1 values over F_2 values during *rabi*, 2003.

4.6.1 Days to 50 per cent flowering

At Mullakkara standard heterosis for this character ranged from 14.17 to 23.18 (Table 26). All the hybrids showed significant positive standard heterosis at both Mullakkara and Mathur. The standard heterosis for this character at Mathur ranged from 5.55 to 16.25 (Table 27).

The percentage of standard heterosis was maximum for hybrid DRRH-1 (15.8) followed by PHB-71 (14.68) at Chittoor. All the seven hybrids exhibited significant positive standard heterosis (Table 28).

At Chittoor (*rabi*, 2003) among seven hybrids studied, three hybrids exhibited negative standard heterosis for this character. Standard heterosis values ranged from –5.69 to 8.45. Inbreeding depression for the character ranged from 4.74 to 12.11. The highest inbreeding depression of 12.11 was observed in case of PHB-71 (Table 29).

4.6.2 Productive tillers plant^{-1}

At Mullakkara (Table 26) standard heterosis for this trait ranged from -12.5 to 28.38. Only the hybrid PA-6201 had recorded significant positive standard heterosis, out of seven hybrids tested. Standard heterosis values ranged from 11.33 to 13.2 per cent, but none of the hybrid recorded significant positive standard heterosis at Mathur (Table 27). At Chittoor the hybrid KRH-2 had recorded high standard heterosis of 13.37 and it is the only hybrid that recorded significant positive standard heterosis (Table 28).

4.6.3 Plant height

The standard heterosis ranged from 1.11 to 12.20 at Mullakkara (Table 26). Out of seven hybrids evaluated only two had recorded significant positive standard heterosis. At Mathur (Table 27) standard heterosis ranged from 1.67 to 23.80. KRH-2 recorded the highest standard heterosis (23.80). At Chittoor (Table 28) all the seven hybrids tested recorded significant positive standard heterosis with values ranging from 15.95 to 29.34.

Among seven hybrids tested, PHB-71 exhibited significant negative heterosis over standard variety, Jyothy at Chittoor (*rabi*, 2003). KRH-2 was the tallest of all the hybrids recording 27.78 per cent standard heterosis. The inbreeding depression in F_2 was negligible in all hybrids except KRH-2, which recorded 29.99 per cent inbreeding depression (Table 29).

4.6.4 Grain yield ha^{-1}

Standard heterosis for this trait ranged from -3.54 to 52.57 at Mullakkara (Table 26). KRH-2 had recorded the maximum significant standard heterosis (52.57). At Mathur all the seven hybrids recorded significant positive standard heterosis. The standard heterosis for this trait ranged from 6.28 to 56.74, the maximum being KRH-2 (Table 27).

At Chittoor, hybrid NSD-2 recorded the maximum significant positive standard heterosis (18.30) for this trait. Out of seven hybrids evaluated four had significant positive standard heterosis (Table 28).

Out of the seven hybrids, six hybrids showed significant positive heterosis ranging from 13.87 to 123.23 at Chittoor (*rabi*, 2003). Only in ADTRH-1, the standard heterosis was not significant. The hybrid PHB-71 exhibited maximum standard heterosis (123.23) over check variety Jyothy (Table 29).

Inbreeding depression in F_2 for grain yield ranged from –2.37 to 35.80. The inbreeding depression was significant for all the hybrids except PA-6201. The maximum inbreeding depression was observed in hybrid KRH-2 (35.80) while the minimum in ADTRH-1 (-2.37).

4.6.5 Straw yield ha^{-1}

At Mullakkara standard heterosis for this character was maximum for hybrid KRH-2 (44.50) followed by NSD-2 (39.90). Out of seven hybrids, five recorded significant positive standard heterosis (Table 26).

Except in ADTHR-1 all other hybrids had exhibited significant positive standard heterosis at Mathur (Table 27). The standard heterosis values ranged from 4.22 to 42.1. Out of the seven hybrids evaluated, only PA-6201 had recorded significant positive standard heterosis at Chittoor (Table 28).

4.6.6 Harvest index

None of the hybrids showed significant positive standard heterosis at all the three locations.

4.6.7 Number of days to physiological maturity

At Mullakkara, maximum standard heterosis for this trait was recorded in hybrid KRH-2 (14.95). All the hybrids had recorded significant positive standard heterosis. Out of seven hybrids tested, six had recorded significant positive standard heterosis for this trait at Mathur. The percentage of standard heterosis was lowest in hybrid NSD-2 (8.53) while highest in hybrid KRH-2 (14.59) at Chittoor.

At Chittoor (*rabi*, 2003) the standard heterosis for this character was negative as well as positive. Four hybrids viz., DRRH-1, KRH-2, PA-6201 and NSD-2 had exhibited negative standard heterosis with values -3.83, -3.83, -0.39 and -3.13 respectively.

Inbreeding depression ranged from 5.08 to 10.59. Out of the seven hybrids only three (ADTRH-1, KRH-2 and PHB-71) have recorded significant inbreeding depression (Table 29).

4.6.8 Productivity day^{-1}

Standard heterosis for this trait was lowest (-13.10) for the hybrid PA-6201 and highest (32.63) for hybrid KRH-2 at Mullakkara (Table 26). At Mathur standard heterosis for this trait ranged from -4.55 to 38.63 (Table 27). Except ADTRH-1, all other hybrids recorded significant positive standard heterosis.

Standard heterosis for this character at Chittoor ranged from –20.46 to 8.99, but only two hybrids ADTRH-1 and PA-6201 had recorded significant positive standard heterosis of 7.52 and 0.76 per cent respectively.

4.6.9 Productivity plant^{-1}

None of the hybrids showed significant standard heterosis for this character at Mullakkara, Mathur and Chittoor.

At Chittoor (*rabi*, 2003) six hybrids exhibited significant positive heterosis for grain yield plant^{-1}. The highest standard heterosis was exhibited by hybrid NSD-2 (33.58) and lowest by CORH-2 (13.21).

Inbreeding depression was significant for all the hybrids studied. The lowest inbreeding depression was observed in hybrid ADTRH-1 (-2.35), while it was highest for KRH-2 (35.83).

4.6.10 Number of grains panicle^{-1}

Standard heterosis values for this trait ranged from 38.51 to 103.76 at Mullakkara. All the hybrids had exhibited significant positive standard heterosis.

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At Mathur also all the hybrids recorded significant positive standard heterosis and standard heterosis values ranged from 40.32 to 69.63.

At Chittoor, standard heterosis values for this character was high for hybrid ADTRH-1and low for hybrid KRH-2. All the hybrids recorded significant positive standard heterosis.

4.6.11 1000 Grain weight

The standard heterosis for this trait ranged from -26.98 to 5.00 per cent, but none had recorded significant standard heterosis at all the three locations.

4.6.12 Density of grain

At Mullakkara (Table 26), standard heterosis for this character ranged from -9.12 to 18.58 per cent. The standard heterosis for this trait was high in case of hybrid PHB-71 (32.24) and low for hybrid ADTRH-1 (-7.35) at Mathur (Table 27). Out of seven, four had recorded significant positive standard heterosis.

At Chittoor (Table 28) standard heterosis values ranged from -24.07 to 9.39. None of the hybrids evaluated had recorded significant positive standard heterosis.

4.6.13 Head rice recovery

Standard heterosis for this trait ranged from -21.94 to -3.15 at Mullakkara (Table 26), -21.36 to -5.97 at Mathur (Table 27) and -19.97 to -2.79 at Chittoor, but none of the hybrids at all the three locations had exhibited significant positive standard heterosis (Table 28).

None of the hybrids evaluated for standard heterosis at Chittoor (*rabi*, 2003) showed significant standard heterosis for head rice recovery (Table 29). All the hybrids except PA-6201 and NSD-2 recorded significant negative inbreeding depression for head rice recovery. The highest inbreeding depression was observed for NSD-2 (0.49), while the least (-15.47) for PA-6201.

4.6.14 Milling percentage

None of the seven hybrids evaluated recorded significant positive standard heterosis for this trait.

4.6.15 *Amylose content*

All the hybrids recorded significant positive standard heterosis which ranged from -11.66 to 9.46 at Mullakkara (Table 26). At Mathur, standard heterosis for this trait ranged from 4.77 to 79.91. Out of seven hybrids, four had recorded significant positive standard heterosis (Table 27). Standard heterosis for this trait was high for hybrid DRRH-1 (58.02) and low for hybrid NSD-2 (5.47) at Chittoor (Table 28).

At Chittoor during *rabi*, among hybrids tested, six hybrids showed significant positive standard heterosis except ADTRH-1 (Table 29). Standard heterosis ranged from 11.34 to 23.45. All the hybrids evaluated showed significant inbreeding depression for amylose content. The hybrid ADTRH-1 recorded the highest (37.57) inbreeding depression for amylose content. CORH-2 recorded the lowest (8.66) inbreeding depression.

4.6.16 Kernel elongation ratio

At Mullakkara and Mathur (Table 26 & 27) none of the hybrids recorded significant positive standard heterosis for this trait, while at Chitttoor (Table 28) hybrids KRH-2 (4.3), DRRH-1 (10.6) and PHB-71 (16.0) recorded significant positive standard heterosis.

Among the seven hybrids studied at Chittoor during *rabi* 2003, two hybrids namely CORH-2 and PHB-71 exhibited significant positive standard heterosis for this character. The standard heterosis ranged from 0.64 to 21.05 (Table 29).

Inbreeding depression was maximum for hybrids CORH-2 (12.86) and PA-6201 (12.86) and lowest in case of ADTRH-1 (0.71).

4.6.17 Volume expansion ratio

At Mullakkara standard heterosis for this trait ranged from -8.17 to 3.53, but none of them had recorded significant positive standard heterosis. Only two hybrids, DRRH-1 (7.31) and ADTRH-1 (7.74) at Mathur and PA-6201 (12.58) at Chittoor exhibited significant positive standard heterosis.

Standard heterosis for volume expansion ratio at Chittoor during *rabi*, ranged from –53.42 to 40.86, but none of the hybrids exhibited significant standard heterosis. DRRH-1 recorded the maximum significant inbreeding depression of 5.71 while lowest inbreeding depression was observed for ADTRH-1 (-30.48).

4.6.18 Alkali spreading value

At Mullakkara none of the hybrids evaluated showed significant positive standard heterosis, though standard heterosis values ranged from -42.40 to 10.39. The hybrids KRH-2, DRRH-1 and PHB-71 at Mathur and DRRH-1 and PA-6201 at Chittoor exhibited significant positive standard heterosis.

At Chittoor (*rabi*, 2003) standard heterosis for alkali spreading value ranged from –30.48 to 5.71. Only three hybrids showed significant standard heterosis for alkali spreading value. Inbreeding depression was as high as 69.09 for CORH-2 and lowest of –34.82 in case of KRH-2.

4.7 PEST AND DISEASE INCIDENCE

In all the four trials conducted, no major pest and disease was observed.

4.7.1 Benefit cost ratio

The cost of cultivation at Mullakkara (Table 30) was Rs. 29579.00 for hybrids and Rs. 27629.00 for varieties. The net returns from cultivating hybrids ranged between Rs. 9496.00 to 31667.00 and for varieties it ranged from Rs. 8614.00 to Rs. 12663.00. The highest net return of Rs. 31667 was recorded for KRH-2. The benefit cost ratio was higher in all hybrids than check varieties except for DRRH-1. Highest BCR was recorded by KRH-2 (2.07) followed by NSD-2 (1.95) and PHB-71 (1.69). For local variety the benefit cost ratio was 1.31 where as for Jyothy it was 1.46.

At Mathur (Table 31) cost of cultivation for hybrids was Rs. 24079.00 while it was Rs. 22129 for check varieties. The gross return was highest for KRH-2 (Rs. 59773.00) while it was lowest for Jyothy (Rs. 38432.00). The net return ranged between Rs. 16303.00 for Jyothy and Rs. 35694.00 for hybrids compared to check varieties, except in the case of ADTRH-1. KRH-2 recorded the highest benefit cost ratio (2.48) while ADTRH-1 recorded lowest (1.69).

At Chittoor (Table 32) cost of cultivation for hybrids (Rs. 24079.00) was higher than check varieties (Rs. 22129.00). The gross returns ranged from Rs. 46249.00 for CORH-2 to Rs. 61875.00 for NSD-2. NSD-2 recorded highest net return (Rs. 37796.00) followed by ADTRH-1 (Rs.36290.00). Except in the case of CORH-2 (1.92), DRRH-1 (2.02) and PHB-71 (2.27) all other hybrids had recorded higher benefit cost than Jyothy.

Table 30. Benefit cost ratio for hybrids and check varieties at Mullakkara, Thrissur (*kharif*, 2003).

Genotypes	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	Benefit cost ratio
ADTRH-1	29579	48648	19069	1.64
CORH-2	29579	46051	16472	1.56
KRH-2	29579	61246	31667	2.07
DRRH-1	29579	42397	12818	1.43
PHB-71	29579	49986	20407	1.69
PA-6201	29579	39075	9496	1.32
NSD-2	29579	57710	28131	1.95
Local variety	27629	36243	8614	1.31
Jyothy	27629	40292	12663	1.46

Table 31. Benefit cost ratio for hybrids and check varieties at Mathur (*kharif*, 2003)

Genotypes	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	Benefit cost ratio
ADTRH-1	24079	40783	16704	1.69
CORH-2	24079	49850	25771	2.07
KRH-2	24079	59773	35694	2.48
DRRH-1	24079	49996	25917	2.08
PHB-71	24079	58054	33975	2.41
PA-6201	24079	55987	31908	2.33
NSD-2	24079	56007	31928	2.33
Local variety	22129	42068	19939	1.90
Jyothy	22129	38432	16303	1.74

Table 32. Benefit cost ratio for hybrids and check varieties at Chittoor (*kharif*, 2003)

Genotypes	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	Benefit cost ratio
ADTRH-1	24079	60369	36290	2.51
CORH-2	24079	46249	22170	1.92
KRH-2	24079	57743	33664	2.40
DRRH-1	24079	48588	24509	2.02
PHB-71	24079	54651	30572	2.27
PA-6201	24079	57404	33325	2.38
NSD-2	24079	61875	37796	2.57
Local variety	22129	50463	28334	2.28
Jyothy	22129	52216	30087	2.36

DISCUSSION

5. DISCUSSION

Rice forms the staple food of Kerala. Currently the state is facing mismatch in its demand and availability of rice, thus depending on neighbouring states for rice supply. High yielding potential of rice hybrids can be utilized for bridging the gap in demand and availability. To fulfil the objective of testing the suitability and adaptability of commercial rice hybrids under Kerala conditions, the present study was undertaken.

5.1 MEAN PERFORMANCE AND VARIABILITY

Mean performance of rice hybrids and check varieties were analysed for each character. Better performing hybrid for each character at each location is discussed below.

At Mullakkara, hybrids expressed more number of days to 50 per cent flowering, compared to check varieties, with a mean value of 101.62 days for hybrids and 86.5 days for check varieties. In general hybrids took more than 120 days for maturity while check varieties took only 110-115 days. Longer duration to 50 per cent flowering and physiological maturity might have contributed to higher grain yield in hybrids. It is supported by significantly high positive genotypic correlation of these characters with grain yield. It was interesting to note that hybrids and varieties produced same number of productive tillers plant^{-1}. This may be due to the fact that hybrids and varieties received the same planting distance (20 x 15 cm). Annaduarai and Nandarajan (2001) also observed similar trends in rice hybrids.

Among the test varieties KRH-2 had recorded the highest grain yield ha^{-1} (7148.13 kg) followed by NSD-2 (6722.23 kg). In general the hybrids had higher grain yield in comparison with check varieties. Significant standard positive heterosis of most of the hybrids over Jyothy supported this finding.

In hybrids the grain yield ha^{-1} ranged from 4518.53 kg to 7148.13 kg with a mean value of 5743.43 kg, while in check varieties yield ranged from

PLATE 3. PLOT VIEW OF KRH-2

PLATE 4. PLOT VIEW OF PHB-71

PLATE 5. PLOT VIEW OF PA-6201

PLATE 6. PLOT VIEW OF NSD-2.

4203.70 to 4685.20 kg ha^{-1} with a mean yield of 4444 kg. Hybrids had a mean yield advantage of about 1298 kg ha^{-1}, which fetches the farmer an additional income of around 10,392 rupees ha^{-1} at the current market rate of Rs 8 kg^{-1} of paddy.

With respect to straw yield ha^{-1}, KRH-2 and NSD-2 had the highest straw yield with 6770.33 kg and 6556.67 kg respectively. The average straw yield was 5590.71 kg ha^{-1} for hybrids while 4519.0 kg ha^{-1} for check varieties. This increase in straw yield of hybrids over check varieties provides an additional income of rupees 643 ha^{-1}. It was interesting to note that both hybrids and check varieties did not differ significantly for their harvest index. Productivity day^{-1}, which had shown positive correlation with yield, was significant high for both KRH-2 and NSD-2, confirming their superiority than other hybrids and check varieties.

Number of grains $panicle^{-1}$ was more in hybrids, highest being observed for the CORH-2 (211.1) and lowest for PHB-71 (130.3). The mean number of grains $panicle^{-1}$ was much lower in check varieties (104.35) than mean of all hybrids (164.61).

With regard to 1000 grain weight, which adds to the acceptability of a genotype, KRH-2, Jyothy and local check variety were on par with each other. All other genotypes recorded lower 1000 grain weight. In general hybrids had recorded intermediate amylose content (20-25 %) indicating smoothness and non-stickiness. Poor milling percentage and head rice recovery was noticed in most of the hybrids compared to check varieties. In other traits such as grain density, kernel elongation ratio, volume expansion ratio and alkali spreading value hybrids did not differ much with check varieties.

Based on three major economically important characters like grain yield ha^{-1}, straw yield ha^{-1} and productivity day^{-1}, KRH-2, PHB-71 and NSD-2 were (Plates 3, 4 and 6) ranked as the promising hybrids at Mullakkara. Comparison of these three hybrids along with Jyothy for yield and quality characteristics is represented in Fig 1. Taking into consideration of grain quality

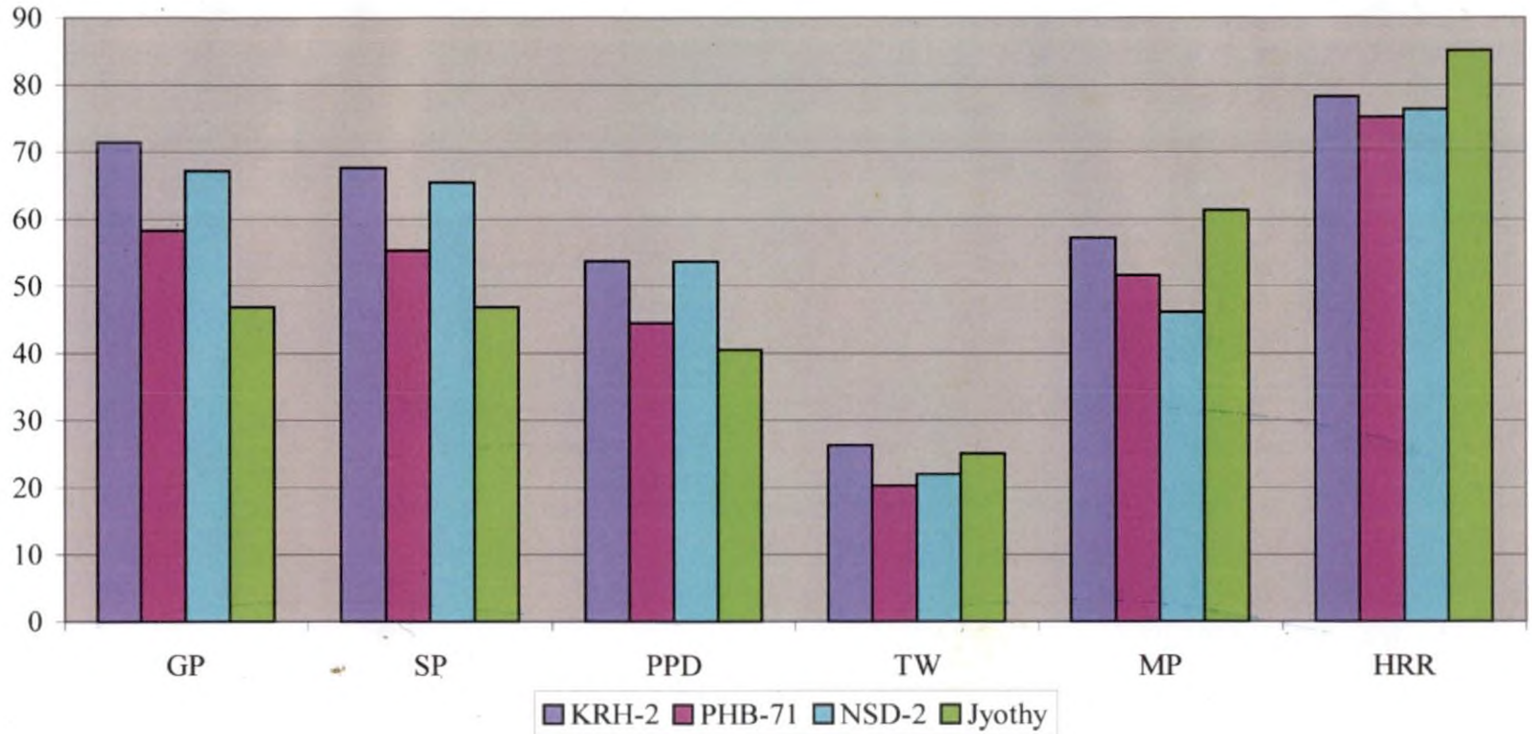


Fig 1. Mean performance of three superior hybrids and Jyothy at Mullakkara (*Kharif*, 2003).

GP- Grain yield ha^{-1} (Quintals)
SP- Straw yield ha^{-1} (Quintals)
PPD- Productivity day^{-1} (g)
TW- 1000 grain weight (g)
MP- Milling percentage (%)
HRR- Head rice recovery

parameters like 1000 grain weight, head rice recovery and milling percentage, KRH-2 was adjudged as the best hybrid among the three, at Mullakkara.

At Mathur also hybrids took longer duration for days to 50 per cent flowering (101.52) over check varieties (91.67) as in Mullakkara, leading to longer duration for physiological maturity. The high correlation coefficient between days to 50 per cent flowering and grain yield (0.718) justified its greater association with grain yield. As far as the productive tillers plant^{-1} is concerned both hybrids and check varieties performed on par with each other. But for plant height, hybrids recorded significantly higher mean values (110.76 cm) than check varieties (94.32 cm). Even though hybrids had recorded higher plant height, none of the hybrids lodged till harvest, indicating their adaptability to mechanical harvest.

Mean grain yield ha^{-1} of hybrids (6127.86 kg) compared to check varieties (4643.00 kg) led to a yield advantage of 1484.86 kg for hybrids, providing an additional income of rupees 11879.00 from one hectare of paddy cultivation. Straw yield ha^{-1} also followed the same trend. Hybrids had recorded a mean straw yield ha^{-1} of 6497.00 kg while check varieties had a mean yield of 5177.00 kg giving a yield advantage of 1320.00 kg and thus an additional income of 792.0 rupees.

For productivity day^{-1} and productivity plant^{-1} the hybrids KRH-2, PHB-71, PA-6201 and NSD-2 were found superior than other hybrids. For number of grains panicle^{-1}, in general, hybrids had higher mean value (205.3) than check varieties (133.70). Hybrids KRH-2 and NSD-2 were on par with check variety for 1000 grain weight. Manuel *et al.* (1999) also observed higher number of grains panicle^{-1} in hybrids compared to varieties. ADTRH-1 performed same as check varieties for the trait milling percentage. But CORH-2 recorded high amylose (>25%) content among hybrids. High amylose content may have less marketability in Kerala, due to stickiness and high volume expansion of rice. In general check varieties had performed better for head rice recovery and milling percentage than hybrids.

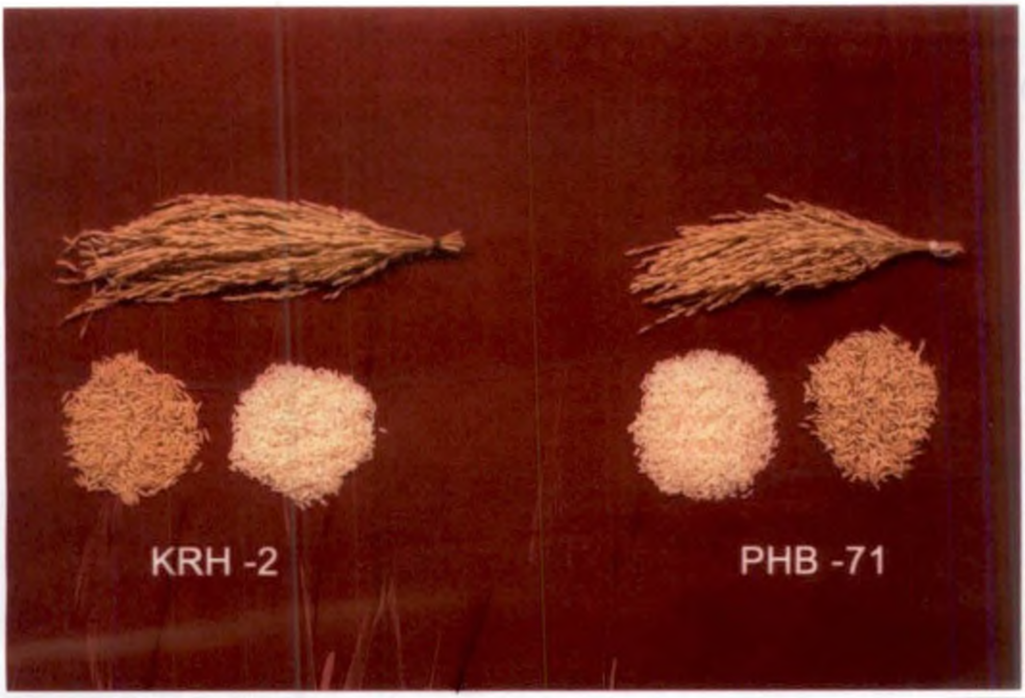


PLATE 7. PANICLE AND GRAIN CHARACTERISTICS OF PROMISING HYBRIDS KRH-2 AND PHB-71

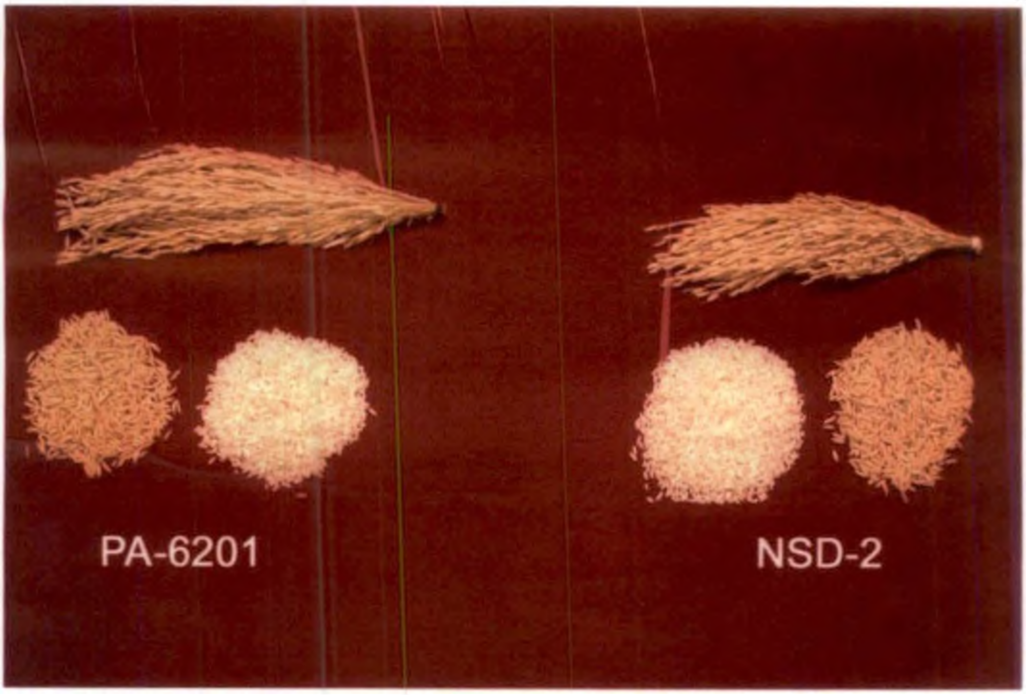


PLATE 8. PANICLE AND GRAIN CHARACTERISTICS OF PROMISING HYBRIDS PA-6201 AND NSD-2.

PLATE 5. PLOT VIEW OF PA-6201

PLATE 6. PLOT VIEW OF NSD-2.

Taking into consideration of major quantitative traits such as grain yield ha^{-1}, straw yield ha^{-1} and productivity day^{-1}, KRH-2, PHB-71, PA-6201 and NSD-2 (Plate 3,4,5 and 6) were selected as most suited hybrids for this specific location (Mathur). The grain and panicle characteristics of these hybrids are depicted in plates 7 and 8. Comparison of these three hybrids along with Jyothy for yield and quality characteristics is represented in Fig. 2. Among these three hybrids, KRH-2 was adjudged as most promising one based an its better performance compared to other two hybrids with respect to qualitative traits such as 1000 grain weight, milling percentage and head rice recovery.

At Chittoor, in general hybrids have more growth duration than check varieties. Mean number of days to 50 per cent flowering for hybrids was 99.8 while it was 87.8 in case of check varieties. As in other two locations there was not much difference in number of productive tillers $plant^{-1}$ between hybrids and check varieties. All the hybrids had recorded a higher plant height of more than 108 cm, whereas it was below 94 cm for check varieties. At this location also none of the hybrids recorded lodging nature thereby confirming their suitability for mechanical harvesting. With respect to grain yield ha^{-1} hybrids were having a mean value of 6390.6 kg whereas check varieties had a mean value of 5882.50 kg. NSD-2 was the top ranking entry at Chittoor with a grain yield ha^{-1} 7103.00 kg followed by ADTRH-1 (7045.67 kg).

The difference in grain yield between hybrids and varieties is less (508.0 kg ha^{-1}) at Chittoor compared to Mullakkara and Mathur, where the differences were more than 1000 kg. It was interesting to note that the mean straw yield ha^{-1} was more for check varieties (7133.0 kg) than hybrids (6906.3 kg). Taking into consideration of mean grain and straw yield ha^{-1} it could be seen that cultivation of hybrids can give an added advantage of Rs.3900/- at Chittoor. The harvest index did not show much difference between hybrids and varieties, as in other locations.

As seen in case of days to 50 per cent flowering, hybrids took more number of days to maturity. In general hybrids took more than 125 days for physiological maturity whereas it was less than 120 days for check varieties. The

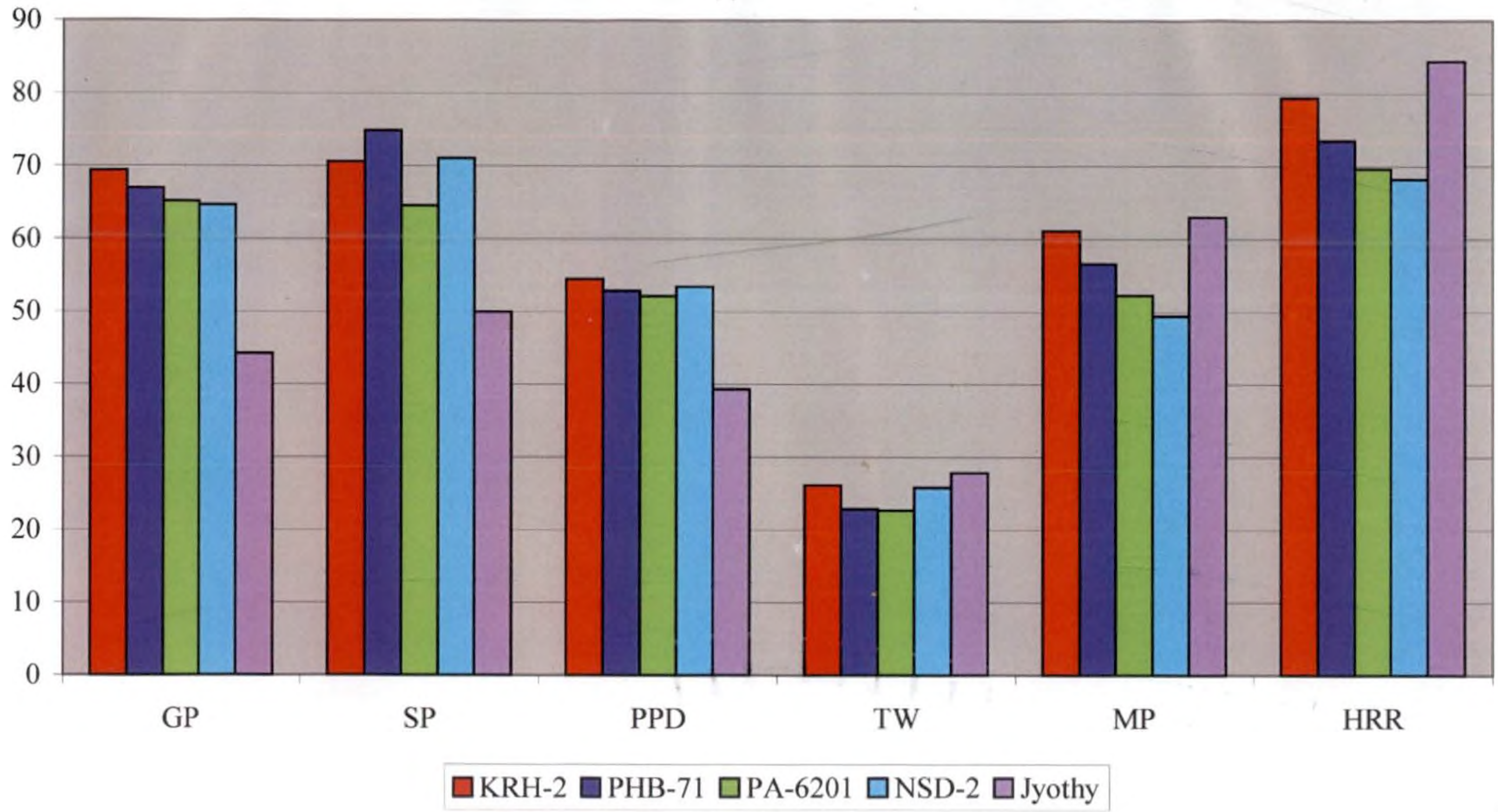


Fig 2. Mean performance of four superior hybrids and Jyothy at Mathur (*kharif*, 2003).

GP- Grain yield ha^{-1} (Quintals)
SP- Straw yield ha^{-1} (Quintals)
PPD- Productivity day^{-1} (g)
TW- 1000 grain weight (g)
MP- Milling percentage (%)
HRR- Head rice recovery (%)

lesser duration of check varieties resulted in a higher productivity day^{-1} in case of check varieties. As observed in other two locations number of grains panicle^{-1} was much higher in hybrids with mean value of (208.5) compared to check varieties (126.8). 1000 grain weight which is a deciding character for better marketability was observed to be high for check varieties.

At Chittoor the hybrids NSD-2, ADTRH-1 and KRH-2 were ranked as the top three hybrids. Climatic condition of Chittoor is same as that of the target area of ADTRH-1 (Tamil Nadu) and this may be the reason for the better performance of ADTRH-1 at Chittoor compared to Mullakkara and Mathur. Comparison of these three hybrids along with Jyothy for yield and quality characteristics is represented in Fig. 3. Considering the other grain characters like 1000 grain weight, milling percentage and head rice recovery, KRH-2 was adjudged as best performing hybrid for this location.

KRH-2 was the promising hybrid at all the three locations, followed by NSD-2. Multilocation evaluation of hybrids by Directorate of Rice Research, Hyderabad had also revealed the superior performance of KRH-2 during *kharif* season at different locations throughout the country (Ahmed *et al.*, 2003). Central Variety Release Committee had released this hybrid. Better performance and adaptability of NSD-2 had also been reported by Ahmed *et al.* (2003). Hegde and Vidyachandra (1998) found KRH-2 as the best performing one among the hybrids tested at Karnataka.

Genetic variability in a crop is the basic requirement for its further genetic improvement. Critical assessment of nature and magnitude of variability is one of the important prerequisites in effective Plant Breeding. Further it also adds to the selection of genotypes with desirable characters catering to the need of different agro ecological situations and demands of local markets.

The analysis of variance revealed that genotypes differed significantly for most of the characters at all the four locations indicating considerable variation among the genotypes. Productive tillers plant^{-1} and harvest index did not show significant difference at two locations indicating absence of variability for those characters. Similar results were found by Sarawagi *et al.* (2000).

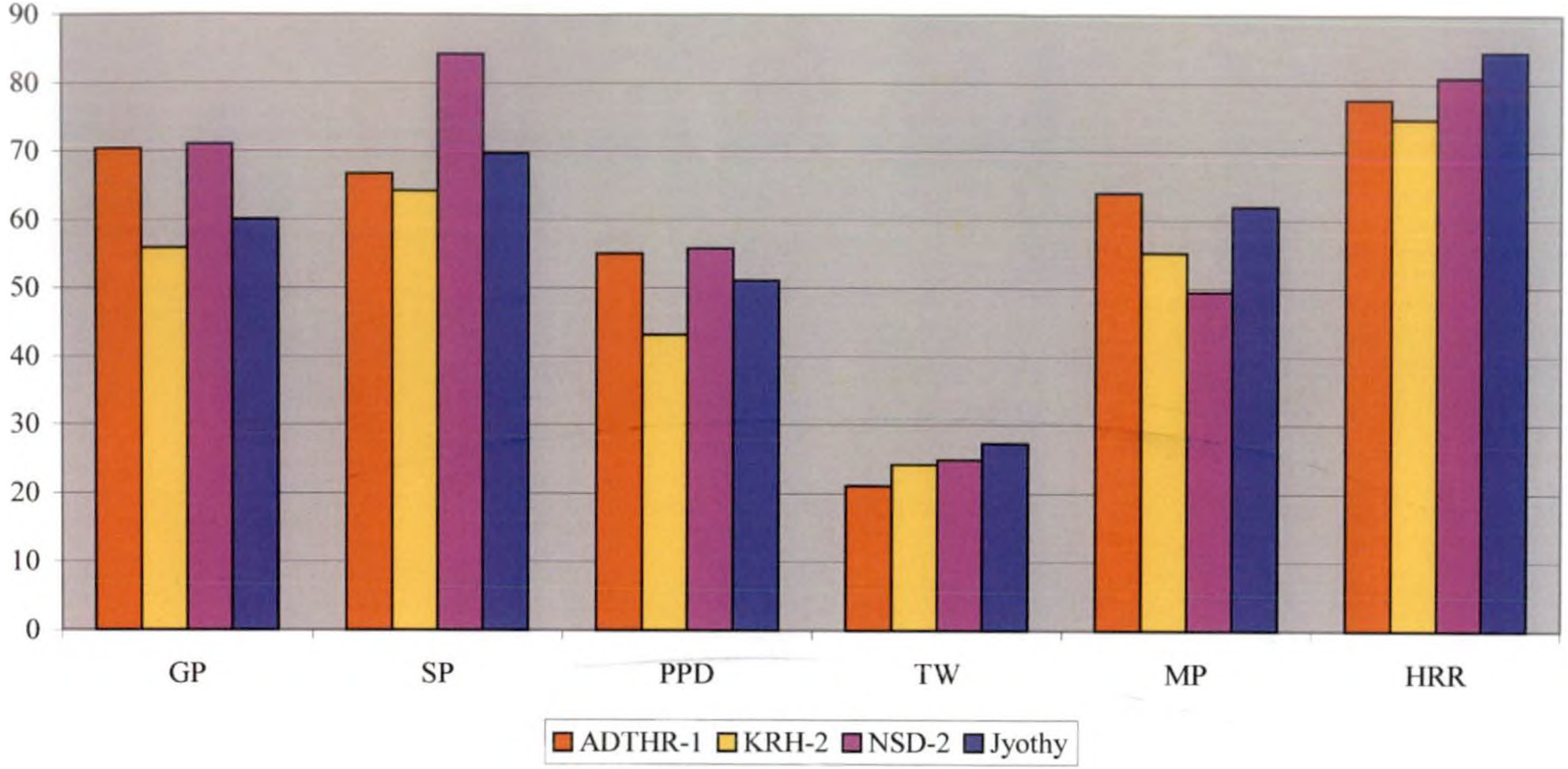


Fig 3. Mean performance of three superior hybrids and Jyothy at Chittoor (*kharif*, 2003).

GP- Grain yield ha^{-1} (Quintals)
SP- Straw yield ha^{-1} (Quintals)
PPD- Productivity day^{-1} (g)
TW- 1000 grain weight (g)
MP- Milling percentage
HRR- Head rice recovery

Grain yield ha^{-1}, grain yield $plant^{-1}$, number of grains $panicle^{-1}$ and alkali spreading value recorded high genotypic coefficient of variation at all the four locations indicating scope for selection in these traits. Balan (1999), Sarawagi *et al.* (2000), Thakur *et al.* (2000) and Yadav (2000) also found same results.

Productive tillers $plant^{-1}$ exhibited higher estimates of phenotypic coefficient of variation in comparison to genotypic coefficient of variation suggesting higher influence of environment on the trait. Similar results were obtained by Chaubey *et al.* (1994) and Raju *et al.* (2004).

The difference between genotypic coefficient of variation and genotypic coefficient of variation was minimum for most of the characters studied. The results revealed that the influence of environment on these characters is low. Balan *et al.* (1999) and Sathyavathi *et al.* (2001) also found similar results.

5.2 HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN

In crop improvement only the genetic component of variation is important, since only this component is transmitted to the next generation.

The values of heritability ranged from 6 per cent to 97.1 per cent. Most of the characters evaluated showed high heritability (>60 %) in general. Similar results were shown by Vivekanandan and Giridharan (1998).

The characters like productive tillers $plant^{-1}$, harvest index and kernel elongation ratio recorded low to medium heritability. Similar results were obtained by Shanthi and Singh (2001).

High genetic advance coupled with high heritability were observed for plant height, grain yield ha^{-1}, straw yield ha^{-1}, number of grains $panicle^{-1}$ and 1000 grain weight indicating presence of additive gene effects. Moreover selection could be effective based on phenotype for these traits for yield improvement. Shivani and Ramareddy (2003a) inferred similarly.

5.3 CORRELATIONS

Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selections can be made for genetic improvement in yield. The estimates of genotypic and phenotypic correlation between various characters help to quantify the intensity and direction of association. Genotypic correlations provide a reliable measure of genetic association between the characters and help to differentiate the vital association useful in breeding from the non vital ones (Falconer, 1967).

In the present study, it is revealed that yield was positively correlated with days to 50 per cent flowering, plant height, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity $plant^{-1}$, productivity day^{-1} and volume expansion ratio indicating the importance of these traits in direct selection. Manuel and Palanisamy (1989) and Sathya (1999) also observed significant positive correlation of grain yield with days to 50 per cent flowering, plant height and number of grains $panicle^{-1}$. These findings are in agreement with those reported by Sathya (1999), Shivani and Ramareddy (2000b) and Raju *et al.* (2003).

Milling percentage exhibited a negative correlation with grain yield at two locations substantiating the low milling percentage observed in hybrids and high milling percentage in check varieties. Significant positive correlation of grain yield with number of grains per panicle was also noticed. Sharma and Muley (2003) and Durai (2001) also observed similar results.

Head rice recovery had also shown significant positive correlation with grain yield at one location. This observation is in agreement with that of Khedikar *et al.* (2004).

Thus from the study, it is revealed that direct selection can be practiced for days to 50 per cent flowering, plant height, number of grains $panicle^{-1}$, number of days to physiological maturity, harvest index, straw yield, productivity day^{-1} and productivity $plant^{-1}$. These characters exhibited positive and significant correlation with grain yield. Moreover the positive correlation of plant height and days to 50 per cent flowering with grain yield ha^{-1} indicated that it might not be possible to exploit heterosis for grain yield in hybrids by reducing plant height and growth duration.

5.4 PATH ANALYSIS

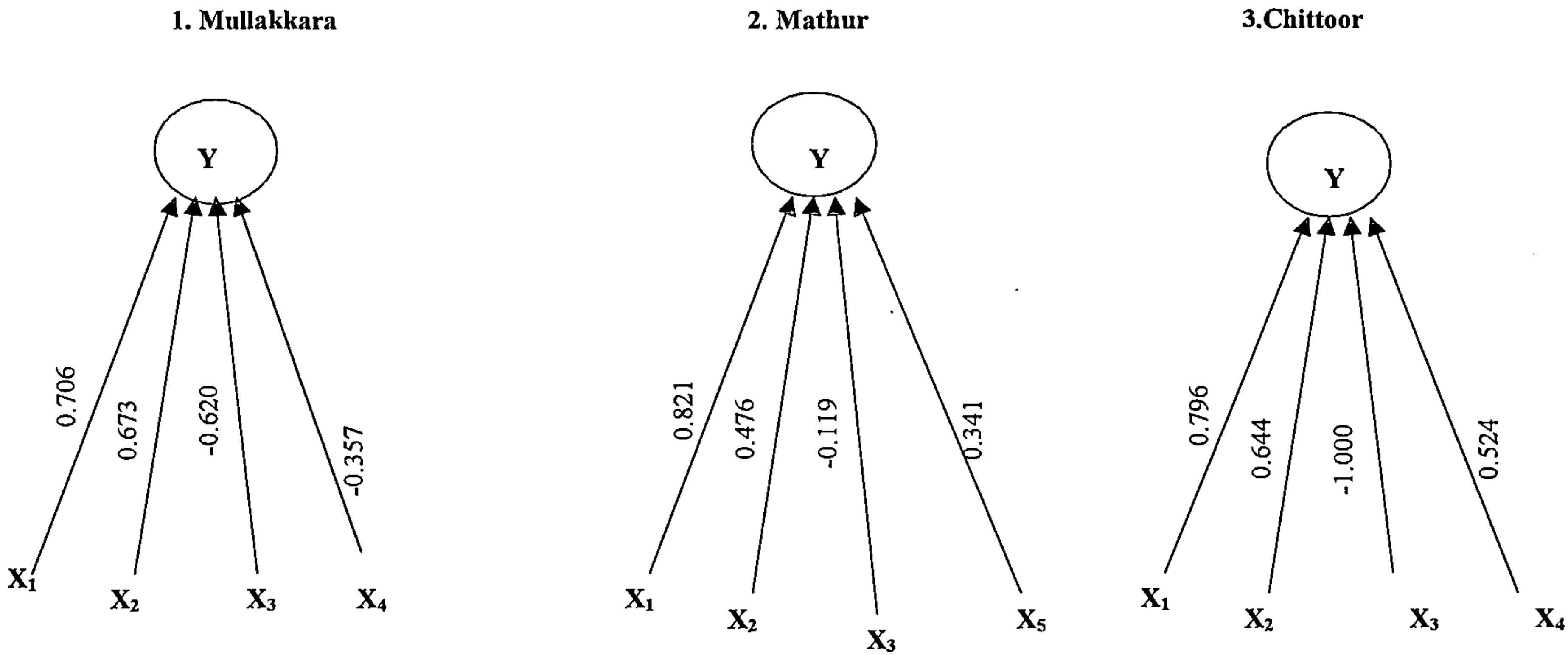
Path coefficient analysis is a standardised partial regression coefficient, which splits correlation coefficient in to measures of direct and indirect effects. It measures the direct and indirect contribution of characters on dependent characters. Even though correlation study is helpful in measuring the association of yield and yield components, it do not provide clear picture of the direct and indirect effects of associations, but through path analysis that can be obtained. Path analysis at each location is represented in fig.4 for Mullakkara, Mahtur and Chittoor.

Path analysis in the present study revealed that the yield attributing characters such as straw yield, days to 50 per cent flowering and plant height had positive direct effects. These characters also exhibited significant positive correlation with grain yield suggesting that selection of these traits could bring improvement in yield of rice. Raju *et al.* (2003), Bala (2001), Kaw *et al.* (1999) also observed same results.

Along with direct effect, days to 50 per cent flowering also exerted high positive indirect effect on grain yield through most of the traits studied signifying its effect on grain yield. Numbers of days to physiological maturity had a high negative direct effect on grain yield. Khedikar *et al.* (2004) noticed high indirect effect of grain yield through most of the yield attributing characters.

Residual effect ranged from 0.143 to 0.494 indicating that most variation in grain yield was contributed genotypically by these selected yield components.

Fig. 4. Path diagram indicating direct effect of yield attributing characters on grain yield at Mullakkara, Mathur and Chittoor respectively.



Y- Grain yield ha^{-1}
X_1-Straw yield ha^{-1}
X_2- Days to 50 % flowering
X_3- Number of days physiological maturity
X_4- Plant height
X_5- Head rice recovery

5.5 G X E INTERACTION

The G x E interaction structure is important for both plant breeding programmes and the introduction of new crop cultivars. Varietal adaptability to environmental fluctuations is important for the stabilisation of crop production both over regions and years. G X E interaction is considered as an important tool in crop breeding. An ideal variety is one that combines high yield, high quality and stability of performance. Young and Virmani (1990) stressed need to evaluate hybrids across environments to identify stable hybrids with high yield that shows least interaction with environment.

The study of G XE interaction provides useful information to identify stable genotypes over a range of environment. The present investigation is therefore undertaken to study G X E interaction and to identify both high yielding and stable genotypes over different agroclimatic situation in central zone of Kerala. To assess the G X E interaction, mainly three parameters are used, namely mean performance of the genotype, its regression coefficient and deviation from the regression environmental index. A stable genotype is one, which shows high mean value, a regression coefficient around unity and a mean square deviation from regression, near zero.

The performance of genotypes for each character in response to environment are discussed adopting the model of Eberhert and Russel (1966).

5.5.1 Days to 50 per cent flowering

Among the hybrids tested, ADTRH-1 and CORH-2, with regression coefficient around unity, low mean value and low mean square deviation can be considered as stable for this character.

5.5.2 Productive tillers plant^{-1}

Stability parameters had identified that DRRH-1 with regression coefficient near unity and low mean square deviation as the most stable over the locations. As far the mean is considered hybrid KRH-2 had high mean value and had exhibited above average stability i.e., best adapted to favourable environments.

5.5.3 Plant height

The local check variety showed to be specially adapted to unfavourable (poor) environments with regression coefficient below unity and low mean value. The hybrid PHB-71 was found to be more stable in different environments with near unity regression coefficient, among the hybrids.

5.5.4 Grain yield ha^{-1}

Stability parameters of maximum mean grain yield, low mean square deviation and regression coefficient near unity for hybrid NSD-2 indicated that this hybrid was more stable for this character. KRH-2 with higher mean performance than the average of all genotypes had a regression coefficient less than unity indicating its suitability even for unfavourable environments.

5.5.5 Straw yield ha^{-1}

The hybrid DRRH-1 with regression coefficient near unity found most stable for this trait, but it recorded low mean value. NSD-2 had recorded highest mean value than average of all the varieties; but has regression coefficient less than unity indicating the suitability of the hybrid in the unfavourable conditions.

5.5.6 Harvest index

The hybrid KRH-2 found most stable for this character having high mean value, regression coefficient unity and zero mean square deviation.

5.5.7 Number of days to physiological maturity

ADTRH-1 having low mean square deviation and regression coefficient near unity found to be more stable in different environments.

5.5.8 Productivity day^{-1}

The hybrid DRRH-1 with regression coefficient nearer unity and low mean deviation was found to be stable. The hybrid NSD-2 with high mean value, low mean square deviation and regression coefficient below unity found suitable for unfavourable environments, while the hybrid PA-6201 with regression coefficient more than one found suitable for more favourable conditions.

5.5.9 Productivity plant^{-1}

KRH-2 recorded mean value higher than the overall mean with a regression coefficient below 1and found to be suitable for unfavourable environments. Hybrid NSD-2 with regression coefficient around unity and low mean square deviation found stable over environments.

5.5.10 Number of grains panicle^{-1}

Hybrid ADTRH-1 with high mean value and regression coefficient near unity found stable for this character.

5.5.11 1000 Grain weight

Local check variety had exhibited high mean value mean square deviation near zero and regression coefficient more than 1 and was found as suitable for more favourable environments. KRH-2 with high mean value and regression coefficient less than unity found to be specially adapted for unfavourable environments. PA-6201 with regression coefficient around one and low mean square deviation found stable across environments.

5.5.12 Density of grain

The hybrid DRRH-1 that recorded higher mean value with regression coefficient near unity and with zero deviation, found to be stable and widely adapted to different environments.

5.5.13 Head rice recovery

The hybrid PA-6201 would be the better choice for favourable environments and where as hybrid KRH-2 to unfavourable environments.

5.5.14 Milling percentage

Local check variety with higher mean value, low mean square deviation and regression coefficient near unity found stable. ADTRH-1 with higher mean value and regression coefficient near unity found to be stable among hybrids tested.

5.5.15 Amylose content

Hybrid KRH-2 showed to be more stable and was adapted to all the environments. Hybrid CORH-2 found to be specially adapted to favourable environments, where as local variety found specially adapted to unfavourable environments.

5.5.16 Kernel elongation ratio

The hybrid CORH-2 with regression coefficient near unity and low mean deviation found stable for this trait. The hybrid NSD-2 showed to be specially adapted to favourable environments and hybrid KRH-2 performed average under poor conditions showed to be specially adapted to unfavourable environments.

5.5.17 Volume expansion ratio

The hybrid PHB-71 with regression coefficient near unity and low mean deviation found stable for this trait.

5.5.18 Alkali spreading value

The hybrid KRH-2 having regression coefficient more than 1 can perform best under most favourable environments.

5.6 HETEROSIS AND INBREEDING DEPRESSION

The exploitation of hybrid vigour appears to be an viable approach for making further breakthrough in rice productivity. Heterotic expression reflects the production potential of an hybrid. Standard heterosis having direct practical value in commercialization of hybrid was calculated in the present study. Inbreeding depression refers to decrease in fitness and vigour of hybrids in succeeding generations. In the present experiment inbreeding depression was also assessed to know the decline in vigour for important characters using Jyothy (Ptb-39) as the standard variety.

5.6.1 Days to 50 per cent flowering

During *kharif* all the hybrids at three locations exhibited significant positive standard heterosis for this trait.

During *rabi*, 2003 at Chittoor KRH-2 had recorded significant negative standard heterosis for this character. Early maturing hybrids with good yield potential are desirable during *rabi* since water scarcity may reduce crop yields in genotypes with longer duration. Heterosis for earliness over standard variety had been reported by Young and Virmani (*1990*) and Singh and Maurya (*1999*).

Significant inbreeding depression was observed only in one hybrid i.e. PHB-71, suggesting that this character is controlled by additive gene action. Singh and Maurya (1999) also reported same results.

5.6.2 Productive tillers plant^{-1}

Except PA-6201 at Mullakkara and KRH-2 at Chittoor, none of the hybrids at all the three locations had recorded significant standard heterosis for this trait. This indicated absence of hybrid vigour for this trait over check variety Jyothy. This is to be viewed from the fact that both the hybrids and Jyothy received the same spacing during planting. May be at a higher planting distance, the hybrids will be able to produce more number of productive tillers plant^{-1}.

5.6.3 Plant height

During *kharif,* none of the hybrids evaluated exhibited less plant height over standard variety, indicating that increased plant height of hybrids is favouring increased grain yield. This is again supported by high correlation observed for this character with grain yield. Present observations are in conformity with the findings of Sharma and Mani (1990).

Only one hybrid i.e. KRH-2 had recorded significant inbreeding depression among seven hybrids. This hybrid also had recorded significant positive heterosis. This indicated presence of non-additive gene action.

5.6.4 Grain yield ha^{-1}

At Mullakkara, the hybrid KRH-2 had recorded the highest significant positive standard heterosis for grain yield followed by NSD-2 and PHB-71. At Mathur KRH-2 recorded the highest standard heterosis followed by PHB-71 and PA-6201. The hybrids NSD-2, ADTRH-1 and KRH-2 had recorded maximum standard heterosis over check variety at Chittoor.

During *rabi* season at Chittoor the hybrid PHB-71 recorded maximum standard heterosis (123.23). Second best was KRH-2 (28.39). The presence of significant amount of inbreeding depression for grain yield in F_2 suggested breakdown of hybrid vigour. Since KRH-2 had recorded significant inbreeding depression, it is suggested not to grow F_2 generation.

5.6.5 Straw yield ha^{-1}

At Mullakkara the hybrid KRH-2 exhibited maximum standard heterosis followed by NSD-2 and PHB-71. PHB-71 exhibited highest standard heterosis at Mathur. The hybrids NSD-2 and KRH-2 ranked next to PHB-71. At Chittoor only the hybrid PA-6201 had recorded significant positive heterosis over check variety.

5.6.6 Harvest index

None of the hybrids evaluated at all the three locations exhibited significant standard heterosis for the character.

5.6.7 Number of days to physiological maturity

During *kharif* all the hybrids showed positive standard heterosis for this trait in all the experiments. At Chittoor during *rabi*, 2003 the hybrids DRRH-1, KRH-2 and NSD-2 recorded significant negative standard heterosis for this trait.

5.6.8 Productivity day^{-1}

At Mullakkara the hybrid KRH-2 recorded the highest positive standard heterosis for this trait followed by NSD-2. Third best hybrid was ADTRH-1. KRH-2 was the best hybrid at Mathur followed by NSD-2 and PHB-71. At Chittoor none of the hybrids showed significant standard heterosis.

5.6.9 Productivity plant^{-1}

KRH-2 (52.54) followed by NSD-2 (43.45) and PHB-71 (24.51) were the top ranked entries based on their performance over check variety Jyothy at Mullakkara, Thrissur. At Mathur except ADTRH-1 all other hybrids exhibited significant positive standard heterosis. KRH-2, PHB-71 and PA-6201 behaved as best three hybrids for this character. PA 6201 and ADTRH-1 were the two hybrids which had recorded positive significant standard heterosis at Chittoor.

During *rabi* season at Chittoor all the hybrids except ADTRH-1 recorded significant positive standard heterosis for this trait. The best three hybrids for this character were NSD-2, KRH-2 and PHB-71 respectively. All the hybrids recorded significant inbreeding depression for this trait indicating presence of dominant type of gene action.

5.6.10 Number of grains panicle^{-1}

All the hybrids at all the three locations exhibited positive significant standard heterosis for this trait, confirming superiority of hybrids for number of grains panicle^{-1} than check variety.

5.6.11 1000 Grain weight

None of the hybrids at all the three locations recorded significant standard heterosis for this trait.

5.6.12 Density of grain

Hybrids CORH-2 followed by DRRH-1 and NSD-2 ranked as top three hybrids with their significant positive standard heterosis at Mullakkara, while at Mathur, PHB-71, KRH-2 and PA-6201 ranked as best genotypes. But at Chittoor none of the hybrids had recorded significant positive standard heterosis.

5.6.13 Head rice recovery

None of the hybrids in all the four trials recorded significant standard heterosis. Standard check variety Jyothy, which was adjudged best for the grain qualities like 1000 grain weight, grain density and milling percentage, performed best for this trait also. It suggested the superiority of Jyothy for grain qualities over hybrids.

5.6.14 Milling percentage

None of the hybrids at all the locations exhibited significant standard heterosis for this trait. The same trend was observed in case of 1000 grain weight and density of grains revealing better performance of check variety Jyothi for these grain qualities.

Negative significant inbreeding depression was observed in all the hybrids evaluated

5.6.15 Amylose content

At Mullakkara, Thrissur five out of seven hybrids recorded significant negative heterosis. Amylose content in most of the hybrids was intermediate, making them acceptable to consumers. On global basis most of the people prefer intermediate amylose content in rice.

At Mathur all the hybrids recorded positive significant standard heterosis. The hybrid PA-6201 had intermediate amylose content and high significant positive standard heterosis over check variety. PA-6201 and PHB-71 had intermediate amylose content and positive standard heterosis.

At Chittoor during *rabi*, 2003, hybrids PHB-71, PA-6201 and NSD-2 had recorded intermediate amylose content with significant positive standard heterosis. All the hybrids exhibited significant inbreeding depression, thus signifying the breaking down of hybrid vigour in F_2 population.

5.6.16 Kernel elongation ratio

None of the hybrids evaluated at Mullakkara and Mathur exhibited significant positive heterosis for this trait. At Chittoor hybrid PHB-71 ranked first followed by KRH-2 and DRRH-1.

Among the seven hybrids only DRRH-1, PHB-71 and NSD-2 had significant inbreeding depression for this character at Chittoor during *rabi* season.

5.6.17 Volume expansion ratio

At Mullakkara none of the hybrids had exhibited significant heterosis and hence Jyothy is best genotype for this trait. At Mathur ADTRH-1 and DRRH-1 have recorded significant positive heterosis and are therefore best performing entries for this trait. Hybrid PA-6201 at Chittoor, had significant positive standard heterosis.

During *rabi* none of the hybrids at Chittoor had exhibited significant standard heterosis but most of them had exhibited significant inbreeding depression.

5.6.18 Alkali spreading value

None of the hybrids at Mullakkara and KRH-2, DRRH-1, PHB-71 at Mathur and PHB-71 and PA-6201 at Chittoor exhibited significant positive heterosis.

During *rabi* at Chittoor hybrid KRH-2 had recorded highest significant negative standard heterosis for this trait. Most of the hybrids showed significant inbreeding depression suggesting hybrid breakdown in F_2 population.

All the above results revealed that the hybrids KRH-2, PHB-71 and NSD-2 had done well with respect to most of quantitative characters such as grain yield, straw yield, productivity day^{-1}, productivity plant^{-1} etc. But most of the hybrids faired poor with respect to grain qualities suggesting superiority of Jyothy for these traits. Hence to realise the potential of rice hybrids there is urgent need to improve qualitative characters. Similar suggestions were given by Virmani (2003) and Mishra (2002).

5.7 PEST AND DISEASES INIDENCE

Pest and disease occurrence was not significant at all locations, indicating the resistance of genotypes tested.

5.8 BENEFIT COST RATIO

Benefit cost ratio was significantly higher for most of the hybrids compared to check varieties at all the three locations indicating better returns in going for cultivation of hybrids. In areas, which suit the cultivation of medium duration genotypes for *kharif* season, farmers can opt for cultivation of those hybrids with higher benefit cost ratio and better grain characteristics.

Future line of work

1. Though in general hybrids fared better than check varieties for yield and yield related traits, their performance was poor as far as the grain quality characters were considered. This can reduce their marketability and further spread. Hence efforts must be directed to evolve hybrids with better grain quality and sustained grain yield.

2. Considering the preference of Kerala people for red bold rice, efforts must be strengthened to evolve better hybrids having red kernel colour. Identification of maintainers or restorer lines having red bold type grains and using them in hybridisation programme may help to evolve such hybrids.

3. High seed cost of hybrids is a serious impediment for their large scale cultivation. To overcome this constraint approaches such as two line heterosis breeding and other alternatives are to be considered.

SUMMARY

6. SUMMARY

Investigations were undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 2002-2004 to evaluate genotype x environment interaction in commercial rice hybrids available in the country.

Seven hybrids viz., ADTRH-1, CORH-2, KRH-2, DRRH-1, PHB-71, PA-6201 and NSD-2 along with a local check variety and a standard check variety (Jyothy) were analysed for mean performance, variability, correlations, path analysis, stability and standard heterosis at three locations viz., Mullakkara (Thrissur), Mathur (Southern Palakkad) and Chittoor (Eastern Palakkad) during *kharif*, 2003. The seven hybrids along with their corresponding F_2 generations and check varieties were analysed for standard heterosis and inbreeding depression at Chittoor during *rabi*, 2003. The results are summarised below.

1. Mean performance of hybrids across the locations revealed that in general hybrids performed better than check varieties with respect to yield and yield attributing characters like grain yield ha^{-1}, straw yield ha^{-1}, number of grains $panicle^{-1}$, productivity day^{-1} and productivity $plant^{-1}$. In hybrids, the grain yield ha^{-1} ranged between 6931 and 5480 kg, whereas in check varieties, it ranged between 4941 and 5039 kg. In hybrids the straw yield ha^{-1} ranged between 5599 and 6970 kg and in check varieties it ranged from 5191 to 5277 kg. Hybrids recorded a significantly higher number of grains $panicle^{-1}$ ranging from 175 to 218 whereas in check varieties it was between 121 and 122 only.

2. Based on the mean performance and extent of standard heterosis for yield and yield attributing characters, promising hybrids for each location were identified. At Mullakkara (Thrissur) the most promising three hybrids identified were KRH-2, PHB-71 and NSD-2. Taking into consideration of quality parameters also, the hybrid KRH-2 was adjudged as the best hybrid at Mullakkara. KRH-2, PHB-71, PA-6201 and NSD-2 were identified as the promising four hybrids at

Mathur. KRH-2 was identified as the best among the four, based on its superiority over others for quality parameters. At Chitttor, ADTRH-1, KRH-2 and NSD-2 were identified as the promising hybrids. When quality parameters were also were taken into account, the hybrid KRH-2 was identified as the most promising hybrid at Chittoor.

3. KRH-2, which was identified as the most promising hybrid at three locations, recorded a mean grain yield $ha^{-1}$of 6931.27 kg, straw yield ha^{-1} of 6946.44 kg, productivity day^{-1} of 52.71g, 1000 grain weight of 26.02 g, milling percentage of 58.81 and head rice recovery of 79.73 per cent. The hybrid took an average of 132 days for maturity. NSD-2 which also performed well in all the three locations had recorded a mean grain yield ha^{-1} of 6764.52 kg, straw yield ha^{-1} of 6969.56 kg, productivity day^{-1} of 54.29 g, 1000 grain weight of 24.24 g, milling percentage of 48.37 and head rice recovery of 75.17 per cent and a mean of 125 days for maturity. This hybrid had expressed stable performance for grain yield ha^{-1} and productivity $plant^{-1}$.

4. It was also noticed that in general hybrids took more number of days (120-130) to physiological maturity compared to check varieties (115-120days).

5. The mean plant height for hybrids ranged from 101 to116 cm compared to 85 to 95 cm in check varieties. It was also worthy to note that, even with increased plant height none of the hybrids exhibited lodging character till physiological maturity, at all the three locations.

6. With regard to grain quality parameters such as 1000 grain weight, milling percentage and head rice recovery, check varieties showed superior performance over hybrids. Amylose content in hybrids ranged between 21-29 percentage while in check varieties amylose content ranged between 18-25 percentage.

7. The analysis of variance revealed the presence of considerable variability for most of the characters among the genotypes, at different agroecological situations of central zone of Kerala.

8. High heritability and genetic gain were observed for characters like grain yield ha^{-1}, straw yield ha^{-1}, productivity $plant^{-1}$, number of grains $panicle^{-1}$, amylose content and alkali spreading value.

9. Days to 50 per cent flowering, plant height, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity day^{-1}, productivity $plant^{-1}$ and volume expansion ratio exhibited positive correlation with grain yield, while milling percentage exhibited negative correlation with grain yield.

10. Path analysis in the present study revealed that, the traits like days to 50 per cent flowering, plant height and straw yield ha^{-1} had significant positive direct effect on grain yield and number of days to physiological maturity had high negative direct effect on grain yield. Days to 50per cent flowering exerted high positive indirect effect on grain yield through most of the characters studied.

11. Genotype x environment interaction showed that, ADTRH-1 was stable for days to 50 per cent flowering, number of grains $panicle^{-1}$, number of days to physiological maturity and milling percentage whereas CORH-2 was the stable hybrid for traits like kernel elongation ratio and alkali spreading value. KRH-2 was stable for harvest index and amylose content, whereas DRRH-1 for productive tillers $plant^{-1}$, straw yield ha^{-1}, productivity $plant^{-1}$ and density of grain. The performance of PHB-71 was stable for plant height, volume expansion ratio and head rice recovery, while PA-6201 was stable for 1000 grain weight. NSD-2 had recorded stable performance for grain yield ha^{-1} and productivity $plant^{-1}$.

12. The hybrids ADTRH-1 and DRRH-1 showed stability for maximum characters in the central zone of Kerala.

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13. In all the experiments, yield and most of the yield attributing characters revealed the presence of significant positive standard heterosis in most of the hybrids over the check variety Jyothy.

14. Significant inbreeding depression was noticed for most of the characters, indicating breakdown of hybrid vigour in F_2 generation.

15. The hybrid KRH-2 which performed best even under poor management conditions is recommended for general cultivation in central zone of Kerala. Under better management conditions NSD-2, which responded well to good management, can be recommended.

16. Most of the hybrids had recorded higher benefit cost ratio than check varieties at all the three locations.

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*- Originals not seen.

GENOTYPE X ENVIRONMENT INTERACTION IN COMMERCIAL RICE (*Oryza sativa* L.,) HYBRIDS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study on "Genotype x Environment interaction in commercial rice (*Oryza sativa* L.) hybrids" was carried out under the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara. Seven commercial rice hybrids and two check varieties were evaluated for eighteen characters across three farming situations of central zone of Kerala during *kharif*, 2003. In the experiment, variability, heritability and genetic advance, path coefficients, stability, standard heterosis and inbreeding depression were estimated.

Mean performance of hybrids across the locations revealed that, in general hybrids performed better than check varieties with respect to yield and yield attributing characters like grain yield ha^{-1}, straw yield ha^{-1}, number of grains $panicle^{-1}$, productivity day^{-1} and productivity $plant^{-1}$. With regard to grain quality parameters such as 1000 grain weight, milling percentage and head rice recovery, check varieties showed superior performance over hybrids. High variability and heritability was noticed for most of the yield characters. High genetic advance coupled with high heritability were observed for plant height, grain yield ha^{-1}, straw yield ha^{-1}, number of grains $panicle^{-1}$ and 1000-grain weight. The traits such as days to 50 per cent flowering, plant height, straw yield ha^{-1}, harvest index, number of days to physiological maturity, productivity day^{-1} and volume expansion ratio can be used for direct selection for yield improvement since they had exhibited significant positive correlation with grain yield.

Stability analysis revealed that the hybrid KRH-2, which had recorded highest mean value and regression coefficient less than unity, performed well even under poor management conditions. Therefore KRH-2 can be recommended for general cultivation in central zone of Kerala. For better management conditions, NSD-2 that had responded well to good management, can be recommended. Heterosis studies revealed the presence of significant amount of standard heterosis in most of the hybrids for yield and yield attributing traits. Significant inbreeding depression was also observed for yield and yield attributing characters.

Appendix I. Climatological details of Thrissur and Palakkad districts (2003)

Particulars	Thrissur Dst.	Palakkad Dst.
MSL (m)	40 m above MSL	76.2 m above MSL
Mean RF (mm)	2228	1548
Maximum temperature (°C)	34±0.3	32±0.2
Minimum temperature (°C)	19±0.3	21±0.2
Relative humidity (%)	68-85	75-92

Appendix II. Agronomic package recommended for cultivation of rice hybrids (Ahmed *et al.*, 2003).

Component	**Recommended**
Seed rate	20 kg/ha
Seed density	20g/m^2
Spacing	15 x 20 cm
Planting	One seedling/hill
Fertilizer dose	120:60:60 (N. P_2O_5 and K_2O kg/ha)
N management	3 splits (1/2 basal + ¼ panicle initiation + ¼ Booting)
Water management	Continuous submergence

Appendix III. Cost of cultivation of rice hybrids and varieties at Mullakkara, Mathur and Chittoor (*kharif*, 2003).

Component	Mullakkara		Mathur		Chittoor	
	Hybrids	Varieties	Hybrids	Varieties	Hybrids	Varieties
Seeds	3000	1050	3000	1050	3000	1050
Labours (110 man days)	16500	16500	11000	11000	11000	11000
Ploughing	5000	5000	5000	5000	5000	5000
Fertiliser	3879	3879	3879	3879	3879	3879
FYM	3000	3000	3000	3000	3000	3000
Ploughing	1200	1200	1200	1200	1200	1200
Total (Rs)	32579	30629	27079	25129	27079	25129

Seed cost: Hybrids @ Rs. 150/kg, varieties @ 15/kg.

Seed requirement: Hybrids @ 20 kg/ha and varieties 70 kg/ha.

Labours: Rs.150/man-day at Mullakkara and Rs.100/ man-day at Mathur and Chittoor.

Cost of ploughing: 4 hrs/ha @ Rs. 300 /hour.

FYM: 5 tons/ha @ Rs.1000 /ton.