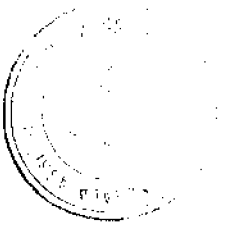
G x E INTERACTION IN THE F_6 GENERATION OF WIDE CROSSES OF RICE (*Oryza sativa* L.)



By

VIDHU FRANCIS PALATHINGAL

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2003

DECLARATION

I here by declare that this thesis entitled **"G x E interaction in the F_6 generation of wide crosses of rice (Oryza sativa L.)"** 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.

Vellanikkara,
15-11-03

Vidhu Francis Palathingal

CERTIFICATE

Certified that this thesis entitled **"G x E interaction in the F_6 generation of wide crosses of rice (*Oryza sativa* L.)"** is a record of work done independently by **Kum. Vidhu Francis Palathingal**, 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 her.

Dr.Kanakamany,M.T.
Chairperson, Advisory Committee
Associate Professor
Agricultural Research Station
Mannuthy

Vellanikkara
15-11-03

CERTIFICATE

We the undersigned members of the Advisory Committee of **Kum. Vidhu Francis Palathingal** a candidate for the Degree of **Master of Science in Agriculture**, agree that this thesis entitled **"G x E interaction in the F_6 generation of wide crosses of rice(*Oryza sativa* L.)"** may be submitted by Kum. Vidhu Francis Palathingal, in partial fulfillment of the requirement for the degree.

Dr. Kanakamany, M.T.
(Chairperson, Advisory Committee)
Associate Professor
Agricultural Research Station
Mannuthy

15/11/03

Dr. K.Pushkaran
(Member, Advisory Committee)
Professor and Head
Department of Plant Breeding & Genetics
College of Horticulture
Vellanikkara

15/11/03

Dr. V.V.Radhakrisnhnan
(Member, Advisory Committee)
Associate Professor
Department of Plant Breeding & Genetics
College of Horticulture
Vellanikkara

15/11/03

Dr. U. Jaikumaran
(Member, Advisory Committee)
Associate Professor and Head
Agricultural Research Station
Mannuthy

15/11/03

(EXTERNAL EXAMINER)
Dr R. THIYAGARAJAN
PROFESSOR AND HEAD
DEPT OF RICE
CENTRE FOR PLANT BREEDING AND GENETICS
COIMBATORE

ACKNOWLEDGEMENT

I have immense pleasure to express my deep sense of gratitude and indebtedness to ***Dr.M.T.Kanakamany****, Associate Professor, ARS, Mannuthy and Chairman of my advisory committee for her valuable guidance, unstinting support rendered at all stages of the work and keen interest shown during the course of my study and preparation of thesis.*

I express my heartful thanks to ***Dr.Radhakrishnan,*** *V.V., Associate Professor, Department of Plant Breeding and Genetics and Member of my advisory committee for kind concern, expert advice and whole hearted co-operation during the course of the study.*

I express my sincere gratitude to ***Dr.Pushkaran,*** *K., Professor and Head, Department of Plant Breeding and Genetics and member of advisory committee for his technical advice and constant encouragement throughout study.*

I express my gratitude to ***Dr.V.Jaikumaran*** *for his valuable guidance, critical suggestions and constant encouragement throughout the investigation.*

I extend my sincere thanks to Mr.Bhaskaran and Mr.Pushkaran for allowing me to carry out my research work in their fields and timely help especially for making the labourers available during the field work.

I take this opportunity to extend my gratitude to all the teaching and nonteaching staff of the Department of Plant Breeding and Genetics for their unbounded support and whole hearted co-operation at different stages of study.

I accord my sincere thanks to all the staff and labourers of Agricultural Research Station, Mannuthy for their sincere help at different stages of my investigation.

A note of thanks to Mr.Santhosh Kumar, Instructor of Computer club, College of Horticulture and Mr.Joy, IMJ Computer Centre for assisting me in compilation of thesis.

The help rendered by my friends Suma, Chandrahasan, Deepa, Subha, Hena, Reshmy, Rajesh, Priyesh, Sinish at various stages of this investigation is valuable and I thank them all from the bottom of my heart.

Words cannot express my soulful gratitude to my father, mother and brother, without whose encouragement the study would have never seen light.

Above all, I bow my head before Jesus, for the unmerited blessings, which lead to every step of the way.

VIDHU FRANCIS PALATHINGAL

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES


Dedicated to my
Dearest Parents

Introduction

INTRODUCTION

In India, rice is the prime cereal crop occupying an area of 44.8 million hectares with a production of 89.3 million tonnes and contributing to major portion of country's food grain production. During sixties, quantum jump in yields were obtained with the advent of high yielding varieties.

The validity of interrelations of inheritance mechanism and prediction of performances in breeding programmes depend on a precise assessment of the true worth of the genotypes. Generally such assessments are made based on the phenotypic data which, reflect both genetic and non genetic influences. The genetic effects are not independent of non genetic effects. Increased concern with the importance of homeostasis in living organisms has estimated plant breeders awareness for the need to develop well buffered cultivars.

The performance of varieties are 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.

Becker (1981) defined stability as capacity to show a high predictable response to the environment.

Measuring G x E interaction is important to determine an optimum breeding strategy to releasing genotypes with adequate adaptation to target environment. Various methods have been proposed for statistical analysis of genotype - environment interactions and to identify the stable genotype.

A stable genotype is one that is able to produce a high mean over diverse environmental conditions. A stable genotype possess an unchanged performance regardless of any variation of environmental conditions.

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 Genotype x Environment (GE) interaction into different components for assessing the genetic worth of genotypes for specific environments.

The present study was undertaken with the following objective.

1. To identify the presence and magnitude of genotype x environment interaction for yield and its component traits.
2. To assess the stability of the genotypes over different environments for yield and its component characters.

Review of Literature

2. REVIEW OF LITERATURE

A brief review of the literature on various aspects related to genotype x environment interactions is presented under the following heads.

1. Genetic variability
2. Heritability, Genetic advance and Genetic gain
3. Phenotypic and genotypic correlation
4. Path analysis
5. Genotype x environment interaction

2.1 Genetic variability

Genetic variability in a crop is the base 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

Sadananda *et al.* (1987) estimated the genetic variability for major cooking and nutritive quality characters in rice collections from north east Indian hills. Water absorption and volume expansion registered high values of coefficient of variation while kernel density and protein content showed low variability. Chauhan *et al.* (1992) studied the quality components in rainfed upland rice. Out of 10 quality indices investigated, alkali-digestion value showed the highest genetic variability irrespective of the growing season. Kumar (1992) reported high variability estimates for plant height, tiller number, boot leaf length, yield per plant 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. Chaubey and Richharia (1993) observed high variability values for spikelets per panicle and lowest for panicle length in indica rice.

Analysis of yield components in rice by Chaubey and Singh (1994) identified wide range of variation for all the traits which 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 and Natarajan (1995) evaluated high density grain characters in rice. Results indicated that high density grains per panicle 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 index. Highest value of genotypic and phenotypic coefficient of variation was observed for high density grain number per panicle. The extent of genetic variation for 11 characters in 99 rice genotypes was assessed by Roy *et al.* (1995). Bacterial blight severity reported the highest genotypic coefficient of variation followed by panicles per plant, grains per panicle and spikelets per panicle. The low estimates of variability was observed in hulling and milling per cent while moderate values were showed by yield per plant, days to 50 per cent flowering and 1000 grain weight.

Ganesan *et al.* (1996) reported high values of genotypic coefficient of variation for panicles per plant, grains per panicle, grain yield per plant, 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. Muker *et al.* (1998) studied the quality and milling characters in fifty 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.

Vanaja (1998) conducted genetic analysis of high yielding rice varieties of diverse origin. High magnitude of PCV and GCV was observed for spikelet sterility percentage, grain yield hectare^{-1}, number of total tillers plant^{-1}, orientation of leaf, harvest index, number of tertiary branches per panicle, number of panicles m^{-2} and alkali spreading value. 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, breadthwise expansion ratio and elongation index recorded the minimum. Kernel length breadth ratio showed the highest phenotypic and genotypic coefficient of variations.

Estimation of variability for five characters in salt tolerant rice genotypes was conducted 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 per cent flowering suggested that these characters were the least affected by the 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 spikelet number per panicle and low for flowering duration, panicle length at all locations. Murthy *et al.* (1999) 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.

Nair (2000) conducted genetic and physiological analysis of ratooning in rice and found that tiller number during panicle initiation and flowering, LAI during panicle initiation and flowering, days to flowering, days taken for completion of flowering within a hill, plant height, number of productive tillers plant^{-1}, number of unproductive tillers plant^{-1}, grains panicle^{-1}, chaff percentage, grain thickness, chlorophyll b content during flowering, flag leaf area, grain yield, grain production day^{-1} and ratooning ability had high PCV and GCV values.

Sarawgi *et al.* (2000) observed high variability in sterile spikelets per panicle, sterility per cent, fertile spikelets per panicle 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 per panicle had maximum variance followed by panicle weight and biological yield indicated 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 were observed for gram yield per plant, total grains per plant and total grains per panicle.

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 per m^2. Minimum difference between phenotypic and genotypic coefficient of variation was observed for days to 50 per cent flowering which suggested that the trait was least affected by environment.

Variability studied in 15 rice varieties by Satyavathi *et al.* (2001) revealed moderate to high coefficient of variation for plant height, number of grains per panicle, spikelet sterility, amylose content, gel consistency, kernel elongation ratio, 100 rice grain weight and yield per plant. Shanthi and Singh (2001) analysed induced mutants of mahsuri rice. He emphasized the importance of traits panicle height, panicle length, 1000 grain weight and number of grains per panicle in selection programme revealed by their low difference between phenotypic and genotypic coefficient of variation.

2.2 Heritability, Genetic advance and Genetic gain

The extent to which the variability of a quantitative character is transferable to the progeny is referred to as heritability for that particular character. The expression of these characters are controlled by many genes whose action may be additive or nonadditive. Therefore the selection of a character should be undertaken only after estimating the heritability of that characters.

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. Kumar (1992) studied the variability and character association in upland rice. Boot leaf length and yield per plant registered high heritability and genetic advance values. Roy and Kar (1992) tested 34 elite breeding lines of rice for heritability of characters. High heritability was observed

for days to 50 per cent flowering and plant height while moderately high heritability was exhibited by panicle number per plant, biological yield and harvest index. High heritability with high genetic advance was found in characters 100 grain weight and plant height. Chaubey and Richharia (1993) analysed the variability in quantitative characters of indica rice varieties. Highest heritability was for test weight and lowest for harvest index. The estimates of genetic advance were highest for spikelets per panicle and lowest for harvest index. Spikelets per panicle and plant height exhibited high heritability coupled with high genetic advance.

Chaubey and Singh (1994) identified high heritability for all the traits studied in yield component analysis in rice, highest for total number of spikelets followed by grain yield per plant, 100 grain weight and lowest for panicle length. The genetic advance as per cent of mean was highest for grain yield per plant while lowest for plant height. High heritability with genetic advance were observed for total number of spikelets, grain yield per plant and panicle weight. Data on analysis of high density grain characters in rice by Govindarasu and Natarajan (1995) indicated high heritability values for all characters except high density grain index. Genetic advance as per cent of mean ranged from 5.42 for high density grain index to 15.48 for number of high density grains per panicle. Roy *et al.* (1995) assessed the ninety nine rice genotypes and observed high heritability estimates ranging from 80 to 99 per cent for most of characters studied which indicated that importance in crop improvement. Bacterial blight severity, plant height, spikelets per panicle and grains per panicle showed high heritability estimates with high genetic advance.

Ganesan *et al.* (1996) studied the heritability in F_2 populations derived from early and extra early rice cultivars. Panicles per plant, grains per panicle, grain yield per plant, 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/AS 89011, ASD 16/Kalyani 11 and IR 50/Heera were identified as best crosses. Quality traits in rice were evaluated by Vivekanandan and Giridharan (1998). They identified high heritability for all the characters studied. The genetic advance as per of mean was highest for kernel length breadth

ratio and lowest for linear elongation ratio and breadthwise expansion ratio. High heritability and genetic advance were showen by kernel length breadth ratio

Estimation of heritability and genetic advance in 15 salt tolerant rice genotypes by Balan *et al.* (1999) resulted in the identification of characters days to 50 per cent flowering, days to maturity with high heritability and straw yield with low heritability. Genetic advance as per cent of mean was high for grain yield followed by harvest index, straw yield and low for days to 50 per cent flowering and days to maturity. Kaw *et al.* (1999) inferred from the variability and inter relations in 94 rice genotypes under cold stress environments that heritability estimates ranged from 82.6 per cent for panicle length to 93.1 per cent for plant height.

Murthy *et al.* (1999) reported from the study of morpho-physiological traits in rice that high heritability and genetic advance was observed for grain yield, total dry matter and leaf area at early stage. Leaf area at flowering, leaf area duration and leaf photosynthetic rate showed high heritability with moderate genetic advance. Morphological characters other than total tillers and number of productive tillers exhibited high heritability. Agromorphological traits in low land rice genotypes were tested by Sarawgi *et al.* (2000). High estimates of heritability of more than 80 per cent and genetic advance more than 18 per cent were observed for plant height, days to 50 per cent flowering and 100 grain weight. Thakur *et al.* (2000) concluded from the genetic parameters of F_2 population and the parents, Anupama and IR 50 that high heritability and genetic advance values were shown by biological yield and grain yield per panicle.

Yadav (2000) observed appreciable amount of genotypic coefficient of variation, heritability and genetic advance for quantitative characters, total grains per panicle, total grains per plant and grain yield per plant which indicated additive gene action and provided scope for crop improvement by selection. Analysis of genetic components in 42 saline and alkaline tolerant rice genotypes by Bala (2001) revealed the association of high heritability with genetic divergence in grain yield per m^2 and plot yield.

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

2.3 Phenotypic and genotypic correlation

Correlation provides 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.

Paramasivan and Rangasamy (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 flowering, plant height, flag leaf area, panicles per plant, panicle length and number of grains per panicle from the evaluation of fifteen hybrids and their parents. Correlation estimated among different traits in upland rice by Kumar (1992) showed significant positive association for tiller number, panicle length and boot leaf breadth.

Rajarathinam and Raja (1992) concluded from the experiments in 40 rice genotypes under alkaline stress conditions that positive phenotypic and genotypic correlations of grain yield occurred with plant height, number of productive tillers and grain number.

Roy and Kar (1992) assessed the phenotypic and genotypic correlations among 11 matric characters in 29 early maturing upland rice genotypes. Yield per plant and harvest index exhibited positive association with plot yield. Significant negative association of days to flowering and plant height with plot yield was

observed. Chaubey and Richharia (1993) studied correlations among 8 quantitative characters in 80 indica rice varieties. Phenotypic correlations of grain yield with plant height, panicle length, spikelets per panicle and panicle weight were significantly positive.

Estimation of genetic parameters in 16 parents and 32 F_1 rice hybrids by Gravois and McNew (1993) revealed a positive relationship between panicle weight and rice yield, whereas panicle number was negatively correlated with rice yield. Panicle weight and panicle length which were negatively correlated at both the additive and broad sense genetic level indicated that a shorter, more compact panicle as the desired panicle shape. Results also identified the negative association of panicle number with plant height at the additive genetic level

Chaubey and Singh (1994) conducted the correlation experiment in 20 rice varieties. Grain yield per plant found positively and significantly associated with panicle weight, number of ear bearing tillers and plant height. The number of ear bearing tillers exerted maximum direct effect followed by plant height and 100 grain weight. Govindarasu and Natarajan (1995) indicated that high density grain number per panicle recorded significant and positive correlations with number of spikelets and high density grain index.

Variability and correlation analysed in 99 rice genotypes by Roy *et al.* (1995) identified the significant positive association of grain yield per plant with days to 50 per cent flowering, spikelets per panicle and milling per cent.

Vanaja (1998) conducted genetic analysis of high yielding rice varieties. The study revealed that ratio of vegetative phase to reproductive phase, number of panicles m^{-2}, number of spikelets per panicle, number of tertiary branches per panicle, number of grains per panicle, 1000 grain weight and harvest index were significantly correlated with yield at genotypic and phenotypic level.

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 per panicle indicated significant correlation with panicle length, harvest index and dry matter production. Genotypic and phenotypic correlation of yield and component characters revealed that harvest index, number of grains per panicle, grain breadth, panicle weight, flag leaf area and grain density had significant positive genotypic correlation with yield (Rosamma, 1998).

Vivekanandan and Giridharan (1998) reported that the elongation index showed positive association with linear elongation ratio and negative correlation with breadthwise expansion ratio from quality traits analysed in rice. Data on analysis of doubled haploid population by Bagali *et al.* (1999) revealed significant genotypic correlation of grain yield with panicle density, number of filled grains per panicle, panicle weight, harvest index and fertility per cent.

Balan *et al.* (1999) suggested from the analysis of salt tolerant rice genotypes that higher genotypic correlations indicated the inherent association between the traits. Significant positive correlation of seed yield with harvest index and straw yield was observed.

Correlations between fertile spikelets per panicle and fertility per cent were highly significant and positive at all locations in 94 rice genotypes tested under cold stress environments (Kaw *et al.*, 1999). The magnitude of association between the various economic traits were analysed in 20 crosses of indica rice by Manonmani *et al.* (1999). He found that grain yield, grains per primary ear and panicle length registered significant and positive association with days to flowering. Correlation studied revealed that selection for very early types resulted in reduction in panicle length, number of grains and 100 grain weight which inturn reduced the yield

Meenakshi *et al.* (1999) worked out the genotypic and phenotypic correlations for yield and physiological characters in rainfed rice. Productive tillers per plant, grains per panicle, dry matter production and harvest index were positively correlated with grain yield.

Analysis of correlation among seed characters, seedling characters and yield attributes performed in 24 genotypes of upland rice by Rao and Saxena (1999) indicated that none of the seed or seedling characters were significantly correlated with grain yield. They also observed that yield attributes like percentage fertile grains per panicle and biological yield had a strong positive association with grain yield. Rao and Shrivastav (1999) studied the association among yield and yield attributes in upland rice genotypes. The results revealed the correlation of moderate stature of plant, moderate number of panicles per m^2, higher number of filled spiklets per panicle with higher grain yield.

Sarawgi *et al.* (2000) recorded IR 57515-PM I-B-1-1-SKN-1-1 as the breeding line with highest grain yield from the correlation studied in lowland rice genotypes. He identified that grain yield was positively and significantly correlated with biological yield, harvest index, number of fertile spikelets per panicle and plant height at both genotypic and phenotypic levels.

Thakur *et al.* (2000) reported from the character association studied in segregating population of rice that grain yield was positively associated with the biological yield per plant and panicle weight. Saline and alkaline tolerant rice genotypes were studied for correlation among characters by Bala (2001). Results indicated significant correlation of plot yield with grain yield per m^2, panicle length and plant height.

In 1998, eight parents and 16 hybrids obtained through line x tester mating design were evaluated at Madurai by Janardhanam *et al.* (2001). Only the number of grains per panicle had direct positive association with single plant yield indicated the importance of this character as a useful selection index for yield Kavitha and Reddi (2001) observed significant phenotypic and genotypic correlation between grain yield and other yield components from the experiment in 21 rice genotypes. Grain yield exhibited significant positive association with number of productive tillers per plant, 100 grain weight, dry matter production per plant and harvest index Experiment identified negative association of spikelet sterility with grain yield.

Satyavathi *et al.* (2001) studied the variability and correlation in rice varieties. He inferred that selection could be practiced for number of productive tillers per plant, number of grains per panicle, length breadth ratio, and 100 grain weight as these characters manifested positive significant correlation with grain yield. The quantitative parameter amylose content showed a significant positive correlation with gel consistency.

Genotypic and phenotypic correlations among 8 characters were analysed in 53 napier grass genotypes by Khan and Sukumar (2002). Highly significant, positive genotypic correlations were observed between green fodder yield and plant height, leaf width and number of tillers per plant. Green fodder yield recorded highly significant, positive, phenotypic correlation coefficient indicated low environmental effect on the expression of characters.

2.4 Path analysis

Path coefficient is simply 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).

Paramasivan and Rangasamy (1988) suggested that the selection for grain yield could be efficient if it is baed on plant height, tiller number, panicle length, grain number per panicle and grain weight as these characters fullfilled 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 given by panicle length followed by plant height and tiller number. Rajarathinam and Raja (1992) inferred from the results of correlation and path analysis of forty genotypes of rice that plant height, number of productive tillers and grain number 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 (1993) 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 per plant followed by plant height and 100 grain weight.

Path coefficient analysis in early rice varieties revealed grains per panicle as the most important character because of its higher positive direct effect followed by productive tillers and panicle weight (Sundaram and Palaniswamy, 1994).

Roy *et al.* (1995) stated that grains per panicle, spikelets per panicle and bacterial blight severity as 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 as 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 was observed from the path coefficient analysis.

Vanaja (1998) revealed that the principal yield determinging components in rice were harvest index, number of tertiary branches per panicle, number of panicles per m^2, number of grains per panicle, number of spikelets per panicle, ratio of vegetative phase to reproductive phase, 1000 grain weight, number of days to 50 per cent flowering, number of days to harvest and spikelet sterility percentage.

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 per panicle and harvest index on grain yield per plant. 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 per cent flowering recorded the highest positive direct effect on seed yield followed by harvest index.

Path coefficient analysis by Kaw *et al.* (1999) indicated fertile spikelet number to have the highest positive influence and panicle length a negative influence, both directly and directly, upon fertility.

Meenakshi *et al.* (1999) evaluated the path coefficients of 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.

Faseela (2000) conducted the genetic analysis in F_2 and F_3 progenies of selected crosses of rice varieties of diverse origin. Highest positive direct effect was exhibited by L/B ratio followed by total tillers per plant, panicle bearing tillers

per plant, panicle length, number of grains per panicle, grain breadth, 1000 grain weight, duration to 50 per cent flowering and grain density.

Sarawgi *et al.* (2000) indicated a greater contribution of harvest index, fertile spikelets per panicle, biological yield and plant height to grain yield from the character association studied in rainfed lowland rice genotypes.

Results of path coefficient analysis in saline and alkaline rice genotypes by Bala (2001) showed that grain yield as per m^2 exerted the maximum direct positive effect on plot yield, followed by panicle length, plant height, and days to 50 per cent flowering.

Janardhanam *et al.* (2001) reported plant height, spikelets per panicle and number of grains per panicle as the most important characters that modify expression of single plant yield, based on direct and indirect effects from path analysis.

Data on path coefficient analysis of Kavitha and Reddi (2001) revealed that the characters filled grains per panicle, dry matter production per plant and harvest index exhibited a high positive direct effect coupled with positive significant correlation with grain yield per plant.

Satyavathi *et al.* (2001) analysed the genetic parameters in 15 rice varieties under different spacings. Number of productive tillers per plant, number of grains per panicle, length breadth ratio and 100 grain weight were found to be the main contributers to grain yield.

Khan and Sukumar (2002) estimated the correlation and path coefficients in 53 genotypes of napier grass. Leaf width recorded the highest direct effect on green fodder yield followed by plant height, panicle length, crude protein content and crude fibre content. The indirect effects of plant height through leaf width and number of tillers per plant contributed towards green fodder yield.

2.5 GENOTYPE X ENVIRONMENT INTERACTION

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.

De *et al.* (1992) analysed the genotype x environment interaction of 47 rice genotypes in four different lowland situations. They identified CR 728-7-2-2, CR 673-431 and Utkal Prava as stable cultures. Of the significant genotype x environment interaction observed, linear component was predominent for ear bearing tillers per hill and non linear component for grain yield.

Sreekumar *et al.* (1993) evaluated the genotypic x environment interaction and stability of pre-release cultures and varieties of rice. The analysis of variance for stability with respect to important yield attributes revealed significant difference between genotypes for height of the plant and grain yield only.

The stability of advanced rice cultures were tested under different environments by Elsy *et al.* (1994). They observed differences among varieties with regard to their relative stability in adapting to specific environments.

Kandaswami and Rajagopal (1995) conducted the stability analysis of rice varieties in sodic soils. None of the genotypes showed stability for all the traits studied. Genotype SSRC 92217 which recorded stable grain yield with average response was found suitable for all environments. Singh *et al.* (1995) observed significant genotype x environment interaction in 15 rice genotypes of Sikkim which indicated the differential response of the genotypes to different environments. Genotypes RCPL 3-6, RCPL 3-2 and TURA 490 with stable performance were recommended for general cultivation in Sikkim.

Mishra and Dash (1997) assessed the stability in 10 aromatic rice genotypes. They found that the genotypes Kasturi, ORP 598-7, ORP 665-14, ORP 665-7 with higher grain yield were stable for most of the yield contributing characters. Evaluation of thirty diverse rice genotypes by Singh *et al.* (1997) for adaptability over two locations and two dates of planting indicated IR 8, PR 106 and IR 64 as stable in their performance for grain yield with unit regression.

Kulkarni and Gangaram (1998) studied the stability parameters in fifty mutants of M5 generation. They reported significant genotype x environment interaction for flowering and grain yield. The mutants M5, M16, M34, M41 and M47 exhibited higher grain yield. Significant pooled deviation which accounted for non linear component of gneotype x environment interaction was also observed and it indicated that genotypes differed considerably with respect to stability of these characters.

Panwar and Dhaka (1998) tested 32 rice genotypes in 16 environments during Kharif 1992 and 1993 to evaluate their stability in performance for grain yield. Eight high yielding genotypes UPR 1125-12-2-2, NDR 637, NDR 3006, HUR 51, NDR 6011, IR 8, PNR 519, IET 11347 were most stable and suggested for commercial cultivation. Five genotypes UPR 990-17-1, Sarju 52, UPR 84-21, UPR 80-120 and NDR 3003 and Basmati P-1 were found suitable for poor environments.

Reddy *et al.* (1998) conducted a critical study of genotype x environment interaction for grain yield in lowland rice cutlivrs. Among the significant linear and non linear components of genotype x environment interaction observed, linear component was found to be predominent and this helped in predicting the performance of the genotypes across environments. Vanniarajan *et al.* (1998) reported from analysis of pigeonpea genotypes that the linear component of genotype x environment interaction was significant for plant height, branches per plant, pods per plant, pod length, seeds per pod, 100 seed weight and seed yield per plant while non linear components were significant for all the characters studied.

Analysis of stability in rice genotypes ADT 36, ADT 41, ADT 42, IR 72 and AD 85361 by Manuel *et al.* (1999) recognised the linear component of genotype x environment interaction to be highly significant for maximum individual grain weight and dry weight of rough rice. This represented the significant difference among genotypes for linear response to environments. ADT 36 and AD 85361 were the most stable for the traits studied in all environments.

Manivel and Hussain (2000) identified the hybrids JP 65 x RC 1226, 240 x USSR 2, LRES 17 x JH 120, LRES 17 x SH 63 and 240 x Salam local which possessed nonsignificant deviation of regression coefficient from unity for seed yield and most other biometric traits, a stable over environments from the phenotypic stability analysis of 79 genotypes of castor.

Effects of genotype x environment interaction were assessed by Saxena and Rajna (2001) for seed weight and grain yield of pigeonpea genotypes tested in 11 environments. Environments accounted for maximum proportion of variation followed by genotype environment interaction and genotypes. Genotypes ICPH 22, ICPH 149, UPAs 120 and Pusa 33 with average performance in all environments were considered as stable for seed weight. ICPH 8 and CO 5 registered higher grain yields from analysis of data.

Shadakshari *et al.* (2001) evaluated 40 long duration rice genotypes for genotype x environment interaction across six farming situations of hill zone during Kharif 1998. Genotype x environment mean squares were significant for all characters indicating differential response of the genotypes in different environments. IET 11865, KHRS 32, IET 10549 and CN 647RRR 27 were identified as suitable genotypes for favourable environments as revealed by their high regression coefficient while BKB, Kempu Sannakki, PUB, IRLON 90/39 for unfavourable environments as indicated by their low regression coefficient values. Stable genotypes for grain yield identified were IR 57773, IET 13736, Puttabatta, IET 11865, KHRS 22, KHRS 28, PUB and BKB revealed by high mean, regression coefficient equal to one and deviation from regression nearer to zero. Vijayakumar *et al.* (2001) recorded a significant genotype x environment interaction for grain yield that resulted in identifying the genotype with specific

adaptation and those with wide adaptation, from the analysis of 16 hybrids and 2 inbread check varieties over 11 locations.

Jyothi (2002) conducted stability analysis for Kunjukunju rice cultures in three locations and identified K-6 as the most stable for many of the yield and yield traits.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was carried out under the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period 2002 to 2003. Field experiments related to the investigation were laid out at Agricultural Research Station, Mannuthy and at farmers fields of Pattikkad and Adatt.

Table 1. Climatological details of the three locations

Particulars	Mannuthy*	Pattikkad**	Adatt***
MSL (m)	15 m above MSL	49.6 m above MSL	0.25-2.25 m below MSL
Mean RF (mm)	2803	2400	2757
Maximum temperature (°C)	32±0.2	31±0.1	38
Minimum temperature (°C)	23±0.3	21±0.2	21
Relative humidity (%)	68-75	80-93	70-95

Source: * Department of Agricultural Meteorology, College of Horticulture, Vellanikkara

** CPCRI Research Centre, Kannara

*** Johnkutty (1993)

3.1 MATERIALS

Seven selected superior F_5 cultures obtained from the cross progenies of the Ph.D. programme "Genetic analysis of high yielding rice varieties of diverse origin" (Vanaja, 1998) along with two local check varieties constituted the material for study.

Table 2. Details of rice cultures used for the experiment

Sl.No.	Name of culture	Parentage
1	C 28	Mahsuri x IR 36
2	C29	Mahsuri x IR 62030-18-2-2
3	C 38	Vytilla 3 x Mattatriveni
4	C 26S	Mahsuri x Vytilla 3
5	C 26T(a)	Mahsuri x Vytilla 3
6	C 26T(b)	Mahsuri x Vytilla 3
7	C 80	PK 3355-5-1-4 x Bhadra
8	Jyothi (local check)	PTB 10 x IR 8
9	Ahalya (local check)	(PTB 10 x TN 1) x TN 1

3.2 METHODS

3.2.1 Experiment 1

The seven selected superior F_5 cultures were raised in the main field at Agricultural Research Station, Mannuthy for multiplication of seed materials.

3.2.2 Experiment 2

Seven cultures of F_6 families from the experiment 1 along with two local checks were analysed in a yield trial. The experiments were conducted in different ecological situations of Mannuthy, Pattikkad and Adatt (Plate 1).

The cultures were raised in randomized block design with three replications at each environment. Each plot was of size 7.2 m^2 and comprised 25 rows of 21 plants, each at a spacing of 15cm x10cm. The data were recorded on 10 randomly selected plants in a plot for the following yield and quality traits. Observations were taken based on the standard evaluation system by Shouichi *et al.* (1976), IRRI (1995) and Directorate of Rice Research (1995).

3.2.3 Observations recorded

1. Days to 50 per cent flowering

Number of days was taken from date of germination to 50 per cent 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. Total number of tillers

Total number of tillers in a plant was counted after 50 per cent flowering. 10 plants from each plot were utilised for this purpose.

PLATE: 1 FIELD VIEW OF EXPERIMENT AT MANNUTHY, PATTIKKAD AND ADATT

4. Number of productive tillers

Number of productive tillers in a plant was recorded prior to harvest

5. Number of days for physiological maturity

Days from date of germination to grain ripening was recorded.

6. Length of panicle

Length of panicles, from selected plants was measured in centimeters from base of panicle to the tip.

7. Number of spikelets per panicle

Ten panicles from the randomly selected plants of each plot were collected and number of spikelets of each panicle was counted and the mean was calculated.

8. Number of grains per panicle

Number of grains from each of the collected panicles was counted and the mean was worked out. Ten panicles/plot were used for this purpose.

9. Colour of grain

Colour of grain was recorded from each of the cultures analysed.

10. Grain length

Length of ten randomly selected grains from each plot was measured in mm using vernier calipers and mean values worked out.

11. Grain breadth

Breadth of the ten randomly selected grains from each plot was measured in mm using vernier calipers and mean values worked out.

12. 1000 grain weight

Thousand fully filled, ripened grains taken at random from each plot, was weighed and recorded in grams.

13. Grain yield

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

14. Straw yield

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

15. Hulling and milling percentage

a) Hulling percentage

Seeds collected from each plot were cleaned and dried to 14 per cent moisture content. The sample was parboiled by double steaming method and dried to 14 per cent moisture. Then the sample was dehulled using laboratory model satake rubber roller. Hulling percentage was calculated as follows (Arumugachamy *et al.*, 1995).

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

b) Milling percentage

The dehulled paddy samples were milled for 30 seconds in a McGill miller.

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

16. Head rice recovery

Five grams of rice per sample was used to study head rice recovery.

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

17. Organoleptic qualities

Organoleptic qualities like amylose content, alkali spreading value, volume expansion ratio and kernel elongation ratio were studied.

a) Amylose content

100 mg paraboiled milled rice was powdered. In this sample, one ml of distilled ethanol was added. 10.0 ml of IN 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 NHCl 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 content 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 ml extract = $\frac{X}{2.5} \times 100$ mg/100 ml amylose = % amylose

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

b) Alkali spreading value

Ten milled rice kernels were placed in 10.0 ml of 1.7 per cent KOH in shallow container (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, 1980).

Description	Score
Kernel not affected	1
Kernel swollen	2
Kernel swollen, collar incomplete or narrow	3
Kernel swollen, collar complete and wide	4
Kernel split or segmented; collar complete and wide	5
Kernel dispersed, merging with collar	6
Kernel completely dispersed and intermingled	7

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

c) Volume expansion ratio

The volume of raw rice as well as cooled rice was determined by water displacement using a measuring cylinder (Onate and Delmundo, 1966).

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

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.

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

3.3 STATISTICAL ANALYSIS

The data obtained from three locations Mannuthy (location 1), Pattikkad (location 2) and Adatt (location 3) were subjected to location wise analysis of variance and stability analysis.

3.3.1 Estimation of genetic parameters

The variance components were estimated.

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

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

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

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

3.3.1(e) Expected genetic advance

The expected genetic advance of the cultures was measured by the formula suggested by Lush (1949), 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.

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

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

Genetic gain was categorised as

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

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).

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

CoVg12 = Genotypic covariance between characters 1 and 2

CoVe12 = Environmental covariance between 1 and 2

Genotypic covariance between two characters 1 and 2

$$CoVg12 = \frac{Mt12 - Me\ 12}{N}$$

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 I was used.

Results

4. RESULTS

The analysis of genotype x environment interaction in seven rice cultures along with two local checks was carried out in three locations Mannuthy, Pattikkad and Adatt. The results of the studies are presented below.

4.1 GENETIC VARIABILITY

The extent of genetic variability with respect to different quantitative and qualitative characters in nine rice cultures was estimated for the three locations Mannuthy, Pattikkad and Adatt. The abstract of analysis of variance and variability parameters of different characters are given in Tables 3 to 6.

Results from analysis of variance revealed highly significant difference among the nine cultures for the characters studied at Pattikkad and Adatt (Table 3). The characters include height of plant at harvest, total number of tillers, number of productive tillers, length of panicle, number of spikelets per panicle, number of grains per panicle, grain length, grain breadth, number of days for physiological maturity, 1000 grain weight, days to 50 per cent flowering, grain yield, straw yield, hulling percentage, milling percentage, amylose content, alkali spreading value, volume expansion ratio, kernel elongation ratio and head rice recovery. At Mannuthy, nine cultures showed significant difference for all the yield attributing characters except grain breadth.

Variability parameters like range, mean, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) computed for characters in three different locations are presented in Tables 4, 5 and 6.

The experiment conducted at Adatt indicated high mean values for thecharacters length of panicle (21.23 cm), grain length (8.007 mm), days to 50 per cent flowering (92.11), grain yield (6545.41 kg ha^{-1}), hulling percentage (75.45), alkali spreading value (3.88), and head rice recovery (82.58) (Table 4). At Pattikkad, height of plant at harvest (99.96 cm), number of spikelets per panicle (122.81), number of grains per panicle (102.70), grain breadth (2.43), 1000 grain

Table 3. Analysis of variance for grain yield and associated characters in nine cultures for locations Mannuthy, Pattikkad and Adatt

Characters	Mean sum of square								
	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
	Mannuthy			Pattikkad			Adatt		
X_1	388.38**	0.75	3.00	423.16**	21.34	12.43	81.49**	0.21	9.41
X_2	11.83**	0.77	1.15	7.67**	0.03	2.28	8.20**	1.14	2.18
X_3	6.98**	0.70	1.82	5.59*	0.48	1.93	7.95**	1.03	1.45
X_4	3.65**	0.18	0.54	2.78**	0.03	0.25	9.77**	0.12	0.41
X_5	726.91**	5.76	125.86	453.92**	3.35	8.37	1147.16**	4.76	6.48
X_6	410.83*	88.11	116.73	380.45**	0.25	6.84	583.91**	5.44	10.27
X_7	1.44**	0.04	0.06	0.85**	0.01	0.01	0.67**	0.001	0.007
X_8	0.09	0.01	0.03	0.05**	0.001	0.008	0.028**	0.002	0.005
X_9	18.41**	0.109	2.81	12.33*	0.32	4.2	19.81**	0.59	4.67
X_{10}	91.48**	6.37	5.53	49.89**	0.14	7.81	36.14**	2.25	3.42
X_{11}	48.84**	0.92	3.38	62.16**	2.10	5.06	113.58**	2.33	4.08
X_{12}	1915354.6**	145280.00	308086.69	2081061.4**	2112.0	267229.31	4301562.8**	2746.35	331043.81
X_{13}	9039296.0**	508544.0	374384.0	17997994.0**	18111968.0	2333387.0	8139010.1**	10320.818	394167.46
X_{14}	22.72**	7.02**	0.53	36.91	1.89*	0.41	24.24**	4.70**	0.45
X_{15}	21.86**	1.03	1.65	26.09**	7.07**	0.69	23.35**	3.94*	1.01
X_{16}	6.72**	0.44	0.12	7.31**	0.28	0.14	10.32**	0.017	0.17
X_{17}	0.15**	0.01	0.004	0.28**	0.013	0.017	0.25**	0.013	0.012
X_{18}	0.65**	0.01	0.04	1.005**	0.14	0.07	0.46**	0.13	0.08
X_{19}	0.01**	0.0005	0.004	0.019**	0.009**	0.002	0.02**	0.002	0.003
X_{20}	40.12**	0.58	2.77	44.25**	2.02	2.26	46.54**	2.69	2.46

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

X_1 - height of plant at harvest, X_2 - total number of tillers, X_3 - number of productive tillers, X_4 - Length of panicle, X_5 - number of spikelets per panicle, X_6 - number of grains per panicle, X_7 - grain length, X_8 - grain breadth, X_9 - number of days for physiological maturity, X_{10} - 1000 grain weight, X_{11} - days to 50 per cent flowering, X_{12} - grain yield, X_{13} - straw yield, X_{14} - hulling percentage, X_{15} - milling percentage, X_{16} - Amylose content, X_{17} - alkali spreading value, X_{18} - volume expansion ratio, X_{19} - kernel elongation, X_{20} - Head rice recovery

Table 4. Variability parameters of nine rice cultures at Adatt

Sl.No.	Characters	Range	Mean	PCV	GCV
1	Height of plant at harvest	91.87 - 105.80	98.94 ± 2.5	5.84	4.95
2	Total number of tillers	7.67 - 12.67	10.03 ± 1.3	20.40	14.11
3	Number of productive tillers	6.33 - 11.0	9.03 ± 1.1	21.05	16.29
4	Length of panicle	19.73 - 25.60	21.23 ± 0.5	8.88	8.31
5	Number of spikelets per panicle	80.33 - 135.33	106.55 ± 2.3	18.46	18.30
6	Number of grains per panicle	63.33 - 104.33	82.55 ± 2.7	17.19	16.75
7	Grain length	7.27 - 8.80	8.007 ± 0.07	5.99	5.89
8	Grain breadth	2.17 - 2.50	2.27 ± 0.05	5.01	3.91
9	Number of days for physiological maturity	107.67 - 115.0	110.40 ± 1.78	2.82	2.03
10	1000 grain weight	23.33 - 33.0	29.00 ± 1.5	13.33	11.63
11	Days to 50 per cent flowering	84.00 - 99.0	92.11 ± 1.6	6.92	6.56
12	Grain yield	4925.90 - 8798.70	6545.41 ± 469.7	19.69	17.61
13	Straw yield	10018.12 - 15136.79	11514.73 ± 512.5	14.98	13.95
14	Hulling percentage	70.70 - 78.84	75.45 ± 0.5	3.84	3.73
15	Milling percentage	60.70 - 68.84	65.23 ± 0.8	4.46	4.18
16	Amylose content	20.40 - 24.80	22.66 ± 0.3	8.32	8.11
17	Alkali spreading value	3.50 - 4.30	3.88 ± 0.09	7.82	7.28
18	Volume expansion ratio	3.40 - 4.50	3.94 ± 0.2	11.71	8.98
19	Kernel elongation ratio	1.16 - 1.40	1.27 ± 0.04	8.41	6.99
20	Head rice recovery	74.20 - 86.80	82.58 ± 1.28	5.02	4.64

Table 5. Variability parameters of nine rice cultures at Pattikkad

Sl.No.	Characters	Range	Mean	PCV	GCV
1	Height of plant at harvest	88.80 - 126.93	99.96 ± 2.8	12.22	11.70
2	Total number of tillers	8.00 - 12.67	9.81 ± 1.2	20.59	13.66
3	Number of productive tillers	7.00 - 11.0	8.51 ± 1.1	20.86	12.95
4	Length of panicle	18.27 - 21.50	20.62 ± 0.4	5.08	4.46
5	Number of spikelets per panicle	107.67 - 140.67	122.81 ± 2.3	10.20	9.92
6	Number of grains per panicle	87.67 - 118	102.70 ± 2.1	11.16	10.87
7	Grain length	7.37 - 9.20	7.91 ± 0.08	6.85	6.71
8	Grain breadth	2.17 - 2.63	2.43 ± 0.07	6.26	5.04
9	Number of days for physiological maturity	114.00 - 119.33	116.77 ± 1.6	2.25	1.41
10	1000 grain weight	26.00 - 37.67	31.40 ± 2.2	14.88	11.93
11	Days to 50 per cent flowering	82.67 - 95.0	88.11 ± 1.8	5.57	4.95
12	Grain yield	5390.07 - 7912.73	6540.04 ± 422.08	14.28	11.89
13	Straw yield	10505.87 - 17092.57	12626.16 ± 1247.2	21.77	18.10
14	Hulling percentage	68.13 - 78.85	75.34 ± 0.5	4.71	4.63
15	Milling percentage	60.46 - 68.85	65.60 ± 0.6	4.61	4.44
16	Amylose content	20.40 - 24.40	22.53 ± 0.03	7.07	6.86
17	Alkali spreading value	3.10 - 4.13	3.33 ± 0.1	9.82	8.98
18	Volume expansion ratio	3.40 - 4.70	4.05 ± 0.22	15.28	13.75
19	Kernel elongation ratio	1.16 - 1.40	1.28 ± 0.03	6.98	5.91
20	Head rice recovery	74.20 - 86.60	82.45 ± 1.2	4.89	4.54

Table 6. Variability parameters of nine rice cultures at Mannuthy

Sl.No.	Characters	Range	Mean	PCV	GCV
1	Height of plant at harvest	74.37 - 106.30	90.56 ± 1.4	12.66	12.51
2	Total number of tillers	9.33 - 15.33	11.22 ± 0.8	19.34	16.81
3	Number of productive tillers	8.00 - 13.00	9.59 ± 1.1	19.63	13.66
4	Length of panicle	18.73 - 22.47	19.84 ± 0.4	6.02	5.32
5	Number of spikelets per panicle	97.33 - 146.33	120.77 ± 9.1	14.95	11.72
6	Number of grains per panicle	82.33 - 116.33	96.55 ± 8.8	15.18	10.25
7	Grain length	7.20 - 9.13	7.81 ± 0.2	9.23	8.68
8	Grain breadth	2.03 - 2.50	2.35 ± 0.15	10.03	5.88
9	Number of days for physiological maturity	115.67 - 124.33	120.44 ± 1.3	2.35	1.89
10	1000 grain weight	22.67 - 37.33	29.25 ± 1.9	19.98	18.29
11	Days to 50 per cent flowering	82.00 - 95.67	90.48 ± 1.5	4.76	4.30
12	Grain yield	4534.17 - 6761.92	5718.14 ± 453.2	16.06	12.80
13	Straw yield	10062.90 - 15189.07	11745.35 ± 499.5	15.38	14.47
14	Hulling percentage	68.65 - 76.64	71.63 ± 0.5	3.93	3.80
15	Milling percentage	58.24 - 66.04	61.74 ± 1.05	4.69	4.20
16	Amylose content	20.40 - 24.80	23.20 ± 0.2	6.57	6.39
17	Alkali spreading value	3.30 - 3.90	3.54 ± 0.05	6.66	6.39
18	Volume expansion ratio	3.20 - 4.50	3.75 ± 0.1	13.31	11.96
19	Kernel elongation ratio	1.16 - 1.40	1.23 ± 0.05	7.92	5.73
20	Head rice recovery	74.20 - 86.60	82.01 ± 1.3	4.76	4.30

weight (31.40), straw yield (12626.16 kg ha^{-1}), milling percentage (65.60), volume expansion ratio (4.05) and kernel elongation ratio (1.28) recorded highest mean values (Table 5). Total number of tillers (11.22), number of productive tillers (9.59), days to physiological maturity (120.44) and amylose content (23.2) had the highest mean values at Mannuthy (Table 6).

Phenotypic and genotypic coefficient of variation were estimated for all the yield attributing characters at Mannuthy, Pattikkad and Adatt. Most of the yield characters like number of productive tillers, total number of tillers, number of spikelets per panicle, number of grains per panicle, grain yield had the highest PCV and GCV at Adatt. Results showed the high level of phenotypic and genotypic variability for these characters at Adatt indicating the scope for further improvement. At Pattikkad total number of tillers, number of productive tillers, straw yield and volume expansion ratio exhibited highest values of PCV. GCV also followed the same trend. Total number of tillers, number of productive tillers, number of grains per panicle, 1000 grain weight, grain yield and straw yield recorded the highest PCV and GCV at Mannuthy (Table 4, 5 and 6).

4.2 HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN

Genetic parameters like heritability, genetic advance and genetic gain estimated for yield attributes at Mannuthy, Pattikkad and Adatt are presented in Tables 7to9.

At Mannuthy, high estimates of heritability were noticed for most of the yield characters studied, Maximum heritability of 97.7 per cent was noticed in the case of height of plant at harvest and the minimum of 34.3 per cent in the case of grain breadth. Genetic advance expressed as percentage of mean was maximum (34.4) for 1000 grain weight and the minimum (3.1) for number of days for physiological maturity. High estimates of heritability coupled with high genetic gain was noticed for height of plant at harvest, total number of tillers, 1000 grain weight, grain yield, straw yield and volume expansion ratio (Table 7).

Table 7 Estimation of genetic parameters for grain yield and associated characters in nine rice cultures
Location - Mannuthy

Sl.No	Characters	Heritability (%)	Genetic advance (GA)	Genetic gain (GG)
1	Height of plant at harvest	97.70	23.08	25.48
2	Total number of tillers	75.50	3.38	30.12
3	Number of productive tillers	48.40	1.88	19.60
4	Length of panicle	78.00	1.92	9.67
5	Number of spikelets per panicle	61.40	22.85	18.90
6	Number of grains per panicle	45.60	13.78	14.20
7	Grain length	88.30	1.31	16.70
8	Grain breadth	34.30	0.17	7.20
9	Number of days for physiological maturity	64.80	3.78	3.10
10	1000 grain weight	83.80	10.09	34.40
11	Days to 50 per cent flowering	81.70	7.25	8.00
12	Grain yield	63.50	1201.44	21.00
13	Straw yield	88.50	3293.99	28.00
14	Hulling percentage	93.20	5.41	7.50
15	Milling percentage	80.30	4.79	7.70
16	Amylose content	94.60	2.97	12.80
17	Alkali spreading value	92.10	0.45	12.70
18	Volume expansion ratio	80.70	0.83	22.10
19	Kernel elongation ratio	52.30	0.11	8.90
20	Head rice recovery	81.80	6.57	8.00

Fig.1 Heritability and GA (% of mean) of rice cultures at Mannuthy

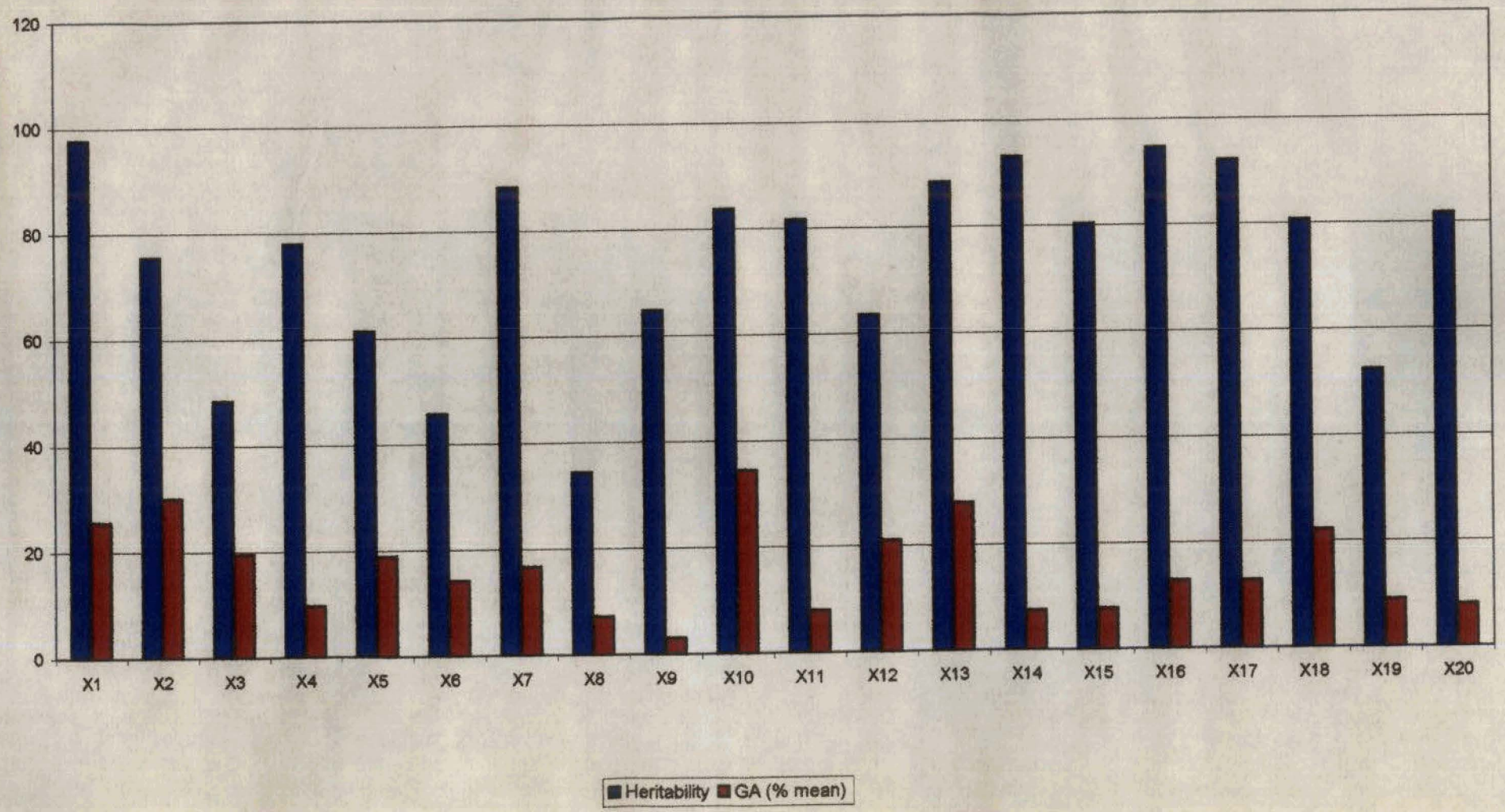


Table 8. Estimation of genetic parameters for grain yield and associated characters in nine rice cultures
Location - Pattikkad

Sl.No.	Characters	Heritability (%)	Genetic advance (GA)	Genetic gain (GG)
1	Height of plant at harvest	91.70	23.08	23.08
2	Total number of tillers	44.00	1.83	18.60
3	Number of productive tillers	38.60	1.41	16.50
4	Length of panicle	76.90	1.66	8.05
5	Number of spikelets per panicle	94.70	24.43	19.80
6	Number of grains per panicle	94.80	22.38	21.70
7	Grain length	96.00	1.07	13.50
8	Grain breadth	64.70	0.20	8.20
9	Number of days for physiological maturity	39.10	2.12	1.80
10	1000 grain weight	64.20	6.18	19.60
11	Days to 50 per cent flowering	79.00	7.99	9.00
12	Grain yield	69.3	1333.90	20.30
13	Straw yield	69.10	3913.37	30.90
14	Hulling percentage	96.70	7.06	9.30
15	Milling percentage	92.40	5.76	8.70
16	Amylose content	94.30	3.09	13.70
17	Alkali spreading value	83.70	0.57	17.10
18	Volume expansion ratio	81.00	1.03	25.40
19	Kernel elongation ratio	71.60	0.13	10.10
20	Head rice recovery	86.10	7.15	8.60

Fig.2 Heritability and GA(% of mean) of rice cultures at Pattikkad

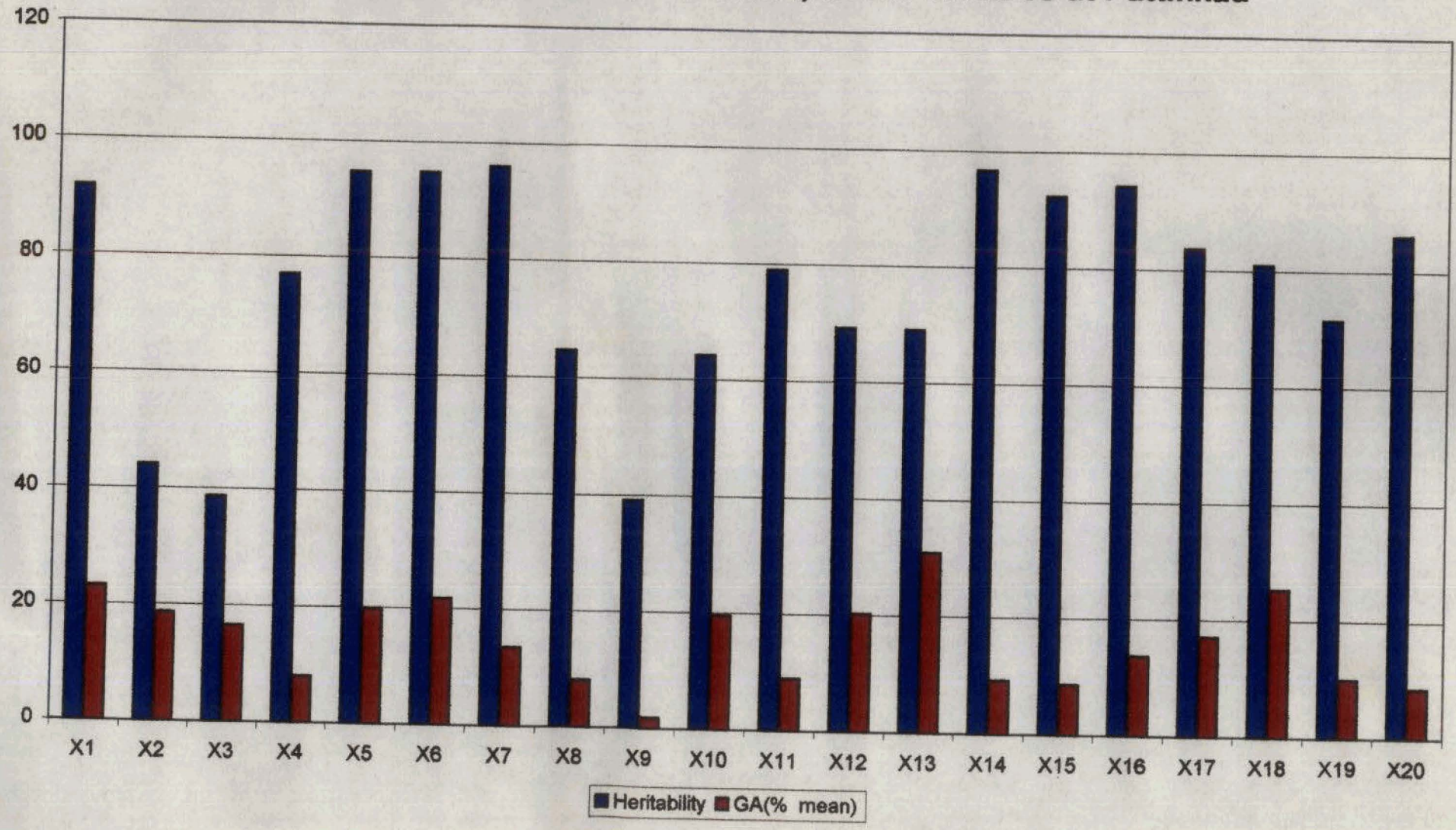
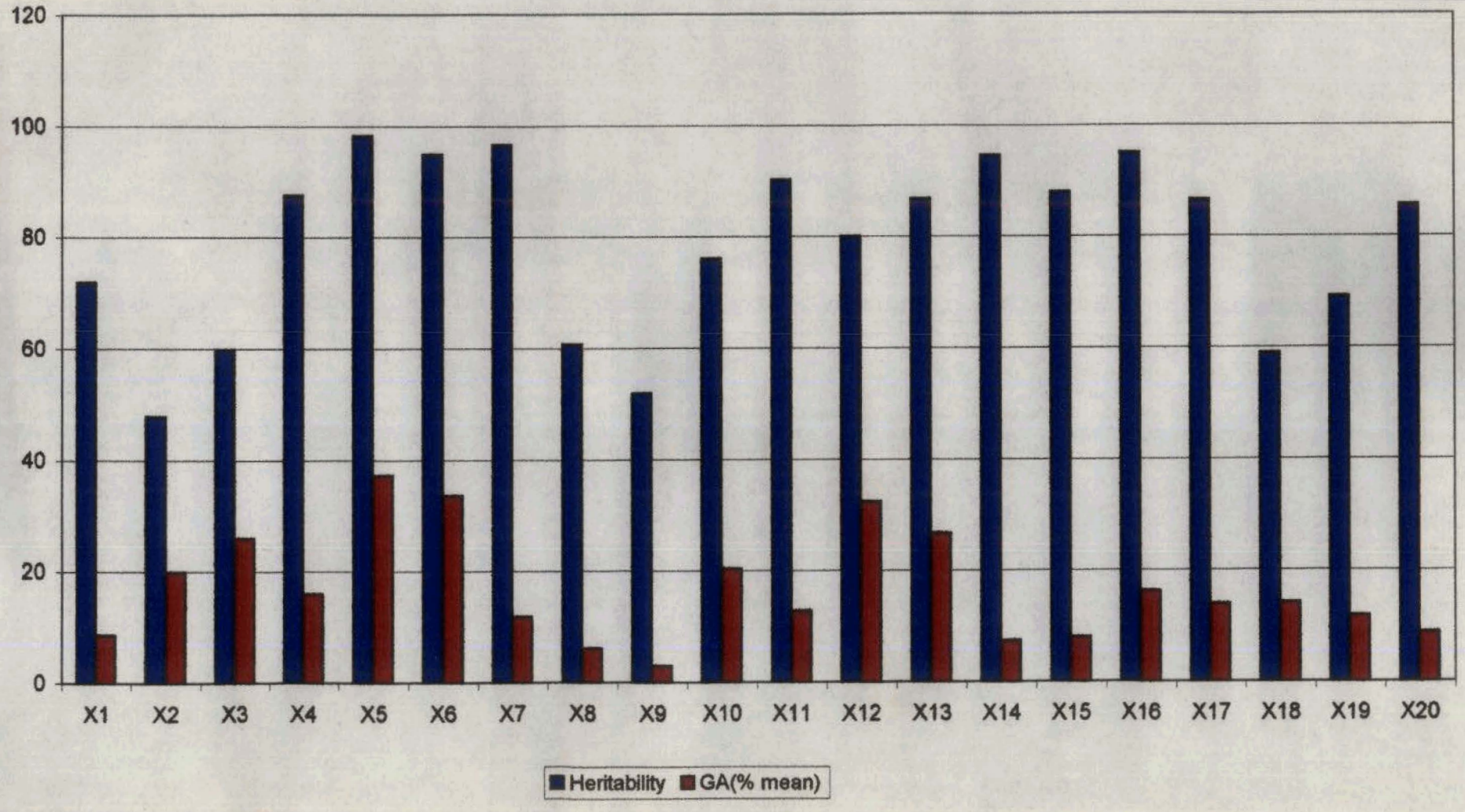


Table 9. Estimation of genetic parameters for grain yield and associated characters in nine rice cultures
Location - Adatt

Sl.No.	Characters	Heritability (%)	Genetic advance (GA)	Genetic gain (GG)
1	Height of plant at harvest	71.90	8.56	8.65
2	Total number of tillers	47.80	2.002	19.96
3	Number of productive tillers	59.80	2.35	26.02
4	Length of panicle	87.60	3.40	16.01
5	Number of spikelets per panicle	98.30	39.83	37.30
6	Number of grains per panicle	94.90	27.75	33.60
7	Grain length	96.60	0.95	11.80
8	Grain breadth	60.70	0.14	6.10
9	Number of days for physiological maturity	51.90	3.33	3.00
10	1000 grain weight	76.10	5.93	20.40
11	Days to 50 per cent flowering	90.20	11.80	12.80
12	Grain yield	80.00	2119.61	32.40
13	Straw yield	86.80	3082.97	26.70
14	Hulling percentage	94.60	5.64	7.40
15	Milling percentage	88.00	5.27	8.00
16	Amylose content	95.00	3.69	16.20
17	Alkali spreading value	86.50	0.54	13.90
18	Volume expansion ratio	58.90	0.56	14.20
19	Kernel elongation ratio	69.10	0.15	11.80
20	Head rice recovery	85.60	7.31	8.80

Fig.3 Heritability and GA(% of mean) of rice cultures at Adatt



At Pattikkad, heritability values ranged from 38.6 per cent for number of productive tillers to 96.7 per cent in the case of hulling percentage. Highest genetic gain value of 30.9 was observed for straw yield and the lowest of 1.8 for number of days for physiological maturity. High heritability and high genetic gain values were exhibited by height of plant at harvest, number of grains per panicle, grain yield, straw yield and volume expansion ratio (Table 8).

At Adatt, most of the yield attributing characters showed high heritability values. Highest heritability value of 98.3 was recorded in the case of number of spikelets per panicle. Lowest heritability value of 47.8 was noticed for total number of tillers. Genetic gain values ranged from 3.0 for number of days for physiological maturity to 37.3 in the case of number of spikelets per panicle. High heritability values along with high genetic gain was indicated by the characters number of spikelets per panicle, number of grains per panicle, 1000 grain weight, grain yield and straw yield (Table 9).

4.3 PHENOTYPIC AND GENOTYPIC CORRELATIONS

The genotypic and phenotypic correlations among yield and yield characters have been worked out for each location and the results are presented in Tables 10, 11 and 12.

At Mannuthy, there was positive significant correlation of grain yield with 1000 grain weight (0.940), number of productive tillers (0.865), total number of tillers (0.829), head rice recovery (0.722), number of grains per panicle (0.655), number of spikelets per panicle (0.634), straw yield (0.586) and amylose content (0.382). Number of spikelets per panicle and number of grains per panicle, total number of tillers and number of productive tillers, hulling and milling percentage, number of productive tillers and 1000 grain weight, number of grains per panicle and 1000 grain weight, amylose content and alkali spreading value, amylose content and head rice recovery, alkali spreading value and head rice recovery, height of plant at harvest and length of panicle, 1000 grain weight and head rice recovery, milling percentage and alkali spreading value, grain length and 1000 grain weight, also exhibited significant positive correlation.

Table 10 Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice cultures. Location - Mannuthy

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	1	-0.722**	-0.879**	0.673**	-0.421*	-0.494**	-0.042	0.469**	-0.628**	0.519**
2	Total number of tillers (X_2)	-0.653**	1	1.003**	-0.112	0.877**	0.948**	0.355	-0.898**	0.910**	-0.872**
3	Number of productive tillers (X_3)	-0.665**	0.920**	1	-0.288	0.722**	0.758**	0.116	-0.858**	0.908**	-0.927**
4	Length of panicle (X_4)	0.581**	-0.122	-0.182	1	0.037	-0.097	0.176	-0.005	0.066	-0.025
5	Number of spikelets per panicle (X_5)	-0.380	0.849**	0.794**	0.035	1	1.005**	0.556**	-0.970**	0.847**	-0.823**
6	Number of grains per panicle (X_6)	-0.384*	0.832**	0.805**	0.011	0.913**	1	0.529**	-0.969**	0.858**	-0.909**
7	Grain length (X_7)	-0.058	0.360	0.170	0.153	0.498**	0.465**	1	-0.283	0.499**	-0.062
8	Number of days for physiological maturity (X_8)	0.426*	-0.824**	-0.815**	-0.063	-0.891**	-0.885**	-0.327	1	-0.891**	0.942**
9	1000 grain weight (X_9)	-0.591**	0.894**	0.817**	0.027	0.828**	0.774**	0.517**	-0.834**	1	-0.829**
10	Days to 50 per cent flowering (X_{10})	0.492**	-0.839**	-0.803**	-0.071	-0.765**	-0.762**	-0.124	0.903**	-0.800**	1
11	Grain yield (X_{11})	-0.580**	0.756**	0.793**	-0.019	0.711**	0.642**	0.308	-0.738**	0.878**	-0.760**
12	Straw yield (X_{12})	0.142	0.231	0.254	0.232	0.165	0.186	-0.020	-0.287	0.279	-0.401*
13	Hulling percentage (X_{13})	0.158	-0.247	-0.157	0.025	-0.108	-0.125	-0.495**	0.005	-0.234	0.026
14	Milling percentage (X_{14})	0.085	-0.239	-0.201	0.003	-0.059	-0.034	-0.316	-0.090	-0.179	0.005
15	Amylose content (X_{15})	-0.548**	0.236	0.199	-0.084	0.074	0.137	0.055	-0.164	0.345	-0.300
16	Alkali spreading value (X_{16})	-0.649**	0.307	0.365	-0.325	0.092	0.127	-0.192	-0.230	0.338	-0.304
17	Volume expansion ratio (X_{17})	-0.582**	0.491**	0.423*	-0.589**	0.428**	0.371	0.074	-0.372	0.324	-0.304
18	Kernel elongation ratio (X_{18})	0.348	-0.158	-0.197	0.460*	-0.275	-0.197	-0.287	0.329	-0.292	0.147
19	Head rice recovery (X_{19})	-0.628**	0.614**	0.595**	-0.176	0.368	0.471*	0.054	-0.456*	0.612**	-0.663**

* Significant at 5% level

** Significant at 1% level

Contd.

Table 10. Continued

Sl.No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}
1	Height of plant at harvest (X_1)	-0.681**	0.154	0.162	0.110	-0.571**	-0.683**	-0.675**	0.433**	-0.707**
2	Total number of tillers (X_2)	0.829**	0.251	-0.367	-0.228	0.722**	0.758**	-0.858**	0.908**	-0.927**
3	Number of productive tillers (X_3)	0.865**	0.340	-0.313	-0.174	0.316	0.566**	0.831**	-0.389**	0.733**
4	Length of panicle (X_4)	-0.055	0.340	0.093	-0.013	-0.132	-0.345	-0.669**	0.659**	-0.171
5	Number of spikelets per panicle (X_5)	0.634**	0.211	-0.188	-0.047	0.087	0.127	0.685**	-0.456*	0.349
6	Number of grains per panicle (X_6)	0.655**	0.239	-0.258	-0.048	0.179	0.282	0.848**	-0.401*	0.563**
7	Grain length (X_7)	0.278	-0.052	-0.555**	-0.415**	0.060	-0.204	0.166	-0.295	0.061
8	Number of days for physiological maturity (X_8)	-0.790**	-0.361	0.013	-0.083	-0.169	-0.351	-0.687**	0.391*	-0.534**
9	1000 grain weight (X_9)	0.940**	0.303	-0.312	-0.203	0.386**	0.400*	0.477*	-0.401*	0.640**
10	Days to 50 per cent flowering (X_{10})	-0.864**	-0.474*	0.043	-0.043	-0.306	-0.391*	-0.450*	0.193	-0.731**
11	Grain yield (X_{11})	1	0.586**	-0.385*	-0.339	-0.382*	0.308	0.318	-0.536**	0.722**
12	Straw yield (X_{12})	0.395*	1	-0.459*	-0.537**	-0.399*	-0.351	-0.291	-0.119	0.166
13	Hulling percentage (X_{13})	-0.279	-0.435*	1	1.020**	0.244	0.405*	0.040	0.185	-0.157
14	Milling percentage (X_{14})	-0.260	-0.427*	0.855**	1	0.337	0.530*	0.183	0.199	0.015
15	Amylose content (X_{15})	0.286	-0.374	0.219	0.308	1	0.784**	0.054	0.168	0.784**
16	Alkali spreading value (X_{16})	0.286	-0.356	0.369	0.427*	0.704**	1	0.495**	-0.036	0.687**
17	Volume expansion ratio (X_{17})	0.132	-0.216	0.023	0.144	0.063	0.442*	1	-0.543**	0.255
18	Kernel elongation ratio (X_{18})	-0.321	-0.116	0.120	-0.039	0.066	0.035	-0.348	1	-0.020
19	Head rice recovery (X_{19})	0.603**	0.158	-0.131	-0.084	0.711**	0.602**	0.197	0.102	1

* Significant at 5% level

** Significant at 1% level

X1 - Total number of tillers

X2 - Number of productive tillers

X3 - Number of spikelets per panicle

X4 - Number of grains per panicle

X5 - Height of plant at harvest

X6 - Number of days for physiological maturity

X7 - 1000 grain weight

X8 - Days to 50 % flowering

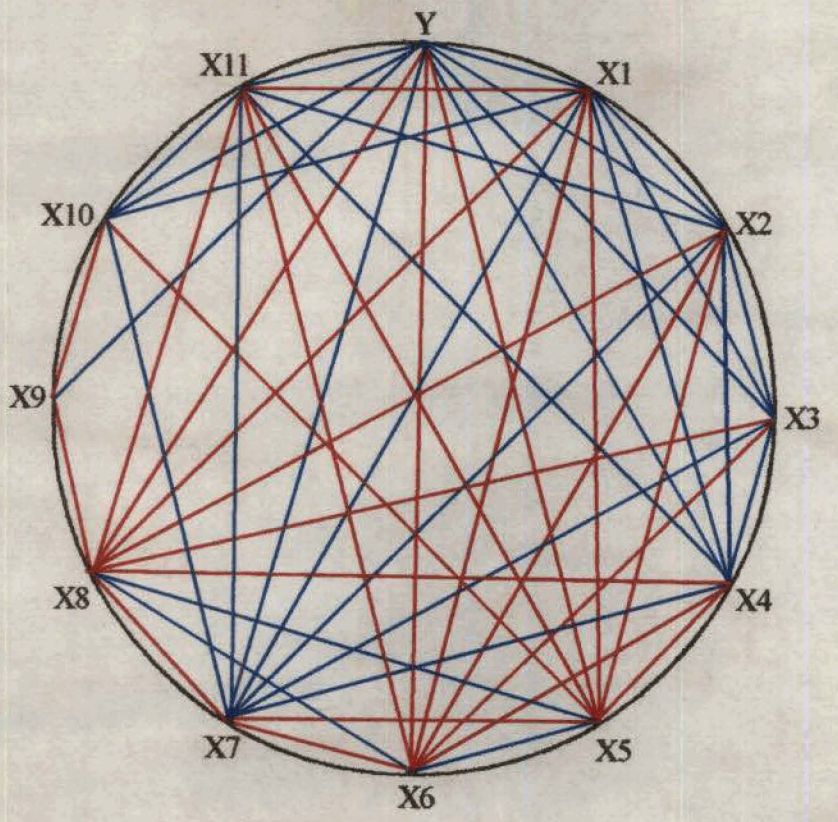
X9 - Straw yield

X10 - Amylose content

X11 - Head rice recovery

Y - Yield

Fig.4 Genotypic correlation between yield and yield characters at Mannuthy



Significant positive correlation
Significant negative correlation

Days to 50 per cent flowering (-0.864), number of days for physiological maturity (-0.790), height of plant at harvest (-0.681) had significant negative correlation with grain yield (Table 10).

At Pattikkad, significant positive correlation of grain yield with number of productive tillers (1.116), total number of tillers (1.079), 1000 grain weight (1.029), number of spikelets per panicle (1.022), number of grains per panicle (1.000) and head rice recovery (0.560) was noticed. Number of productive tillers and number of spikelets per panicle, total number of tillers and number of grains per panicle, number of productive tillers and number of grains per panicle, number of productive tillers and 1000 grain weight, total number of tillers and 1000 grain weight, number of spikelets per panicle and 1000 grain weight, number of grains per panicle and 1000 grain weight, hulling and milling percentage, total number of tillers and numbers per panicle, number of spikelets per panicle and number of grains per panicle, total number of tillers and number of productive tillers, number of days for physiological maturity and days to 50 per cent flowering, height of plant at harvest and straw yield, 1000 grain weight and head rice recovery, straw yield and volume expansion ratio, grain length and hulling percentage also recorded significant positive correlation.

Significant negative correlation with grain yield was indicated by number of days for physiological maturity (-0.984), days to 50 per cent flowering (-0.938), height of plant at harvest (-1.058) (Table 11).

At Adatt, grain yield showed positive significant correlation with total number of tillers (1.056), number of grains per panicle (0.997), number of spikelets per panicle (0.989), 1000 grain weight (0.965), number of productive tillers (0.961), head rice recovery (0.606) and volume expansion ratio (0.457). Height of plant at harvest and days to 50 per cent flowering, height of plant at harvest and number of days for physiological maturity, total number of tillers and number of spikelets per panicle, total number of tillers and number of grains per panicle, total number of tillers and 1000 grain weight, total number of tillers and number of productive tillers, total number of tillers and head rice recovery, number of

Table 11. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in rice cultures. Location - Pattikkad

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	1	-0.769**	-0.838**	0.339	-0.761**	-0.780**	-0.258	0.067	0.679**	-0.809**
2	Total number of tillers (X_2)	-0.626**	1	0.978**	0.220	1.102**	1.089**	-0.160	-0.301	-0.853**	1.038**
3	Number of productive tillers (X_3)	-0.656**	0.955**	1	-0.070	1.116**	1.084**	0.105	-0.120	-0.918**	1.070**
4	Length of panicle (X_4)	0.250	0.167	0.053	1	0.088	0.071	-0.879**	-0.813**	0.073	-0.022
5	Number of spikelets per panicle (X_5)	-0.758**	0.862**	0.831**	0.091	1	0.990**	-0.025	-0.249	01.057**	1.032**
6	Number of grains per panicle (X_6)	-0.771**	0.832**	0.783**	0.075	0.978**	1	-0.023	-0.264	-1.013**	1.025**
7	Grain length (X_7)	-0.256	-0.071	0.102	-0.762**	-0.017	-0.019	1	0.376	-0.067	0.104
8	Grain breadth (X_8)	0.149	-0.260	-0.173	-0.532**	-0.229	-0.278	0.268	1	-0.175	-0.155
9	Number of days for physiological maturity (X_9)	0.559**	-0.870**	-0.871**	0.029	-0.804**	-0.769**	-0.063	0.114	1	-0.917
10	1000 grain weight (X_{10})	-0.728**	0.892**	0.866**	0.014	0.912**	0.934**	0.090	-0.286	-0.866**	1
11	Days to 50 per cent flowering (X_{11})	0.749**	-0.861**	-0.835**	-0.005	-0.931**	-0.949**	-0.099	0.261	0.842**	-0.937**
12	Grain yield (X_{12})	-0.757**	0.878**	0.878**	0.037	0.928**	0.898**	0.061	-0.186	-0.798**	0.911**
13	Straw yield (X_{13})	0.740**	-0.390*	-0.421*	0.410*	-0.501**	-0.503**	-0.279	-0.014	0.509**	-0.504**
14	Hulling percentage (X_{14})	-0.375	0.072	0.204	-0.361	0.210	0.121	0.490**	0.303	-0.222	0.174
15	Milling percentage (X_{15})	-0.360	0.149	0.282	-0.335	0.187	0.095	0.490**	0.284	-0.236	0.183
16	Amylose content (X_{16})	-0.231	0.133	0.016	0.409*	0.053	0.108	-0.429*	-0.490**	0.220	0.075
17	Alkali spreading value (X_{17})	-0.261	0.179	0.068	-0.037	0.268	0.388*	-0.288	0.134	-0.245	0.302
18	Volume expansion ratio (X_{18})	0.324	-0.036	0.032	-0.019	-0.064	-0.151	0.034	0.139	0.054	-0.127
19	Kernel elongation ratio (X_{19})	-0.303	0.139	0.098	0.176	0.200	0.145	-0.444*	0.074	-0.047	-0.009
20	Head rice recovery (X_{20})	-0.075	0.323	0.375	-0.294	0.430*	0.385*	0.449*	0.202	-0.426*	0.379

* Significant at 5% level

** Significant at 1% level

Contd.

Table 11. Continued

Sl.No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
1	Height of plant at harvest (X_1)	0.769**	-1.058**	-0.939**	-0.412*	-0.397*	-0.266	-0.333	0.358	-0.377	-0.129
2	Total number of tillers (X_2)	-0.949**	1.079**	-0.462**	0.230	0.134	0.206	0.307	0.095	0.311	0.536**
3	Number of productive tillers (X_3)	-0.943**	1.116**	-0.626**	0.462*	0.357	0.035	0.188	0.176	0.185	0.730**
4	Length of panicle (X_4)	0.045	-0.016	0.392**	-0.436**	-0.431*	0.476*	-0.063	-0.030	0.174	-0.324
5	Number of spikelets per panicle (X_5)	-0.969**	1.022**	-0.574**	0.232	0.189	0.058	0.307	-0.045	0.245	0.503**
6	Number of grains per panicle (X_6)	-0.989**	1.000**	-0.559**	0.140	0.084	0.107	0.408**	-0.116	0.225	0.457*
7	Grain length (X_7)	-0.100	0.074	-0.341	0.520**	0.511**	-0.434*	-0.326	0.034	-0.513**	0.459*
8	Grain breadth (X_8)	0.226	-0.186	-0.142	0.353	0.346	-0.595**	0.249	0.169	-0.048	0.184
9	Number of days for physiological maturity (X_9)	0.943**	-0.984**	0.566**	-0.456*	-0.334	0.408*	-0.353	-0.093	-0.275	-0.867**
10	1000 grain weight (X_{10})	-0.978**	1.029**	-0.547**	0.261	0.190	0.066	0.311	-0.032	0.169	0.592**
11	Days to 50 per cent flowering (X_{11})	1	-0.938**	0.554**	-0.142	-0.073	0.012	-0.386*	0.105	-0.210	-0.582**
12	Grain yield (X_{12})	-0.904**	1	-0.627**	0.315	0.295	0.172	0.402	0.055	0.271	0.560**
13	Straw yield (X_{13})	0.471*	-0.448*	1	-0.722**	-0.646**	0.016	-0.275	0.537**	-0.349	-0.008
14	Hulling percentage (X_{14})	-0.092	0.244	-0.563**	1	1.014**	-0.283	-0.287	-0.280	-0.102	0.142
15	Milling percentage (X_{15})	-0.105	0.235	-0.540**	0.934**	1	-0.217	-0.379	-0.212	-0.020	0.114
16	Amylose content (X_{16})	0.004	0.075	0.009	-0.269	-0.204	1	0.055	-0.287	0.331	-0.697**
17	Alkali spreading value (X_{17})	-0.322	0.166	-0.281	-0.241	-0.342	0.100	1	-0.458*	0.244	-0.165
18	Volume expansion ratio (X_{18})	0.155	-0.033	0.489**	-0.241	-0.195	-0.269	-0.451*	1	-0.029	0.599**
19	Kernel elongation ratio (X_{19})	-0.132	0.156	-0.125	-0.076	-0.016	0.279	0.126	-0.035	1	-0.299
20	Head rice recovery (X_{20})	-0.422**	0.385*	0.010	0.116	0.089	-0.631**	-0.122	0.511**	-0.270	1

* Significant at 5% level

** Significant at 1% level

X1 - Total number of tillers

X2 - Number of productive tillers

X3 - Number of spikelets per panicle

X4 - Number of grains per panicle

X5 - Height of plant at harvest

X6 - Days to 50 % flowering

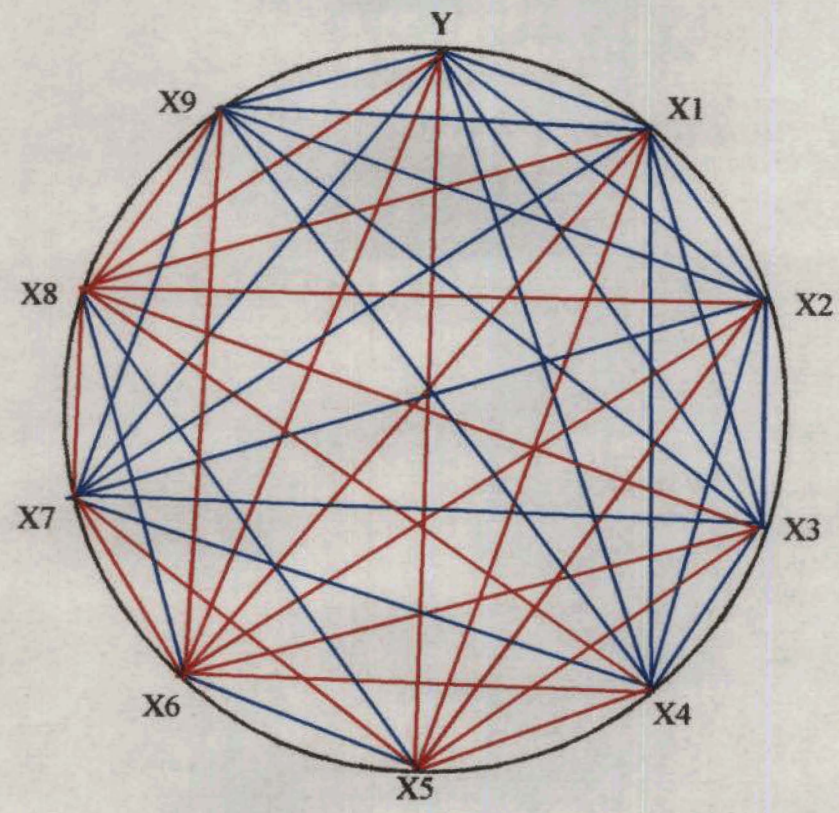
X7 - 1000 grain weight

X8 - Number of days for physiological maturity

X9 - Head rice recovery

Y - Yield

Fig.5 Genotypic correlation between yield and yield characters at Pattikkad



Significant positive correlation
Significant negative correlation

productive tillers and number of spikelets per panicle, number of productive tillers and number of grains per panicle, number of productive tillers and 1000 grain weight, length of panicle and straw yield, number of spikelets per panicle and 1000 grain weight, number of spikelts per panicle and number of grains per panicle, number of spikelets per panicle and head rice recovery, number of grains per panicle and 1000 grain weight, number of grains per panicle and head rice recovery, grain breadth and volume expansion ratio, number of days for physiological maturity and days to 50 per cent flowering, 1000 grain weight and head rice recovery, days to 50 per cent flowering and kernel elongation ratio, straw yield and volume expansion ratio, hulling and milling percentage, hulling percentage and kernal elongation ratio, milling percentage and kernel elongation ratio, alkali spreading value and head rice recovery also recorded significant positive correlation.

Negative association of number of days for physiological maturity (-0.949), height of plant at harvest (-0.932) and days to 50 per cent flowering (-0.909) with grain yield was observed (Table 12).

4.4 PATH ANALYSIS

Based on the high correlation of yield and components, path analysis was carried out to elicit further information through direct and indirect effects of important yield attributes. The results are presented in Tables 13, 14 and 15.

Location I (Manuthy)

Direct effects

Among the 18 component characters involved in path analysis, 1000 grain weight exerted highest positive direct effect (1.610) on grain yield. Number of days for physiological maturity (0.961) and number of spikelets per panicle (0.760) also showed positive direct effect on grain yield.

Indirect effect

Number of spikelets per panicle, number of productive tillers, number of grains per panicle, number of days for physiological maturity, head rice

Table 12. Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield characters in cultures. Location - Adatt

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	1	-1.003**	-0.977**	0.423*	-1.010**	-0.999**	-0.322	-0.019	0.958**	-0.983**
2	Total number of tillers (X_2)	-0.914**	1	1.007**	-0.228	1.119**	1.101**	0.218	0.109	-0.971**	1.030**
3	Number of productive tillers (X_3)	-0.937**	0.953**	1	-0.245	1.042**	1.031**	0.332	0.145	-0.987**	1.004**
4	Length of panicle (X_4)	0.327	-0.174	-0.187	1	-0.187	-0.201	-0.126	-0.109	0.175	-0.159
5	Number of spikelets per panicle (X_5)	-0.901**	0.849**	0.869**	-0.178	1	0.999**	0.230	0.064	-1.059**	1.020**
6	Number of grains per panicle (X_6)	-0.919**	0.874**	0.894**	-0.180	0.991**	1	0.211	0.144	-1.034**	1.011**
7	Grain length (X_7)	-0.294	0.183	0.280	-0.120	0.228	0.208	1	-0.491**	-0.487**	0.320
8	Grain breadth (X_8)	-0.126	0.131	0.150	-0.061	0.061	0.128	-0.342	1	0.108	0.060
9	Number of days for physiological maturity (X_9)	0.925**	-0.950**	-0.963**	0.143	-0.837**	-0.861**	-0.373	-0.060	1	-1.006**
10	1000 grain weight (X_{10})	-0.947**	0.944**	0.963**	-0.161	0.941**	0.958**	0.292	0.100	-0.958**	1
11	Days to 50 per cent flowering (X_{11})	0.942**	-0.875**	-0.895**	0.228	-0.963**	-0.962**	-0.276	-0.063	0.871**	-0.957**
12	Grain yield (X_{12})	-0.890**	0.910**	0.916**	-0.173	0.920**	0.932**	0.099	0.195	-0.871**	0.922**
13	Straw yield (X_{13})	-0.139	0.285	0.346	0.616**	0.313	0.294	0.281	-0.031	-0.344	0.357
14	Hulling percentage (X_{14})	0.219	-0.245	-0.246	-0.409*	-0.335	-0.339	-0.418*	-0.031	0.302	-0.349
15	Milling percentage (X_{15})	0.146	-0.164	-0.206	-0.378	-0.259	-0.272	-0.327	-0.169	0.206	-0.269
16	Amylose content (X_{16})	-0.060	-0.035	-0.111	-0.011	0.009	-0.001	0.244	-0.186	0.049	-0.002
17	Alkali spreading value (X_{17})	-0.201	0.182	0.180	-0.113	0.209	0.171	0.218	-0.478*	-0.261	0.184
18	Volume expansion ratio (X_{18})	-0.381*	0.451*	0.525**	0.282	0.371	0.393*	0.279	0.412*	-0.460*	0.439*
19	Kernel elongation ratio (X_{19})	0.247	-0.187	-0.226	-0.341	-0.388*	-0.396*	-0.118	-0.026	0.241	-0.350
20	Head rice recovery (X_{20})	-0.637**	0.508**	0.483*	-0.257	0.669**	0.622	0.317	-0.489**	-0.549**	0.582**

* Significant at 5% level

** Significant at 1% level

Contd.

Table 12. Continued

Sl.No.	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
1	Height of plant at harvest (X_1)	0.998**	-0.932**	-0.180	0.304	0.256	-0.056	-0.178	-0.354	0.439*	-0.787**
2	Total number of tillers (X_2)	-1.017**	1.056**	0.376	-0.421*	-0.396*	-0.086	0.205	0.472*	-0.613**	0.776**
3	Number of productive tillers (X_3)	-0.972**	0.961**	0.391*	-0.392*	-0.366	-0.136	0.179	0.557**	-0.455*	0.680**
4	Length of panicle (X_4)	0.239	-0.197	0.736**	-0.459*	-0.461*	-0.029	-0.134	0.223	-0.436*	-0.288
5	Number of spikelets per panicle (X_5)	-0.982**	0.989**	0.327	-0.350	-0.289	0.007	0.231	0.454*	-0.501**	0.728**
6	Number of grains per panicle (X_6)	-0.973**	0.997**	0.311	-0.360	-0.322	-0.012	0.181	0.474*	-0.540**	0.683**
7	Grain length (X_7)	-0.287	0.086	0.292	-0.415*	-0.348	0.238	0.240	0.328	-0.164	0.376
8	Grain breadth (X_8)	-0.021	0.255	-0.014	-0.006	-0.267	-0.347	-0.696**	0.475*	-0.195	-0.660**
9	Number of days for physiological maturity (X_9)	0.966**	-0.949**	-0.441*	0.480*	0.439*	0.076	-0.308	-0.490**	0.585**	-0.809**
10	1000 grain weight (X_{10})	-0.975**	0.965**	0.377	-0.431*	-0.392*	-0.013	0.186	0.519**	-0.561**	0.733**
11	Days to 50 per cent flowering (X_{11})	1	-0.909**	-0.280	0.360	0.296	-0.143	-0.155	-0.427*	0.501**	-0.765**
12	Grain yield (X_{12})	-0.882**	1	0.300	-0.396*	-0.379	-0.049	0.109	0.457*	-0.523**	0.606**
13	Straw yield (X_{13})	-0.275	0.302	1	-0.688**	-0.685**	-0.037	-0.122	0.885**	-0.343	-0.003
14	Hulling percentage (X_{14})	0.322	-0.313	-0.644**	1	0.997**	-0.541**	0.446*	-0.746**	0.800**	-0.147
15	Milling percentage (X_{15})	0.230	-0.272	-0.574**	0.926**	1	-0.456**	0.571*	-0.845**	0.794**	0.067
16	Amylose content (X_{16})	-0.135	-0.067	-0.049	-0.539**	-0.415**	1	-0.436**	-0.48	-0.440*	0.308
17	Alkali spreading value (X_{17})	-0.142	0.105	-0.119	0.435*	0.564**	-0.385*	1	-0.517**	0.222	0.570**
18	Volume expansion ratio (X_{18})	-0.380	0.471*	0.651**	-0.498**	-0.532**	-0.038	-0.345	1	-0.355	-0.207
19	Kernel elongation ratio (X_{19})	0.338	-0.386*	-0.297	0.637**	0.616**	-0.315	0.127	-0.121	1	-0.327
20	Head rice recovery (X_{20})	-0.671**	0.506**	-0.039	-0.106	0.037	0.265	0.479*	-0.137	-0.167	1

* Significant at 5% level

** Significant at 1% level

X1 - Total number of tillers

X2 - Number of productive tillers

X3 - Number of spikelets per panicle

X4 - Number of grains per panicle

X5 - Height of plant at harvest

X6 - Number of days for physiological maturity

X7 - 1000 grain weight

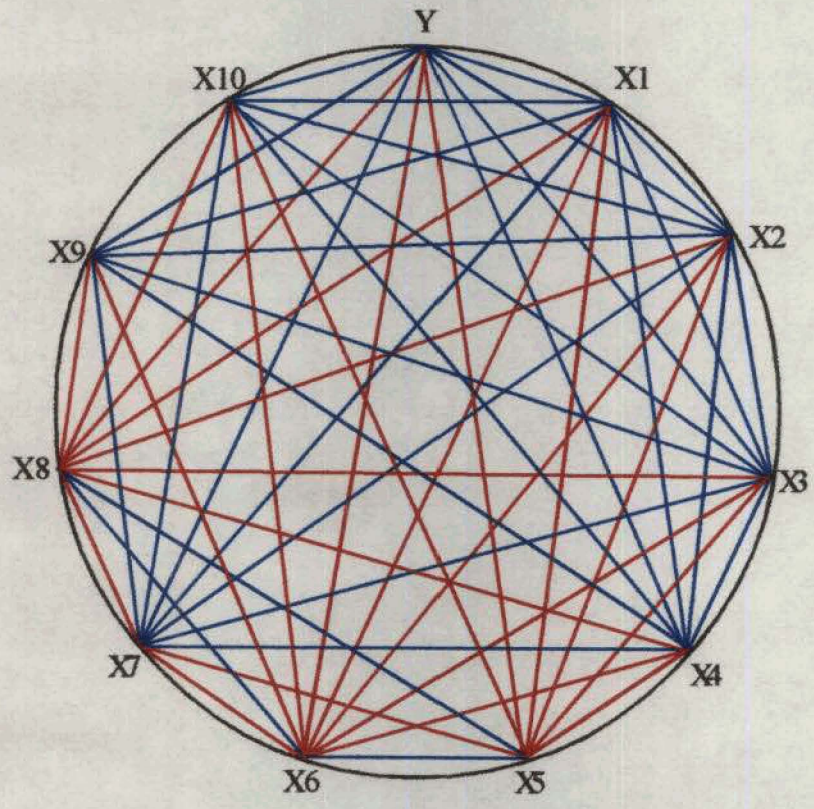
X8 - Days to 50 % flowering

X9 - Volume expansion ratio

X10 - Head rice recovery

Y - Yield

Fig.6 Genotypic correlation between yield and yield characters at Adatt



Significant positive correlation
Significant negative correlation

recovery, 1000 grain weight, total number of tillers had high indirect effects on grain yield. Number of spikelets per panicle, number of grains per panicle, number of productive tillers, total number of tillers exerted indirect effect on grain yield through 1000 grain weight and days to 50 per cent flowering. Number of days for physiological maturity showed indirect effects through total number of tillers. It was also observed that head rice recovery and 1000 grain weight exerted indirect effect through 1000 grain weight and days to 50 per cent flowering respectively(Table 13).

Location II (Pattikkad)

Direct effect

Among the 19 component characters involved in path analysis, maximum positive direct effect was shown by number of spikelets per panicle (1.584) followed by 1000 grain weight (0.884).

Indirect effect

Height of plant at harvest, total number of tillers, number of productive tiller, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight, days to 50 per cent flowering, and straw yield exerted high indirect effects on grain yield. Number of grains per panicle, total number of tillers, number of productive tillers, 1000 grain weight exerted indirect effects through number of spikelets per panicle and days to 50 per cent flowering. Height of plant at harvest, number of days for physiological maturity, days to 50 per cent flowering, and straw yield had indirect effect through number of grains per panicle. Indirect effect on grain yield was indicated by number of productive tillers through number of spikelets per panicle. Number of spikelets per panicle had indirect effect through days to 50 per cent flowering (Table 14).

Location III (Adatt)

Direct effect

The estimates of path coefficients for the 19 component characters indicated that maximum positive direct effect was for number of spikelets per

Table 13. Direct and indirect effect of 18 characters on grain yield.
Location - Mannuthy

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	0.455	0.814	-0.112	-0.371	-0.320	-0.131	0.027	0.451	-1.012	-0.687
2	Total number of tillers (X_2)	-0.329	-1.127	0.128	0.062	0.666	0.251	-0.229	-0.863	1.465	1.156
3	Number of productive tillers (X_3)	-0.400	-1.131	0.127	0.159	0.549	0.201	-0.075	-0.825	1.462	1.228
4	Length of panicle (X_4)	0.306	0.126	-0.037	-0.551	0.028	-0.026	-0.114	-0.005	0.106	0.033
5	Number of spikelets per panicle (X_5)	-0.192	-0.989	0.092	-0.021	0.760	0.266	-0.359	-0.933	1.364	1.090
6	Number of grains per panicle (X_6)	-0.225	-1.069	0.097	0.054	0.763	0.265	-0.342	-0.932	1.381	1.205
7	Grain length (X_7)	-0.019	-0.400	0.015	-0.097	0.422	0.140	-0.646	-0.272	0.803	0.082
8	Number of days for physiological maturity (X_8)	0.213	1.012	-0.109	0.003	-0.737	-0.257	0.183	0.961	-1.435	-1.249
9	1000 grain weight (X_9)	-0.286	-1.026	0.116	-0.036	0.644	0.227	-0.322	-0.857	1.610	1.099
10	Days to 50 per cent flowering (X_{10})	0.236	0.983	-0.118	0.014	-0.625	-0.241	0.040	0.906	-1.335	-1.325
11	Straw yield (X_{11})	0.070	-0.282	0.043	-0.188	0.160	0.063	0.033	-0.347	0.488	0.628
12	Hulling percentage (X_{12})	0.074	0.413	-0.040	-0.051	-0.143	-0.069	0.356	0.012	-0.502	-0.058
13	Milling percentage (X_{13})	0.050	0.257	-0.022	0.007	-0.036	-0.013	0.268	-0.080	-0.326	0.057
14	Amylose content (X_{14})	-0.260	-0.326	0.040	0.073	0.066	0.047	-0.038	-0.162	0.622	0.405
15	Alkali spreading value (X_{15})	-0.311	-0.457	0.072	0.190	0.097	0.075	0.132	-0.338	0.644	0.518
16	Volume expansion ratio (X_{16})	-0.308	-0.790	0.106	0.369	0.521	0.225	-0.107	-0.661	0.767	0.596
17	Kernel elongation ratio (X_{17})	0.197	0.321	-0.050	-0.363	-0.347	-0.106	0.191	0.376	-0.645	-0.256
18	Head rice recovery (X_{18})	-0.322	-0.754	0.093	0.094	0.265	0.149	-0.039	-0.514	1.030	0.969

Contd.

Table 13. Continued

Sl.No	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	r_g
1	Height of plant at harvest (X_1)	-0.038	-0.146	0.002	-0.098	-0.452	0.416	-0.033	0.554	-0.681
2	Total number of tillers (X_2)	-0.061	0.331	-0.005	0.050	0.268	-0.432	0.022	-0.524	0.829
3	Number of productive tillers (X_3)	-0.083	0.283	-0.003	0.054	0.375	-0.512	0.030	-0.574	0.865
4	Length of panicle (X_4)	-0.083	-0.084	0.000	-0.023	-0.228	0.413	-0.050	0.134	-0.055
5	Number of spikelets per panicle (X_5)	-0.052	0.170	-0.001	0.015	0.084	-0.422	0.035	-0.273	0.634
6	Number of grains per panicle (X_6)	-0.059	0.234	-0.001	0.031	0.186	-0.523	0.031	-0.441	0.655
7	Grain length (X_7)	0.013	0.498	-0.008	0.010	-0.135	-0.102	0.022	-0.048	0.278
8	Number of days for physiological maturity (X_8)	0.089	-0.012	-0.002	-0.029	-0.232	0.423	-0.030	0.418	-0.79
9	1000 grain weight (X_9)	-0.074	0.282	-0.004	0.066	0.265	-0.294	0.031	-0.501	0.940
10	Days to 50 per cent flowering (X_{10})	0.116	-0.039	-0.001	-0.052	-0.258	0.277	-0.015	0.573	-0.864
11	Straw yield (X_{11})	-0.245	0.415	-0.011	-0.068	-0.232	0.180	0.009	-0.130	0.586
12	Hulling percentage (X_{12})	0.113	-0.904	0.020	0.042	0.268	-0.025	-0.014	0.123	-0.385
13	Milling percentage (X_{13})	0.132	-0.922	0.020	0.058	0.351	-0.113	-0.015	-0.012	-0.339
14	Amylose content (X_{14})	0.098	-0.220	0.007	0.171	0.519	-0.033	-0.013	-0.614	0.382
15	Alkali spreading value (X_{15})	0.086	-0.366	0.011	0.134	0.661	-0.305	0.003	-0.538	0.308
16	Volume expansion ratio (X_{16})	0.071	-0.037	0.004	0.009	0.327	-0.616	0.041	-0.199	0.318
17	Kernel elongation ratio (X_{17})	0.029	-0.167	0.004	0.029	-0.024	0.335	-0.076	0.016	-0.536
18	Head rice recovery (X_{18})	-0.041	0.142	0.000	0.134	0.454	-0.157	0.002	-0.783	0.722

Fig. 7 Path diagram indicating direct and indirect effects of the component characters on yield at Mannuthy

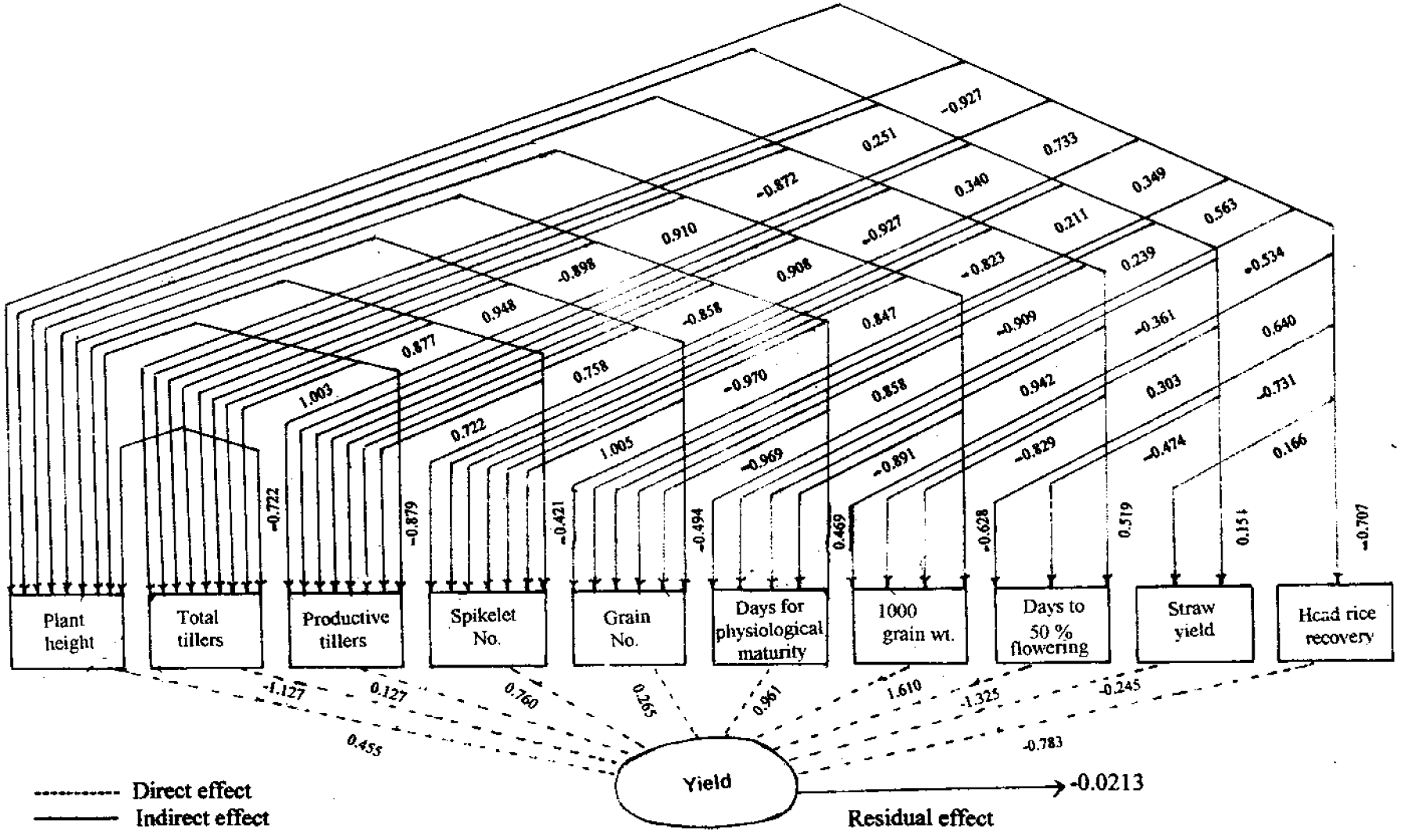


Table 14. Direct and indirect effect of 19 characters on grain yield .
Location - Pattikkad

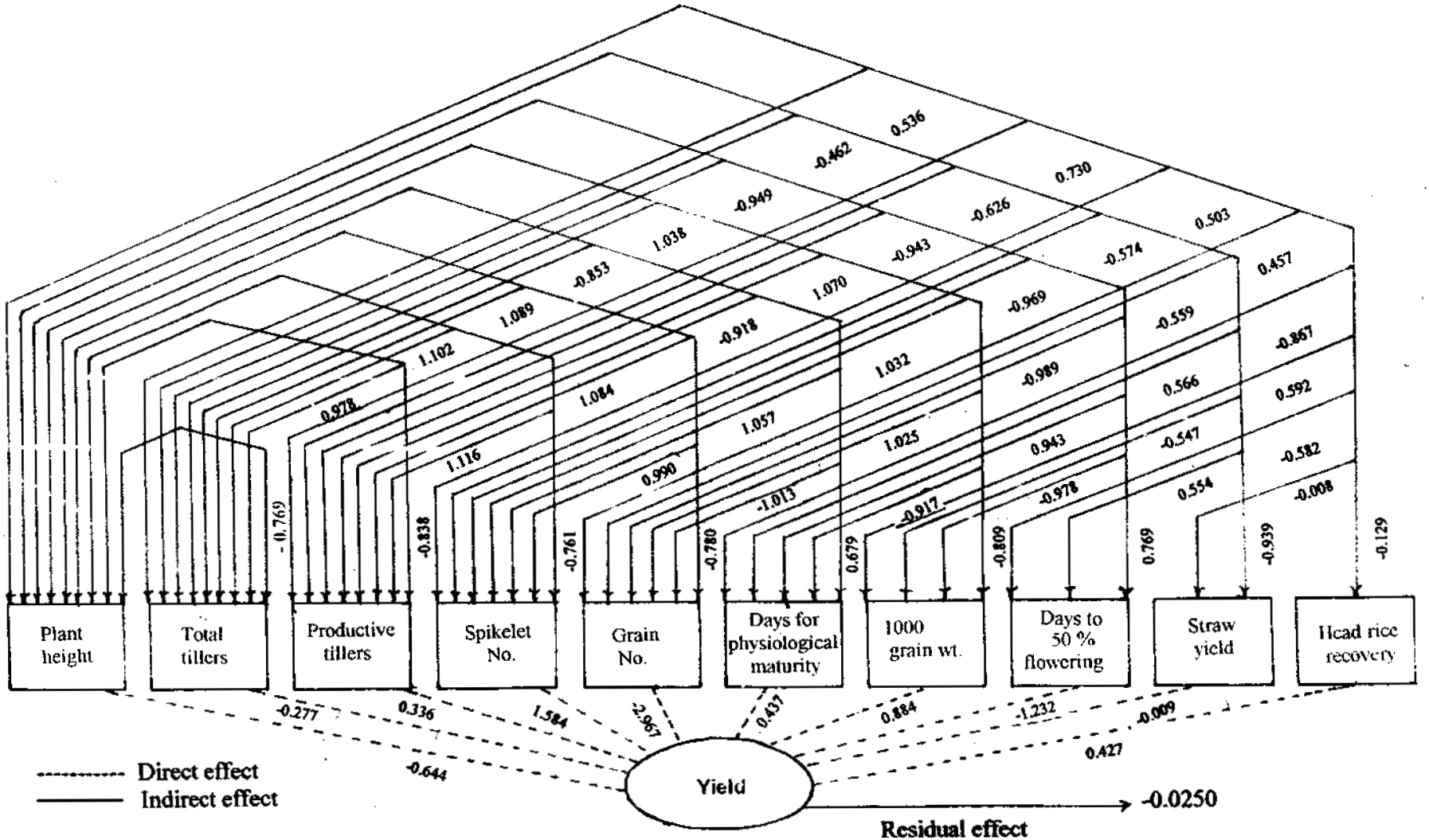
Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	-0.644	0.213	-0.281	-0.051	-1.205	2.316	0.231	0.008	0.297	-0.715
2	Total number of tillers (X_2)	0.495	-0.277	0.329	-0.033	1.745	-3.231	0.143	-0.034	-0.373	0.917
3	Number of productive tillers (X_3)	0.539	-0.271	0.336	0.011	1.768	-3.216	-0.094	-0.014	-0.401	0.946
4	Length of panicle (X_4)	-0.218	-0.061	-0.023	-0.152	0.139	-0.209	0.786	-0.092	0.032	-0.019
5	Number of spikelets per panicle (X_5)	0.490	-0.306	0.375	-0.013	1.584	-2.937	0.023	-0.028	-0.462	0.915
6	Number of grains per panicle (X_6)	0.502	-0.302	0.364	-0.011	1.568	-2.967	0.021	-0.030	-0.443	0.906
7	Grain length (X_7)	0.166	0.044	0.035	0.133	-0.040	0.069	-0.895	0.043	-0.029	0.092
8	Grain breadth (X_8)	-0.043	0.084	-0.040	0.123	-0.395	0.783	-0.337	0.114	-0.077	-0.137
9	Number of days for physiological maturity (X_9)	-0.437	0.237	-0.308	-0.011	-1.674	3.005	0.060	-0.020	0.437	-0.811
10	1000 grain weight (X_{10})	0.521	-0.288	0.359	0.003	1.635	-3.040	-0.093	-0.018	-0.401	0.884
11	Days to 50 per cent flowering (X_{11})	-0.495	0.263	-0.317	-0.007	-1.534	2.936	0.089	0.026	0.412	-0.865
12	Straw yield (X_{12})	-0.604	0.128	-0.210	-0.060	-0.909	1.659	0.305	-0.016	0.247	-0.484
13	Hulling percentage (X_{13})	0.265	-0.064	0.155	0.066	0.368	-0.415	-0.465	0.040	-0.199	0.231
14	Milling percentage (X_{14})	0.255	-0.037	0.120	0.065	0.299	-0.250	-0.457	0.039	-0.146	0.168
15	Amylose content (X_{15})	0.172	-0.057	0.012	-0.0072	0.092	-0.318	0.388	-0.068	0.178	0.058
16	Alkali spreading value (X_{16})	0.214	-0.085	0.063	0.010	0.486	-1.029	0.292	0.028	-0.154	0.275
17	Volume expansion ratio (X_{17})	-0.230	-0.026	0.059	0.005	-0.071	0.344	-0.030	0.019	-0.041	-0.028
18	Kernel elongation ratio (X_{18})	0.242	-0.086	0.062	-0.026	0.387	-0.666	0.459	-0.005	-0.120	0.149
19	Head rice recovery (X_{19})	0.083	-0.149	0.245	0.049	0.797	1.356	-0.411	-0.385	-0.379	0.523

Contd.

Table 14. Continued

Sl.No	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	r_y
1	Height of plant at harvest (X_1)	-0.948	-0.008	-0.169	-0.119	-0.048	0.013	0.004	0.103	-0.055	-1.058
2	Total number of tillers (X_2)	1.169	0.004	0.094	-0.040	0.038	-0.012	0.001	-0.085	0.229	1.079
3	Number of productive tillers (X_3)	1.162	0.006	0.189	-0.107	0.006	-0.007	0.002	-0.051	0.312	1.116
4	Length of panicle (X_4)	-0.055	0.003	-0.179	0.129	0.087	0.002	0.000	-0.048	-0.138	-0.016
5	Number of spikelets per panicle (X_5)	1.193	0.005	0.095	-0.057	0.011	-0.012	0.000	-0.067	0.215	1.022
6	Number of grains per panicle (X_6)	1.219	0.005	0.057	-0.025	0.020	-0.016	-0.001	-0.062	0.195	1.000
7	Grain length (X_7)	0.123	0.003	0.213	-0.153	-0.079	0.013	0.000	0.140	0.196	0.074
8	Grain breadth (X_8)	-0.279	0.001	0.145	-0.104	-0.108	-0.010	0.002	0.013	0.079	-0.186
9	Number of days for physiological maturity (X_9)	-1.162	-0.005	-0.187	0.100	0.074	0.014	-0.001	0.075	-0.370	-0.984
10	1000 grain weight (X_{10})	1.205	0.005	0.107	-0.057	0.012	-0.012	0.000	-0.046	0.253	1.029
11	Days to 50 per cent flowering (X_{11})	-1.232	-0.005	-0.058	0.022	0.002	0.015	0.001	0.0057	-0.248	-0.938
12	Straw yield (X_{12})	-0.683	-0.009	-0.296	0.193	0.003	0.011	0.005	0.096	-0.003	-0.627
13	Hulling percentage (X_{13})	0.175	0.006	0.410	-0.304	-0.051	0.011	-0.003	0.028	0.061	0.315
14	Milling percentage (X_{14})	0.090	0.006	0.416	-0.300	-0.039	0.015	-0.002	0.005	0.048	0.295
15	Amylose content (X_{15})	-0.015	0.000	-0.116	0.065	0.182	-0.002	-0.003	-0.091	-0.297	0.172
16	Alkali spreading value (X_{16})	0.475	0.002	-0.118	0.114	0.010	-0.039	-0.005	-0.067	-0.070	0.402
17	Volume expansion ratio (X_{17})	-0.129	-0.005	-0.115	0.063	-0.052	0.018	0.010	0.008	0.256	0.055
18	Kernel elongation ratio (X_{18})	0.258	0.003	-0.042	0.006	0.060	-0.009	0.000	-0.274	-0.127	0.271
19	Head rice recovery (X_{19})	-0.716	0.021	-0.058	-0.034	-0.127	0.006	-0.306	-0.382	0.427	0.560

Fig. 8 Path diagram indicating direct and indirect effects of the component characters on yield at Pattikkad



panicle (2.098) followed by 1000 grain weight (1.431) and days to 50 per cent flowering (1.089).

Indirect effects

Height of plant at harvest, total number of tillers, number of productive tillers, number of grains per panicle, days to 50 per cent flowering, number of days to physiological maturity, 1000 grain weight, volume expansion ratio, kernel elongation ratio, head rice recovery had high indirect effects on grain yield. Total number of tillers, number of productive tillers, number of grains per panicle, 1000 grain weight and head rice recovery exerted indirect effect through number of spikelets per panicle and number of days to physiological maturity . Height of plant at harvest, days to 50 per cent flowering, kernel elongation ratio, and number of days for physiological maturity had indirect effects through 1000 grain weight. volume expansion ratio showed indirect effect through number of spikelets per panicle. Indirect effect on grain yield was indicated by height of plant at harvest and number of days for physiological maturity through days to 50 per cent flowering (Table 15).

4.5 GENOTYPE X ENVIRONMENT INTERACTIONS

The analysis of cultures in relation to the environment was carried out in nine rice cultures at Mannuthy,Pattikkad and Adatt. Pooled analysis of variance for 20 characters in 9 ccultures are shown in Table 16. .

Results indicated that the characters height of plant at harvest, total number of tillers, number of productive tillers, length of panicle, number of spikelets per panicle, number of gains per panicle, grain length, number of days for physiological maturity, 1000 grain weight, grain yield straw yield, and head rice recovery showed significant difference among genotypes. With respect to the location, the characters height of plant at harvest, total number of tillers, length of panicle, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, grain yield, straw yield, hulling percentage, milling percentage and alkali spreading value differed significantly. Variety x environment component was found significant for the characters height of the plant at harvest, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight, days to 50 per cent

Table 15. Direct and indirect effect of 19 characters on grain yield.

Location - Adatt

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	Height of plant at harvest (X_1)	0.081	-0.194	-0.176	-0.075	-2.120	-0.041	0.040	0.000	-1.032	1.406
2	Total number of tillers (X_2)	-0.081	0.193	0.182	0.040	2.346	0.045	-0.027	-0.002	1.045	-1.473
3	Number of productive tillers (X_3)	-0.079	0.195	0.180	0.043	2.186	0.042	-0.041	-0.003	1.063	-1.436
4	Length of panicle (X_4)	0.034	-0.044	-0.044	-0.177	-0.392	-0.008	0.015	0.002	-0.189	0.228
5	Number of spikelets per panicle (X_5)	-0.082	0.216	0.188	0.033	2.098	0.041	-0.028	-0.001	1.141	-1.460
6	Number of grains per panicle (X_6)	-0.081	0.213	0.186	0.036	2.096	0.041	-0.026	-0.003	1.113	-1.446
7	Grain length (X_7)	-0.026	0.042	0.060	0.022	0.483	0.009	-0.123	0.010	0.525	-0.458
8	Grain breadth (X_8)	-0.002	0.021	0.026	0.019	0.135	0.006	0.060	-0.020	-0.116	-0.086
9	Number of days for physiological maturity (X_9)	0.077	-0.187	-0.178	-0.031	-2.222	-0.042	0.060	-0.002	-1.077	1.439
10	1000 grain weight (X_{10})	-0.179	0.099	0.081	0.028	1.140	0.041	-0.139	-0.201	1.083	1.431
11	Days to 50 per cent flowering (X_{11})	0.081	-0.196	-0.175	-0.042	-2.060	-0.040	0.035	0.000	-1.040	1.395
12	Straw yield (X_{12})	-0.015	0.073	0.070	-0.130	0.685	0.013	-0.036	0.000	0.475	-0.540
13	Hulling percentage (X_{13})	0.025	-0.081	-0.071	0.081	-0.734	-0.015	0.051	0.000	-0.517	0.617
14	Milling percentage (X_{14})	0.021	-0.076	-0.066	0.082	-0.606	-0.013	0.043	0.005	-0.473	0.561
15	Amylose content (X_{15})	-0.005	-0.017	-0.024	0.005	0.015	0.000	-0.029	0.007	-0.082	0.018
16	Alkali spreading value (X_{16})	-0.014	0.040	0.032	0.024	0.484	0.007	-0.029	0.014	0.332	-0.266
17	Volume expansion ratio (X_{17})	-0.029	0.091	0.100	-0.039	0.951	0.019	-0.040	-0.010	0.528	-0.742
18	Kernel elongation ratio (X_{18})	0.036	-0.118	-0.082	0.077	-1.051	-0.022	0.020	0.004	-0.630	0.803
19	Head rice recovery (X_{19})	-0.064	0.150	0.122	0.051	1.526	0.028	-0.046	0.013	0.871	-1.049

Contd.

Table 15. Continued

Sl.No	Characters	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	r_g
1	Height of plant at harvest (X_1)	1.086	-0.048	0.177	-0.001	-0.016	0.059	-0.005	-0.130	0.057	-0.932
2	Total number of tillers (X_2)	-1.107	0.100	-0.245	0.001	-0.025	-0.068	0.006	0.182	-0.056	1.056
3	Number of productive tillers (X_3)	-1.059	0.104	-0.229	0.001	-0.040	-0.059	0.007	0.135	-0.049	0.961
4	Length of panicle (X_4)	0.260	0.196	-0.267	0.001	-0.009	0.044	0.003	0.129	0.021	-0.197
5	Number of spikelets per panicle (X_5)	-1.069	0.087	-0.204	0.001	0.002	-0.076	0.006	0.149	-0.053	0.989
6	Number of grains per panicle (X_6)	-1.059	0.083	-0.210	0.001	-0.004	-0.060	0.006	0.160	-0.049	0.997
7	Grain length (X_7)	-0.312	0.078	-0.242	0.001	0.070	-0.079	0.004	0.049	-0.027	0.086
8	Grain breadth (X_8)	-0.023	-0.004	-0.003	0.001	-0.101	0.230	0.006	0.058	0.048	0.255
9	Number of days for physiological maturity (X_9)	1.051	-0.118	0.280	-0.001	0.022	0.102	-0.006	-0.174	0.058	-0.949
10	1000 grain weight (X_{10})	-1.061	0.001	-0.451	0.001	-0.365	-0.365	0.007	0.067	-0.353	0.965
11	Days to 50 per cent flowering (X_{11})	1.089	-0.075	0.210	-0.001	-0.042	0.051	-0.005	-0.149	0.055	-0.909
12	Straw yield (X_{12})	-0.305	0.267	-0.401	0.002	-0.011	0.040	0.011	0.102	0.000	0.300
13	Hulling percentage (X_{13})	0.392	-0.183	0.583	-0.003	-0.158	-0.147	-0.010	-0.237	0.011	-0.396
14	Milling percentage (X_{14})	0.322	-0.183	0.581	-0.003	-0.133	-0.189	-0.011	-0.236	-0.005	-0.379
15	Amylose content (X_{15})	-0.156	-0.010	-0.315	0.001	0.292	0.144	-0.001	0.130	-0.022	-0.049
16	Alkali spreading value (X_{16})	-0.169	-0.033	0.260	-0.002	-0.127	-0.330	-0.007	-0.066	-0.041	0.109
17	Volume expansion ratio (X_{17})	-0.465	0.236	-0.435	0.002	-0.014	0.171	0.013	0.105	0.015	0.457
18	Kernel elongation ratio (X_{18})	0.546	-0.091	0.466	-0.002	-0.128	-0.073	-0.005	-0.297	0.024	-0.523
19	Head rice recovery (X_{19})	-0.833	-0.001	-0.086	0.000	0.090	-0.188	-0.003	0.097	-0.072	0.606

Fig. 9 Path diagram indicating direct and indirect effects of the component characters on yield at Adatt

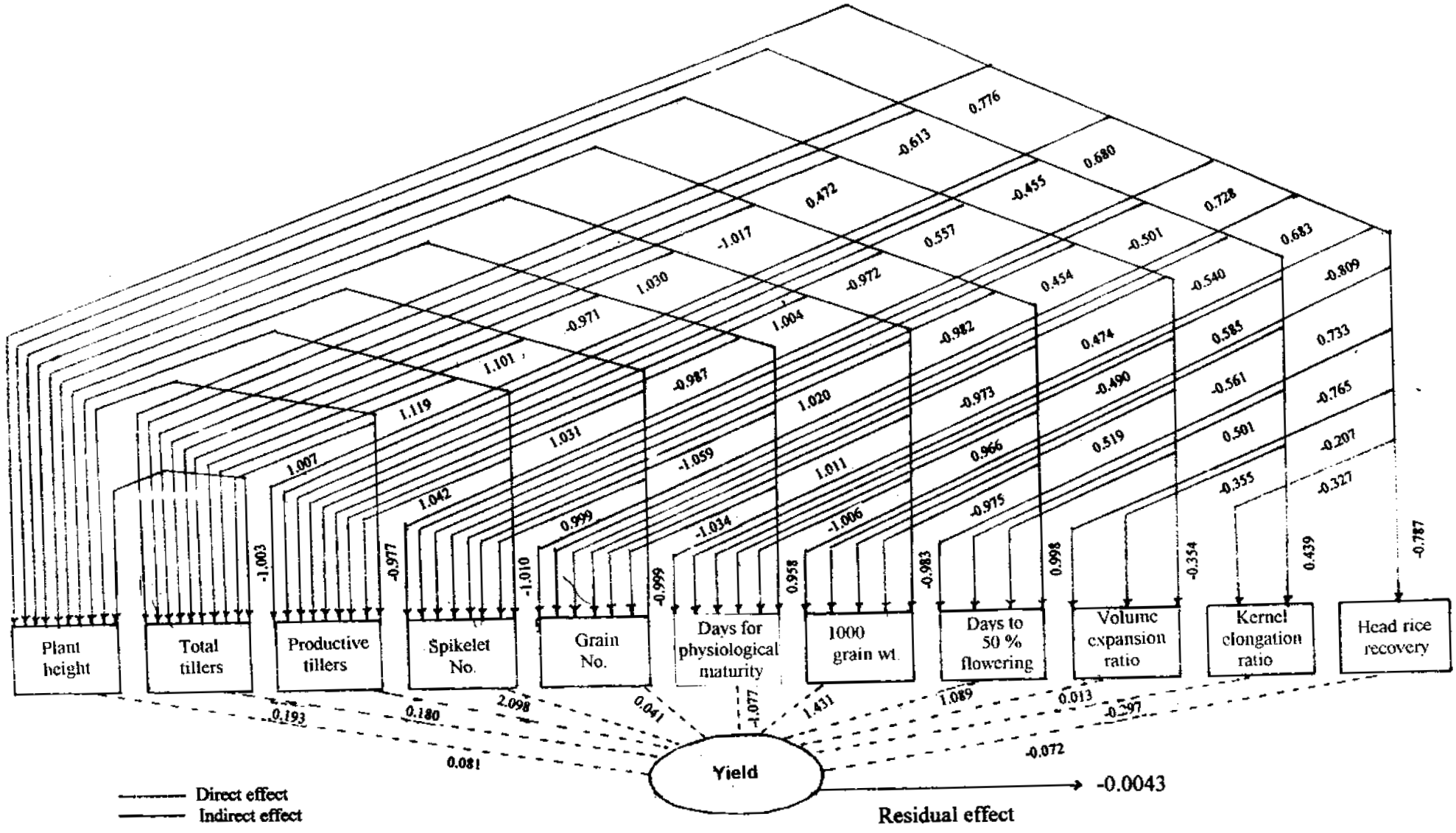


Table 16 . Pooled analysis of variance for 20 characters of three locations on rice cultures

Sl.No.	Characters	Mean sum of squares of					
		Varieties df = 8	Environment df = 2	V x E df = 16	ENV (linear) df = 1	V x E (linear) df = 8	Pooled deviation df = 9
1	Height of plant at harvest	176.91*	239.47*	60.38**	478.94*	42.84	69.26*
2	Total number of tillers	5.64*	5.15**	1.79	10.30*	2.10	1.31
3	Number of productive tillers	4.69**	2.59	1.07	5.19*	1.18	0.85
4	Length of panicle	3.76**	4.35*	0.82	8.72	0.37	1.13*
5	Number of spikelets per panicle	416.50*	706.16*	179.74**	1412.35*	163.30	51.55
6	Number of grains per panicle	221.62*	9596.50**	118.38**	1919.24**	11.33	109.74
7	Grain length	0.70**	0.08	0.14	0.16	0.15	0.11*
8	Grain breadth	0.019	0.059	0.019	0.11	0.009	0.02*
9	Number of days for physiological maturity	10.43*	223.09**	3.21**	462.79**	2.03	3.88
10	1000 grain weight	35.41*	21.51	11.88**	43.02*	15.39	7.43
11	Days to 50 per cent flowering	41.15	36.39	16.85**	72.82**	26.72*	6.34
12	Grain yield	1836313.20**	2012706.00*	464835.70**	4025046.40*	203975.10	645104.01
13	Straw yield	10123748.00**	3096100.70*	800883.22**	6192931.50**	975710.47	556413.08
14	Hulling percentage	13.35	42.55*	7.30**	85.05**	9.17	4.83
15	Milling percentage	9.51	40.76*	7.12**	81.50**	9.06	4.61
16	Amylose content	2.04	1.12	3.03**	2.24	1.84	3.76
17	Alkali spreading value	0.088	0.67**	0.072	1.35**	0.106	0.033
18	Volume expansion ratio	0.37	0.206	0.16	0.41*	0.24*	0.07
19	Kernel elongation ratio	0.004	0.06	0.008	0.013	0.006	0.009*
20	Head rice recovery	41.86**	0.85	0.89	1.64*	1.44*	0.30

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

flowering, grain yield, straw yield, hulling percentage, milling percentage and amylose content. The significance of V x E indicated the importance for estimating the stability parameters. Linear component of environment was significant for the characters height of plant at harvest, total number of tillers, number of productive tillers, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight, days to 50 per cent flowering, grain yield, straw yield, hulling percentage, milling percentage, alkali spreading value, volume expansion ratio, head rice recovery indicating that the environments tested differed significantly. V x E (linear) was significant for the characters days to 50 per cent flowering volume expansion ratio and head rice recovery indicating that the significant difference among genotypes for these characters was due to the linear response to environments.

The results of analysis of G x E interactions are indicated by stability parameters. The stability parameters like mean, regression coefficient, mean square deviation are given in Table 17.

Height of plant at harvest

Stability parameters for this character revealed that the culture C 26 T (b) had a mean value of 86.51 cm with a regression coefficient of 1.04 and a mean deviation 2.55. Culture C 80 recorded 88.79 cm with a regression coefficient of 0.8 and mean square deviation 14.72. Local check Jyothi had a mean value of 89.18 cm with 1.89 regression coefficient and 2.06 mean square deviation.

Total number of tillers

The culture C 80 had the maximum mean value of 13 with a regression coefficient of 0.98 and mean square deviation of 0.07. The second highest mean number of tillers (11.56) was for genotype C 26 T (b) with a regression coefficient of 1.48 and mean square deviation of 0.40. The local check Jyothi recorded a mean of 11 with a regression coefficient of 0.87 and mean square deviation 0.84.

Number of productive tillers

In the case of number of productive tillers, C 26 T (b) recorded the maximum mean value of 11.22, followed by Jyothi with mean value of 10.44

Table 17. Analysis of G x E interaction in rice cultures for 20 characters at 3 locations

Cultures	Height of plant at harvest			Total number of tillers			Number of productive tillers		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	99.28	0.14	66.10	9.00	0.15	2.24	7.56	-0.27	1.67
C 29	106.47	2.02	407.50	9.67	1.01	2.42	8.78	2.13	1.76
C 38	88.07	0.22	39.54	9.11	0.47	0.98	7.89	0.03	0.60
C 26 S	106.34	0.09	36.69	10.22	1.73	-0.43	8.56	1.85	0.25
C 26 T(a)	101.32	0.10	-0.68	8.89	0.98	-0.31	7.89	0.23	-0.26
C 26 T(b)	86.51	1.04	2.55	11.56	1.48	0.07	11.22	1.25	0.22
C 80	88.79	0.80	14.72	13.00	0.98	0.40	9.78	3.11	0.53
Jyothi	89.18	1.89	2.06	11.00	0.87	0.84	10.44	1.15	0.07
Ahalya	91.49	1.69	39.27	10.78	0.47	0.98	9.33	0.02	0.09

Cultures	Length of panicle			Number of spikelets per panicle			Number of grains per panicle		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	20.81	1.01	0.04	106.67	0.26	219.36	88.33	2.08	-26.97
C 29	20.29	0.68	1.13	110.22	-0.28	58.09	88.56	0.14	20.01
C 38	20.78	0.39	1.05	102.22	1.74	239.68	84.89	1.73	64.34
C 26 S	23.19	0.91	0.43	117.44	1.04	255.18	93.00	0.81	82.73
C 26 T(a)	20.22	1.58	1.10	106.78	1.48	114.33	85.44	0.83	49.10
C 26 T(b)	20.11	1.91	0.89	139.11	1.19	-14.08	110.56	0.82	19.57
C 80	20.63	1.38	0.73	124.44	1.04	-163.31	101.11	0.69	368.00
Jyothi	19.03	2.10	0.79	126.56	0.96	13.79	100.78	0.38	183.56
Ahalya	20.03	0.29	1.04	117.00	1.96	79.12	92.78	1.73	93.55

Contd.

Table 17. Continued

Cultures	Grain length			Grain breadth			Number of days for physiological maturity		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	7.38	0.44	0.12	2.31	1.80	0.03	117.44	0.59	4.48
C 29	8.10	1.03	0.00	2.27	1.87	0.08	116.33	1.20	-0.63
C 38	7.99	4.99	0.03	2.26	-0.16	0.03	118.44	1.07	3.03
C 26S	7.78	-3.05	0.77	2.36	0.65	0.03	116.00	0.95	8.59
C 26 T(a)	7.69	-1.60	-0.01	2.50	0.90	0.00	117.78	0.90	-0.31
C 26 T(b)	7.60	1.57	0.00	2.32	0.58	0.02	112.44	0.93	0.17
C 80	7.61	1.71	0.03	2.36	1.93	0.00	114.56	1.83	0.01
Jyothi	9.04	0.98	0.00	2.36	2.47	0.02	114.67	1.13	3.25
Ahalya	8.04	0.36	-0.01	2.46	0.83	0.00	115.78	1.10	5.04

Cultures	1000 grain weight			Days to 50 per cent flowering			Grain yield		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	26.78	3.41	2.85	91.67	3.33	3.66	5509.90	0.90	1259126.12
C 29	27.33	-0.87	2.78	91.00	2.45	-0.77	6021.86	0.16	820985.62
C 38	26.33	2.90	7.41	93.56	2.82	1.66	5352.64	1.51	898956.12
C 26 S	30.22	-0.72	17.28	91.22	0.62	9.75	6210.57	0.09	78844.41
C 26 T(a)	25.11	0.24	2.60	95.89	0.62	0.26	5430.31	1.55	-6518.28
C 26 T(b)	34.67	0.85	0.57	86.78	1.46	1.61	7594.26	0.99	20250.07
C 80	32.44	0.24	0.60	83.44	1.15	0.56	7164.99	1.21	1155705.38
Jyothi	33.44	-0.81	0.41	88.00	1.79	-0.27	6547.66	0.48	120614.27
Ahalya	30.89	2.84	-1.68	90.56	3.54	-0.14	6545.30	0.81	592096.81

Contd.

Table 17. Continued

Cultures	Straw yield			Hulling percentage			Milling percentage		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	10513.96	1.38	-305820.38	75.17	-0.56	10.34	65.17	-0.69	8.78
C 29	14976.65	0.81	208525.27	72.66	1.59	2.15	62.66	1.61	2.21
C 38	10841.45	2.34	-332872.47	74.12	1.27	2.19	64.12	1.83	3.48
C 26 S	15305.34	1.04	284025.31	69.81	-0.30	3.24	60.59	-0.001	1.35
C 26 T(a)	10743.79	0.34	-256496.91	75.58	1.29	1.93	65.24	2.83	5.73
C 26 T(b)	11506.32	-1.23	927891.81	73.91	0.56	1.58	63.91	0.65	4.21
C 80	11601.88	0.22	1716736.38	76.60	0.86	0.58	66.60	0.82	0.11
Jyothi	11178.55	2.80	775384.81	73.19	1.78	17.76	63.86	1.42	13.59
Ahalya	10990.80	2.30	-126653.98	76.26	1.19	-0.17	65.60	1.13	0.41

Cultures	Amylose content			Alkali spreading value			Volume expansion ratio		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	24.00	2.57	2.14	3.78	2.89	0.07	4.13	1.00	-0.02
C 29	21.73	0.43	3.85	3.39	1.64	0.00	3.40	3.89	0.09
C 38	23.47	-0.64	-0.05	3.63	1.00	0.00	3.53	0.05	-0.02
C 26 S	23.07	-2.14	1.47	3.44	1.80	0.01	4.10	5.14	0.02
C 26 T(a)	21.60	-3.86	4.89	3.36	1.13	0.00	4.03	1.10	0.10
C 26 T(b)	22.80	1.79	8.01	3.63	1.83	0.00	4.36	-0.22	0.09
C 80	22.93	2.57	0.10	3.86	1.66	0.02	3.93	-2.40	0.14
Jyothi	23.47	4.29	6.05	3.53	1.99	0.07	4.27	0.44	0.09
Ahalya	22.13	0.86	0.94	3.67	1.92	0.05	3.50	0.00	-0.02

Contd.

Table 17. Continued

Cultures	Kernel elongation ratio			Head rice recovery		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
C 28	1.30	0.00	0.00	81.70	-3.02	-0.69
C 29	1.25	0.58	0.03	83.13	5.78	0.72
C 38	1.30	1.28	0.00	81.03	-0.34	-0.77
C 26 S	1.26	0.66	0.02	80.53	0.53	0.78
C 26 T(a)	1.27	1.85	0.00	74.20	0.01	-0.83
C 26 T(b)	1.27	3.69	0.00	86.27	-0.36	-0.83
C 80	1.23	2.22	0.00	84.47	0.27	0.82
Jyothi	1.18	1.87	0.00	86.67	1.32	0.23
Ahalya	1.30	2.60	0.01	83.17	0.92	-0.55

(Plate 2) and C 80 with 9.78. The corresponding regression coefficients and mean square deviations are 1.25, 1.15, 3.11 and 0.22, 0.07, 0.53 respectively.

Length of panicle

Mean length of panicle was highest (23.19) for culture C 26 S. C 28 had a mean value of 20.81 and ranked second (Plate 2). C 26 S recorded a regression coefficient of 0.91 and a low mean square deviation of 0.43.

Number of spikelets per panicle

The highest mean value for this character was reported for C 26 T (b) (139.11) followed by Jyothi (126.56). The corresponding regression coefficients are 1.19 and 0.96 respectively.

Number of grains per panicle

Maximum number of grains per panicle (110.56) was observed for C 26 T (b) and had the low mean square deviation of 19.57. The regression coefficient for this culture was 0.82.

Grain length

Mean grain length recorded was highest (9.04 mm) for local check variety Jyothi followed by C 29 (8.10mm). The corresponding regression coefficients are 0.98 and 1.03 respectively.

Grain breadth

Culture C 26 T (a) showed the highest mean value of 2.50 mm with a regression coefficient of 0.90 and zero mean square deviation. Local check variety Ahalya had mean value of 2.46 mm with regression coefficient of 0.83 and zero mean square deviation.

Number of days for physiological maturity

Stability parameters for number of days for physiological maturity revealed that the culture C 38 had the highest mean value of 118.44 with a regression coefficient of 1.07 and a mean square deviation of 3.03 (Plate 3).As far as a low mean value with good stability is concerned, the culture C 26 T (b) was

PLATE: 2 EARHEAD CHARACTERS OF CULTURES

having the lowest mean value of 112.44 for this character with a regression coefficient of 0.93 and deviation of 0.17.

1000 grain weight

The mean of the character 1000 grain weight was maximum (34.67) for C 26 T (b). The corresponding regression coefficient and mean square deviations are 0.85 and 0.57 respectively. Local check Jyothi had mean value of 33.44, regression coefficient of 0.81 and mean square deviation of 0.41.

Days to 50 per cent flowering

The culture C 80 was having lowest mean value (83.44) for days to 50 per cent flowering with a mean square deviation of 0.56 and regression coefficient of 1.15. Culture C 26 T (b) gave a mean value of 86.78 days to 50 per cent flowering. The regression coefficient recorded was 1.46 and mean square deviation of 1.61. Local check Ahalya had a mean value of 90.56 days while maximum was recorded for C 26T (a) (95.89) (Plate 3).

Grain yield

Mean grain yield was maximum (7594.26 kg ha^{-1}) for C 26 T (b) with regression coefficient of 0.99 and deviation of 20250.07. The second important culture to be considered for selection was C 80 which recorded 7164.99 kg ha^{-1}, 1.21, 1155705.38 for the parameters mean, regression coefficient and mean square deviation respectively.

Straw yield

Culture C 26 S ranked first with respect to straw yield (15305.34 kg ha^{-1}) immediately followed by C 29 (14976.65 kg ha^{-1}) (Plate 4). The corresponding regression coefficients and mean square deviations are 1.04, 0.81 and 284025.31 and 208525.27.

Hulling percentage

Hulling percentage was maximum for C 80 (76.60) with a regression coefficient of below 1 (0.86) and a comparatively low mean square deviation of 0.58.Ahalya had a mean value of 76.26, regression coefficient of 1.19 and deviation of 0.17.

PLATE: 3 PLOT VIEWS OF CULTURES C38, C26T (a) AND AHALYA (LOCAL CHECK)

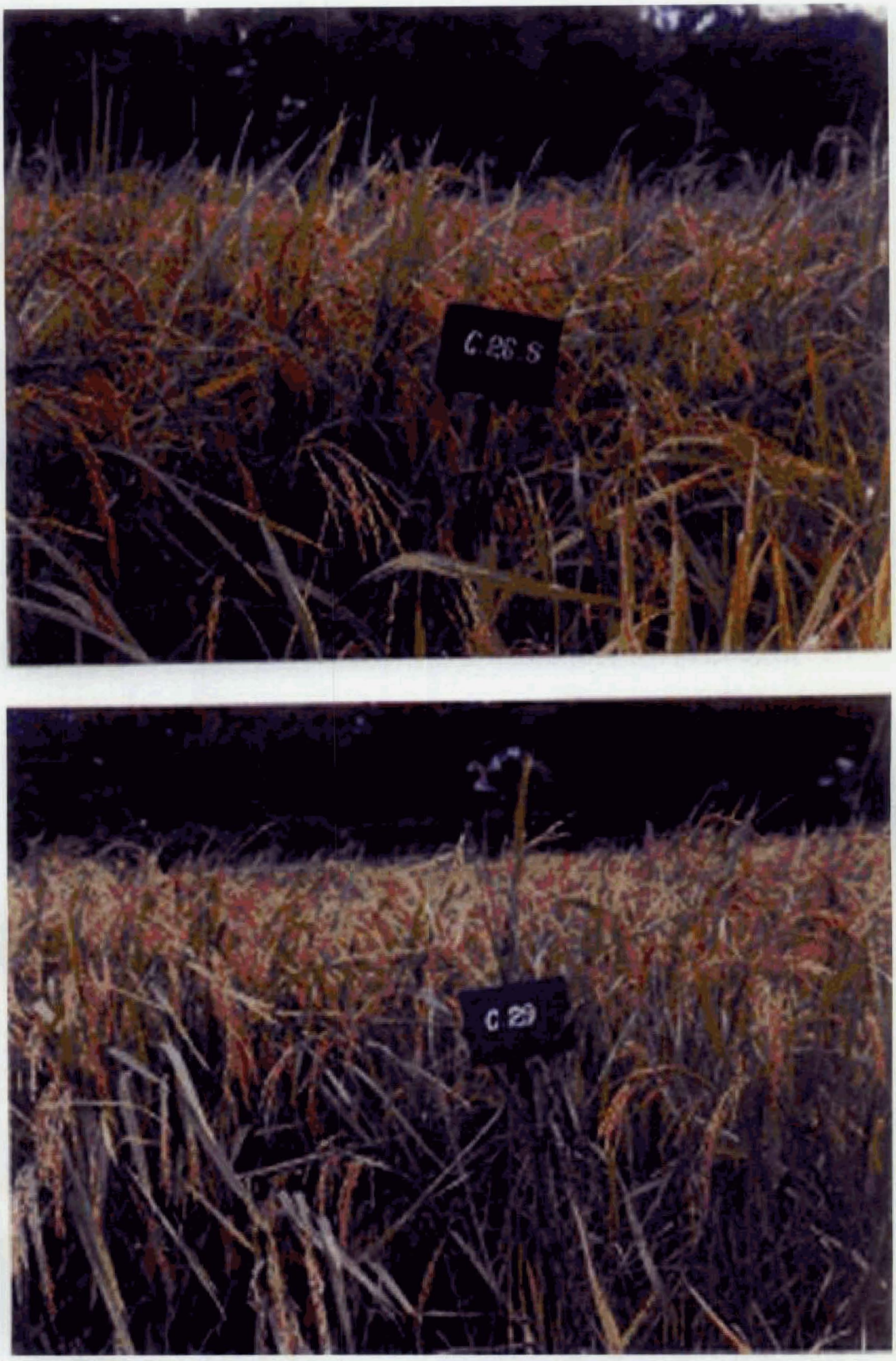


PLATE: 4 PLOT VIEWS OF CULTURES C26S AND C29

Milling percentage

Milling percentage recorded highest mean value of 66.60 for C 80 with regression coefficient of 0.82 and mean square deviation of 0.11. Ahalya had mean value of 65.60 with regression coefficient of 1.13 and mean square deviation of 0.41.

Amylose content

Maximum mean value of amylose content (24) was noticed for culture C 28 with regression coefficient 2.57 and mean square deviation 2.14. But with regard to stability, culture C 80 which recorded a regression coefficient of 1.19 and mean square deviation 0.10 could be considered as stable. C 80 has mean amylose content of 22.80. Ahalya recorded a mean value of 22.13, regression coefficient of 0.86 and deviation 0.94 and ranked second with respect to stability.

Alkali spreading value

Among the nine rice cultures, highest mean value of 3.86 was shown by C 80 having a regression coefficient of 1.66 and mean square deviation 0.02. The culture C 38 with mean value of 3.63, regression coefficient unity and zero mean square deviation was ranked first with regard to stability. Culture C 26 T (a) with zero deviation, regression coefficient of 1.13 and mean value of 3.36 was the second stable culture for this character.

Volume expansion ratio

The culture C 28 recorded mean value (4.13) for the character volume expansion ratio with low mean square deviation and regression coefficient unity. C 26 T (a) had mean value 4.03, regression coefficient of 1.10 and mean square deviation 0.10 .

Kernel elongation ratio

C 38 exhibited a mean value of 1.30 with regression coefficient of 1.28 and zero deviation.

Head rice recovery

The local check Jyothi recorded highest mean value of 86.67 with a regression coefficient of 1.32 and mean deviation of 0.23. Ahalya had mean value of 83.17, regression coefficient of 0.92 and deviation 0.55.

Colour of grain

The colour of grain was red for cultures C28, C38, C26S, C26T(b), C80, Jyothi and Ahalya while white for C29 and C26T(a).

Discussion

5. DISCUSSION

Genotype x environment interaction provides useful information to identify stable genotypes over a range of environments. Wide adaptation to a particular environment and consistent performance of cultures are very important for the development of varieties. The present investigation was undertaken to study genotype x environment interaction and to identify both high yielding and stable genotypes over different locations.

The study "Genetic analysis of high yielding rice varieties of diverse origin" evaluated 56 high yielding genotypes representing various eco-geographical conditions. The F_3 seeds of promising crosses were handed over to the Agricultural Research Station, Mannuthy for further evaluation and this formed the material for the present investigation.

The experiment on nine rice cultures was carried out in three different locations namely Mannuthy, Pattikkad and Adatt. Studies on variability, heritability, correlation, path analysis and stability in rice cultures were carried out. The study involved twenty characters namely height of plant at harvest, total number of tillers, number of productive tillers, length of panicle, number of spikelets per panicle, number of grains per panicle, grain length, grain breadth, number of days for physiological maturity, 1000 grain weight, days to 50 per cent flowering, grain yield, straw yield, hulling percentage, milling percentage, amylose content, alkali spreading value, volume expansion ratio, kernel elongation ratio and head rice recovery.

The results obtained are discussed below.

5.1 GENETIC VARIABILITY

The improvement of crops is dependent on magnitude to genetic variability and extend to which desirable characters are heritable.

The analysis of variance revealed that genotypes differed significantly for all the characters studied in three locations indicating considerable variation among the genotypes for all the characters. High genotypic coefficient of variation (GCV) was observed for total number of tillers, number of productive tillers, number of spikelets per panicle, 1000 grain weight, grain yield and straw yield over locations indicating the scope of improvement of these traits. Similar results have been reported by Bhattacharya (1978) and Das and Borthakur (1974).

Most of the characters showed low difference between PCV and GCV suggesting that these characters were least affected by environment and thus emphasized the importance of these traits during selection programme. Dash *et al.* (1995) and Singh and Choudary (1996) also reported similar findings in rice.

5.2 HERITABILITY, GENETIC ADVANCE AND GENETIC GAIN

The values of heritability ranged from 34.3 per cent to 98.3 per cent. In general, high estimates of heritability was indicated by most of yield characters studied. Similar results were also recorded by Ghosh *et al.* (1981) and Chauhan and Tandon (1984).

Genetic advance as per cent of mean was high for height of plant at harvest, total number of tillers, number of productive tillers, number of spikelets per panicle, number of grains per panicle, 1000 grain weight, grain yield, straw yield and volume expansion ratio. Similar results were also observed by Sawant and Patil (1995).

The association of high heritability with high genetic advance was observed for height of plant at harvest, number of spikelets per panicle, number of grains per panicle, 1000 grain weight, grain yield, straw yield and volume expansion ratio which indicated the presence of additive gene effects and consequently a high genetic gain from phenotypic selection which will effective. The results were in accordance with the findings of Singh *et al.* (1986) and Nath and Talukdar (1997).

High heritability and genetic advance with high genotypic coefficient of variation (GCV) was identified for number of spikelets per panicle, number of grains per panicle, 1000 grain weight, grain yield, straw yield and volume expansion ratio indicating the preponderance of additive gene action controlling these traits and scope for selections. The results are in confirmation with the earlier findings of Panse (1957).

5.3 PHENOTYPIC AND GENOTYPIC CORRELATION

A knowledge on the degree of association among the quantitative characters would help the breeder to select those characters which are positively correlated with yield and elimination of characters which are negatively correlated with yield. Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. It is represented by 'r'. A positive value of 'r' shows that the changes of two variables are in the same direction. When 'r' is negative, the movements are in opposite direction.

Character association of a particular character in relation to other traits contributing towards yield is of greater importance in planning successful breeding programme. Correlations between characters is important in estimating the relative influence of various characters on yield and the magnitude of direct and indirect effects of yield attributes on grain yield.

In the present study, it is revealed that grain yield was positively correlated with number of productive tillers, total number of tillers, number of grains per panicle, number of spikelets per panicle, 1000 grain weight and head rice recovery over locations. These findings are in agreement with those reported by Singh *et al.* (1984) and Janardhanam *et al.* (2001). This type of positive and significant association between yield and its components is highly desirable. Hence selection of these traits is useful in obtaining simultaneous improvement of the associated characters resulting in increased yields in rice. Significant positive association of grain yield with number of grains per panicle was noticed. Bhattacharyya (1981) also reported significant positive correlation of grain yield

with number of grains per panicle under saline stress condition. Number of productive tillers was significantly and positively associated with grain yield. Similar result was reported by Manonmani *et al.* (1999).

Contrary to this, Chaubey and Richharia (1993) observed number of productive tillers and grain yield did not exhibit positive correlation.

Grain yield showed positive association with number of spikelets per panicle. Roy and Kar (1992) and Chauhan *et al.* (1993) also observed positive association of grain yield with number of spikelets per panicle. All the cultures recorded highly significant and positive relationship between total number of tillers and grain yield as recorded by Mahajan *et al.* (1981). Therefore selection for any one of the characters would offer scope for simultaneous improvement in all these characters in addition to improving the yield.

The interrelationship among characters showed that number of grains per panicle and 1000 grain weight had positive significant correlation. Head rice recovery and number of grains per panicle indicated significant positive association. There was significant association between number of spikelets per panicle, total number of tillers and number of productive tillers per panicle. Significant positive association of total number of tillers, number of spikelets per panicle, number of productive tillers with 1000 grain weight was observed. Head rice recovery had positive association with 1000 grain weight and number of productive tillers. Number of grains per panicle and number of spikelets per panicle showed positive significant correlation. Significant association of total number of tillers with number of grains per panicle was observed. This points out to a fact that selection for total number of tillers will simultaneously improve the number of grains per panicle. The same trend was noticed for number of productive tillers and number of grains per panicle. Number of productive tillers was positively associated with number of spikelets per panicle and number of grains per panicle while number of spikelets per panicle was positively associated with number of grains per panicle. This was in concurrence with earlier reports of Janardhanam *et al.* (2001).

Association of number of days for physiological maturity, days to 50 per cent flowering and height of plant at harvest with grain yield is negative which is advantageous. This indicated that it may be possible to obtain heterosis for grain yield by reducing the plant height and duration. The negative and significant association of number of days for physiological maturity with yield indicated that long duration varieties were less productive. Negative association of height of plant at harvest with grain yield is due to characteristic feature of semi dwarf genotypes. This was in confirmity with the findings of Hargrove *et al.* (1988).

Correlation studies showed that selection can be practised for number of productive tillers, total number of tillers, number of spikelets per panicle, number of grains per panicle, 1000 grain weight and head rice recovery as these characters manifested positive and significant correlation with grain yield in all the three locations.

5.4 PATH ANALYSIS

Path analysis provided an aid for sorting out total correlation into direct and indirect effects of different characters on grain yield. Many authors utilised path analysis to categorize the direct and indirect effects on grain yield in rice (Chaubey and Richharia, 1993; Rajarathinam and Raja, 1992; Sundaram and Palanisamy, 1994).

The results of path analysis revealed that 1000 grain weight and number of spikelets per panicle had the maximum positive direct effect on grain yield. These characters exhibited positive significant correlation with grain yield suggesting that selection of these traits could bring improvement in yield of rice.

Path coefficient analysis at Mannuthy revealed 1000 grain weight as the most important character because of its higher direct effect followed by number of days for physiological maturity and number of spikelets per panicle. Rajeswari and Nadarajan (1997) also observed number of spikelets per panicle had direct effect on grain yield.

Days to 50 per cent flowering recorded negative direct effect on grain yield. But this was not in agreement with findings of Balan *et al.* (1999). They observed very high positive direct effect of days to 50 per cent flowering on grain yield.

The high correlation of the characters number of grains per panicle, total number of tillers, number of productive tillers and head rice recovery with grain yield was due to the high indirect effects of these characters on yield. Therefore these characters should be utilised in the selection programme to obtain higher grain yield.

Analysis of path coefficients at Pattikkad revealed highest direct effect on grain yield for number of spikelets per panicle followed by 1000 grain weight.

Number of grains per panicle exhibited negative direct effect on grain yield but had positive significant correlation with grain yield. This is due to the high indirect effect of number of grains per panicle through number of spikelets per panicle and days to 50 per cent flowering on grain yield. Due importance might be given in selection programme for the character number of grains per panicle as this character recorded positive and significant association with grain yield and they exerted high indirect effects on grain yield.

The total number of tillers, number of productive tillers and number of grains per panicle should be considered for selection programme for grain yield indicated by its high indirect effect on grain yield through number of spikelets per panicle and days to 50 per cent flowering. This was also supported by their high correlation coefficient with grain yield.

It is suggested that in general selection for grain yield could be efficient if it is based on 1000 grain weight and number of spikelets per panicle as these characters satisfied both the requirements of association analysis and path coefficient analysis.

At Adatt, path coefficient analysis showed that number of spikelets per panicle had the highest positive direct effect followed by 1000 grain weight and days to 50 per cent flowering on grain yield. The importance of high direct effects of number of spikelets per panicle on grain yield was noticed by Janardhanam *et al.* (2001).

Maximum negative direct effect on grain yield was observed for number of days for physiological maturity. This is in contrary to observation of this character at Mannuthy. At Mannuthy number of days for physiological maturity showed positive direct effect on grain yield. This indicated that this character is influenced by the environment.

The high correlation of the characters total number of tillers, number of productive tillers, number of grains per panicle and head rice recovery with grain yield was due to the high indirect effects of these characters through number of spikelets per panicle and number of days for physiological maturity.

The direct and indirect effects of the constituents yield traits on yield differed from location to location showing the fluctuations in the quantum of its contribution in relation to environment. Hence from the results, it could be inferred that the traits 1000 grain weight, number of spikelets per panicle were to be accounted for direct selection during yield improvement.

5.5 GENOTYPE X ENVIRONMENT INTERACTIONS

Lerner (1954) coined the term 'Genetic homeostasis' for the mechanism by which genotypes are flexible and can adjust their genotypic and phenotypic states in response to the different environmental conditions. Genotype x Environment (GE) interaction has been an important and challenging issue among plant breeders, geneticists and agronomists engaged in performance testing. GE interaction is noticeable, when genotypes subjected to evaluation rank differently in different environments. To assess the genotype x environment interaction, mainly three parameters are used namely mean performance of the character, its regression coefficient and deviation from the regression environmental index.

A stable genotype is one which shows (1) a high mean yield (2) a regression coefficient around unity and (3) a mean square deviation from regression near zero.

To assure the stability of genotypes linear regression could be regarded as a measure of response of a particular genotypes and deviation from regression should be considered as a better measure of stability (Jatasra and Paroda, 1979 and Becker, 1981).

The results obtained for stability analysis are discussed character-wise adopting the model of Eberhart and Russel (1966).

Height of plant at harvest

Stability parameters identified C 26 T (b) with low mean square deviation and regression coefficient of near unity as the most stable over the locations. As far as mean value is considered, this culture has lowest mean value which is desirable in the case of height of plant at harvest.

Total number of tillers

The culture C 80 with the maximum mean value and regression coefficient near unity and lowest mean square deviation is considered stable over the locations.

Number of productive tillers

The culture C 26 T (b) and local check Jyothi with high mean value, low mean square deviation and regression coefficient of near unity are stable and are suited to the environments.

Length of panicle

Mean length of panicle was maximum for culture C 26S. The culture showed low deviation and regression coefficient of near unity. Stability parameters indicated that C 26S is stable for this character.

Number of spikelets per panicle

C 26 T (b) had maximum mean number of spikelets per panicle followed by local check variety Jyothi. They had low mean square deviation and regression coefficient around unity. Fluctuations due to the environments was much restricted for these traits.

Number of grains per panicle

C 26 T (b) had the highest mean number of grains per panicle. The culture recorded lowest mean square deviation and regression coefficient of near unity. High and desirable performance of the culture in different environments is a positive point to rate it as better and stable one.

Grain length

C 29 and Jyothi showed stability for grain length indicated by their high mean value, zero mean square deviation and regression coefficients around unity.

Grain breadth

C 26 T (a) had the maximum mean grain breadth followed by Ahalya Their zero mean square deviation and regression coefficient of around unity, along with high mean indicated their stable performance across environments.

Number of days for physiological maturity

C 26 T (b) with low mean square deviation and regression coefficient of near unity is stable over locations. As far as the mean value is concerned, this culture has the lowest mean value, which is desirable in the case of number of days for physiological maturity.

1000 grain weight

C 26 T (b) and local check Jyothi are stable and suited to different environments indicated by high mean values, low deviation from regression line and regression coefficient around unity.

Days to 50 per cent flowering

The culture C 80 which exhibited lowest mean value for the character with low mean square deviation and regression coefficient of near unity is stable.

Grain yield

Stability parameters of maximum mean grain yield, low mean square deviation and regression coefficient near unity for culture C 26 T (b) indicated that this culture was most stable for this character. The second highest grain yield was indicated by C 80 with regression coefficient near unity but with a slightly higher deviation from regression.

Straw yield

Stability for the cultures C 29 and C 26 S was indicated by the high mean values, low mean square deviation and regression coefficient near unity.

Hulling percentage

The culture C 80 and Ahalya with a regression coefficient of around unity and low mean square deviation are stable over locations. The local check Jyothi with maximum deviation and high regression coefficient showed good performance only in favourable environments.

Milling percentage

Mean milling percentage was highest for culture C 80 followed by ahalya. They are stable due to their regression coefficient near unity and low mean square deviation.

Amylose content

C 80 and ahalya showed less fluctuations due to environments for amylose content indicated by their regression coefficients near unity and mean deviation near to zero. The culture C 28 eventhough not stable had the maximum mean value.

Alkali spreading value

The highest mean alkali spreading value was indicated by the culture C 80. With respect to the stability, C 38 and C 26 T (a) are most stable with zero mean square deviation and regression coefficient of unity.

Volume expansion ratio

The highest mean volume expansion ratio was for culture C 26 T (b). In terms of stability, C 26 T (a) and C 28 are the most stable with regression coefficient of unity and near zero mean square deviation.

Kernel elongation ratio

The culture C 38 was less fluctuated by the environments indicated by their high mean value, zero deviation and regression coefficient near unity.

Head rice recovery

The local checks Jyothi and Ahalya with high mean values, regression coefficient near unity and low deviation were found stable and suited for all locations.

Stability parameters showed that out of 9 cultures, C 26T(b) was stable for height of plant at harvest, C 80 for total number of tillers, C 26T(b) and Jyothi for number of productive tillers, C 26S for length of panicle, C 26T(b) and Jyothi for number of spikelets per panicle, C 26T(b) for number of grains per panicle, C 29 and Jyothi for grain length, C 26T(a) and Ahalya for grain breadth, C 26T(b) for number of days for physiological maturity, C 26T(b) and Jyothi for 1000 grain weight, C 80 for days to 50 per cent flowering, C 26T(b) for grain yield, C 29 and C 26S for straw yield, C 80 and Ahalya for hulling percentage, C 80 and Ahalya for milling percentage, C 80 and Ahalya for amylose content, C 38 and C 26T(a) for alkali spreading value, C 28 and C 26T(a) for volume expansion ratio, C 38 for kernel elongation ratio and Jyothi and Ahalya for head rice recovery as indicated in Table 18. Thus culture C 26 T (b) had maximum grain yield and was stable for most of the yield contributing characters like height of plant at harvest, number of productive tillers, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight and grain yield. Stability parameters indicated C 80 as the next stable culture. C 80 was stable for

the characters total number of tillers, days to 50 per cent flowering, hulling percentage, milling percentage and amylose content (Plate 5).

Table 18. Stability of grain yield and yield components in nine rice cultures

Genotype	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total stable characters
C28																		*			1
C29							*						*								2
C38																	*		*		2
C26S				*									*								2
C26T(a)								*									*	*			3
C26T(b)	*		*		*	*			*	*		*									7
C80		*									*			*	*	*					5
Jyothi			*		*		*			*										*	5
Ahalya								*						*	*	*				*	5

1 - Height of plant at harvest, 2 - Total number of tillers, 3 - Number of productive tillers, 4 - Length of panicle, 5 - Number of spikelets per panicle, 6 - Number of grains per panicle, 7 - Grain length, 8 - Grain breadth, 9 - Number of days for physiological maturity, 10 - 1000 grain weight, 11 - Days to 50 per cent flowering, 12 - Grain yield, 13 - Straw yield, 14 - Hulling percentage, 15 - Milling percentage, 16 - Amylose content, 17 - Alkali spreading value, 18 - Volume expansion ratio, 19 - Kernel elongation, 20 - Head rice recovery


C 80

Summary

6. SUMMARY

A systematic study was undertaken in the Department of Plant Breeding and Genetics. College of Horticulture, Vellanikkara during 2002-2003 to analyse the stability of rice cultures under different locations.

Seven rice cultures C 28, C 29, C 38, C 26 S, C 26 T (a), C 26 T (b), C 80 along with two local checks Jyothi and Ahalya were analysed for stability at three locations Mannuthy, Pattikkad and Adatt. The results are summarized as below.

1. Significant difference among nine cultures were observed for most of the characters. But the variability estimates varied from location to location.
2. High heritability estimates were identified for most of the characters. Heritability of characters differed from location to location.
3. Correlation estimates indicated that the characters total number of tillers, number of productive tillers, 1000 grain weight, number of grains per panicle, number of spikelets per panicle and head rice recovery showed positive correlation with grain yield over the locations. The characters showed differential rates of correlations at different locations.
4. Height of plant at harvest, number of days for physiological maturity and days to 50 per cent flowering exhibited negative correlation with grain yield over locations indicating that lower magnitude of these characters increase yield.
5. Direct and indirect effects of characters on yield showed variation between locations.
6. 1000 grain weight and number of spikelets per panicle showed maximum positive direct effect on grain yield in all the locations.
7. Number of days for physiological maturity had high positive direct effect on grain yield at Mannuthy whereas the same character showed high negative direct effect on yield at Adatt.
8. Stability parameters showed that out of 9 cultures, C 26T(b) was stable for height of plant at harvest, C 80 for total number of tillers, C 26T(b) and Jyothi for number of productive tillers, C 26S for length of panicle, C 26T(b) and Jyothi for number of spikelets per panicle, C 26T(b) for number of grains per

panicle, C 29 and Jyothi for grain length, C 26T(a) and Ahalya for grain breadth, C 26T(b) for number of days for physiological maturity, C 26T(b) and Jyothi for 1000 grain weight, C 80 for days to 50 per cent flowering, C 26T(b) for grain yield, C 29 and C 26S for straw yield, C 80 and Ahalya for hulling percentage, C 80 and Ahalya for milling percentage, C 80 and Ahalya for amylose content, C 38 and C 26T(a) for alkali spreading value, C 28 and C 26T(a) for volume expansion ratio, C 38 for kernel elongation ratio and Jyothi and Ahalya for head rice recovery.

9. Culture C 26 T (b) had maximum grain yield and was stable for most of the yield contributing characters like height of plant at harvest, number of productive tillers, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight and grain yield. Stability parameters indicated C 80 as the next stable culture. C 80 was stable for the characters total number of tillers, days to 50 per cent flowering, hulling percentage, milling percentage and amylose content.

References

REFERENCES

Allard, R.W. 1960. *Principles of Plant Breeding.* John Wiley and Sons, New York, p.98

Arumugachamy, S., Giridharan, S., Soundararaj, A.P.M.K., Vivekanandan, P., Anthoniraj, S. and Thiyagarajan, T.M. 1995. Milling characters of raw and parboiled popular rice cultivars. *int. Rice Res. Newsl.* 20: 3

Azeez, M.H. and Shafi, M. 1966. *Quality in Rice.* Technical Bulletin No.13. Department of Agriculture, West Pakistan, p.50

Bagali, P.G., Nittalmani, S. and Shashidhar, H.E. 1999. Character association and path coefficient analysis in indica x japonica doubled haploid population of rice. *Oryza* 36: 10-12

Bala, A. 2001. Genetic variability, association of characters and path coefficient analysis of saline and alkaline rice genotypes under rainfed conditions *Madras agric. J.* 88: 356-357

Balan, A., Muthiah, A.R. and Boopathi, S.N.M. 1999. Genetic variability, character association and path coefficient analysis in rainfed rice under alkaline condition. *Madras agric. J.* 86: 122-124

Becker, H.C. 1981. Correlation among some statistical measures of phenotypic stability. *Euphytica* 30: 835-840

Bhattacharya, R.K. 1978. Estimates of genetic parameters of some quantitative characters in rice under stress soil (saline) conditions. *Oryza* 15: 146-150

Bhattacharyya, R.K. 1981. Interrelationship between grain yield and some quantitative characters in rice adopted to saline soils. *Oryza* 18: 147-149

Breese, E.L. 1969. The measurement and significance of genotype environment interaction in grasses. *Heredity* 24: 27-44

Burton, G.W. and Devane, E.H. 1953. Estimating heritability in tall fescue from replicated clonal material. *Agron. J.* 45: 478-481

Chauhan, V.S. and Tandon, J.P. 1984. Genetic variability and character association in hill rice. *Oryza* 21: 138-142

Chaubey, P.K. and Richharia, A.K. 1993. Genetic variability, correlations and path coefficients in indica rices. *Indian J. Genet. Pl. Breed.* 53: 356-360

Chaubey, P.K. and Singh, R.P. 1994. Genetic variability, correlation and path analysis of yield components of rice. *Madras agric. J.* 81: 468-470

Chauhan, J.S., Chauhan, V.S., Lodh, S.B. and Dash, A.B. 1992. Environmental influence on genetic parameters of quality components in rainfed upland rice (*Oryza sativa* L.). *Indian J. agric. Sci.* 62: 773-775

Chauhan, J.S., Chauhan, V.S. and Variar, M. 1993. Genetic variation and character association in rainfed upland rice. *Oryza* 30: 116-119

Das, G.R. and Borthakur, D.N. 1974. Variability parameters for quantitative characters in photoperiod insensitive tall and semidwarf rice varieties. *Indian J. agric. Sci.* 44: 613-616

Dash, S.K., Singh, J., Shahi, J.P. and Tripathy, M. 1995. Variability, heritability and genetic advance in medium land rice. *J. appl. Biol.* 5: 10-12

De, R.N., Reddy, J.N., Rao, A.V.S., Ramakrishnayya, G. and Pande, K.L. 1992. Stability of rice yield under different low land situations. *Indian J. Genet. Pl. Breed.* 52: 139-143

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 51: 515-518

Directorate of Rice Research (DRR). 1995. *Annual report for 1994*. Directorate of Rice Research, Hyderabad, India, p.238

Eberhart, S.A. and Russel, W.A. 1966. Stability parameters for comparing varieties. *Crop Sci.* 6: 36-40

Elsy, C.R., Rosamma, C.A. and Prabhakaran, P.V. 1994. Stability of new rice genotypes for grain yield. *J. trop. Agric.* 32: 7-9

Faseela, K.V. 2000. Genetic analysis in F_2 and F_3 progenies of selected crosses of rice varieties of diverse origin. M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, p.123

Fisher, R.A. 1954. A full theory of 'junctions' in breeding. *Heredity* 8: 187-197

Ganesan, K., Manuel, W.W., Vivekanandan, P. and Pillai, M.A. 1996. In breeding, variability, heritability and genetic advance in F_2 populations derived from early and extra-early rice cultivars. *Oryza* 33: 163-167

Ganesan, K., Subramanian, M., Manuel, W.W. and Sundaram, T. 1998. Correlation and path coefficient analysis of yield components in F_2 and F_3 generations of tall x dwarf rice crosses. *Oryza* 35: 329-332

Ghosh, A.K., Bhattacharya, P.K. and Asthana, A.N. 1981. Genetic variability in indigenous rice varieties of Meghalaya. *Indian J. agric. Sci.* 51: 281-283

Govindarasu, R. and Natarajan, M. 1995. Analysis of variability and correlation among high density grain characters in rice. *Madras agric. J.* 82: 681-682

Gravois, K.A. and McNew, R.W. 1993. Genetic relationships among and selection for rice yield and yield components. *Crop Sci.* 33: 249-252

Hargrove, T., Cabanilia, V.L. and Coffman, W. 1988. Twenty years of rice breeding. *Bioscience* 38: 675-681

IRRI. 1972. *Annual Report for 1971.* International Rice Research Institute, Los Banos, Philippines, p.238

IRRI. 1980. *Standard Evaluation System for Rice.* International Rice Research Institute, Manila, Philippines, p.44

IRRI. 1995. *Standard Evaluation System for Rice.* International Rice Research Institute, Manila, Philippines, p.44

Janardhanam, V., Nadarajan, N. and Jebaraj, S. 2001. Correlation and path analysis in rice (*Oryza sativa* L.). *Madras agric. J.* 88: 719-720

Jatasra, D.S. and Paroda, R.S. 1979. Genotype x environment interactions and environmental sampling in wheat. *Crop Improv.* 6: 86-90

Johnkutty, I. 1993. *Kole lands of Kerala.* Kerala Agricultural University, Vellanikkara, p. 68

Johnson, H.W., Robinson, H.P. and Comstock, R.E. 1955a. Estimates of genetical and environmental variability in soyabeans. *Agron. J.* 47: 314-318

Johnson, H.W., Robinson, H.P. and Comstock, R.E. 1955b. Genotypic and phenotypic correlations in soyabean and their implications in selection. *Agron. J.* 47: 477-482

Jyothi, R. 2002. Stability analysis of Kunjukunju rice cultures (*Oryza sativa* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, p.71

Kandaswami, M. and Rajagopalan, R. 1995. Analysis of stability parameters for rice grown in sodic soils. *Madras agric. J.* 82: 371-375

Kavitha, S. and Reddi, N.S.R. 2001. Correlation and path analysis of yield components in rice (*Oryza sativa* L.). *Andhra agric. J.* 48: 311-314

Kaw, R.N., Aquino, R.C., Moon, H.P., Yae, J.D. and Haq, N. 1999. Variability and interrelations in rice under cold stress environments. *Oryza* 36: 1-4

Khan, A.K.F. and Sukumar, K. 2002. Genotypic and phenotypic correlation and path analysis in napier grass *Pennisetum purpureum* (K) Schum, germplasm. *Madras agric. J.* 89: 164-166

Kulkarni, N. and Gangaram, A. 1998. Genetic changes and phenotypic stability in mutants of rice variety Samba Mahsuri. *Oryza* 35: 322-324

Kumar, C.R.A. 1992. Variability and character association studies in upland rice. *Oryza* 29: 11-13

Lerner, I.M. 1954 *Genetic Homeostasis.* Oliver and Boyd, London. p.115

Lush, J.L. 1949. *Animal Breeding Plans* Lown State University Press. Annes p.473

Mahajan, R.K., Rao, A.V. and Agarwall, D.K. 1981. Principal component analysis of some late maturity rice varieties. *Indian J. agric. Sci.* 51: 9-12

Manivel, P and Hussain, H.S.J. 2000 Genotype x environment interaction in castor. *Madras agric J.* 87: 394-397

Manonmani, S., Ranganathan, T.B. and Narasimman, R. 1999. Interrelationship between earliness and yield components in rice. *Madras agric. J.* 86: 124-126

Manuel, W.W. and Palaniswamy, S. 1989. Heterosis and correlation in rice. *Oryza* 26: 238-242

Manuel, W.W., Vivekanandan, P. and Ranganathan, T.B. 1999. Genetics of Oryza 1 plant input parameters. *Oryza* 36: 98-100

Meenakshi, T., Ratinam, A.A.D. and Backiyarani, S. 1999. Correlation and path analysis of yield and some physiological characters in rainfed rice. *Oryza* 36: 154-156

Mishra, D. and Dash, S.K. 1997. Genetic diversity and stability in aromatic rice (*Oryza sativa*). *Indian J. agric. Sci.* 67: 27-29

Muker, H.S., Gautam, R.K., Randhawa, A.S. and Sidhu, G.S. 1998. Variability among state released varieties of rice for quality and milling characteristics. *Oryza* 35: 367-369

Murthy, P.S.S., Kumar, B.V. and Narayanan, A. 1997. Path coefficient analysis of physiological productive and chemical parameters on the yield of ratoon rice crop. *Oryza* 34: 292-294

Murthy, N., Kulkarni, R.S. and Udaykumar, M. 1999. Genetic variability, heritability and genetic advance for morpho-physiological traits in rice. *Oryza* 36: 159-160

Nair, A.S. 2000. Genetic and physiological analysis of ratooning in rice (*Oryza sativa* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, p.108

Nath, N. and Talukdar, P. 1997. Genetic variability and correlation studies in segregating populations of indigenous scented x high yielding non-scented crosses of rice. *Oryza* 34: 91-93

Onate, L.U. and Delmundo, H.M. 1966. Eating quality of some varieties of low land rice. *Philipp. J. Agric.* 47: 208

Panse, V.G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.* 17: 318-328

Panwar, A. and Dhaka, R.P.S. 1998. Phenotypic stability for grain yield in rice. *Oryza* 35: 269-271

Paroda, R.S., Panwar, D.V.S. and Sharma, G.D. 1973. Genotype x environment interaction for fodder yield in sorghum. *Indian J. agric. Sci.* 43: 336-385

Paramasivan, K.S. and Rangasamy, S.R. 1988. Genetic analysis of yield and its components in rice. *Oryza* 25: 111-119

Rajarathinam, S. and Raja, V.D.G. 1992. Correlation and path analysis in some rice varieties under alkaline stress. *Madras agric. J.* 79: 374-378

Rajeswari, S. and Nadarajan, N. 1997. Character association and path analysis in rice (*Oryza sativa* L.). *Crop Res.* 11: 189-193

Rao, S.S. and Saxena, R.R. 1999. Correlation and regression analysis in upland rice. *Oryza* 36: 82-84

Rao, S.S. and Shrivastava, M.N. 1999. Association among yield attributes in upland rice. *Oryza* 36: 13-15

Reddy, J.N., Pani, D. and Roy, J.K. 1998. Genotype x environment interaction for grain yield in lowland rice cultivars. *Indian J. Genet.* 58: 209-213

Rosamma, C.A. 1998. Identification of stable male sterile lines and better combiners for exploitation of hybrid vigour in rice (*Oryza sativa* L.). Ph.D. thesis, Kerala Agricultural University, Trichur, p.183

Roy, A. and Kar, M.K. 1992. Heritability and correlation studies in upland rice. *Oryza* 29: 195-199

Roy, A., Panwar, D.V.S. and Sarma, R.N. 1995. Genetic variability and causal relationships in rice. *Madras agric. J.* 82: 251-255

Sadananda, A.R., Zamen, F.U. and Siddiq, E.A. 1987. Genetic variability for indices of major cooking and nutritive quality characters in rice (*Oryza sativa* L.) collections from north east Indian hills. *Indian J. Genet.* 47: 249-255

Sadasivam, S. and Manickam, A. 1992. *Biochemical methods*. New Age International Limited, Coimbatore, p.50

Sarawgi, A.K., Rastogi, N.K. and Soni, D.K. 2000. Studies on some quality parameters of indigenous rice in Madhya Pradesh. *Ann. agric. Res.* 21: 258-261

Satyavathi, L.T., Bharadwaj, C. and Subramanyam, D. 2001. Variability correlation and path analysis in rice varieties under different spacings. *Indian J. agric. Res.* 35: 79-84

Sawant, D.S. and Patil, S.C. 1995. Genetic variability and heritability in rice. *Ann. agric. Res.* 16: 59-61

Saxena, K.B. and Rajna, R. 2001. Pattern analysis for genotype by environment effects for seed weight and grain yield in pigeon pea hybrids. *Indian J. Genet.* 61: 226-231

Shadakshari, Y.G., Chandrappa, H.M., Kulkarni, R.S. and Shashidhar, H.E. 2001. Genotype x environment interaction in low land rice genotypes of hill zone of Karnataka. *Indian J. Genet. Pl. Breed.* 61: 350-352

Shanthi, P. and Singh, J. 2001. Variability studies in induced mutants of Mahsuri rice (*Oryza sativa* L.). *Madras agric. J.* 88:707-709

Shouichi, Y., Douglas, F., James, H.C. and Kwanchai, A.G. 1976. Physiological studies of Rice. *Indian J. Genet.* 47: 99-103

Singh, R.P., Rao, M.J.B.K. and Rao, S.K. 1984. Genetic evaluation of upland rice germplasm. *Oryza* 21: 132-137

Singh, S. and Choudary, B.S. 1996. Variability, heritability and genetic advance in cultivars of rice. *Crop Res.* (Hissar). 12: 165-167

Singh, R.S., Chauhan, S.P. and Maurya, D.M. 1986. Genetic variability in 98 upland rice cultivars of India. *Int. Rice Res. Newsl.* 11: 9-10

Singh, R.K. and Chaudhary, B.D. 1985. *Biometrical methods in Quantitative Genetic Analysis.* Kalyani Publishers, New Delhi, p.182

Singh, M., Singh, G., Bhutia, D.T. and Awasthi, R.P. 1995. Genotype x environment interaction in rice (*Oryza sativa*). *Indian J. agric. Sci.* 65:832-833

Singh, A., Chabra, B.S. and Sabbarwal, P.S. 1997. Stability analysis for yield and its components in rice (*Oryza sativa*). *Indian J. agric. Res.* 31:149-155

Sreekumar, S.G., Nair, V.G. and Asan, R.B. 1993. Genotype x environment interaction and stability of pre-release cultures and varieties of rice. *J. trop. Agric.* 31: 1-4

Sundaram, T. and Palanisamy, S. 1994. Path analysis in early rice (*Oryza sativa* L.). *Madras agric. J.* 81: 28-20

Thakur, S.K., Sharma, N.P. and Sharma, S.N. 2000. Genetic variation and association studies in segregating population of rice (*Oryza sativa* L.) *J. Soils and Crops.* 10:316-318

Vanaja, T. 1998. Genetic analysis of high yielding rice varieties of diverse origin. Ph.D. thesis, Kerala Agricultural University, Trichur, p.350

Vanniarajan, C., Rangasamy, P., Nadarajan, N. and Ramalingam, J. 1998. Genotype x environment interaction and environmental indices for biometrical traits in pieonpea. *Indian J. agric. Res.* 32:111-115

Vijayakumar, C.H.M., Ahmed, M.I., Viraktamath, B.C., Balakrishnan, R. and Ramesha, M.S. 2001. Genotype x Environment interaction effects on yield of rice hybrids in India. *Indian J. Genet.* 61: 101-106

Vivekanandan, P. and Giridharan, S. 1998. Genetic variability and character association for kernel and cooking quality traits in rice. *Oryza.* 35:242-245

Yadav, R.K. 2000. Studies on genetic variability for some quantitative characters in rice (*Oryza sativa* L.) *Adv. agric. Res.* in India. 13:205-207

G x E INTERACTION IN THE F_6 GENERATION OF WIDE CROSSES OF RICE (*Oryza sativa* L.)

By

VIDHU FRANCIS PALATHINGAL

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2003

ABSTRACT

The present study 'G x E interaction in the F_6 generation of wide crosses of rice (*Oryza sativa* L.)' was carried out under the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara. The study was carried out for 20 characters in nine rice cultures at three locations viz., Mannuthy, Pattikkad and Adatt. The experiment estimated the variability, heritability, correlation, path coefficients and stability for the characters

High variability and heritability was noticed for most of the yield characters. The estimates of variability and heritability vaired widely between locations indicating the preponderance of the environment. Correlation and direct and indirect effects of the characters on yield also differed between the environments indicating the profound influence of location on the character.

Stability analysis revealed that among the nine rice cultures studied, culture C 26T(b) was found to be stable over locations for most of the yield traits. Culture C 26T(b) had maximum grain yield and was stable for most of the yield contributing characters like height of plant at harvest, number of productive tillers, number of spikelets per panicle, number of grains per panicle, number of days for physiological maturity, 1000 grain weight and grain yield. C 26T(b) showed superior and stable performance in the hill tracts of Pattikkad, Kole land of Adatt and at Mannuthy. Stability parameters indicated C 80 as the next stable culture. C 80 was stable for the characters total number of tillers, days to 50 per cent flowering, hulling percentage, milling percentage and amylose content.