GENETIC ANALYSIS IN F_2 AND F_3 PROGENIES OF SELECTED CROSSES OF RICE VARIETIES OF DIVERSE ORIGIN

By

K. V. FASEELA

THESIS

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DECLARATION

I hereby declare that this thesis entitled "**GENETIC ANALYSIS IN F_2 AND F_3 PROGENIES OF SELECTED CROSSES OF RICE VARIETIES OF DIVERSE ORIGIN**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara **K.V. FASEELA**

26.02.2000

MAREEN ABRAHAM
Assistant Professor
Dept. of Plant Breeding & Genetics
College of Horticulture
Kerala Agricultural University

CERTIFICATE

Certified that this thesis entitled **"GENETIC ANALYSIS IN F_2 AND F_3 PROGENIES OF SELECTED CROSSES OF RICE VARIETIES OF DIVERSE ORIGIN"** is a record of research work done independently by Ms. **Faseela, K.V.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara

Mareenabraham

MAREEN ABRAHAM
Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of Ms. **Faseela, K.V.**, a candidate for the Degree of **Master of Science in Agriculture** agree that this thesis entitled **"GENETIC ANALYSIS IN F_2 AND F_3 PROGENIES OF SELECTED CROSSES OF RICE VARIETIES OF DIVERSE ORIGIN"** may be submitted by **Ms. Faseela, K.V.**, in partial fulfilment of the requirement for the Degree.

MAREEN ABRAHAM
(Chairman, Advisory Committee)
Assistant Professor
Dept. of Plant Breeding and Genetics
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

DR. V.V. RADHAKRISHNAN
(Member, Advisory Committee)
Associate Professor
Dept. of Plant Breeding & Genetics
College of Horticulture
KAU, Vellanikkara

DR. V.K.G. UNNITHAN
(Member, Advisory Committee)
Associate Professor
Dept. of Agricultural Statistics
College of Horticulture
KAU, Vellanikkara

DR. K. PUSHKARAN
(Member, Advisory Committee)
Associate Professor & Head (i/c.)
Dept. of Plant Breeding & Genetics
College of Horticulture
KAU, Vellanikkara

EXTERNAL EXAMINER

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Faseela KV

K.V. Faseela

Dedicated To My

Little love, Aami

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Introduction

1. INTRODUCTION

Rice is the most important food crop cultivated in the tropical and subtropical regions of the world, which often exceeds in demand when compared to supply, in most of the developing countries. Inspite of large area under rice, the production is insufficient to feed the population. Therefore many attempts were made to increase the production of this staple food. By the year 2025, the global rice requirement is estimated to be about 758 million tonnes, which is 50 per cent more than what is consumed today (IRRI, 1994).

Green Revolution Technology, centred on high yielding varieties, have revolutionized rice production since the late 1960's. These varieties are characterized by higher yield potential, better grain quality, shorter growth duration, multiple resistance to diseases and insects and tolerance to problem soils. Seventy per cent of the world's rice producing land is under high yielding rice varieties. Most countries in the Asian rice belt have become self sufficient in rice. Rice varieties with multiple resistance have reduced the application of agrochemicals.

In India major increase in rice production had occurred in the last 30 years because of large scale adoption of high yielding varieties and improved technology. The new high yielding rice varieties characterized by short stature, profuse tillering, sturdy stem, dark green and erect leaves, are extremely effective in increasing productivity in mid-sixties and more than 68 per cent of rice area in India is now planted with them. However, this led to the depletion of genetic base of rice varieties, as thousands of land races were replaced by a handful of modern rice varieties, resulting in genetic erosion. Extensive genetic uniformity in the field can lead to devastating yield losses, due to greater vulnerability to insect pests and diseases. Therefore knowledge of genetic diversity among the released varieties is important to breeders for understanding the germplasm usage and to avoid employment of varieties with a narrow genetic base as parents in the breeding programmes.

An examination of the pedigrees of 29 rice (*Oryza sativa* L.) varieties of hybrid derivatives released in Kerala during 1966-95 revealed a narrow genetic base, as only 37 ancestors were used directly or indirectly for their development (Shivkumar *et al.*, 1998). Out of the 37 ancestors, only ten contributed to 74.14 per cent of the genetic base. Similarly, cytoplasmic diversity was also limited since 41.38 per cent varieties could be traced back maternally to the same ancestor `Ptb 10' (Thekkencheera) and thus probably carried its cytoplasm. Dee-geo-woo-gen was the most frequently appeared ancestor (96.55%) as it was the source of dwarfening gene.

Hence rice yields have apparently reached a plateau. Thus the way out is the production of high yielding varieties by genetic improvement of the local types, which have a broad genetic base. Richness of the varietal diversity in cultivated rice and the easy crossability between the varieties helped in the development of a large number of improved strains through intervarietal hybridisation followed by selection of appropriate genotypes.

Rice consuming populations are increasing at the rate of 2 per cent annually, but the growth rate of rice production has reduced to 1.2 per cent (Khush, 1995). To reverse this trend, rice plant types with higher yield potential are being developed.

The improved plant ideotype is seen as having reduced tillering, larger panicles, improved grain size, density and filling, better leaf and canopy characteristics, optimal growth duration (120 days in tropics) and better plant height, stem thickness, biomass production, harvest index, vigorous root system and pathogen resistance (Khush, 1994). One possible way of increasing rice yield is by increasing number of high density grains per panicle without increasing number of spikelets. Venkateswaralu *et al.* (1986 b) suggested that yield can be increased upto 30 per cent through higher number of high density grains panicle^{-1}. Higher head-rice recovery from high density grain is also a major factor for enhancing yield potential (Venkateswaralu *et al.*, 1986 a).

The improvement of crop is dependent on the magnitude of genetic variability and the extent to which the desirable characters are heritable. A critical survey of genetic variability is, therefore, a pre-requisite for planning an effective breeding programme. Yield being a complex character, direct selection would not be a reliable approach without giving due importance to genetic background.

Yield is a highly complex character, whose inheritance is dependant upon the functioning of an intricately organized polygenic system. Further, the character is influenced by a number of variables. Each variable is found to influence the character in a different fashion and in different magnitude. The objective of a practical breeder is therefore, to identify the more important components from the others and direct selection, preferably on the basis of such criteria alone. Following the identification of components, involves the analysis of their interrelationship. Genotypic correlation is estimated as a routine in this regard. An understanding of the heritability, genetic advance and genetic gain helps in confirmation of the relative importance of the components. Further, these components exert their influence directly as well as indirectly.

Wright (1934) derived a technique widely known as path-coefficient analysis, which in combination with information from correlation studies helps in identifying more reliable and important criteria upon which the selection should be based.

With this view in mind, the present investigation was undertaken to fulfil the following objectives.

1. To assess the genetic variability in the F2 and F3 progenies of four diverse crosses selected.
2. To determine genetic parameters like heritability, genetic advance and genetic gain of different characters.
3. To determine genotypic and phenotypic correlation between yield and yield components.
4. To find the direct and indirect effects of different components towards yield.
5. Formulation of suitable selection model and ranking of genotypes.
6. Identification of superior genotypes from F3 for developing new ideotypes having high yield and qualities suited to Keralites.

Review of Literature

2. REVIEW OF LITERATURE

Breeding programmes can be well orchestrated when the genetics of the crop is well understood. By conducting systematic analysis, genetic parameters can be estimated to understand the nature of gene action in the crops. A review of literature on these subjects is attempted in this chapter. Details of information available have been pooled and a brief review made covering, components of variance, gene action, heritability, genetic advance, correlation, path analysis and selection index.

2.1 COMPONENTS OF VARIANCE AND NATURE OF GENE ACTION

Mathew (1976) studied nine characters in F_3 generation of the intervarietal crosses of rice. The characters like flowering duration, plant height, total number of tillers, number of productive tillers, panicle length, grain yield, 1000 grain weight, ear weight and spikelet sterility were inherited quantitatively and were controlled by polygenes.

Shamsuddin (1982) analysed data from 53 ecotypically diverse varieties indicating considerable genetic variation for the traits studied, including, 100 grain weight and volume, grain number panicle^{-1}, grain yield plant^{-1} and panicle length.

Subramanian and Rathinam (1984b) reported that grain and straw yields in rice were under the influence of dominance gene action, while plant height, number of grains panicle^{-1}, 100 grain weight, harvest index, grain length, grain width and length : width ratio were found to be governed by additive gene action mainly.

Tiller number was controlled by dominance gene action and panicle length was influenced by both additive and dominance gene action.

While studying on the inheritance of grain size and shape in rice, Jun (1985) reported that F_2's showed transgressive segregation towards shorter grains in every cross.

Sundaram *et al.* (1988) conducted an experiment with six F_1 progenies and their seven parents at Ambasamudram to evaluate the variability. Estimates of phenotypic and genotypic variances were higher for grains panicle^{-1}, followed by plant height and drymatter and lowest for productive tillers.

According to Kato (1989) additive effects were more important than non-additive effects, for both grain length and width. The alleles for shorter grains were estimated to be partially dominant and more frequent than those for longer grain. No clear dominance effect was detected for grain width. Grain length and width were considered to be controlled by different genetic system.

Studies were made on F_2 population generated by two crosses by Sahu and Sahu (1990). Transgressive segregation was noted for the characters studied. Panicle length and 50 per cent flowering in both crosses were highly influenced by environment. In cross 1, number of effective tillers plant^{-1} and plant height have been influenced greatly by environment. Where as in cross 2, grain weight panicle^{-1} has been influenced by environment, as their PCV value was higher than GCV value.

Marimuthu *et al.* (1990 b) assessed genetic variability in F_2 population of six intervarietal crosses of rice and their three parents. Wide variability was observed for number of productive tillers plant^{-1}, grain number panicle^{-1} and single plant yield.

The trials indicated role of additive gene action in controlling these traits.

Genetic variability of yield and yield characters in early maturing indica and japonica genotypes were examined by Amrithadevarathinam (1990). Indica were characterised by greater values of variance components for yield and yield characters. GCV was highest for grains panicle^{-1} followed by tiller number, culm length and seedling height, in both indica and japonicas.

Takeda (1991) studied inheritance of grain size and reported that grain length was the most adequate trait for analysing grain size because of high heritability. Grain length was controlled by polygenes, but in extraordinarily large or small grain it was controlled by major gene or genes. Dominant small grain gene *mi* reduced kernel weight to 2/3rd of normal, while incompletely dominant large grain gene Lk-f give kernel 1.4 times normal weight. Large grain types form fewer spikelets plant^{-1} and therefore does not necessarily out yield the normal counterpart.

Reddy (1991) evaluated genotype and environment interaction in short duration rice and reported that any genotype possessing stability in different environment with considerably good yield is of practical importance in a plant breeding programme. G x e interaction was highly significant. Environment mean square and genotypic mean square was also highly significant, revealing differential behaviour of genotypes to different environment, for grain yield.

Inheritance of grain size, nature of panicle, awning and plant habit was studied in three crosses at CRRI, Cuttack by Prasad and Seetharaman (1991). A tall variety with normal panicle having long grain crossed with two phenotypically similar dwarf mutants with cigar shaped panicle having short and round grains. Monogenic and trigenic ratios for grain size obtained in F_2. Dwarf plant habit was associated with cigar shaped panicle possessing short and round grains indicating pleotropic gene action. Digenic and tetragenic ratios were obtained for awning indicating two and four gene interactions for expression of awn in these crosses.

Information on variability was derived from data on performance of six yield related traits in the parents and F_2 progeny of eight crosses involving seven short duration cultivars. Additive gene action was predominent for control of plant height, 100 grain weight, days to panicle emergence and grain yield (Santhalingam *et al.*, 1992).

Data on eight quantitative traits in six rice generations (parental, F_1, F_2, BC_1 and BC_2) from a cross was analysed by Reddy and Nerkar (1992). The segregation ratios indicated monogenic control of plant height.

Inheritance interrelationship of panicle type and spreading panicle branch were studied in the F_1, F_2 and F_3 generations from cross between D-6-2-2 (green with normal panicle) and HY 256 (purple). Lax (open) panicle type was monogenic while spreading panicle branch was under the control of two complementary (Spr a and Spr b) and two inhibitory duplicate genes. Tight linkage was detected between the gene for lax panicle and one of the two inhibitory duplicate genes for spreading panicle branch (Nadaf *et al.*, 1992).

Nature of gene interaction in the inheritance of quantitative characters were studied by Roy and Panwar (1993) in two rice crosses. Additive gene effects were high for all traits except grain yield plant^{-1} (YP) and panicles plant^{-1} (PP) in cross 1 and PP and panicle length (PL) in cross 2. Dominance was significant for all traits except grain length (GL), grain breadth (GB) in cross 1 and days to heading (DH) and plant height (PH) in cross 2. Dominance x Dominance interaction was more important than additive x additive and additive x dominance interactions for all traits. Duplicate epistasis played an important role in the inheritance of YP, DH, PH, PP and grain panicle^{-1} (GP) in cross 1 and PP, GP, GL and GB in cross 2.

According to Singh *et al.* (1993 b), days to heading appeared to be controlled by both additive and dominance gene effects. Their study on the components of genetic variance indicated that the non-additive gene effects were more important. One to five dominant genes governed the inheritance of grain yield (Singh *et al.*, 1993 a).

In a study of F_2 rice crosses under different environments, Tiwari *et al.* (1993) found that the characters showed wide range of variation in changing environments. The highest GCV was recorded by seed yield plant^{-1} followed by seed weight panicle^{-1}. Similar findings have also been reported by Chaudhary *et al.* (1980) and Kaul and Kumar (1982).

Chaubey and Singh (1994) evaluated 20 rice varieties for eight yield related traits and reported that all the traits studied had higher PCV compared to GCV.

In order to understand the nature and extent of variability, Regina *et al.* (1994) conducted a yield experiment with 45 short duration rice genotypes. The environmental influence on the different traits was evident from PCV being higher than GCV.

Genetic studies in F_2 and F_3 of tall x dwarf rice crosses were carried out by Ganesan and Subramanian (1994). In F_2 of all crosses, PCV and GCV were high for the number of productive tillers, grain number panicle^{-1} and single plant yield, low for days to panicle emergence and 100 grain weight and moderate for plant height. In F_3, all characters had low variability except single plant yield which had moderate variability.

The degree of variability for yield and its component in F_2 plants gradually decline with each subsequent generation though amount of decrease varies with each selection methods and environments (Mishra *et al.*, 1994).

The components of gene effects for yield and five yield traits were studied in four crosses by Ram (1994). The analysis revealed the importance of dominance and epistatic components for yield, tillers plant^{-1}, grains panicle^{-1} and 1000 grain weight, in all the crosses. Additive and dominance effects were important for plant height and panicle length. Among digenic interaction additive x additive and dominance x dominance components contributed more, in most of the characters. Additive x dominance effects were important for 100 grain weight. Most crosses revealed duplicate epistasis for majority of characters. All crosses exhibited heterosis in F_1 and inbreeding depression in F_2.

Dhanakodi and Subramanian (1994) reported additive x additive interaction for productive tillers plant^{-1}, grains panicle^{-1} and 100 grain weight. Additive x dominance effect for plant height and dominance x dominance for panicle length and grain yield, was also revealed.

Ahmed *et al.* (1995) reported that grain length, breadth and shape were largely controlled by polygenes. Transgressive segregation was also observed for these characters.

Inheritance and linkage relationship of leaf angles were studied by Nadaf *et al.* (1995 a) revealed that acute leaf angle was a dominant trait under the control of 4-5 non-allelic mutually interacting genes. Similarly inheritance of four spikelet characters were also studied by Nadaf *et al.* (1995 b) revealing that awning character behaved as recessive trait, controlled by five genes, of which four were inhibitory duplicate genes. Character is monogenic dominant in the absence of the inhibitory genes.

A six parameter model generation mean analysis was done by Chakraborthy and Hazarika (1995) for studying the inheritance of yield and yield traits in rice. Additive genetic variance was high for 50 per cent flowering, panicle length, spikelets panicle^{-1} and panicle number. Dominance variance was high for plant height and yield plant^{-1}.

Analysis of variability among high density grain characters in rice was carried out by Govindarasu and Natarajan (1995). They reported that the characters, high density grain and 100 grain weight recorded high GCV and were less influenced by environment as indicated by low difference in PCV and GCV.

Data from trials of 10 scented rice genotypes over four seasons indicated that PCV and GCV were high for grains panicle^{-1}, but PCV was high for number of chaffs panicle^{-1}, 100 grain weight and yield. Role of additive gene action prevailed in all the traits (Mishra *et al.,* 1996).

Study of genetic variability on yield and yield traits under semidry rice cultivation was done by Rao *et al.* (1996) in two environments revealed high GCV and PCV and predominance of additive gene effects. Difference in GCV estimate over environment was found to be a good tool to find out favourable environment to exploit genotypic variation.

The genetic nature of high density (HD) grain was studied in six crosses using six parameter model by Mallik *et al.* (1997). The multiple genes with both dominance and additive effects controlled the HD grain index, though the dominance were greater in most of the crosses.

Basavaraja *et al.* (1997) evaluated genetic variability of ten characters in two F_4 population of fine grained rice. High PCV was observed for total tillers plant^{-1}, productive tillers plant^{-1}, total spikelets panicle^{-1} and grain yield.

Chauhan (1998) indicated the involvement of inter allelic interaction in inheritance of grain weight, size and shape. Dominance effects and Dominance x dominance effects were more important for grain weight and grain shape. However grain length and breadth were governed predominantly by additive gene effects and their interaction.

Vanaja (1998) reported high GCV and PCV of secondary and tertiary branches panicle^{-1} and moderate variability of L/B ratio. The characters panicle length, grain length and days to 50 per cent flowering exhibited low GCV and PCV. Results of generation mean analysis indicated that both additive and non-additive gene effects played important role in the inheritance of yield and its components, with predominance of additive x additive and dominance x dominance type of gene effects.

2.2 HERITABILITY AND GENETIC ADVANCE

The concept of heritability is one of the most important and frequently used parameters in quantitative genetics. It is difficult to judge whether a phenotypic variability is heritable or due to environment. Heritability denotes the proportion of phenotypic variance that is due to genotypes, and is heritable. The progress in a breeding programme depends on the extent to which desirable traits are heritable. Johnson *et al.* (1955) suggested that for more reliable conclusion, estimates of heritability and genetic advance (GA) should be considered together and also suggested that heritability along with genetic advance is more useful than heritability alone.

Shamsuddin (1982) analysed genetic variation for panicle and grain characteristics, reported high heritability estimates for all the characters, ranging from 98.04 per cent (yield plant^{-1}) to 86.94 per cent. High heritability with GA was obtained for 100 grain weight and volume, grain number panicle^{-1} and grain yield plant^{-1}.

According to Subramanian and Rathinam (1984 b) grain and straw yield has moderate heritability. Plant height, number of grains panicle^{-1}, 100 grain weight, grain length, grain width and L : W ratio were having high heritability as they were governed by additive gene action. Tiller number had low heritability and was controlled by dominance action, while panicle length was influenced by both additive and dominance action with high heritability.

Rao *et al.* (1986) suggested that heritability differed between crosses and tended to decrease from F_3 to F_4 population.

In a study carried out by Moeljopawiro (1986) in the F_1 and F_2 of a diallel cross between two long, two medium and two short grained cultivars, narrow sense heritability estimates were moderate for plant height, panicle length, grain length, grain width and 100 grain weight.

Study of a group of rice lines for obtaining early varieties revealed that plant height showed high broad sense heritability. The characters, number of panicles m^{-2}, number of grains panicle^{-1} and 1000 grain weight showed sufficient heritability for effective selection (Morales- ramos, 1987).

Sundaram *et al.* (1988) conducted an experiment with five F_1 progenies and their seven parents at Ambasamudram and found that all the characters had high heritability (72.37 to 99.4%). Plant height had highest heritability followed by grain panicle^{-1}. GA was higher for straw yield followed by chaffs panicle^{-1}, grains panicle^{-1}, productive tillers and grain yield (46.47 %).

Studies were made on two F_2 population by Sahu and Sahu (1990) revealed that in both crosses 50 per cent flowering and panicles length were greatly influenced by environment and in one cross number of grains panicle^{-1} and yield plant^{-1} had shown moderate genetic gain. The characters like effective tillers and height of plant had low heritability and poor genetic gain. In latter cross grain weight panicle^{-1} had been influenced by environment, accompanied by poor genetic gain.

Marimuthu *et al.* (1990 b) recorded high heritability coupled with high GA for number of productive tillers plant^{-1}, grain number panicle^{-1} and single plant yield. High heritability with moderate to low GA was recorded for days to flowering, plant height, panicle length and 100 grain weight. Later Roy *et al.* (1995) and Lalitha and Sreedhar (1996) also reported the same.

Two crosses of rice were used to investigate effectiveness of selection in F_2 and F_3 generations by Mishra *et al.* (1991). Heritability estimates improved in F_3 for all characters when single characters were considered. When combined characters were considered there was no consistency in heritability. In population selected on the basis of yield or more than one character, genetic gain was high. Highest genetic gain was for grain yield plant^{-1}. In unselected population genetic gain decreased greatly.

Narrow sense heritability estimates were high for number of effective tillers plant^{-1} and 100 grain weight and moderate for grain yield (Reddy and Nerkar, 1991). Similar findings were also reported by Santhalingam *et al.* (1992) and Yadav (1992).

Sreekumar *et al.* (1992) evaluated pre-release cultures and varieties of rice and reported that 50 per cent flowering and plant height had high heritability and GA. The characters like number of productive tillers, grain yield and 1000 grain weight recorded moderate to high heritability and low GA.

According Lokaprakash *et al.* (1992), in general, heritability showed an increasing trend from F_2 to F_3, while GA was reduced. Panicle weight, 1000 seed weight, number of fertile spikelets panicle^{-1} recorded high heritability coupled with moderate to high GA indicating additive gene action.

Singh *et al.* (1993 a) suggested that all yield traits studied in a half diallel cross of eight diverse cultivars of rice showed moderate narrow sense heritability except for plant height, which showed high heritability.

Twenty rice varieties were evaluated for eight yield related traits revealed that heritability was high for all traits, highest for number of spikelet followed by yield and 100 grain weight, GA was highest for grain yield plant^{-1} followed by panicle weight and number of spikelet (Chaubey and Singh, 1994). This was also reported by Paramasivam *et al.* (1995).

In a field experiment conducted with 45 short duration rice genotypes at Rice Research Station, Moncompu, to understand nature and extent of variability, Regina *et al.* (1994) reported that plant height, flag leaf area, panicle exsertion, number of grains panicle^{-1} and grain yield exhibited moderate to high heritability and GA. This was also reported by Ganesan and Subramanian (1994) and they also found that days to panicle emergence had high heritability with low GCV and GA, indicating non-additive gene action.

The inheritance of grain size, shape and weight studied in five inter varietal crosses by Chauhan and Chauhan (1994) revealed that grain length, breadth, weight and shape had high narrow sense heritability together with high to moderate GA. Reddy and De (1996) also reported the same.

Analysis of variability among high density grain characters in rice was conducted by Govindarasu and Natarajan (1995). HD grain and 1000 grain weight recorded high heritability and GA and were less influenced by environment. High density grain index and number of spikelet recorded low values of heritability and GA, and high influence of environment was also found.

According to Manomani *et al.* (1996) characters, days to flowering, plant height, 100 grain weight, number of grains in primary ear and grain yield had high values of heritability and GA and thus provide good base for selection.

Mishra *et al.* (1996) studied ten scented rice genotypes over four seasons indicated that all yield traits had high heritability except panicle length, number of tillers hill^{-1} and number of chaffs panicle^{-1}. However GA was low for most of the traits studied.

Genetic variability of ten characters were studied in two F_4 populations of fine grained rice. High to moderate heritability and GA were observed for total tillers plant^{-1}, productive tillers plant^{-1} and total spikelets panicle^{-1}. Grain yield plant^{-1} showed low heritability and GA (Basavaraja *et al.,* 1997).

In a study Chauhan (1998) reported that the estimates of heritability and genetic advance were fairly consistent for grain length and breadth in F_2 and F_3, where as there was appreciable reduction for grain weight.

In a study conducted to analyse genetic parameters of rice varieties of diverse origin, Vanaja (1998) reported high heritability and moderate to high GA for plant height, panicle length, number of grains panicle^{-1}, 1000 grain weight and duration to 50 per cent flowering. Moderate heritability was reported for productive tillers. The characters, plant height, total tillers, number of grains panicle^{-1}, number of tertiary branches, yield ha^{-1} and L/B ratio were controlled mainly by additive gene action.

2.3 CORRELATION AND PATH ANALYSIS

The main objective in any crop improvement programmes is to improve yield per unit area and time. Since yield is an end product of interaction of several attributes, an attempt was made to asses the genetic relationship among the yield components. Though correlations give information about the components of yield, they do not provide a true picture of relative importance of direct and indirect influence of component traits towards yield. Path analysis help in finding direct and indirect effects of components towards yield.

The path analysis furnishes a method of partitioning the correlation coefficients into direct and indirect effects and measures the relative importance of the causal factors involved (Dewey and Lu, 1959).

In one of the earlier works Sivasubramanian and Madavamenon (1973) reported a negative correlation between plant height and yield. Later Mathew (1976) and Reuber and Kisanga (1989) also reported same. Mathew found a significant correlation of grain yield with total tiller number, 1000 grain weight and panicle number.

Path analysis in rice was carried out by Chalapathy (1978) revealed that relatively short statured plants, having more number of panicle bearing tillers and more number of heavier grains on relatively shorter panicles with few primary branches was ideal for high grain yield potential.

Shamsuddin (1982) reported that 1000 grain weight and volume were having significant positive correlation but grain number panicle^{-1} did not show correlation.

The F_1 progenies of a diallel cross involving ten parents of rice varieties were studied for finding direct and indirect effects of eight characters on grain yield. Path analysis showed that grain:straw ratio exerted maximum positive direct effect on yield followed by panicle length (0.82), plant height (0.5) and 100 grain weight (0.28). Character, L/B ratio, showed highest negative direct effect (-0.72) followed by number of grains panicle^{-1} (-0.32). High positive indirect effect showed by panicle length and plant height through straw yield. Hundred grain weight showed high positive indirect effect through grain:straw ratio (Subramanian and Rathinam, 1984 a).

Study on the inheritance of grain size and shape in rice was carried out by Jun (1985). Genotypic correlations in F_1 showed that grain length was positively correlated with grain weight and with l:w ratio. Width of grain was negatively correlated with l:w ratio and positively correlated with thickness. Grain weight and l:w ratio had highest indirect effect on length. In F_2 there was difference according to cross but grain weight tended to be closely correlated with length, width and thickness. Length was closely correlated with width and thickness. Similar findings were reported also by Moeljopawiro (1986).

Morales-ramos (1987) evaluated early rice varieties and reported that number of grains panicle^{-1} was the character that most closely correlated with yield followed by 1000 grain weight, days to 100 per cent flowering, number of panicles m^{-2} and days to 50 per cent flowering.

Wu *et al.* (1987) after analysis concluded that panicle weight plant^{-1} was an important character for increased yield and it was closely associated with effective number of tillers, filled grain number plant^{-1} and 1000 grain weight. Sundaram *et al.* (1988) have also proved these reports.

According to Gomathinayagam *et al.* (1988), in upland varieties of rice, duration and plant height had high correlation with yield followed by grains panicle^{-1} and 1000 grain weight. Total tillers showed negative correlation with yield. Yield was directly contributed by plant height, duration and grains panicle^{-1}. Plant height contributed maximum to yield. Later Regina *et al.* (1994) had also proved these results.

Genetic relationships among yield components in rice was evaluated by Prasad *et al.* (1988) and indicated direct effects by fertile grains panicle^{-1}, panicle number and 100 grain weight. Total spikelet had negative direct effect, but they exert indirect effects through fertile grains panicle^{-1}. Contribution of days to flowering, plant height and panicle length to yield was negligible.

Maximum direct effect of spikelet number on yield was reported by Panwar *et al.* (1989).

Babu and Soundrapandian (1990) studied F_3 generation and showed that number of productive tillers and 100 grain weight had positive and direct effect. Days to panicle emergence had negative direct effect.

Reddy and Ramachandriah (1990) evaluated F_2 progeny from three crosses for yield components and showed that yield had highly significant positive correlation with plant height, panicle length, flag leaf area, number of effective tillers plant^{-1}, number of fertile grains panicle^{-1}, number of primary branchs panicle^{-1}, secondary branches panicle^{-1} and 1000 grain weight. Highest direct contribution to yield plant^{-1}

was from secondary branches panicle^{-1}. Marimuthu *et al.* (1990 a) also studied association of yield and its components and reported the same. He also reported positive intercorrelation of plant height with tiller number and panicle length. Panicle length was positively correlated to grain number.

Amrithadevarathinam (1990) studied correlation and path analysis in indica and japonica genotypes. In Indicas, days to 50 per cent flowering, tiller number and panicle length were positively correlated with yield. Tiller number had positive direct effect. In japonicas, days to 50 per cent flowering was positively and tiller number was negatively correlated with yield. Days to 50 per cent flowering had positive direct effect. In both indica and japonica, seedling height and culm length had direct effect on yield. Panicle length was closely associated with yield, the selection for which would serve as best criterion for higher yield, in both indicas and japonicas. Sreekumar *et al.* (1992) also reported that duration to 50 per cent flowering and number of productive tillers plant^{-1} had significant correlation with yield. Yadav (1992) also reported the same.

Fifty eight medium duration rice cultivars were grown in wet and dry seasons in Kerala and studies conducted by Bai *et al.* (1992) revealed that yield plant^{-1} was positively correlated with productive tillers, plant height, panicle length and grain number panicle^{-1}.

According to Reddy and Nerkar (1992) yield was correlated significantly with straw yield and number of productive tillers.

Ramalingam *et al.* (1993) studied rice panicle traits and reported that for higher yield in rice, plants should have long panicle, large number of filled grains and long primary and secondary branches, as these traits had positive effect on yield. Positive indirect effect of several panicle traits on yield through total filled grains were also observed.

Gravois and Mcnew (1993) suggested on the basis of their study that panicle weight had positive and panicle number had negative correlation with yield. Both of them had positive direct effect and panicle weight had larger direct effect on yield.

Chaubey and Singh (1994) conducted an experiment on twenty rice varieties for eight yield related traits. Grain yield plant^{-1} was positively correlated with productive tillers plant^{-1}, height and panicle weight. Panicle weight was positively correlated with primary branches, number of spikelet, 100 grain weight and grain yield plant^{-1}. Positive direct effect on yield were recorded for number of productive tillers (0.44) followed by plant height (0.34), 100 grain weight (0.12) and total number of spikelets (0.09). Later Basavaraja *et al.* (1997) got similar results.

Chauhan and Chauhan (1994) analysed the association of grain dimensions and weight with grain yield in rainfed rice. The results indicated that there is no correlation for yield with grain length, breadth, weight and shape.

According to Abd-el-samie and Hassan (1994), main contributors to grain yield hill^{-1} were number of panicle hill^{-1} and number filled grains panicle^{-1}. All characters studied showed positive significant genotypic correlation with yield except 100 grain weight. Similar finding was later reported by Sawant (1995) and Yadav *et al.* (1995).

Sundaram and Palanisamy (1994) studied eleven early rice varieties for ten quantitative characters. Grains panicle^{-1} had highest positive direct effect and highest positive indirect effect on yield through productive tillers, panicle weight and grain weight.

In a study conducted by Roy *et al.* (1995), yield plant^{-1} was positively correlated with days to 50 per cent flowering, spikelets panicle^{-1} and milling per cent. Path analysis showed that grains panicle^{-1} and spikelets panicle^{-1} were most important characters contributing to yield.

Reddy *et al.* (1995) carried out correlation coefficient analysis and a significant positive relationship of grain yield with production tillers, filled grain number panicle^{-1}, 1000 grain weight and harvest index was reported. Yolanda and Das (1995) also reported the same.

According to the work done by Lalitha and Sreedhar (1996), grain yield had significant association with plant height, productive tillers, panicle length, grain number and 100 grain weight. These traits also had positive direct effect on yield.

Mishra *et al.* (1996) showed that number of tillers hill^{-1} and grain number panicle^{-1} exhibited high positive correlation with yield.

A study on semidry rice by Rao *et al.* (1996) indicated positive significant correlation of yield with productive tiller number, dry matter and harvest index. Harvest index had positive direct effect on yield. Correlation and path analysis in F_2 and F_3 of rice by Ganesan *et al.* (1996) also revealed the same.

Analysis of data from an incomplete diallel cross of early varieties showed additive correlation to be more important than dominant ones, for most of the agronomic traits like grain length, breadth, l : b ratio, grain shape and other yield traits (Shi and Shen, 1996).

Study of Murty *et al.* (1997) on ratoon rice crop revealed that total regenerated tillers, panicle number m^{-2}, total carbohydrate and nitrogen per cent were positively correlated with yield. Similar results were also reported by Prakash and Prakash (1987) and Arumugachamy *et al.* (1993).

Rice genotypes from diverse origin were studied by Gupta *et al.* (1998) for correlation and path analysis under cold stress condition for grain yield, using nine characters. Yield was positively correlated with 1000 grain weight and negatively with sterility per cent and plant height. Direct positive effect on yield was contributed by panicle length, panicle density and sterility(%). High positive indirect effect by 1000 grain weight and days to flowering through grains panicle^{-1} and panicle length respectively, was also revealed.

According to Vanaja (1998), a positive correlation was observed for tertiary branches towards grain yield and negative correlation for 1000 grain wieght with yield. Phenotypic correlation was much higher than genotypic correlation for panicle length and tertiary branches. Panicle and tiller number were highly correlated and they had positive correlation with grain length, L/B ratio and negative correlation with plant height. Path analysis showed that breeder should give emphasis for semidwarf plants with optimum combination of yield components, coupled with earliness.

2.4 SELECTION INDEX

Yield is a highly complex character and influenced by a number of components which effect the yield in different fashion and different magnitude. Objective of a practical breeder is to identify more important components from the others and select for high yield on the basis of such criteria. Following the identification of components through genetic correlation, an understanding of the heritability, genetic advance and genetic gain helps in confirmation of the relative importance of these components. Further, these components influence the yield directly as well as indirectly. Based on these factors a selection index can be worked out, the selection based on which will help in achieving higher yield potential.

When biometrical studies on forty divergent varieties of indica rice (*Oryza sativa* L.) were conducted at Kerala Agricultural University, Chalapathy (1978) found that the estimates for genotypic correlation of yield and eight components, and path coefficients of yield and the first, second and third order of the components revealed, relatively short statured plants having more number of panicle bearing tillers and more number of heavier grain on relatively shorter panicles, preferably with few primary branches was ideal for high yield potential. Therefore it is recommended that selection for high yield should be based on this criteria.

Shamsuddin (1982) analysed grain characteristics and suggested that individual selection for rachilla number panicle^{-1}, 100 grain weight, volume and panicle length resulted in higher GA for grain yield. Hence selection for these traits might improve the yield.

Data from 13 varieties were analysed using path coefficients for an unspecified number of traits as relative weights, for the construction of discriminant functions. Analysis revealed that selection indices based on phenotypic correlation and path coefficients produced three per cent and nine per cent superiority respectively in GA, over an index based on economic weights (Rao *et al.*, 1984).

According to Subramanian and Rathinam (1984 a) straw yield followed by panicle length, plant height and 100 grain weight appeared to be efficient indices of selection for higher yield in rice. Later, studies of Babu and Soundrapandian (1990) proved this report. They reported the importance of productive tillers also for selection.

Genetic relationship between grain types and agronomic traits in rice was studied by Moeljopawiro (1986) and revealed that selection applied to several traits simultaneously was more efficient than selection based on individual trait.

Wu *et al.* (1987) conducted a study on 41 cultivars of rice and indicated that panicle weight plant^{-1} was an important character to use in selection. Its genetic gain under five per cent selection pressure was 21.59 per cent. Selection of individuals with high panicle weight plant^{-1} might give both high yield and good grain quality. Selecting for effective panicle number plant^{-1}, fertility, filled grain number panicle^{-1} would increase the genetic gain of panicle weight plant^{-1}. Reports of Prasad *et al.* (1988) also revelaed the same results.

F_2 and F_3 family study by Roy (1991) indicated that selection for harvest index was not much effective, even though harvest index had high heritability and GA.

Mishra *et al.* (1991) evaluated effectiveness of selection in F_2 and F_3 based on productive tillers plant^{-1}, grains panicle^{-1}, 100 grain weight and yield plant^{-1}, in all possible combinations. Genetic gain was higher in groups where more than one character or yield was taken as selection criterion. Highest genetic gain for yield plant^{-1} was observed when multi trait selection was practised or when yield plant^{-1} was the selection criterion.

In a study Vivekanandan *et al.* (1992) concluded that individual plant selection for plant height, number of grains panicle^{-1} and grain yield would be effective in F_2 and backcross hybrids.

In a field experiment conducted at Rajendranagar, with 12 early varieties of rice, Rao (1992) found that flag leaf area was positively correlated with several yield traits such as high density grain, number of spikelets m^{-2}, grains m^{-2} and panicle length. He suggested that flag leaf area might be considered as selection criterion for further exploitation of potential yields in rice.

Lokaprakash *et al.* (1992) reported additive gene action for panicle weight, 1000 seed weight and fertile spikelets panicle^{-1}. These characters offered greater scope for improvement through selection as they had high heritability and GA.

Results of the study done by Sreekumar *et al.* (1992) suggested that selection of dwarf types with medium duration and higher number of productive tillers would result in higher grain yield.

Gravois and Mcnew (1993) reported that selection for either panicle number or panicle weight would be enough for getting high yield.

The importance of panicle bearing tillers plant^{-1} as selection criterion was reported by Chaubey and Singh (1994).

Govindarasu and Natarajan (1995) studied variability and correlation among high density grain characters in rice and revealed that high density (HD) grain and 1000 grain weight had high GCV, heritability and GA and was less influenced by environment. These characters could be included in selection index.

Results of experiment carried out by Reddy *et al.* (1995) indicated that selection of genotypes with large number of productive tillers and filled grains panicle^{-1} might be worth while.

Variability and heritability in early rice lines were evaluated by Manomani *et al.* (1996). Their study indicated that days to flowering, plant height, 100 grain weight, number of grains primary ear^{-1} and grain yield had high heritability and genetic advance. Emphasis should be laid on these characters for formulating reliable selection indices and for developing high yielding rice with early maturity.

Reddy and De (1996) carried out a study on lowland rice at CRRI and reported that direct selection for yield hill^{-1} itself would be effective and satisfactory in lowland rice. Among the yield components, selection for panicle weight and grain number panicle^{-1} would be more reliable to increase the grain yield.

Discriminant function analysis conducted by Vanaja (1998) revealed that during selection, breeder should give emphasis on yield ha^{-1}, harvest index, number of days to harvest, number of tertiary branches panicle^{-1}, ratio of vegetative phase to reproductive phase and number of grains panicle^{-1}.

Materials and Methods

3. MATERIALS AND METHODS

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

3.1 EXPERIMENT NO.1

3.1.1 Materials

Under the All India Co-ordinated Rice Improvement Project, crop improvement programme in rice using varieties of diverse origin was carried out at Agricultural Research Station, Mannuthy. Fifty six high yielding diverse rice genotypes, representing various ecogeographical conditions, were tested and grouped into nine clusters. Based on desirable characters twelve genotypes were selected belonging to different clusters and crossed in all possible combinations. F_1 generation and their parents were raised and crosses were evaluated. Out of the 96 F_1 cross combinations evaluated at Agricultural Research Station, based on the score of sca effects, sca effect on yield and *per se* yield performance top ranked (Vanaja, 1998) four crosses were selected. F_2 seeds of the four selected crosses and their parents formed the materials for experiment no.1 of this investigation.

The selected crosses and their parents are given in Table 1.

Table 1 Selected crosses and their parents evaluated in F_2 generation from January to May, 1998

V_1	VYTILLA 3 X MATTATHRIVENI
V_2	VYTILLA 3 X KAOHSIUNG SEN YU 338
V_3	MATTATHRIVENI X MAHSURI
V_4	IR 36 X MATTATHRIVENI
V_5	VYTILLA 3
V_6	MATTATHRIVENI
V_7	IR 36
V_8	KAOHSIUNG SEN YU - 338
V_9	MAHSURI

The parents of selected crosses were diverse in origin and belonged to different clusters. Kaohsiung Sen Yu-338 originated in Taiwan (China) was one of the best entries tested at Agricultural Research Station, Mannuthy. It had good mean yield (4.9 t/ha), medium height (94 cm), 93 days to 50 per cent flowering and resistance to bacterial leaf streak. Other parents include Vytilla 3, Mattathriveni and Mahsuri, which are indigenous to Kerala and IR-36, from IRRI. Parents belonged to different geographical areas of the world. The parentage, source and desirable characters of selected parents are given in Table 2.

3.1.2 METHODOLOGY

3.1.2.1 Raising F_2 generation of selected crosses and their parents

Seeds of four different selected crosses and their parents were sown in nursery bed, in separate rows, on 29th December 1997. Seedlings were transplanted when 18-25 days old, according to their maturity duration. The experiment was laid out in Randomised Block Design with three replications for each of the nine treatments. Seedlings were transplanted keeping an inter and intra spacing of 20 cm and 15 cm respectively. Plots consisted of 11 rows of 16 hills, with single seedling $hill^{-1}$. All cultural operations were carried out as per the Package of Practices Recommendations of KAU, 1994.

Observations on growth and yield parameters were recorded on twenty five randomly selected plants in each replication for each treatment after leaving the border rows. Observations of fifteen characters were taken as per the standard evaluation system for rice (IRRI, 1995).

Table 2 **Pedigree of parents of selected crosses**

Sl. No.	Genotype	Parentage	Origin	Desirable charactors	Cluster No.*
1	VYTILLA 3	VYTILLA 1 x TNI	INDIA (KERALA)	Maximum panicle length, heavy grains and red kernel	II
2	MATTATHRIVENI	ANNAPOORNA x Ptb-15	INDIA (KERALA)	High harvest index, red kernel and highly adapted throughout Kerala	IX
3	KAOHSIUNG SEN YU-338	SUWEON-264/NAKING// IR 1780-150-3	TAIWAN	Maximum number of spikelets panicle^{-1}, compact panicles, increased grain size and grain shape, long panicle and white kernel	I
4	MAHSURI	TAICHUNG-65/ MAYANG EBOS	MALAYSIA	Maximum number of days to 50% flowering, long panicle and white kernel	VI
5	IR 36	IR 1561-228//IR 24/ O NIVARA///CR-94-13	IRRI	Maximum number of panicles per m^2, white kernel, dwarf plant type	IV

* Data on cluster number was available from D^2 analysis done at ARS, Mannuthy, by Vanaja (1998)

3.1.2.2 CHARACTERS TAKEN FOR OBSERVATION

1. *Duration to 50% flowering*

Number of days were counted from day of sowing to the day when 50% of the plants in the plot started flowering.

2. *Height of the plant at harvest in cm*

At the time of harvest, height of the plants were measured in centimetres from the surface of the soil to the tip of the longest panicle.

3. *Tiller number plant^{-1}*

At the time of harvest, total number of tillers present in each plant was counted.

4. *Panicle bearing tillers plant^{-1}*

Number of panicle bearing tillers were counted at the time of harvest.

5. *Panicle length*

Length of panicle was measured in centimetres from the panicle base to the tip of the topmost spikelet.

6. *Number of grains panicle^{-1}*

The sum of number of grains of all panicles gave the total grains plant^{-1}. It was divided by number of panicles to get the number of grains panicle^{-1}.

7. *Secondary branches panicle^{-1}*

Number of side branches from primary branch was counted.

8. *Tertiary branches panicle^{-1}*

Number of branches from secondary branches were counted.

9. *Grain length*

Length of the grain was measured in millimetres from the base of the lower most sterile lemma to the tip.

10. *Grain breadth*

The distance across the fertile lemma and the palea, at the widest point was measured in millimetres.

11. *L/B ratio*

Ratio of the length to breadth of the grain was calculated.

12. *Thousand grain weight*

Thousand filled grain were selected randomly from each plant and the weight was measured in grams.

13. *Grain density*

Thousand grains from each plant was weighed in grams. Volume displacement was also measured in millilitre using the same 1000 grains.

$$\text{Grain density (g/ml)} = \frac{\text{1000 grain weight}}{\text{Volume displaced by 1000 grains}}$$

14. *Grain yield*

Yield in kg ha^{-1} was calculated using the formula

$$\frac{\text{Total number of grains plant}^{-1} \times \text{No. of plants in one ha} \times \text{1000 grain weight in kg}}{1000}$$

15. *Kernel colour*

After dehulling, colour of the kernel was recorded as red or white.

For characters, two to fourteen, after taking observations in each plant, average of twenty five plants were calculated to get the plant^{-1} value.

3.1.3 Statistical analysis

3.1.3.1 Estimation of components of variation

a) Variability

Genotypic variance, phenotypic variance, environmental variance, PCV and GCV were estimated as per the procedure suggested by Burton (1952).

The estimates of PCV and GCV were classified as:

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

b) Heritability

Heritability, in broad sense, was calculated according to the formula suggested by Hanson *et al.* (1956). The heritability was categorised as:

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

c) Genetic advance (GA)

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

d) Genetic gain (gg)

Expected genetic gain under selection was calculated by the formula suggested by Johnson *et al.* (1955). Genetic gain was categorised as:

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

3.1.3.2 Phenotypic and genotypic correlation

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

3.1.3.3 Path analysis

To study the cause and effect relationship of yield and its attributes, direct and indirect effects were analysed using path coefficient analysis as suggested by Wright (1923).

3.2 EXPERIMENT NO.2

3.2.1 Materials

The grains after taking observation in F_2 generation, were used as seeds for raising F_3 generation. Seeds of twenty five plants from each cross and their parents formed the material for experiment no.2.

3.2.2. Methodology

3.2.2.1 Raising F_3 generation of selected crosses and parents

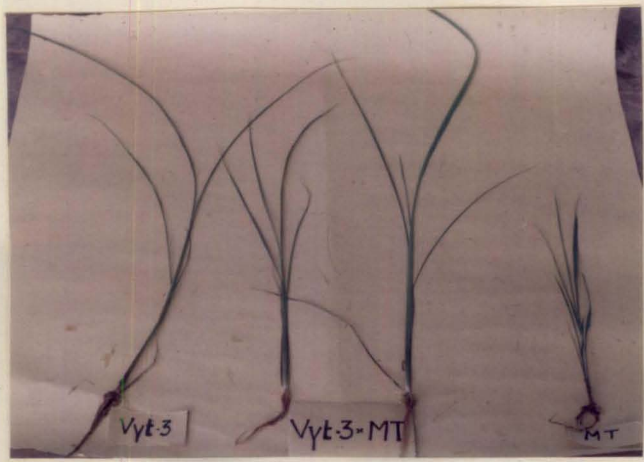
Twenty five plants from each of the four crosses from which observations were taken in F_2 and their parents formed the 105 treatments of second part of investigation. Seeds from each of the twenty five plants of different crosses were

PLATE 1 PLOT VIEW OF EXPERIMENT NO.1

PLATE 2 PLOT VIEW OF EXPERIMENT NO.2

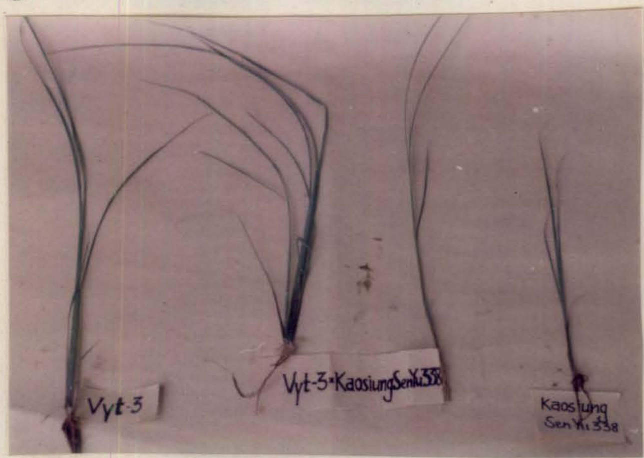
PLATE 3 SEEDLING OF SELECTED CROSSES SHOWING HIGHER VIGOUR

3A



3B

3C



3D

3E Comparison of four crosses

3F Nursery view of F_3

separately germinated and sown in nursery bed on 22nd August 1998. Seedlings in the nursery were highly vigorous. Twenty five days old seedlings were transplanted to the plots, laid out in a Randomised Block Design, with two replications for each of the 105 treatments. The treatments in experiment no.2 are given in Table 3.

Seedlings were transplanted keeping an inter and intra spacing of 25 cm and 20 cm respectively. Plots consisted of 10 rows of 5 hills, with single seedling per hill. All cultural operations were carried out as per the Package of Practice Recommendation of KAU, 1994.

Observation were taken on 10 plants in each replication of each treatment, after leaving the border rows. Characters observed were the same as in experiment no.1.

Observations on the following characters were recorded

1. Duration to 50% flowering; 2. Height of the plant at harvest; 3. Total tillers plant^{-1}; 4. Panicle bearing tillers plant^{-1}; 5. Panicle length; 6. Number of grains panicle^{-1}; 7. Secondary branches panicle^{-1}; 8. Tertiary branches panicle^{-1}; 9. Grain length; 10. Grain breadth; 11. L/B ratio;12. 1000 grain weight; 13. Grain density; 14. Grain yield; 15. Kernel colour of grain.

*The procedures followed in experiment no.1 were adopted for recording the above observations.

Statistical analysis

All the analyses in experiment no.1 namely, components of variation, heritability, genetic advance, genetic gain, correlation and path analysis were also done in experiment no.2. Besides this, following analysis was also done.

PLATE 4 CROSSES SELECTED FOR THE EXPERIMENTS

4A

4B

4C

4D

4E Selected crosses showing superior performance in the field

PLATE 5 PARENTS OF SELECTED CROSSES

5A

5D

5B

5E

5C

5F Mahsuri - long duration to 50% flowering

Table 3 Details of F_3 generation grown during August 1998

No	Treatment	Accession Number
1	Vytilla 3 x Mattathriveni	V_1 to V_{25}
2	Vytilla 3 x Kaochsiung Sen Yu 338	V_{26} to V_{50}
3	Mattathriveni x Mahsuri	V_{51} to V_{75}
4	IR 36 x Mattathriveni	V_{76} to V_{100}
5	Mahsuri	V_{101}
6	Kaohsiung Sen Yu 338	V_{102}
7	IR 36	V_{103}
8	Vytilla 3	V_{104}
9	Mattathriveni	V_{105}

a) Selection index using discriminant function

A selection index was evolved using discriminant function (Hazel, 1943). The discriminant function analysis based on minimum number of most reliable and effective characters, was done.

Results

4. RESULTS

4.1 EXPERIMENT NO. I - F_2

4.1.1 GENETIC VARIABILITY

A generally determined variability in plant population is essential for making effective selection in crop improvement programmes. Hence estimation of genetic variability is a pre-requisite in crop improvement. A knowledge on the type of gene action of the quantitatively inherited traits is important to decide the appropriate breeding procedures that could be used for crop improvement. It is difficult to estimate whether a phenotypic variability is heritable or due to environment. Heritability denotes the proportion of phenotypic variance that is due to genotypes, and is heritable. The progress in breeding programme depends on the extent to which desirable traits are heritable. Hence it becomes necessary to split the variability into genotypic and phenotypic coefficient of variability. In the present study extent of genetic variability with respect to fourteen characters, in four selected crosses of high yielding diverse genotypes of rice, was estimated.

Mean performance of nine different genotypes for fourteen characters are given in Appendix I. The abstract of analysis of variance of these characters are given in Table 4. The data on range, mean and estimates of genetic parameters for various quantitative characters are presented in Table 5.

Results of analysis of variance for fourteen characters revealed that all the characters studied had high significant differences among four crosses and five parents (Table 4).

Table 4 Analysis of variance for grain yield and associated characters in F_2 progenies of selected crosses of rice varieties of diverse origin

Source of variation	Degrees of freedom	Mean sum of squares						
		Plant height at harvest	Total tillers $plant^{-1}$	Panicles $plant^{-1}$	Panicle length	No. of grains $panicle^{-1}$	Secondary branches $panicle^{-1}$	Tertiary branches $panicle^{-1}$
Replication	2	28.89	0.120	0.148	0.16	323.16	0.032	5.5*
Treatment	8	1266.71**	25.27**	40.98**	8.82**	1399.9**	18.51**	121.27**
Error	16	35.74	1.54	1.37	0.886	138.29	0.327	12.41

Source of variation	Degrees of freedom	Grain length	Grain breadth	L/B ratio	1000 grain weight	Duration to 50% flowering	Grain yield	Grain density
Replication	2	0.013	0.023	0.024	6.63	4.12	336160	0.019
Treatment	8	0.709**	0.329**	0.507**	100.19**	134.75**	11879472**	0.238**
Error	16	0.024	0.017	0.015	4.66	15.40	1231812	0.011

** Significant at 1% level

Table 5 Range, mean and estimates of genetic parameters for grain yield and associated characters in F_2 progenies of selected crosses of rice varieties of diverse origin

Sl. No.	Characters	Range	Mean ± SEM	GCV (%)	PCV (%)	Heritability (broadsense) (%)	Genetic advance	Genetic gain (%)
1	Plant height at harvest (cm)	70.20 (IR36 x MT*) to 136.8 (Mahsuri)	96.23 ± 4.88	21.05	21.95	92.0	40.02	41.59
2	Tiller number	4.3 (Mahsuri) to 13.44 (IR36)	9.59 ± 1.01	29.34	32.07	83.7	5.3	55.27
3	Panicle bearing tillers	1.00 (Mahsuri) to 13.05 (IR36)	8.96 ± 0.95	40.53	42.58	90.6	7.13	79.52
4	Panicle length (cm)	22.27 (IR36 x MT) to 27.3 (Vytilla-3)	25.20 ± 0.77	6.45	7.46	74.9	2.9	11.51
5	No. of grains panicle^{-1}	67.51 (Vytilla-3 x K-338) to 134.2 (Mahsuri)	93.47 ± 9.6	21.94	25.29	75.3	36.65	39.21
6	Secondary branches panicle^{-1}	5.96 (Vytilla3 x K.-338) to 13.6 (Mahsuri)	8.59 ± 0.47	28.67	29.44	94.9	4.94	57.51
7	Tertiary branches panicle^{-1}	14.16 (Vytilla 3 x K-338) to 35.67 (K-338)*	24.37 ± 2.88	24.72	28.64	74.5	10.71	43.95

Contd....

* K-338 - Kaohsiung Sen Yu-338   * MT - Mattathriveni

Table 5 contd....

8	Grain length (mm)	7.67 (MT)* to 8.99 (IR36 x MT)	8.21 ± 0.13	5.82	6.12	90.6	0.94	11.45
9	Grain breadth (mm)	2.59 (IR36 x MT) to 3.6 (Vytilla3)	3.17 ± 0.11	10.17	10.98	85.8	0.62	19.56
10	L:B ratio	2.24 (Vytilla3) to 3.48 (IR36 x MT)	2.63 ± 0.1	15.43	16.12	91.6	0.80	30.42
11	1000 grain weight (g)	22.83 (MT x Mahsuri) to 28.91 (Vytilla 3 x K 338)	27.4 ± 1.76	20.59	22.05	87.2	10.86	39.64
12	Days to 50% flowering	75.00 (Vytilla3 x MT) to 94.33 (Mahsuri)	82.89 ± 3.2	7.61	8.96	72.1	11.03	13.31
13	Grain yield kg ha^{-1}	1872.47 (Mahsuri) to 7532.33 (Vytilla3)	6008.41 ± 906.21	31.35	36.39	74.2	3343.79	55.65
14	Grain density (g ml^{-1})	1.15 (MT x Mahsuri) to 2.08 (Mahsuri)	1.37 ± 0.087	20.1	21.55	87.0	0.53	38.69

* MT - Mattathriveni

There was a large range of variation for all the characters studied (Table 5). Plant height at harvest varied from 70.2 to 136.8 cm, its average being 96.23 cm. Number of tillers plant^{-1} and number of panicle bearing tillers ranged from 4.3 to 13.44 and 1.00 to 13.05 respectively and their averages were 9.59 and 8.96 respectively. In the case of panicle length range of variation was from 22.27 to 27.3 cm and the average was 25.2 cm. Number of grains panicle^{-1} ranged from 67.51 to 134.2 with an average of 93.47. Number of secondary branches panicle^{-1} varied from 5.96 to 13.6 with average number of secondaries being 8.59. Range of variation of number of tertiary branches was from 14.16 to 35.67, average being 24.37. Grain length and breadth ranged from 7.67 to 8.99 mm and 2.59 to 3.6 mm respectively with an average of 8.21 mm and 3.17 mm respectively. The characters L:B ratio varied from 2.24 to 3.48 and average was 2.63.

In the case of 1000 grain weight, range of variation was from 22.83 to 28.91 g with an average weight of 27.4 g. Duration to 50% flowering varied from 75 to 94.33 days, its average being 82.89 days. Grain yield ha^{-1} varied from 1872.47 to 7532.33 kg, the average being 6008.41 kg. Grain density ranged between 1.15 to 2.08 g ml^{-1} with an average of 1.37 g ml^{-1}.

4.1.2 GENOTYPIC AND PHENOTYPIC COEFFICIENT OF VARIATION

Among the various characters observed, all the characters showed moderate to high magnitude of GCV and PCV except for characters like grain length (5.82, 6.12), panicle length (6.45, 7.46) and duration to 50% flowering (7.61, 8.96) which showed low GCV and PCV respectively. Higher magnitude of GCV and PCV were observed for plant height at harvest, number of tillers plant^{-1}, panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, 1000 grain weight, grain yield and grain density. Number of panicle bearing tillers showed highest magnitude of GCV and PCV (40.53, 42.58). Grain yield showed GCV and PCV of 31.35 and 36.39 respectively. GCV and PCV values for plant height and tiller number plant^{-1} were 21.05, 21.95 and 29.34, 32.07 respectively. Higher coefficients of variability were also exhibited by number of grains panicle^{-1} (21.94, 25.29), secondary branches panicle^{-1} (28.67, 29.44), tertiary branches panicle^{-1} (24.72, 28.64), 1000 grain weight (20.59, 22.05) and grain density (20.1, 21.55).

Moderate GCV and PCV were observed for characters grain breadth (10.17, 10.98) and L:B ratio (15.43, 16.12). Lowest variability was for grain length (5.82, 6.12).

PCV was higher than GCV, in all the characters observed. In the case of plant height and secondary branches, PCV was nearly equal to GCV.

4.1.3 HERITABILITY

Broad sense heritability estimates ranged from 72.1 per cent to 94.9 per cent. Hence all the characters showed high heritability. Maximum heritability was observed for secondary branches panicle^{-1}(94.9 %). All other characters, namely, plant height at harvest (92%), L:B ratio (91.6%), panicle bearing tillers plant^{-1} (90.6%), grain length (90.6%), 1000 grain weight (87.2%), grain density (87%), grain breadth (85.8%), Tiller number plant^{-1} (83.7%). Number of grains panicle^{-1} (75.3%), panicle length (74.9%), Tertiary branches panicle^{-1} (74.5%), grain yield (74.2%) and duration to 50% flowering (72.1%) exhibited high heritability.

4.1.4 EXPECTED GENETIC ADVANCE AND GENETIC GAIN

Among the characters studied, genetic advance, expressed as percentage of the mean, varied from 11.45 per cent for grain length to 79.52 per cent for number of panicle bearing tillers plant^{-1}. Genetic gain was high for the characters secondary branches panicle^{-1} (57.51%), grain yield ha^{-1} (55.65%), Tiller number plant^{-1} (55.27%), Tertiary branches panicle^{-1} (43.95%), plant height at harvest (41.59%), Number of grains panicle^{-1} (39.21%), 1000 grain weight (39.64%), grain density (38.69%) and L:B ratio (30.42%). Genetic gain was moderate for the characters like grain breadth (19.56%), duration to 50% flowering (13.31%), length of panicle (11.51%) and grain length (11.45%). The estimates of genetic advance, expressed as percentage of mean, for all the characters were moderate to high.

Among the fourteen characters studied, plant height at harvest, Tiller number plant^{-1}, Panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, Secondary branches and tertiary branches panicle^{-1}, 1000 grain weight, grain yield ha^{-1} and grain density showed high values of genotypic coefficient of variation (GCV), heritability (broad sense) and expected genetic advance. Grain breadth had moderate GCV, expected genetic advance and high heritability in broad sense. High heritability, moderate expected genetic advance and low GCV was observed for the characters, panicle length, grain length and duration to 50% flowering. L:B ratio showed high heritability (broad sense), high value of expected genetic advance and moderate GCV.

4.1.5 CORRELATION

The genotypic and phenotypic correlation coefficients between grain yield ha^{-1} and thirteen different yield component characters and corrlation coefficents among the component characters are presented in Table 6.

Direction of genotypic and phenotypic correlations for all the thirteen component characters with yield ha^{-1} was the same. Genotypic correlation with yield was always higher than phenotypic correlation, except for panicle length, tertiary branches $panicle^{-1}$, L:B ratio and grain breadth.

Grain yield in kg ha^{-1} had positive and significant correlation, both at genotypic and phenotypic levels, with panicle number $plant^{-1}$ (0.951*, 0.896*), Tiller number $plant^{-1}$ (0.910**, 0.873**), and tertiary branches $panicle^{-1}$ (0.383**, 0.433**).

Significant negative correlation both at genotypic and phenotypic levels, with yield ha^{-1} was exhibited by the characters, 1000 grain weight (-0.933**, -0.723**), grain density (-0.882**, -0.681**) and plant height at the time of harvest (-0.830**, -0.592**). The characters secondary branches $panicle^{-1}$ (-0.405**) and number of grains $panicle^{-1}$ (-0.403**) showed significant negative correlation with yield, but only at genotypic level.

Grain yield exhibited no significant correlation with L:B ratio, grain length, grain breadth, duration to 50% flowering and panicle length.

Only genotypic correlation is dealt in detail among the different yield components. Panicle bearing tillers $plant^{-1}$ showed significant positive correlation with total tillers $plant^{-1}$, grain length and tertiary branches $panicle^{-1}$ and significant negative

Table 6 Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients between yield and yield component characters in F2 progenies of selected rice crosses

Sl. No.	Characters	Plant height (cm)	Tiller No.	Panicle No.	Panicle length (cm)	No. of grains panicle^{-1}	Secondary branches panicle^{-1}	Tertiary branches panicle^{-1}	Grain length (mm)	Grain breadth (mm)	L/B ratio	1000 grain weight (g)	Days to 50% flowering (days)	Grain yield (Kg ha^{-1})	Grain density (g ml^{-1})
1	Plant height at harvest		-0.960	-0.951	0.229	0.360	0.431	-0.247	-0.446	0.167	-0.313	0.948	0.325	-0.830	0.923**
2	Tiller No.	-0.768		0.984	-0.161	-0.357	-0.323	0.411	0.499	-0.139	0.312	-0.892	-0.114	0.910	-0.838
3	Panicle No.	-0.817	0.976		-0.035	-0.462	-0.454	0.310	0.435	0.018	0.179	-0.948	-0.282	0.951	-0.913
4	Panicle length	0.289	-0.035	0.037		-0.047	0.028	0.199	-0.828	0.943	-1.003	-0.080	-0.060	0.204	0.121
5	No. of grains panicle^{-1}	0.404	-0.178	-0.305	0.105		0.784	0.346	-0.531	-0.367	0.035	0.528	0.648	-0.403	0.589
6	Secondary branches	0.442	-0.252	-0.399	0.075	0.699		0.696	-0.402	-0.343	0.064	0.627	1.023	-0.405	0.680
7	Tertiary branches	-0.113	0.429	0.355	0.311	0.406	0.652		-0.218	-0.115	-0.011	-0.091	0.853	0.383	-0.019
8	Grain length	-0.380	0.418	0.374	-0.630	-0.381	-0.355	-0.145		-0.535	0.792	-0.250	-0.134	0.232	-0.221
9	Grain breadth	0.151	-0.071	0.060	0.751	-0.240	-0.328	-0.052	-0.502		-0.935	-0.219	-0.440	0.227	-0.293
10	L:B ratio	-0.278	0.234	0.126	-0.809	0.015	0.078	-0.021	0.774	-0.928		0.032	0.248	-0.039	0.101
11	1000 grain weight	0.860	-0.734	-0.838	-0.056	0.438	0.579	-0.123	-0.213	-0.212	0.047		0.603	-0.933	0.990
12	Days to 50% flowering	0.234	-0.124	-0.232	-0.069	0.422	0.811	0.644	-0.151	-0.324	0.169	0.317		-0.209	0.666
13	Grain yield	-0.592	0.873	0.896	0.282	-0.148	-0.291	0.433	0.195	0.256	-0.071	-0.723	-0.205		-0.882
14	Grain density	0.834	-0.688	-0.807	-0.090	0.486	0.625	-0.065	-0.190	-0.274	0.106	0.991	0.366	-0.681	

correlation with plant height at harvest, 1000 grain weight, grain density, secondary branches panicle^{-1} and number of grains panicle^{-1}. Total tillers plant^{-1} exhibited positive and significant correlation with panicle bearing tillers plant^{-1}, tertiary branches panicle^{-1}, grain length and L:B ratio, while significant negative correlation with plant height, 1000 grain weight, grain density, secondary branches panicle^{-1} and number of grains panicle^{-1}. Tertiary branches panicle^{-1} had significant positive association with secondary branches panicle^{-1}, duration to 50% flowering, number of grains panicle^{-1}, Tiller number and panicle number plant^{-1}. Tertiary branches exhibited no significant negative correlation. The character 1000 grain weight was found to be positively and significantly associated with plant height, grain density, number of grains panicle^{-1}, duration to 50% flowering and secondary branches panicle^{-1}. Tiller number and panicle number plant^{-1} showed significant negative association with 1000 grain weight. Grain density was correlated positively and significantly with plant height, 1000 grain weight, duration to 50% flowering, number of grains panicle^{-1} and secondary branches panicle^{-1}, while it had significant negative association with tiller and panicle number plant^{-1}. Plant height at harvest exhibited significant positive association with 1000 grain weight, grain density, duration to 50% flowering, secondary branches panicle^{-1} and number of grains panicle^{-1}. It had negative association with tiller and panicle number plant^{-1}, grain length and L:B ratio.

The character, secondary branches panicle^{-1} showed significant positive correlation with number of grains panicle^{-1}, tertiary branches panicle^{-1}, 1000 grain weight, duration to 50% flowering, plant height and grain density. While its association with tiller number plant^{-1}, panicle number plant^{-1}, grain length and breadth was significantly negative. Number of grains panicle^{-1} showed significantly positive association with secondary branches panicle^{-1}, tertiary branches panicle^{-1}, duration to 50% flowering, 1000 grain weight, grain density and plant height, while its association was significantly negative with characters like tiller and panicle number plant^{-1}, grain length and breadth.

Panicle length was positively and significantly correlated to grain breadth, while it was significantly and negatively correlated with grain length and L:B ratio. Grain length was positively correlated to tiller number, panicle number and L:B ratio, while it was associated negatively with panicle length, number of grains panicle^{-1}, secondary branches panicle^{-1} and grain breadth. The character grain breadth was associated significantly positive with panicle length, and its association was significantly negative with grain length, L:B ratio, duration to 50% flowering, number of grains panicle^{-1} and secondary branches panicle^{-1}. The character, L:B ratio exhibited positive association with grain breadth and tiller number and significant negative association with panicle length, plant weight and grain breadth. The character, duration to 50% flowering exhibited significant positive correlation with secondary and tertiary branches panicle^{-1}, 1000 grain weight, grain density, number of grains panicle^{-1} and plant height at harvest and its association with panicle bearing tillers plant^{-1} and grain breadth was significantly negative.

4.1.6 PATH ANALYSIS

Among the thirteen yield components observed, eight characters showed significant correlation with yield. The characters, namely, plant height at harvest, Total tillers plant^{-1}, panicle bearing tillers plant^{-1}, 1000 grain weight, grain density, tertiary branches panicle^{-1}, secondary branches panicle^{-1} and number of grains panicle^{-1} showed significant association while L:B ratio showed least significance in association with yield. Grain length, breadth, panicle length, and 50% duration also showed low association. A path analysis excluding L:B ratio was done and estimates of direct and indirect effects of these selected component characters on yield are presented in Table 7.

Residual effect of path analysis was found to be 0.0017. It was observed that maximum positive direct effect was exerted by grain density (1.956) followed by total tillers plant^{-1} (1.032). Characters namely, panicle length (0.303), secondary branches panicle^{-1} (0.268), plant height (0.202) and grain breadth (0.104) also showed positive direct effects. Lowest positive direct effect was shown by grain length (0.002) followed by panicle bearing tillers plant^{-1} (0.039). Maximum negative direct effect on yield was exhibited by the character 1000 grain weight (-2.022). Duration to 50% flowering (-0.244) and tertiary branches panicle^{-1} (-0.133) also showed negative direct effect. Least negative direct effect on yield was exerted by number of grains panicle^{-1} (-0.129).

The highest positive indirect influence was exerted by 1000 grain weight through grain density (1.937). This was followed by panicle number plant^{-1} through 1000 grain weight (1.916), plant height through grain density (1.805), total tillers plant^{-1} through 1000 grain weight (1.803), secondary branches panicle^{-1} through grain density (1.329), number of panicles plant^{-1} through duration to 50% flowering (1.303), number of grains panicle^{-1} (1.153) and total tillers plant^{-1} (1.015).

Table 7 **Direct and indirect effects of yield components on grain yield in F2 progenies of selected crosses of rice varieties of diverse origin**

Characters	Plant height	Tiller No.	Panicle No.	Panicle length	No. of grains panicle^{-1}	Secon-dary branches	Tertiary branches	Grain length	Grain breadth	1000 grain weight	Duration to 50% flowering	Grain density	Correlat-ion with yield
Plant height (cm)	**0.202**	-0.991	-0.037	0.069	-0.046	0.115	0.033	-0.001	0.017	-1.917	-0.079	1.805	-0.830**
Tiller No.	-0.194	**1.032**	0.038	-0.049	0.046	-0.087	-0.055	0.001	-0.014	1.803	0.028	-1.640	0.910**
Panicle No.	-0.192	1.015	**0.039**	-0.011	0.059	-0.122	-0.041	0.001	0.002	1.916	0.069	-1.785	0.951**
Panicle Length (cm)	0.046	-0.166	-0.001	**0.303**	0.006	0.008	-0.026	-0.001	0.098	0.161	0.015	-0.237	0.204
No. of grains panicle^{-1}	0.073	-0.368	-0.018	-0.014	**-0.129**	0.210	-0.046	-0.001	-0.038	-1.067	-0.158	1.153	-0.403**
Secondary branches	-0.087	-0.334	-0.018	0.009	-0.101	**0.268**	-0.092	-0.001	-0.036	-1.267	-0.249	1.329	-0.405**
Tertiary branches	-0.050	0.425	0.012	0.060	-0.044	0.187	**-0.133**	0.000	-0.012	0.185	-0.208	-0.038	0.383**
Grain length (mm)	-0.090	0.515	0.017	-0.250	0.068	-0.108	0.029	**0.002**	-0.056	0.505	0.033	-0.433	0.232
Grain breadth (mm)	0.034	-0.143	0.001	0.285	0.047	-0.092	0.015	-0.001	**0.104**	0.443	0.107	-0.573	0.227
1000 grain weight (g)	0.192	-0.920	-0.037	-0.024	-0.068	0.168	0.012	0.000	-0.023	**-2.022**	-0.147	1.937	-0.933**
Days to 50% flowering	0.066	-0.118	-0.011	-0.018	-0.083	0.274	-0.113	0.000	-0.046	-1.219	**-0.244**	1.303	-0.209
Grain density (g ml^{-1})	0.186	-0.865	-0.035	-0.037	-0.076	0.182	0.003	0.000	-0.030	-2.002	-0.162	**1.956**	-0.882**

Bold figures represent direct effects; Residual effect = 0.0017

Grain length influenced yield indirectly through total tillers plant^{-1} (0.515) and 1000 grain weight (0.505). Tertiary branches panicle^{-1} exerted positive indirect effect on yield through total tillers plant^{-1} (0.425).

Highest negative direct influence on yield was exerted through 1000 grain weight (-2.022) by grain density followed by plant height through 1000 grain weight (-1.917). Panicle bearing tillers plant^{-1} (-1.785) and total tillers plant^{-1} (-1.640) exerted negative indirect influence through grain density. Secondary branches panicle^{-1} (-1.267), duration to 50% flowering (-1.219) and number of grains panicle^{-1} (-1.067) exerted negative indirect influence through 1000 grain weight. Plant height (-0.991), 1000 grain weight (-0.920) and grain density (-0.865) showed indirect negative influence on yield through total tillers plant^{-1}.

4.2 EXPERIMENT NO.2 - F_3

4.2.1 GENETIC VARIABILITY

Mean performance of 105 different genotypes for fourteen characters are given in Appendix II. Analysis of variance of these characters are presented in Table 8. Data on range, mean, phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic gain are given in Table 9.

Analysis of variance for grain yield and associated characters in F_3 progenies of four selected crosses of rice varieties of diverse origin and their parents revealed that all the characters studied are significantly different (Table 8). Range of variation for all the fourteen characters studied were also large (Table 9).

Table 8 Analysis of variance for grain yield and associated characters in F_3 progenies of selected crosses of rice varieties of diverse origin

Source of variation	Degrees of freedom	Mean sum of squares						
		Plant height at harvest	Total tillers plant^{-1}	Panicle bearing tillers	Panicle length	No. of grains panicle^{-1}	Secondary branches panicle^{-1}	Tertiary branches panicle^{-1}
Replication	1	198.75	50.77	6.7	0.047	280.5	0.74	32.83
Treatment	104	1292.62**	30.14**	20.35**	13.54**	601.3**	1.63**	54.70**
Error	104	39.46	4.54	1.96	0.831	176.34	0.12	8.21

Source of variation	Degrees of freedom	Grain length	Grain breadth	L/B ratio	1000 grain weight	Duration to 50% flowering	Grain yield	Grain density
Replication	1	3.40	0.55	0.009	4.53	0.88	988160	0.001
Treatment	104	0.57**	0.49**	1.18**	43.37**	42.58**	2061508.9**	0.018**
Error	104	0.15	0.046*	0.038	1.94	1.14	817166.77	0.002

** Significant at 1% level

Table 9 Range, mean and estimates of genetic parameters for grain yield and associated characters in F_3 progenies of selected crosses of rice varieties of diverse origin

Sl. No.	Characters	Range	Mean ± SEM	GCV (%)	PCV (%)	Heritability (Broad sense) (%)	Genetic advance	Genetic gain (%)
1	Plant height at harvest (cm)	74.1 (IR36 x MT*) to 145.05 (Vytilla3 x MT & Mahsuri)	106.16±6.28	23.58	24.31	94.1	50.01	47.11
2	Total tillers plant^{-1}	8.00 (MT x Mahsuri) to 24.18 (IR36)	13.34±2.13	26.81	31.20	73.8	6.33	47.45
3	Panicle bearing tillers	7.35 (Vytilla x K-338) to 21.00 (IR36)	10.91±1.39	27.8	30.61	82.4	5.67	51.97
4	Panicle length (cm)	22.05 (IR36 x MT) to 32.4 (Vytilla3 x K-338)*	25.97±0.912	9.71	10.32	88.4	4.88	18.79
5	No. of grains panicle^{-1}	93.1 (Vytilla3) to 205.9 (Mahsuri)	138.83±13.28	10.5	14.20	54.6	22.2	15.99
6	Secondary branches	6.6 (Vytilla3) to 12.9 (Mahsuri)	8.5±0.346	10.22	11.00	86.3	1.66	19.53
7	Tertiary branches	16.5 (Vytilla3) to 52.4 (Mahsuri)	27.19±2.87	17.73	20.63	73.9	8.54	31.41

* MT - Mattathriveni   * K-338 - Kaohsiung Sen Yu 338

Contd....

Table 9 contd....

8	Grain length (mm)	7.00 (Mahsuri) to 9.9 (IR36)	8.46±0.388	5.38	7.08	57.9	0.71	8.39
9	Grain breadth (mm)	2.00 (IR36 x MT* & IR36) to 3.9 (Vytilla3 x K-338)	2.87±0.214	16.45	18.05	83.0	0.89	31.01
10	L:B ratio	2.22 (Vytilla3 x K-338) to 4.95 (IR36)	3.08±0.194	24.63	25.42	93.8	1.51	49.03
11	1000 grain weight (g)	19.45 (Mahsuri) to 36.5 (Vytilla3 x MT)	27.68±1.39	16.45	17.20	91.40	8.97	32.41
12	Days to 50% flowering	69.5 (Vytilla3 x MT) to 106.00 (Mahsuri)	77.75±1.07	5.85	6.01	94.8	9.13	11.74
13	Grain yield (kg ha^{-1})	3639.19 (Mahsuri) to 9226.35 (Vytilla3 x K-338)*	6003.78±903.97	13.14	19.98	43.2	1068.31	17.79
14	Grain density (g ml^{-1})	1.12 (IR36 x MT) to 1.51 (Vytilla3 x MT)	1.25±0.043	7.17	7.95	81.3	0.17	13.6

* MT - Mattathriveni

* K-338 - Kaohsiung Sen Yu 338

Plant height varied from 74.1 to 145.05 cm its average being 106.16 cm. Total tillers plant^{-1} ranged from 8.0 to 24.8 and average was 13.34. Range of variation of panicle bearing tillers plant^{-1} was from 7.35 to 21.00 its average being 10.91. Length of panicle varied from 22.05 to 32.4 cm and the average length of panicle was 25.9 cm. The character number of grains panicle^{-1} varied from 93.1 to 205.9 with an average of 138.8. Number of secondary and tertiary branches panicle^{-1} ranged from 6.6 to 12.9 and 16.5 to 52.4 respectively, the average being 8.5 and 27.19 respectively. Grain length and breadth ranged from 7.00 to 9.9 mm and 2.00 to 3.9 mm, their average being 8.46 and 2.87 mm respectively. L/B ratio ranged from 2.22 to 4.95 with an average of 3.08. Range of variation of 1000 grain weight was from 19.45 to 36.5 g and the average was 27.68 g. In the case of duration to 50% flowering, variability ranged from 69.5 to 106.0 days and the average value was 77.75 days. Grain yield showed an average value of 6003.78 kg ha^{-1} and variability ranging between 3639.19 and 9226.35 kg ha^{-1}. Density of the grain varied between 1.12 and 1.51 g ml^{-1} and average value was 1.25 g ml^{-1}.

4.2.2 GENOTYPIC AND PHENOTYPIC COEFFICIENT OF VARIATION

All the characters under study showed either high or moderate value of GCV and PCV except panicle length (9.71, 10.32), grain length (5.38, 7.08), duration to 50 per cent flowering (5.85, 6.01) and grain density (7.17, 7.95), which showed low values of GCV and PCV.

Higher magnitude of GCV and PCV were exhibited by the characters panicle bearing tillers plant^{-1} (27.8, 30.61), total tillers plant^{-1} (26.81, 31.2), L/B ratio (24.63, 25.42) and plant height (23.58, 24.31). The characters which expressed moderate value of GCV and PCV include tertiary branches panicle^{-1} (17.73, 20.63), grain breadth (16.45, 18.05), 1000 grain weight (16.45, 17.2), grain yield (13.14, 19.98), number of grains panicle^{-1} (10.5, 14.2) and secondary branches panicle^{-1} (10.22, 11.00).

All the characters studied showed higher values of PCV than GCV. Plant height at harvest and duration to 50 per cent flowering showed nearly equal PCV and GCV. Highest magnitude of coefficient of variability was expressed by panicle bearing tillers plant^{-1} and lowest by grain length.

4.2.3 HERITABILITY

Range of broad sense heritability in percentage was from 43.2 to 94.8. All the characters expressed high heritability except grain yield, number of grains panicle^{-1} and grain length. The characters which showed higher heritability values include duration to 50 per cent flowering (94.8%), plant height at the time of harvest (94.1%), L/B ratio (93.8%), 1000 grain weight (91.4%), panicle length (88.4%), secondary branches (86.3%), panicle bearing tillers plant^{-1} (82.4%), grain breadth (83%), grain density (81.3%), tertiary branches panicle^{-1} (73.9%) and total tillers plant^{-1} (73.8%). Moderate values of heritability was expressed by the characters, grain length (57.9%), number of grains panicle^{-1} (54.1%) and grain yield (43.2%). Low heritability estimates were not noticed for any of the fourteen characters studied.

4.2.4 GENETIC ADVANCE AND GENETIC GAIN

The estimates of genetic advance, expressed as the percentage of mean, for all the characters were moderate to high except for the lowest value of genetic gain expressed by the character grain length (8.39%). Highest value was observed for the character panicle bearing tillers plant^{-1} (51.97%). High values were also observed for L/B ratio (49.03%), tiller number plant^{-1} (47.45%), height at the time of harvest (47.11%), 1000 grain weight (32.41%), tertiary branches panicle^{-1} (31.41%) and grain breadth (31.01%). Genetic gain was moderate for the characters like secondary branches panicle^{-1} (19.53%), panicle length (18.79%), grain yield (17.79%), number of grains panicle^{-1} (15.99%), grain density (13.6%) and duration to 50 per cent flowering (11.74%). Only one character exhibited low genetic gain, which was grain length (8.39%).

Among the characters under study, high GCV, PCV, heritability and genetic gain was expressed by the characters plant height at harvest, total tillers plant^{-1}, panicle bearing tillers plant^{-1} and L/B ratio. Moderate values of genotypic and phenotypic coefficient of variation, heritability and genetic advance (expressed as percentage of mean) was exhibited by number of grains panicle^{-1} and grain yield ha^{-1}. Moderate values of GCV and PCV, high values of heritability and genetic gain was exhibited by the characters tertiary branches panicle^{-1}, grain breadth and 1000 grain weight. Moderate GCV and PCV, high heritability and moderate genetic gain was exhibited by secondary branches panicle^{-1}. In the case of characters panicle length, duration to 50% flowering and grain density, a low estimate of GCV and PCV but high heritability and moderate genetic gain was expressed. The character grain length showed a moderate heritability but a low GCV, PCV and genetic gain was observed.

4.2.5 CORRELATION

Phenotypic and genotypic correlation coefficients between grain yield and thirteen component characters are presented in Table 10 genotypic and phenotypic correlation coefficients among the component characters are also presented in Table 10.

Direction of genotypic and phenotypic correlation coefficients were the same for all the characters under study. Genotypic correlation was always higher than phenotypic correlation, except for the characters like number of grains panicle^{-1} and grain density.

Grain yield ha^{-1} was positively and significantly correlated, both at genotypic and phenotypic levels, with grain length (0.769**, 0.391**), L:B ratio (0.739**, 0.480**), panicle bearing tillers plant^{-1} (0.654**, 0.586**), total tillers plant^{-1} (0.598**, 0.506**), tertiary branches panicle^{-1} (0.329**, 0.317**) and number of grains panicle^{-1} (0.291**, 0.332**). Significant negative correlation with yield was exhibited by grain breadth (-0.661**, -0.435), at both genotypic and phenotypic levels. The character 1000 grain weight was also correlated significantly and negatively with grain yield (-0.291), but only at genotypic level. The characters which showed very low association with yield, both at genotypic and phenotypic levels, include panicle length, plant height at harvest, secondary branches panicle^{-1}, duration to 50% flowering and grain density.

Genotypic correlation coefficients among yield components showed that grain length had significant positive association with total tillers plant^{-1}, L:B ratio and number of panicles plant^{-1} and significant negative association with secondary branches

Table 10 **Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients in F_3 progenies of selected crosses of rice varieties of diverse origin**

Sl. No.	Characters	Plant height (cm)	Tiller No.	Panicle No.	Panicle length (cm)	No. of grains $panicle^{-1}$	Secon-dary branches	Tertiary branches	Grain length (mm)	Grain breadth (mm)	L:B ratio	1000 grain weight (g)	Days to 50% flowering	Grain yield ($Kg\ ha^{-1}$)	Grain density ($g\ ml^{-1}$)
1	Plant height at harvest		-0.529	-0.676	0.930	-0.110	-0.288	-0.030	0.033	0.739	-0.590	0.819	-0.136	-0.224	0.330
2	Tiller No.	-0.434		0.976	-0.712	0.091	-0.165	0.217	0.762	-0.958	0.991	-0.603	0.498	0.598	-0.349
3	Panicle bearing tillers	-0.574	0.900		-0.766	0.105	-0.084	0.152	0.682	-0.971	0.978	-0.683	-0.389	0.654	-0.378
4	Panicle length	0.898	-0.543	-0.634		-0.056	-0.072	-0.026	-0.179	0.820	-0.720	0.764	-0.225	-0.249	0.361
5	No. of grains $panicle^{-1}$	0.053	0.047	0.027	0.046		0.715	0.981	-0.259	-0.278	0.134	-0.521	0.381	0.291	0.087
6	Secondary branches	-0.265	-0.125	-0.064	-0.058	0.590		0.579	-0.648	-0.016	-0.172	-0.518	0.314	-0.131	0.120
7	Tertiary branches	0.004	0.156	0.103	0.045	0.900	0.544		-0.137	-0.301	0.190	-0.464	0.448	0.329	0.090
8	Grain length	0.020	0.428	0.434	-0.090	-0.097	-0.468	-0.090		-0.578	0.748	0.141	0.138	0.769	-0.163
9	Grain breadth	0.650	-0.784	-0.843	0.729	-0.181	-0.009	-0.243	-0.311		-0.974	0.805	-0.381	-0.661	0.379
10	L:B ratio	-0.553	0.821	0.870	-0.664	0.101	-0.159	0.164	0.612	-0.932		-0.599	0.353	0.739	-0.362
11	1000 grain weight	0.766	-0.495	-0.592	0.690	-0.407	-0.487	-0.436	0.114	0.698	-0.555		-0.386	-0.291	0.309
12	Days to 50% flowering	-0.117	0.414	0.345	-0.205	0.281	0.277	0.381	0.096	-0.348	0.341	-0.359		0.077	-0.208
13	Grain yield	-0.085	0.506	0.586	-0.053	0.332	-0.045	0.317	0.391	-0.435	0.480	-0.146	0.046		0.021
14	Grain density	0.292	-0.251	-0.293	0.315	0.040	0.090	0.061	-0.100	0.320	-0.324	0.316	-0.182	0.073	

** Significant at 1% level * Significant at 5% level panicle^{-1} and grain breadth. The character L:B ratio showed significant and positive correlation when total tiller number plant^{-1}, panicle number plant^{-1}, grain length and 50% flowering duration. It showed significant negative association with grain breadth, panicle length, 1000 grain weight, plant height at harvest and grain density. Panicle bearing tillers plant^{-1} and tiller number plant^{-1} showed significant positive association with each other as well as with L:B ratio, grain length and duration to 50% flowering. Significant negative correlation was shown with grain breadth, panicle length, 1000 grain weight, plant height and grain density. The characters, number of grains panicle^{-1} and tertiary branches panicle^{-1} showed significant positive association with each other and with characters like secondary branches panicle^{-1} and duration to 50% flowering. Significant negative association was expressed with 1000 grain weight and grain breadth. Significant positive association was seen between characters 1000 grain weight and grain breadth. Both these characters showed association, significantly and positively, with plant height at harvest, panicle length and grain density. Both the characters showed negative significant association with total tillers plant^{-1}, panicle bearing tillers plant^{-1}, tertiary branches panicle^{-1}, duration to 50% flowering, L:B ratio and number of grains panicle^{-1}. Thousand grain weight showed significant negative association with secondary branches panicle^{-1} and grain breadth showed negative correlation with grain length.

Panicle length, plant height and grain density exhibited significant association with each other as well as with grain breadth and 1000 grain weight. Significant negative association of these three characters were expressed with panicle number plant^{-1}, tiller number plant^{-1} and L:B ratio. The character, secondary branches panicle^{-1} showed significant positive association with number of grains panicle^{-1}, tertiary branches panicle^{-1} and duration to 50% flowering. Significant negative association was seen with grain length, 1000 grain weight and plant height at harvest. The character, duration to 50% flowering exhibited a positive significant degree of association with tiller number plant^{-1}, tertiary branches panicle^{-1}, panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary branches panicle^{-1} and L:B ratio. Significant negative association with 50% flowering duration was noted with 1000 grain weight and grain density.

4.2.6 PATH ANALYSIS

The genotypic correlation of all the characters under study, with yield, were included in the path analysis. The estimates of direct and indirect effect of these characters on yield are presented in Table 11.

Residual effect of path analysis was found to be 0.06. The highest positive direct effect on yield was exerted by L:B ratio (2.912). This was followed by number of grains panicle^{-1} (1.459) and panicle length (1.029). Other characters, which showed positive direct effect, include grain breadth (0.910), panicle number plant^{-1} (0.786) and 1000 grain weight (0.537). The lowest value of direct positive effect was exhibited by duration to 50% flowering (0.020) followed by grain density (0.299). The highest negative direct effect on yield was exerted by tertiary branches panicle^{-1} (-0.913) followed by tiller number plant^{-1} (-0.770), grain length (-0.744), plant height at harvest (-0.539) and secondary branches panicle^{-1} (-0.518).

The highest positive indirect effect with yield was exhibited by tiller number plant^{-1} (0.887) followed by panicle number plant^{-1} (2.849) grain length (2.179) and

Table 11 Direct and indirect effects of yield components on grain yield in F_3 progenies of selected crosses of rice varieties of diverse origin

Characters	Plant height	Tiller No.	Panicle No.	Panicle length	No. of grain panicle^{-1}	Secondary branches	Tertiary branches	Grain length	Grain breadth	L/B ratio	1000 grain weight	Days to 50% flowering	Grain density	Total effect
Plant height (cm)	**-0.539**	0.407	-0.531	0.957	-0.160	0.149	0.028	-0.025	0.672	-1.719	0.440	-0.003	0.099	-0.224
Tiller No.	0.285	**-0.770**	0.767	-0.733	0.133	0.086	-0.198	-0.567	-0.872	2.887	-0.324	0.010	-0.104	0.598**
Panicle No.	0.365	-0.752	**0.786**	-0.789	0.154	0.044	-0.139	-0.507	-0.883	2.849	-0.367	0.008	-0.113	0.654**
Panicle Length (cm)	-0.501	0.549	-0.602	**1.029**	-0.081	0.037	0.024	0.133	0.747	-2.098	0.410	-0.004	0.108	-0.249
No. of grains panicle^{-1}	0.059	-0.070	0.083	-0.057	**1.459**	-0.370	-0.895	0.193	-0.253	0.390	-0.280	0.007	0.026	0.291*
Secondary branches	0.155	0.127	-0.066	-0.074	1.043	**-0.518**	-0.528	0.482	-0.014	-0.500	-0.278	0.006	0.036	-0.131
Tertiary branches	0.016	-0.167	0.120	-0.027	1.431	-0.300	**-0.913**	0.102	-0.274	0.553	-0.249	0.009	0.027	0.329*
Grain length (mm)	-0.018	-0.587	0.536	-0.185	-0.378	0.336	0.125	**-0.744**	-0.526	2.179	0.076	0.003	-0.049	0.769**
Grain breadth (mm)	-0.398	0.738	-0.763	0.844	-0.406	0.003	0.275	0.430	**0.910**	-2.838	0.432	-0.007	0.113	-0.661**
L/B ratio	0.318	-0.764	0.769	-0.742	0.195	0.089	-0.173	-0.556	-0.887	**2.912**	-0.322	0.007	-0.108	0.739**
1000 grain weight (g)	-0.442	0.465	-0.537	0.787	-0.761	0.269	0.423	-0.105	0.732	-1.745	**0.537**	-0.008	0.092	**-0.291***
Days to 50% flowering	-0.073	-0.383	0.306	-0.232	0.556	-0.163	-0.409	-0.102	-0.347	1.028	-0.208	**0.020**	-0.062	0.077
Grain density (g ml^{-1})	-0.178	0.269	-0.297	0.372	0.126	-0.062	-0.082	0.121	0.345	-1.054	0.166	0.004	**0.299**	0.021

Bold figures represent direct effects; Residual effect = 0.06

duration to 50% flowering (1.028) through L:B ratio. Positive indirect effect on yield was also exerted by tertiary (1.431) and secondary branches panicle^{-1} (1.043) through number of grains panicle^{-1}. Through panicle length, indirect positive effect was exerted by the characters, plant height at harvest (0.957) grain breadth (0.844) and 1000 grain weight (0.787).

Negative indirect effects were exerted through L/B ratio by various characters namely, grain breadth (-2.838), panicle length (-2.098), 1000 grain weight (-1.745), plant height at harvest (-1.719) and grain density (-1.054). Through tertiary branches panicle^{-1} (-0.895), negative indirect effect was exerted by number of grains panicle^{-1}. Negative indirect effects were exhibited by L/B ratio (-0.887), panicle bearing tillers plant^{-1} (-0.883) and tiller number plant^{-1} (-0.872), through grain breadth.

4.3 SELECTION INDEX

A discriminant function analysis (Hazel, 1943) was carried out and selection models, making simultaneous selection on several characters, with their efficiency over direct selection and gain in efficiency was presented in Table 12. All possible combinations of fourteen characters were formulated and models with maximum efficiency was selected from models with equal number of character combinations. Eight models were ranked based on their efficiency and were presented in Table 12 with their percentage of gain in efficiency.

Maximum efficiency (1.37) was noted when yield (y) and thirteen yield components were used in the selection model namely, plant height at harvest (x_1), total tillers plant^{-1} (x_2), panicle bearing tillers plant^{-1} (x_3), panicle length (x_4), number

Table 12 **Discriminant function for different yield components, genetic advance through selection index, efficiency over direct selection and gain in effeciency**

Sl. No.	Combination	Discriminant function	Genetic advance through selection index	Efficiency over direct selection (maximum value)	Gain in efficiency (%)
1	y, x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{14}	$0.264y - 3.106x_1 - 55.86\,x_2 - 49.922\,x_3 + 114.307\,x_4 - 10.455\,x_5 + 28.231\,x_6 + 33.649\,x_7 - 666.6\,x_8 + 1944.004\,x_9 + 2706.728\,x_{10} - 19.633\,x_{11} - 23.525\,x_{12} + 1400.082\,x_{14}$	1459.51	1.37	37.0
2	y, x_2, x_3, x_7, x_8, x_9, x_{10}, x_{14}	$0.297y - 61.655\,x_2 - 39.143\,x_3 + 9.932\,x_7 - 495.185\,x_8 + 1718.836\,x_9 + 2259.889\,x_{10} + 1419.934\,x_{14}$	1415.36	1.325	32.5
3	y, x_2, x_7, x_8, x_9, x_{10}, x_{14}	$0.271y - 75.61\,x_2 + 13.132\,x_7 - 422.354\,x_8 + 1625.204\,x_9 + 2100.885\,x_{10} + 1465.788\,x_{14}$	1413.04	1.323	32.3
4	y, x_2, x_8, x_9, x_{10}, x_{14}	$0.293y - 78.467\,x_2 - 477.391\,x_8 + 1643.315\,x_9 + 2152.002\,x_{10} + 1528.487\,x_{14}$	1406.47	1.317	31.7
5	y, x_2, x_9, x_{10}, x_{14}	$0.268y - 67.632\,x_2 + 572.315\,x_9 + 1231.326\,x_{10} + 1393.437\,x_{14}$	1394.87	1.306	30.6
6	y, x_2, x_{10}, x_{14}	$0.274y - 72.417\,x_2 + 896.344\,x_{10} + 1439.937\,x_{14}$	1377.5	1.289	28.9
7	y, x_2, x_{10}	$0.309y - 74.52\,x_2 + 819.478\,x_{10}$	1351.38	1.265	26.5
8	y, x_{10}	$0.273y + 521.537\,x_{10}$	1304.39	1.221	22.1
9	Direct selection based on yield		1068.31	1.000	

y = yield in kg ha^{-1} | x_1 = plant height at harvest | x_2 = total tillers $plant^{-1}$ | x_3 = panicle bearing tillers $plant^{-1}$
x_4 = panicle length | x_5 = number of grains $panicle^{-1}$ | x_6 = secondary branches $panicle^{-1}$ | x_7 = tertiary branches $panicle^{-1}$
x_8 = grain length | x_9 = grain breadth | x_{10} = L/B ratio | x_{11} = Thousand grain weight
x_{12} = duration to 50% flowering | x_{14} = grain density

Table 13 Estimates of selection index using characters namely, yield (Y), total tillers plant^{-1} (X_2), grain breadth (X_9), L/B ratio (X_{10}) and grain density (X_{14}) and ranking of 105 genotypes according to selection index and yield

According to selection index		Accession No.	Genotype	According to yield	
Estimate	Rank			Rank	Estimate
9239.910	1	V_{82}	IR 36 x Mattathriveni	3	8301.06
9161.344	2	V_{89}	IR 36 x Mattathriveni	13	7321.78
9155.175	3	V_{85}	IR 36 x Mattathriveni	6	7734.65
9144.600	4	V_{84}	IR 36 x Mattathriveni	5	8057.01
9122.525	5	V_{83}	IR 36 x Mattathriveni	4	8238.32
9016.854	6	V_{77}	IR 36 x Mattathriveni	19	6898.59
9009.938	7	V_{87}	IR 36 x Mattathriveni	16	7122.16
8916.736	8	V_{94}	IR 36 x Mattathriveni	10	7366.52
8914.182	9	V_{76}	IR 36 x Mattathriveni	9	7581.17
8833.672	10	V_{103}	IR 36	47	5938.00
8825.366	11	V_{98}	IR 36 x Mattathriveni	11	7366.51
8804.868	12	V_{81}	IR 36 x Mattathriveni	8	7605.97
8767.084	13	V_{79}	IR 36 x Mattathriveni	41	6266.83
8734.467	14	V_{86}	IR 36 x Mattathriveni	12	7346.75
8732.651	15	V_{96}	IR 36 x Mattathriveni	36	6378.51
8725.446	16	V_{93}	IR 36 x Mattathriveni	37	6354.13
8722.493	17	V_{100}	IR 36 x Mattathriveni	24	6698.77
8712.201	18	V_{42}	Vytilla 3 x Kaohsiung Sen Yu 338	1	9226.35
8696.943	19	V_{80}	IR 36 x Mattathriveni	29	6546.93
8628.178	20	V_{88}	IR 36 x Mattathriveni	53	5804.05
8603.862	21	V_{92}	IR 36 x Mattathriveni	31	6512.52
8557.541	22	V_{99}	IR 36 x Mattathriveni	25	6683.75
8549.193	23	V_{78}	IR 36 x Mattathriveni	27	6637.91

Contd.....

Table 13 contd...

8549.047	24	V_{90}	IR 36 x Mattathriveni	18	6914.34
8462.115	25	V_{14}	Vytilla 3 x Mattathriveni	2	8568.42
8434.739	26	V_{91}	IR 36 x Mattathriveni	39	6306.75
8411.182	27	V_6	Vytilla 3 x Mattathriveni	7	7655.28
8389.633	28	V_{95}	IR 36 x Mattathriveni	46	5941.19
8270.977	29	V_{97}	IR 36 x Mattathriveni	20	6872.53
8236.269	30	V_{18}	Vytilla 3 x Mattathriveni	17	6951.41
8215.327	31	V_{22}	Vytilla 3 x Mattathriveni	14	7294.17
8214.655	32	V_{25}	Vytilla 3 x Mattathriveni	38	6355.62
8172.115	33	V_{13}	Vytilla 3 x Mattathriveni	30	6542.28
8114.398	34	V_{16}	Vytilla 3 x Mattathriveni	22	6767.74
8047.072	35	V_5	Vytilla 3 x Mattathriveni	67	5488.21
8033.219	36	V_{12}	Vytilla 3 x Mattathriveni	45	5947.96
8031.891	37	V_{53}	Mattathriveni x Mahsuri	21	6854.64
8005.827	38	V_7	Vytilla 3 x Mattathriveni	40	6286.71
7996.448	39	V_3	Vytilla 3 x Mattathriveni	87	5124.98
7957.745	40	V_2	Vytilla 3 x Mattathriveni	26	6647.04
7956.929	41	V_{10}	Vytilla 3 x Mattathriveni	54	5799.48
7949.307	42	V_9	Vytilla 3 x Mattathriveni	15	7219.76
7904.041	43	V_{11}	Vytilla 3 x Mattathriveni	33	6453.20
7901.888	44	V_{23}	Vytilla 3 x Mattathriveni	34	6408.82
7896.980	45	V_8	Vytilla 3 x Mattathriveni	23	6714.78
7885.265	46	V_{40}	Vytilla 3 x Kaohsiung Sen Yu 338	63	5609.82
7865.775	47	V_{24}	Vytilla 3 x Mattathriveni	51	5867.20
7790.117	48	V_4	Vytilla 3 x Mattathriveni	77	5332.89
7778.786	49	V_{15}	Vytilla 3 x Mattathriveni	62	5618.72
7705.539	50	V_{32}	Vytilla 3 x Kaohsiung Sen Yu 338	43	6084.41

Contd.....

Table 13 contd.....

7694.166	51	V_{1}	Vytilla 3 x Mattathriveni	76	5357.34
7648.686	52	V_{47}	Vytilla 3 x Kaohsiung Sen Yu 338	89	5075.60
7642.634	53	V_{17}	Vytilla 3 x Mattathriveni	80	5247.18
7629.240	54	V_{19}	Vytilla 3 x Mattathriveni	65	5559.51
7622.469	55	V_{38}	Vytilla 3 x Kaohsiung Sen Yu 338	49	5896.68
7602.085	56	V_{46}	Vytilla 3 x Kaohsiung Sen Yu 338	82	5211.86
7582.082	57	V_{41}	Vytilla 3 x Kaohsiung Sen Yu 338	48	5912.49
7576.563	58	V_{30}	Vytilla 3 x Kaohsiung Sen Yu 338	28	6634.44
7574.509	59	V_{43}	Vytilla 3 x Kaohsiung Sen Yu 338	58	5701.64
7570.373	60	V_{28}	Vytilla 3 x Kaohsiung Sen Yu 338	60	5646.32
7566.969	61	V_{71}	Mattathriveni x Mahsuri	42	6262.63
7539.717	62	V_{37}	Vytilla 3 x Kaohsiung Sen Yu 338	50	5888.40
7532.797	63	V_{55}	Mattathriveni x Mahsuri	55	5790.23
7531.948	64	V_{21}	Vytilla 3 x Mattathriveni	52	5810.09
7530.254	65	V_{48}	Vytilla 3 x Kaohsiung Sen Yu 338	84	5193.02
7508.715	66	V_{44}	Vytilla 3 x Kaohsiung Sen Yu 338	95	4914.19
7497.172	67	V_{70}	Mattathriveni x Mahsuri	75	5372.82
7483.100	68	V_{45}	Vytilla 3 x Kaohsiung Sen Yu 338	64	5597.15
7482.450	69	V_{36}	Vytilla 3 x Kaohsiung Sen Yu 338	57	5770.19

Contd....

Table 13 contd....

7477.350	70	V_{35}	Vytilla 3 x Kaohsiung Sen Yu 338	56	5772.12
7467.865	71	V_{49}	Vytilla 3 x Kaohsiung Sen Yu 338	102	4549.74
7461.067	72	V_{102}	Kaohsiung Sen Yu 338	32	6499.07
7428.737	73	V_{52}	Mattathriveni x Mahsuri	66	5553.38
7416.139	74	V_{54}	Mattathriveni x Mahsuri	72	5439.36
7407.725	75	V_{39}	Vytilla 3 x Kaohsiung Sen Yu 338	69	5453.70
7407.011	76	V_{20}	Vytilla 3 x Mattathriveni	59	5665.87
7399.718	77	V_{56}	Mattathriveni x Mahsuri	88	5094.36
7394.235	78	V_{72}	Mattathriveni x Mahsuri	92	4943.26
7389.447	79	V_{57}	Mattathriveni x Mahsuri	74	5395.30
7389.347	80	V_{31}	Vytilla 3 x Kaohsiung Sen Yu 338	85	5170.58
7364.282	81	V_{59}	Mattathriveni x Mahsuri	71	5441.13
7360.428	82	V_{74}	Mattathriveni x Mahsuri	68	5484.92
7359.542	83	V_{73}	Mattathriveni x Mahsuri	90	5046.26
7357.701	84	V_{51}	Mattathriveni x Mahsuri	61	5635.75
7345.479	85	V_{50}	Vytilla 3 x Kaohsiung Sen Yu 338	100	4696.17
7344.651	86	V_{29}	Vytilla 3 x Kaohsiung Sen Yu 338	78	5264.10
7270.330	87	V_{26}	Vytilla 3 x Kaohsiung Sen Yu 338	55	5790.23
7263.675	88	V_{58}	Mattathriveni x Mahsuri	44	6035.38
7256.667	89	V_{34}	Vytilla 3 x Kaohsiung Sen Yu 338	73	5398.51
7256.136	90	V_{75}	Mattathriveni x Mahsuri	83	5206.41
7235.845	91	V_{64}	Mattathriveni x Mahsuri	94	4293.19

Contd....

Table 13 contd.....

7219.133	92	V_{68}	Mattathriveni x Mahsuri	86	5150.06
7216.324	93	V_{105}	Mattathriveni	103	4346.11
7211.003	94	V_{65}	Mattathriveni x Mahsuri	70	5451.97
7208.559	95	V_{60}	Mattathriveni x Mahsuri	81	5218.14
7208.031	96	V_{62}	Mattathriveni x Mahsuri	99	4740.81
7179.322	97	V_{33}	Vytilla 3 x Kaohsiung Sen Yu 338	97	4848.53
7167.623	98	V_{27}	Vytilla 3 x Kaohsiung Sen Yu 338	79	5254.38
7157.550	99	V_{63}	Mattathriveni x Mahsuri	96	4850.12
7151.380	100	V_{66}	Mattathriveni x Mahsuri	101	4550.75
7141.774	101	V_{61}	Mattathriveni x Mahsuri	91	4990.42
7072.765	102	V_{67}	Mattathriveni x Mahsuri	93	4938.06
7068.197	103	V_{69}	Mattathriveni x Mahsuri	98	4765.58
6808.712	104	V_{104}	Vytilla 3	104	4116.27
6222.422	105	V_{101}	Mahsuri	105	3639.19

of grains panicle^{-1} (x_5), secondary (x_6) and tertiary branches panicle^{-1} (x_7), grain length (x_8), grain breadth (x_9), L/B ratio (x_{10}), 1000 grain weight (x_{11}), duration to 50% flowering (x_{12}) and grain density (x_{14}). This model gave 37 per cent gain in efficiency than direct selection based on yield.

From the proposed eight models, the model having minimum number of character combination, including yield (y) and four yield components namely, total tillers plant^{-1} (x_2), grain breadth (x_9), L/B ratio (x_{10}) and grain density (x_{14}) was selected. This model gave gain in efficiency of 30.6 per cent. This selection model was utilized for ranking 105 genotypes studied in F_3 generation.

Estimates of selection index using characters namely yield (y), total tillers plant^{-1} (x_2), grain breadth (x_9), L/B ratio (x_{10}) and grain density (x_{14}) and ranking given to 105 genotypes according to the selection index and yield were given in Table 13. The best 10 genotype based on selection index and yield are given in Table 13. According to selection index first 10 ranks were obtained for accession numbers namely V_{82}, V_{89}, V_{85}, V_{84}, V_{83}, V_{77}, V_{87}, V_{94}, V_{76}, and V_{103}. All the superior genotypes, except V_{103}, belonged to the cross IR 36 x Mattathriveni and tenth rank was obtained for the parent, IR 36. According to yield, first 10 ranks were obtained for the accession numbers namely, V_{42}, V_{14}, V_{82}, V_{83}, V_{84}, V_{85}, V_6, V_{81}, V_{76}, and V_{94}. Based on selection index and yield, V_{82}, V_{83}, V_{84}, V_{85}, V_{76} and were found to be superior in the order of ranking.

Discussion

5. DISCUSSION

5.1. EXPERIMENT NO. I

5.1.1. Genetic variability in F_2

The development of an effective plant breeding programme is dependant upon the existence of genetic variability. The efficiency of selection largely depends upon the magnitude of genetic variability present in the plant population. An insight into the magnitude of variability, present in the gene pool of a crop species, is of utmost importance for starting a judicious plant breeding programme.

Genetic variability in F_2 population of the present study was high among the genotypes and there was sufficient scope for improvement through selection for all the characters studied. The magnitude of range of variation for all the characters studied was also high. Variability for different characters were previously observed by workers like Shamsuddin (1982), Sundaram *et al.* (1988), Marimuthu *et al.* (1990b) and Basavaraja *et al.* (1997) for number of grains panicle^{-1}, plant height, total and productive tillers plant^{-1}, panicle length, 1000 grain weight and grain yield plant^{-1}. Santhalingam *et al.* (1992), Regina *et al.* (1994), Ganesan and Subramanian (1994) and Rao (1996) reported variability in yield and yield components. Govindarasu and Natarajan (1995) reported high genetic variability of grain density and 1000 grain weight.

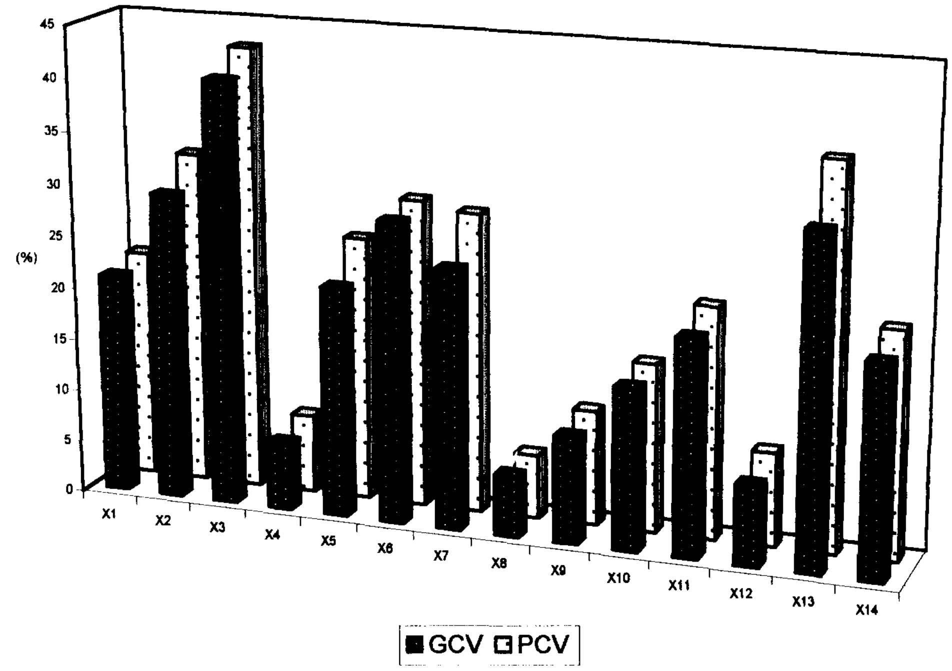
5.1.2. Genotypic and phenotypic coefficients of variation

High GCV and PCV for characters like plant height, number of tillers plant^{-1}, panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, 1000 grain weight, grain yield and grain density indicate that these characters have greater scope for genetic improvement through selection. Highest GCV was observed for productive tillers plant^{-1}. Ganesan and Subramanian (1994) and Basavaraja (1997) also reported high variability for number of panicles plant^{-1}. Similar results were also reported by Sundaram *et al.* (1988) and Ganesan and Subramanian (1994) for plant height and number of grains panicle^{-1}; Amrithadevarathinam (1990) and Basavaraja *et al.* (1997) for total tillers plant^{-1}; Shamsuddin (1982), Sundaram *et al.* (1988), Amrithadevarathinam (1990) and Ganesan and Subramanian (1994) for number of grains panicle^{-1}; Shamsuddin (1982), Ganesan and Subramanian (1994) and Govindarasu and Natarajan (1995) for 1000 grain weight; Vanaja (1998) for secondary and tertiary branches and Govindarasu and Natarajan (1995) for grain density. The variability for grain yield was earlier reported by Shamsuddin (1982), Tiwari *et al.* (1993), Ganesan and Subramanian (1994), Rao *et al.* (1996) and Basavaraja *et al.* (1997).

Moderate level of variability was observed for the characters grain breadth and L/B ratio. Hence these characters are also useful in the rice genetic improvement programme. Report of Vanaja (1998) supported the moderate variability of L/B ratio. GCV and PCV of fourteen characters in F_2 are presented in Fig.1.

The scope of improvement through selection for the characters, panicle length, grain length and duration to 50% flowering is less, as these characters were observed to have low GCV and PCV. Low variability of these three characters were also reported by Vanaja (1998). Slightly deviating from this result, Shamsuddin (1982) reported high genetic variation for panicle length.

Fig.1. Genotypic and Phenotypic coefficients of variation of fourteen characters in F_2



X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}

X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio

X11 - Thousand grain weight
X12 - Days to 50% flowering
X13 - Grain yield
X14 - Grain density

From the results, it was observed that almost all the characters were influenced by environmental factors, as the PCV for all the characters were higher than GCV. This was also reported by Chaubey and Singh (1994) and Regina *et al.* (1994). Duration to 50% flowering was the character, most influenced by environment, followed by grain yield, tertiary branches panicle^{-1}, panicle length and number of grains panicle^{-1}. Similar findings were also reported by Sahu and Sahu (1990) for panicle length and duration to 50% flowering.

Any genotype possessing stability in different environments with considerably good yield is of practical importance in plant breeding programme. Influence of environment on grain yield was also reported by Reddy (1991), Mishra *et al.* (1996) and Rao *et al.* (1996). Closeness in GCV and PCV values in the characters secondary branches panicle^{-1}, plant height at harvest, L/B ratio and panicle bearing tillers, shows that these characters are less influenced by environment, compared to yield and panicle length. Deviating from this result, Sahu and Sahu (1990) and Vanaja (1998) reported high influence of environment on plant height.

5.1.3. Heritability

The progress in a breeding programme depends on the extent to which desirable traits are heritable. All the characters under study showed high heritability in broadsense. High heritability for yield and yield components were also reported by Shamsuddin (1982), Sundaram *et al.* (1988), Chaubey and Singh (1994) and Mishra *et al.* (1996). Highest heritability was observed for the character secondary branches panicle^{-1} (94.9%) followed by plant height (92%). All other characters namely L/B ratio, panicle bearing tillers plant^{-1}, grain length, 1000 grain weight, grain density, grain breadth, total tillers plant^{-1}, number of grains panicle^{-1}, panicle length, tertiary branches panicle^{-1}, grain yield ha^{-1} and duration to 50% flowering exhibited high heritability estimates. Similar findings were also reported by Subramanian and Rathinam (1984b), Morales-ramos (1987), Sundaram *et al.* (1988), Marimuthu *et al.* (1990b), Sreekumar *et al.* (1992), Singh *et al.* (1993), Regina *et al.* (1994), Manomani *et al.* (1996) and Vanaja (1998) for plant height. Moderate heritability for plant height was reported by Moeljopawiro (1986) and low heritability by Sahu and Sahu (1990). High heritability of total tillers plant^{-1} was also reported by Basavaraja *et al.* (1997) and Vanaja (1998) and of productive tillers plant^{-1} was supported by Marimuthu *et al.* (1990b), Reddy and Nerkar (1991), Yadav (1992), Santhalingam *et al.* (1992), Sreekumar *et al.* (1992) and Basavaraja *et al.* (1997). Deviating from the results, moderate heritability of productive tillers plant^{-1} was reported by Vanaja (1998) and low heritability by Sahu and Sahu (1990). Subramanian and Rathinam (1984b) and Mishra *et al.* (1996) reported low heritability of total tillers plant^{-1}. High heritability of panicle length was reported by Subramanian and Rathinam (1984b), Marimuthu *et al.* (1990b), Roy *et al.* (1995), Lalitha and Sreedhar (1996) and Vanaja (1998), where as different results were reported by Moeljopawiro (1986), Sahu and Sahu (1990) and Mishra *et al.* (1996).

Number of grains panicle^{-1} and 1000 grain weight showed higher heritability, which was supported by Subramanian and Rathinam (1984b), Morales-ramos (1987), Marimuthu *et al.* (1990b), Lokaprakash *et al.* (1992) and Vanaja (1998). Reports of Subramanian and Rathinam (1984b) and Chauhan and Chauhan (1994) supported the high heritability of grain length, breadth and L/B ratio. Takeda (1991) suggested that grain length was the most adequate trait for studying grain size because of high heritability. Govindarasu and Natarajan (1995) recorded high heritability of 1000 grain weight and grain density. High heritability of yield was supported by the findings of Shamsuddin (1982), Marimuthu *et al.* (1990b), Sreekumar *et al.* (1992), Chaubey and Singh (1992), Regina *et al.* (1994), Manomani *et al.* (1996), Mishra *et al.* (1996) and Vanaja (1998). Deviating from this result, low heritability of yield was reported by Basavaraja *et al.* (1997) and moderate heritability of yield by Subramanian and Rathinam (1984b), Reddy and Nerkar (1991), Santhalingam (1992) and Yadav (1992). Duration to 50% flowering was noted to have 72.9 per cent heritability, which was the lowest among fourteen characters in the experiment. High heritability of duration to 50% flowering was also noticed by Sreekumar *et al.* (1992) and Vanaja (1998) while low heritability of this character was reported by Sahu and Sahu (1990), who suggested that this character was greatly influenced by environment. From the results observed, all the fourteen characters seem to be useful in rice breeding programme.

5.1.4. Genetic advance and genetic gain

Heritability only denotes the percentage of effectiveness with which the selection can be based on the phenotypic performance. In order to assess the genetic progress, genetic gain should be measured along with heritability. Genetic advance, as the per cent of mean, was calculated for all the fourteen characters and found that all the characters had high or moderate genetic advance. The characters which showed high genetic advance (GA) include, plant height at harvest, total tillers and panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, L/B ratio, 1000 grain weight, grain yield and grain density. The character panicle bearing tillers plant^{-1} showed highest GA. Similar findings were also reported by Sundaram *et al.* (1988), Marimuthu *et al.* (1990b), Basavaraja *et al.* (1997) and Vanaja (1998), while low GA was reported by Sahu and Sahu (1990) and Sreekumar *et al.* (1992). High expected genetic advance of these characters suggests that these characters can be improved genetically by selection from a segregating population. Moderate expected genetic advance was recorded for grain breadth, grain length, panicle length and duration to 50% flowering. Hence these characters will have a moderate level of improvement on selection. In present investigation, all the characters reported moderate to high expected GA. Moderate to high genetic advance for all these fourteen characters were also reported by Vanaja (1998). High expected genetic advance were also reported by Sreekumar *et al.* (1992), Regina *et al.* (1994), Manomani *et al.* (1996) and Vanaja (1998) for plant height and yield ha^{-1}; Vanaja (1998) for L/B ratio, tertiary branches and total tillers plant^{-1}; Basavaraja *et al.* (1997) for total tillers; Shamusuddin (1982), Sundaram *et al.* (1988), Marimuthu *et al.* (1990b), Lokaprakash *et al.* (1992), Regina *et al.* (1994) and Vanaja (1998) for number of grains panicle^{-1}; Govindarasu and Natarajan (1995) for 1000 grain weight and grain density; Shamsuddin (1982), Manomani *et al.* (1996) and Vanaja (1998) for 1000 grain weight and yield; Sundaram *et al.* (1988), Marimuthu *et al.* (1990b), Mishra *et al.* (1991), Sreekumar *et al.* (1992) and Regina *et al.* (1994) for grain yield. Moderate expected GA for grain length and breadth was reported by Chauhan and Chauhan (1994) and Reddy and De (1996). Vanaja (1998) reported moderate expected GA for duration to 50% flowering, length and breadth of grain and panicle length, which was further confirmed through this investigation. Marimuthu *et al.* (1990b) also reported the moderate GA of panicle length. Slightly deviating from these results, Sahu and Sahu (1990) reported poor genetic gain of plant height, panicle bearing tillers plant^{-1} and moderate GA of yield and number of grains panicle^{-1}. Marimuthu *et al.* (1990b) reported moderate to low GA of plant height and 1000 grain weight. Sreekumar *et al.* (1992) reported low GA for 1000 grain weight, grain yield and number of productive tillers and high expected genetic advance for duration to 50% flowering. Moderate GA of secondary branches panicle^{-1} was reported by Vanaja (1998) and low GA of yield by Basavaraja *et al.* (1997).

For more reliable conclusion, estimates of heritability and genetic advance should be considered together, which is more useful than heritability alone (Singh and Narayanan, 1993). Expected genetic advance would be high, if the heritability is due to additive gene effects. When non-additive gene effects govern heritability, the expected GA would be low. The characters under present investigation, which have high broadsense heritability, high expected genetic advance and high GCV include plant height at harvest, total tillers plant^{-1}, panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, 1000 grain weight, grain yield and grain density. High heritability and high expected genetic advance coupled with moderate GCV was exhibited by L/B ratio. These results suggested that these ten characters are under additive gene effect. These findings were supported by Vanaja (1998) with respect to plant height, total tillers, number of grains panicle^{-1}, number of tertiary branches, yield ha^{-1} and L/B ratio. Similar results were also reported by Subramanian and Rathinam (1984b) for plant height, number of grains panicle^{-1}, 1000 grain weight, grain breadth and L/B ratio; Santhalingam *et al.* (1992) for plant height, 1000 grain weight and grain yield. Roy and Panwar (1993) for plant height, number of grains panicle^{-1} and grain breadth; Marimuthu *et al.* (1990b) for effective tillers plant^{-1}, number of grains panicle^{-1} and single plant yield. Lokaprakash *et al.* (1992) reported high heritability and moderate to high GA, hence additive gene action for 1000 grain weight and number of grains panicle^{-1}. Rao *et al.* (1996) revealed predominance of additive gene effects for yield and yield traits. Slightly deviating from the results, Subramanian and Rathinam (1984b) and Ram (1994) reported dominance gene action for yield and tiller number; Sreekumar *et al.* (1992) and Roy and Panwar (1993) reported low GA for grain yield, panicle number and 1000 grain weight. Chakraborthy and Hazarika (1995) reported that yield and plant height were largely controlled by dominance action. Mallik *et al.* (1997) suggested greater dominance action in controlling the character grain density.

High heritability coupled with moderate to high expected genetic advance and moderate to low GCV were observed for the character grain breadth, which suggests that grain breadth is mostly controlled by additive gene action and is important component of yield. High heritability along with moderate to low GA and low GCV were observed for the characters, length of panicle, grain length and duration to 50% flowering. This shows that both additive and non-additive effects govern these characters. Panicle length and grain length are mostly influenced by non-additive (dominance and epistaris) gene actions. Scope of improving these characters through direct selection is meagre. But grain length, panicle length and duration to 50% flowering can be improved through hybridization and selection. High heritability with moderate expected genetic advance and low GCV for panicle length, grain length and duration to 50% flowering were also observed by Vanaja (1998). Predominance of additive effect for grain breadth was supported by the findings of Subramanian and Rathinam (1984b), Kato (1989), Roy and Panwar (1993) and Chauhan (1998). According to Subramanian and Rathinam (1984b), Roy and Panwar (1993) and Ram (1994), additive and dominance effects influenced panicle length. According to Kato (1989) grain length was influenced by both additive and non-additive effects and grain length and width were considered to be controlled by different genetic system. Deviating from the results of present investigation, Chakraborthy and Hazarika (1995) reported additive gene action for panicle length and number of days to 50% flowering. Additive gene action for grain length was suggested by Subramanian and Rathinam (1984b) and Roy and Panwar (1993).

In general, present investigation revealed that the characters namely, plant height at harvest, tiller number plant^{-1}, panicle bearing tillers plant^{-1}, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, 1000 grain weight, L/B ratio, grain yield ha^{-1}, grain breadth and grain density, provide great help in direct selection from phenotypic performance.

5.1.5. Correlation

Study of the association of characters is a must to understand the genetics of the crop. Correlation study helps the plant breeder to understand genetic architecture of the crop as the correlation occur due to genetic reasons namely, linkage or pleiotropy. From the knowledge of association of various characters with yield and among themselves, breeders can assess the complexity of the character and can practice selection based on appropriate selection criteria. In the present investigation, correlation between grain yield ha^{-1} and thirteen yield components were studied and the results are discussed below.

Among the correlation coefficients of thirteen characters with yield, only three characters showed significant positive correlation, both at genotypic and phenotypic levels. These characters include panicle bearing tillers $plant^{-1}$, total tillers $plant^{-1}$ and tertiary branches $panicle^{-1}$. Significant negative correlation, at both levels, was observed for 1000 grain weight, grain density and plant height at harvest. Two characters namely, secondary branches $panicle^{-1}$ and number of grains $panicle^{-1}$ showed significant negative association with yield but only at genotypic level. Panicle length, tertiary branches, L/B ratio and grain breadth showed higher phenotypic correlation than genotypic correlation, which indicate the influence of environment on these four characters. Genotypic correlation coefficients are discussed in detail.

The character, panicle bearing tillers $plant^{-1}$ exhibited highest significant positive association with grain yield. This was followed by total tillers $plant^{-1}$ and tertiary branches $panicle^{-1}$. Significant negative association was exhibited by 1000 grain weight, grain density, plant height, secondary branches $panicle^{-1}$ and number of grains $panicle^{-1}$ with yield. This indicates that simultaneous selection on increased panicles $plant^{-1}$, increased tillers $plant^{-1}$, increased tertiary branches, reduced 1000 grain weight, reduced density, reduced plant height, reduced secondary branches $panicle^{-1}$ and reduced number of grains $panicle^{-1}$, higher grain yield could be achieved. The above results were in agreement with the reports of Sivasubramanian and Madavamenon (1973) and Reuber and Kisanga (1989) for plant height;

Mathew (1976) for plant height, tiller and panicle number; Chalapathy (1978) and Lalitha and Sreedhar (1996) for panicle number and plant height; Amrithadevarathinam (1990), Abd-el-smie and Hassan (1994), Sawant (1995), Yadav *et al.* (1995), Mishra *et al.* (1996) and Vanaja (1998) for total tillers plant^{-1}; Reddy and Ramachandraiah (1990), Sreekumar *et al.* (1992), Yadav (1992), Bai *et al.* (1992), Reddy and Nerkar (1992), Chaubey and Singh (1994), Reddy *et al.* (1995), Rao *et al.* (1996) and Ganesan *et al.* (1996) for panicle bearing tillers plant^{-1}; Abd-el-samie and Hassan (1994), Sawant (1995), Yadav *et al.* (1995) and Lalitha and Sreedhar (1995) for 1000 grain weight, number of grains panicle^{-1} and panicle number plant^{-1}. Results of Vanaja (1998) supported positive correlation of tertiary branches panicle^{-1}, negative correlation of 1000 grain weight and confirmed the environmental influence on panicle length and tertiary branches with yield, as they had higher phenotypic correlation than genotypic correlation. Shamsuddin (1982) reported negative association of number of grains panicle^{-1}, but slightly deviating from present results, he suggested that 1000 grain weight and density were associated positively with yield. Gomathinayagam *et al.* (1988), Reddy and Ramachandraiah (1990) and Regina *et al.* (1994) were also reported positive correlation of plant height, number of grains panicle^{-1} and 1000 grain weight with yield. Results of Chauhan and Chauhan (1994), indicating absence of correlation for grain length, breadth and L/B ratio with yield, confirmed the results of present investigation.

The highest significant positive association, both at genotypic and phenotypic levels, between panicle bearing tillers plant^{-1} and grain yield ha^{-1} suggest that panicle number plant^{-1} can very well be utilised as an yield indicator in yield trials. Higher significant positive association of tertiary branches with yield indicate that more compact panicles give higher yield. Results revealed the positive association of tiller and panicle number with tertiary branches as well as with yield. But tertiary branches exhibited positive correlation with secondary branches and number of grains panicle^{-1}, which are negatively associated with yield. Hence during selection, we should go for optimum level of character combination of tiller number, panicle number, secondary branches, tertiary branches and number of grains panicle^{-1} so that final grain yield is maximum.

Intercorrelations among yield components suggested that heavy selection pressure on optimum number of total and panicle bearing tillers plant^{-1} will result in the correlated response for desirable characters like more tertiary branches panicle^{-1} with long slender grains, optimum number of grains in each panicle, shorter stature, reduced grain weight, reduced density and optimum number of secondary branches panicle^{-1}, which ultimately result in higher yield.

Absence of significant correlation of the characters panicle length, grain length and breadth, L/B ratio and duration to 50% flowering indicate that these characters can be recombined as desired. Genotypic correlation among different yield components in F_2 are shown in Fig.5.

From the inter correlation studies of tiller and panicle number plant^{-1}, it was evident that whenever number of tillers and panicles increase, long slender grains were produced. Significant negative association of tertiary branches panicle^{-1} and tiller number with plant height indicate the fact that in shorter statured plants, more number of effective tillers will be produced with more tertiary branches, making the

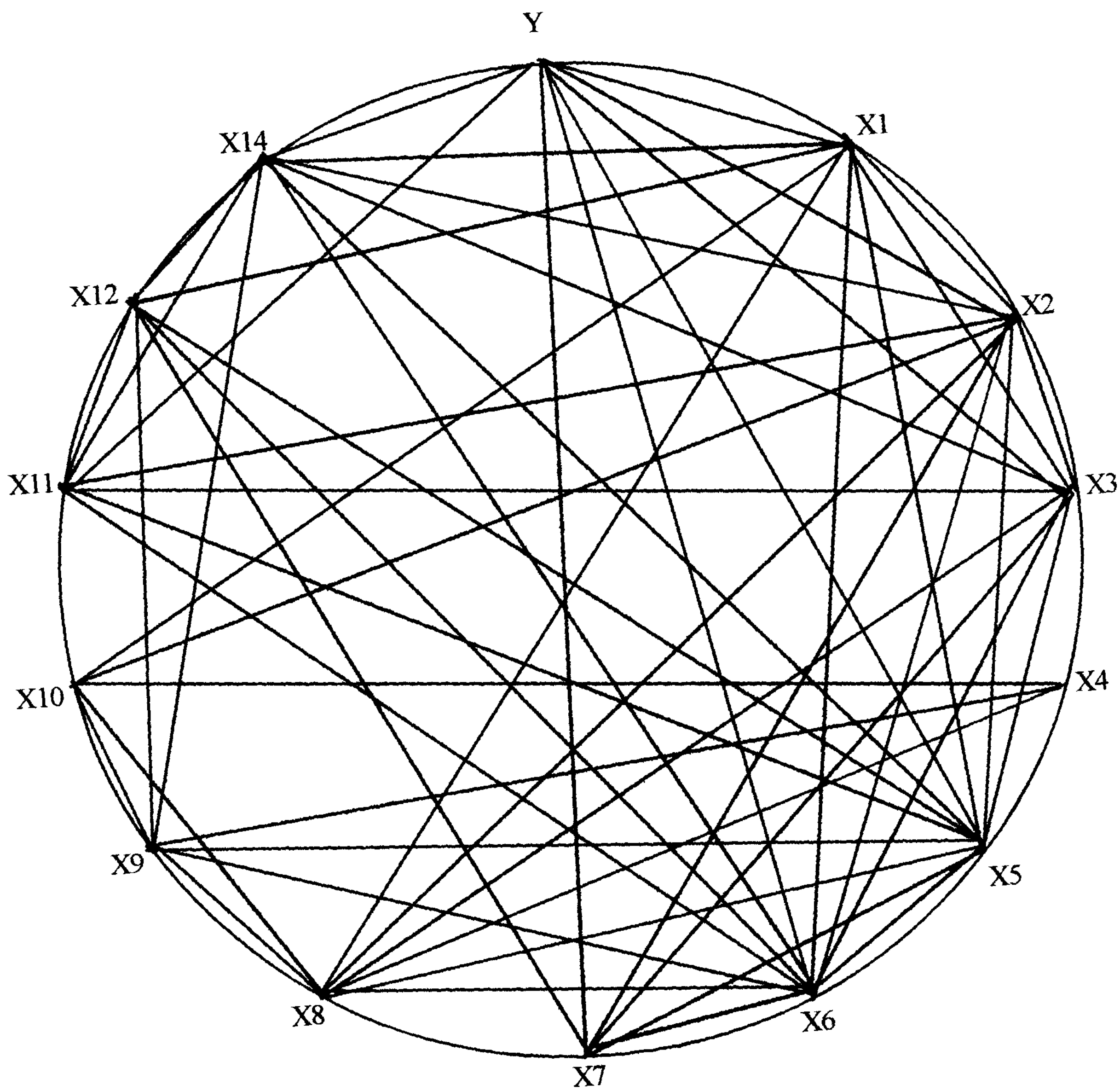


Fig.5. Genotypic correlation among different characters in F_2 generation

X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}
X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio
X11 - Thousand grain weight
X12 - Days to 50% flowering
X14 - Grain density
Y - Grain yield

——— Significant negetive correlation

——— Significant positive correlation

plant itself more compact and more productive. The positive association of tertiary branches with secondary branches, number of grains panicle^{-1}, duration to 50% flowering, tiller and panicle number and with yield, suggests that whenever we select for more tertiary branches to increase the yield, duration to 50% flowering, secondary branches and number of grains panicle^{-1} will also increase, which in turn reduce the final yield. Hence optimisation of all the characters under selection is essential for getting an optimum yield. This was also reported by Vanaja (1998).

Plant height, 1000 grain weight, grain density, secondary branches panicle^{-1} and number of grains panicle^{-1} had significant positive correlation with each other and all these characters exhibited significant negative association with yield. This result reveal that in tall plants, more secondary branches will be produced with more number of heavier and denser grains. But the tillers and panicles will be few with short and bold grains, because plant height showed negative association with tiller number, panicle number, grain length and L/B ratio. Since the number of panicles are less in tall plants, total number of grains plant^{-1} and yield will be lower than shorter plants with more number of panicles plant^{-1}. Hence for increasing yield potential, reduced plant height, or more specifically a semidwarf plant ideotype is to be preferred.

The correlations of secondary branches panicle^{-1} with various characters suggests that selection for more number of secondary branches panicle^{-1} may increase the duration and height of the plants with reduced number of tillers and panicles. When the number of grains panicle^{-1} increases, the size of the grain will decrease. This is evident from the negative association of number of grains panicle^{-1} with grain length and breadth.

Duration to 50% flowering, panicle length, grain length, grain breadth and L/B ratio did not exhibit any significant correlation with yield. The inter correlations of duration to 50% flowering suggested that plants having long duration will be taller with fewer number of panicles, heavier and denser grains with low grain breadth. Long duration genotypes exhibited more number of secondary and tertiary branches panicle^{-1}. Hence short to medium duration to 50% flowering is prefered for higher grain yield potential. Correlation of panicle length with other characters revealed that shorter panicles will produce long slender grains and when panicle length increases, boldness of grain also increase. This is evident from significant positive association of panicle length with grain breadth and highly significant negative association with L/B ratio. The significant positive association of grain length with tiller number and panicle number, L/B ratio with tiller number, significant negative association of grain breadth and grain length with secondary branches panicle^{-1} and number of grains panicle^{-1} and L/B ratio with plant height suggested that grain length, breadth and L/B ratio exhibited indirect association with yield. In the light of present results it is evident that shorter panicles and slender grains indirectly increase the yield.

Association of shorter plant height with more number of productive tillers were also reported by Chalapathy (1978), Wu *et al.* (1987) and Vanaja (1998). Reports of shorter panicles for higher yield was supported by Chalapathy (1978). The reports of Vanaja (1998) supported the results of present investigation namely, semidwarf plant ideotypes for higher yield, short duration to 50% flowering for high yield, association of wide grains with short panicles, increase of number of grains panicle^{-1} with tertiary branches, positive association of 1000 grain weight with plant height and duration to 50% flowering. Significant positive association of grain length with L/B ratio and negative association of grain breadth with L/B ratio was also noticed by Jun (1985). Deviating from the results, positive association of 1000 grain weight with yield was reported by Chalapathy (1978) and plant height with tiller number was reported by Marimuthu *et al.* (1990a).

In general, the present study revealed that a strong positive correlation existed between yield and characters like panicle bearing tillers plant^{-1}, total tillers plant^{-1}, tertiary branches panicle^{-1} and strong negative correlation of yield with 1000 grain weight, grain density, plant height, secondary branches panicle^{-1} and number of grains panicle^{-1}. The characters grain length, breadth and L/B ratio showed indirect association with yield. Shorter panicle length and short to medium duration to 50% flowering, together with optimum value of yield component combination, considered desirable for yield improvement in F_2 generation.

5.1.6. Path analysis

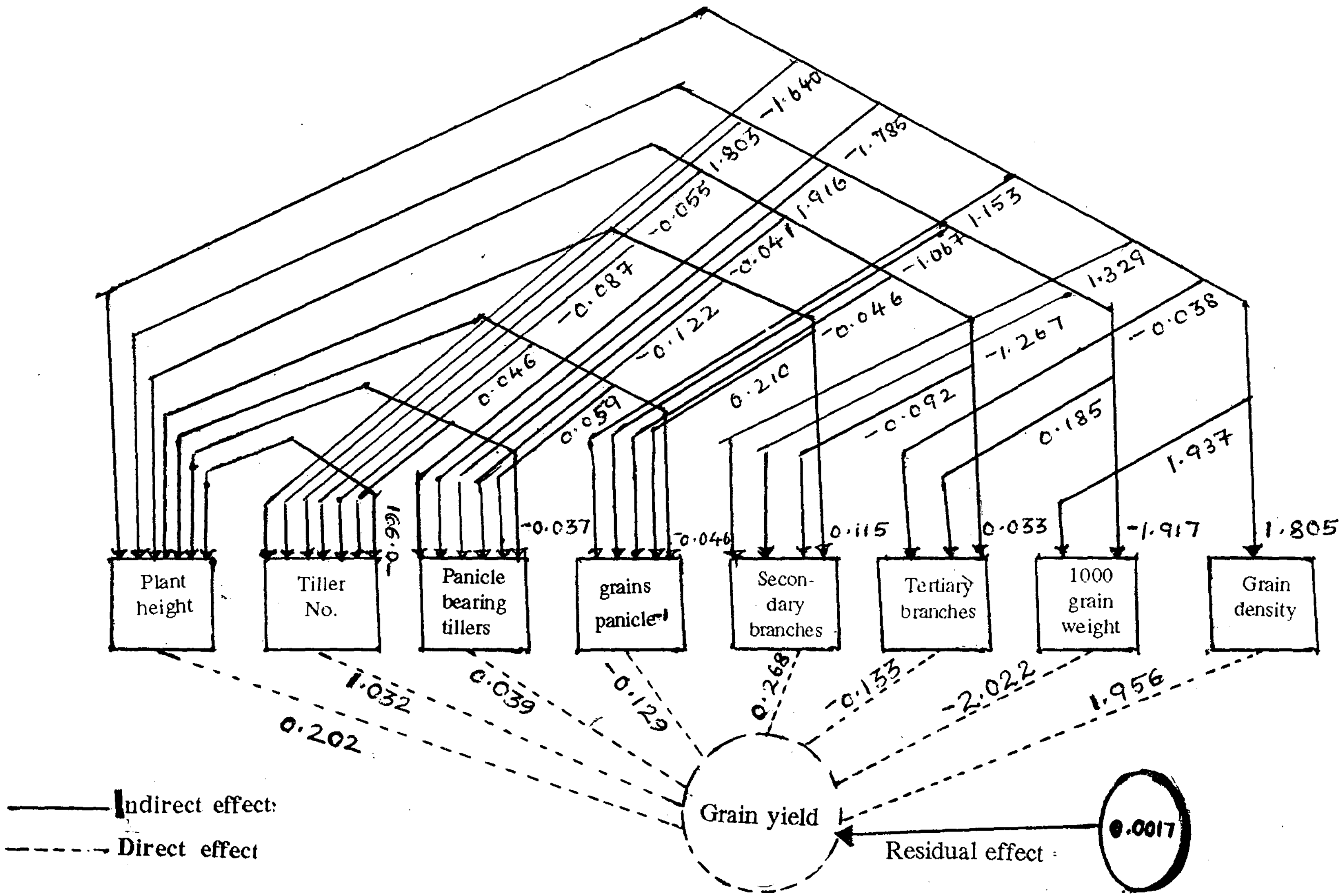
Path analysis provide information on the direct and indirect causes for association between yield and various yield components. If the correlation between yield and a character is due to direct effect of a character, it reflects a true relationship between them and selection can be practised for such a character to improve the yield. But if the correlation is mainly due to indirect effect of the character through another trait, the breeder has to select for the latter trait through which the indirect effect is exerted (Singh and Chaudhary, 1985). Information obtained from path analysis has been extensively used in different crops for indirect selection for yield. A greater yield response is obtained when the character for which indirect selection is practised has a high heritability and a high correlation with yield.

In the present investigation, a path coefficient analysis of F_2 population was performed, using twelve yield component characters with yield. L/B ratio was not included as it exhibited very low correlation coefficient with yield at genotypic level. The cause effect relationship between yield and its twelve components are illustrated in Fig.7.

The very low residual effect (R = 0.0017) noted in path analysis indicated that causative factors included in the analysis have been adequate to explain variability in yield. Thus 99.9 per cent variation in grain yield was contributed genotypically by the 12 yield components namely, plant height at harvest, total tillers plant^{-1}, panicle bearing tillers plant^{-1}, panicle length, number of grains panicle^{-1}, secondary and tertiary branches panicle^{-1}, grain length, grain breadth, 1000 grain weight, duration to 50% flowering and grain density.

In F_2, the highest positive direct effect on yield was exhibited by grain density. The highly significant negative correlation coefficient of grain density with yield might be due to high negative indirect effects exerted tnrough 1000 grain weight and total tillers plant^{-1}. Grain density was positively correlated with 1000 grain weight and both of them had negative correlation with yield. Total tillers showed negative correlation with grain density and positive correlation with yield. Hence when grain density increase, 1000 grain weight increase and total tillers decrease, thus reducing the yield. This explains for the negative indirect effects by grain density through total tillers and 1000 grain weight. The high positive direct effect of grain density and

Fig.7 Path diagram indicating the direct and indirect effects of component characters on yield in F_2 generation



positive indirect effects exerted through grain density by various characters namely, tiller number, panicle number and 1000 grain weight, indicate that grain density directly influence the yield by increasing the yield. But considering the simultaneous negative indrect effects and negative correlation of grain density with yield, it can be suggested that density should be intermediate, not too low or high.

Second highest positive direct effect was exhibited by the character, total tillers plant^{-1}. High positive correlation between total tillers and yield was mainly due to its direct effect. Positive direct effect of tiller number was reported by Amrithadevarathinam (1990) and that of grain density was reported by Gupta *et al.* (1998). The slightly diminished positive correlation coefficient of total tillers plant^{-1} with yield compared to its high positive direct effect might be due to combined effects of high negative indirect effect through grain density and high positive indirect effect through 1000 grain weight, in almost equal and opposite manner, along with negative indirect effect through plant height. High positive direct effect and high correlation between total tillers and yield indicate that total tillers plant^{-1} is an important component of yield and selection based on increased tillers will be highly effective in increasing the yield.

Panicle length exerted positive direct effect on yield. The positive correlation between panicle length and yield is the reflection of its positive direct effect. Positive direct effect of panicle length was reported earlier by Subramanian and Rathinam (1984a), Ramalingam *et al.* (1993), Lalitha and Sreedhar (1996) and Gupta *et al.* (1998). From the insignificant correlation of panicle length with yield and a direct effect which is not very high, it may be indicated that panicle length do not affect the yield directly. But an indirect effect can be noticed from the positive indirect effect through 1000 grain weight and negative indirect effects through tiller number and grain density. Considering the indirect effects of related characters, as in the case of grain density, it can be suggested that panicle length should not be very high or low.

Positive direct effect of secondary branches panicle^{-1} on yield was earlier reported by Reddy and Ramachandraiah (1990). Eventhough the direct effect of secondary branches was positive, the combined indirect effects through the characters which were highly correlated with secondary branches, namely, plant height, 1000 grain weight, grain density and duration to 50% flowering, led to the significant negative correlation of secondary branches with yield. The low positive direct effect and negative indirect effects by secondary branches panicle^{-1} together with the negative correlation with yield confirm the importance of reduced number of secondary branches panicle^{-1} for maximising the yield.

The positive direct effect of plant height was also supported by reports of Subramanian and Rathinam (1984a), Chaubey and Singh (1994), Lalitha and Sreedhar (1996) and Basavaraja *et al.* (1997). The negative indirect contribution through tiller number and 1000 grain weight by plant height were of such a magnitude that it led to a significant negative correlation of plant height with yield. High positive indirect effect exerted through grain density was cancelled by high negative indirect effect through 1000 grain weight. Low positive direct effect and highly significant negative correlation between plant height and yield confirm the importance of semidwarf plant ideotype for higher yield.

Panicle bearing tillers plant^{-1} showed positive direct effect on yield. This was reported also by Prasad *et al.* (1988), Babu and Soundrapandian (1990), Gravois and Mcnew (1993), Chaubey and Singh (1994), Lalitha and Sreedhar (1996) and Basavaraja *et al.* (1997). Negative indirect effect exerted through grain density by panicles plant^{-1} was seen to be cancelled by almost equal value of positive indirect effect exerted through 1000 grain weight on yield. The positive indirect effect through 1000 grain weight on yield by productive tillers was in agreement with the reports of Sundaram and Palanisamy (1994). The high positive correlation of panicle bearing tillers plant^{-1} was not as such reflected in its direct effect, but it is reflected in the higher positive indirect effect on yield through total tillers plant^{-1} and 1000 grain weight. Considering the high positive direct effect of tillers plant^{-1} and positive indirect effect on yield by panicle bearing tillers through total tillers plant^{-1}, it is evident that more emphasis should be laid on increased tillers plant^{-1} during selection. Moreover the total tillers showed high correlation with panicle bearing tillers and with yield. Hence for maximisation of yield during selection there should be more number of tillers, all of which bearing panicles. The new ideotype was concept in rice proposed by IRRI is in agreement with this result, as reported by Singh (1988).

Correlation of grain length with yield was partly exerted by its direct effect and partly by positive indirect effects through total tillers and 1000 grain weight. Negative indirect effects through panicle length and grain density had led to insignificant positive correlation of grain length with yield. Grain breadth exerted a positive direct effect and positive indirect effects through panicle length and 1000 grain weight. Grain breadth exerted negative indirect effect through tiller number.

This suggests that medium boldness indirectly increase the yield. Indirect positive effect through 1000 grain weight by length and positive direct effect of length was reported also by Jun (1985) and Moeljopawiro (1986). Low positive direct effect and insignificant positive correlation of grain length and breadth on yield indicated the absence of direct influence of these characters on yield. But the indirect influence on yield by both length and breadth was exerted through tillers plant^{-1}, 1000 grain weight, panicle length and grain density. Intercorrelations and indirect effects indicated that plants with more tillers and the reduced grain weight produce longer grains, which indirectly increase yield.

Highest negative direct effect exerted by 1000 grain weight on yield was reflected on the high negative correlation with yield. Thousand grain weight exhibited negative indirect effect through total tillers, which add to the high negative correlation exhibited by 1000 grain weight on yield. High negative direct effect of 1000 grain weight on yield and highly significant negative correlation with yield indicate the importance of 1000 grain weight during selection and increase in yield is achieved by reducing the grain weight.

The character tertiary branches panicle^{-1} showed negative direct effect on yield. The positive correlation value of tertiary branches with yield might be resulted from the positive indirect effects exerted through highly correlated characters like total tillers, secondary branches and 1000 grain weight. The positive correlation of tertiary branches panicle^{-1} with yield and the negative direct effects by it indicate that breeders should give more weightage on characters like tiller number and 1000 grain weight than compactness of panicle.

Negative correlation coefficient of number of grains panicle^{-1} is partly due to the negative direct effect of grains panicle^{-1} and negative indirect effects through tillers plant^{-1} and 1000 grain weight, combined with positive indirect effect through grain density on yield by grains panicle^{-1}. The negative significant correlation and negative direct effect between number of grains panicle^{-1} and yield suggest that panicles with reduced number of grains should be selected. But very low negative direct effect of grains panicle^{-1} on yield indicate that number of grain should not be too low to reduce the yield. The negative direct effect of number of grains panicle^{-1} was reported by Subramanian and Rathinam (1984a) and positive direct effect was reported by Prasad *et al.* (1988), Ramalingam *et al.* (1993), Sundaram and Palanisamy (1994) and Lalitha and Sreedhar (1996).

The negative correlation between duration to 50% flowering and yield was mainly due to the negative direct effect exerted by duration to 50% flowering on yield. This was reported earlier by Vanaja (1998). Eventhough the correlation with yield was insignificant, the indirect effects through highly intercorrelated characters like 1000 grain weight and secondary branches, indicate that duration to 50% flowering had an indirect influence on yield. The negative direct effect and indirect negative effect through 1000 grain weight suggest short to medium duration to 50% flowering for maximising the yield.

In general, the study of correlation and path analysis on yield and yield components of F_2 population of four crosses and their parents of diverse origin revealed that during yield improvement programme in rice, the emphasis must be given on the semidwarf plant type with more number of tillers which are fully productive, reduced number of secondary branches, compact panicle, longer grains with medium boldness, reduced 1000 grain weight coupled with short to medium duration to 50% flowering. Length of panicle, density of grain and number of grains panicle^{-1} should not be very high or very low.

5.2. EXPERIMENT NO. II

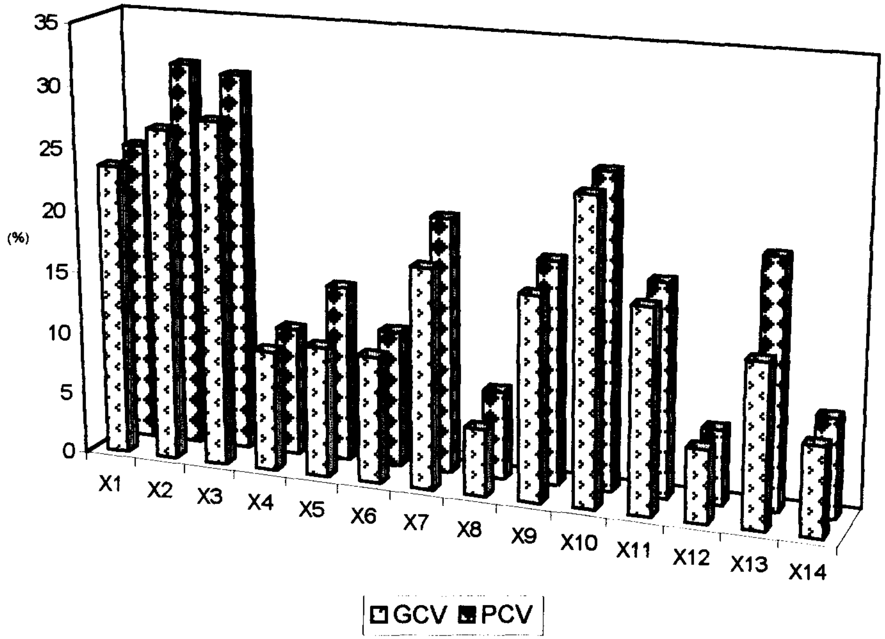
5.2.1. Genetic variability in F_3

Study of analysis of variances indicated significant differences among 105 genotypes for all the fourteen characters studied. This suggests the usefulness of all the characters for yield improvement. Large range of variation also existed in all the characters under study. Similar reports were given by Shamsuddin (1982), Marimuthu *et al.* (1990b), Amrithadevarathinam (1990), Reddy (1991) and Tiwari *et al.* (1993). From the results it was evident that mean performance of characters plant height at harvest, tillers and panicle plant^{-1}, tertiary branches panicle^{-1}, number of grains panicle^{-1}s and L/B ratio were increased and mean performance of grain breadth and duration to 50% flowering showed a decreasing fashion from F_2 to F_3 generation. For other characters, mean value remained almost the same. The increase in mean value might be the results of persistence of heterozygosity and expression of genes hidden in F_2, as suggested by Ganesan and Subramanian (1994).

5.2.2. Genotypic and phenotypic coefficients of variation

Analysis of the results revealed that there existed higher PCV than GCV for all the characters. This was also reported by Chaubey and Singh (1994) and Regina *et al.* (1994). Higher values of GCV and PCV were observed for the characters

Fig.2. Genotypic and Phenotypic coefficients of variation of fourteen characters in F_3



X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}
X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio
X11 - Thousand grain weight
X12 - Days to 50% flowering
X13 - Grain yield
X14 - Grain density

panicle bearing tillers plant^{-1} (which showed highest magnitude of GCV), total tillers plant^{-1}, plant height and L/B ratio. This suggests the existence of large variability and high chance of improvement of these characters through selection. The result was supported by Sundaram *et al.* (1988) for plant height; Basavaraja *et al.* (1997) for tillers plant^{-1} and productive tillers plant^{-1}; Amrithadevarathinam (1990) and Vanaja (1998) for tiller number plant^{-1}; Ganesan and Subramanian (1994) for productive tillers. Moderate variability for plant height, productive tillers, L/B ratio was reported by Vanaja (1998).

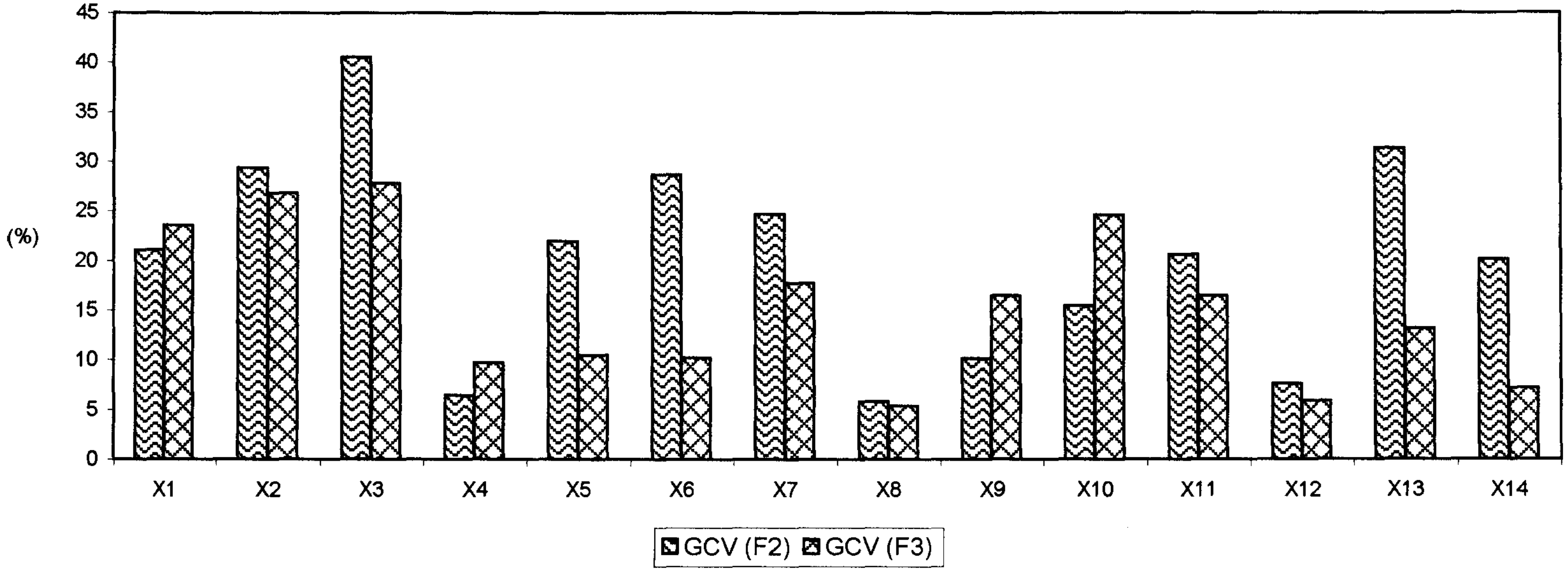
A moderate level of variability noticed in the characters namely, secondary branches, tertiary branches panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight, grain yield and grain breadth indicated the usefulness of these characters in breeding programme. Moderate GCV and PCV was also reported by Vanaja (1998) for number of grains panicle^{-1}, 1000 grain weight and secondary branches panicle^{-1}. Moderate variability of yield was reported by Ganesan and Subramanian (1994). Deviating from the result, high variability for grains panicle^{-1}, 1000 grain weight and yield was reported by Ganesan and Subramanian (1994) and Mishra *et al.* (1996). Similarly Tiwari *et al.* (1993), Basavaraja *et al.* (1997) and Vanaja (1998) also reported high variability of grain yield ha^{-1}. Very little scope of improvement through selection for the characters panicle length, grain length, duration to 50% flowering and grain density was reflected on the low GCV and PCV exhibited by them. Low variability of these characters, except grain density, was reported by Vanaja (1998). Lowest GCV was observed for grain length. Genotypic and phenotypic coefficients of variation of all the characters in F_3 are presented in Fig.2.

Considerable influence of environment was seen on yield ha^{-1}, grains panicle^{-1} and grain length as the PCV was much higher than GCV. Environmental influence on number of days to 50% flowering and plant height was minimum, which was indicated by nearly equal PCV and GCV. This was in agreement with reports of Reddy (1991), Mishra *et al.* (1996) and Vanaja (1998) for yield. Deviating from this result, Sahu and Sahu (1990) reported high environmental influence on plant height and duration to 50% flowering. Decreasing trend of variability for almost all characters from F_2 to F_3 except for L/B ratio was noticed from the results, as reported also by Ganesan and Subramanian (1994). Mishra *et al.* (1994) reported that amount of variability reduction vary with selection methods and environment. A comparison of genotypic coefficients of variations in F_2 and F_3 are shown in Fig.3.

5.2.3. Heritability

All the characters under the investigation exhibited moderate to high heritability. Highest heritability (94.8%) was noticed for duration to 50% flowering. The characters namely, plant height, L/B ratio, 1000 grain weight, panicle length, secondary branches panicle^{-1}, tertiary branches panicle^{-1}, total tillers plant^{-1}, panicle bearing tillers plant^{-1}, grain breadth and grain density also expressed high values of heritability in broadsense. Hence these characters have more reliable phenotypic performance and there could be more correspondence between phenotypic and breeding values. Subramanian and Rathinam (1984b) reported high heritability of plant height, 1000 grain weight, grain breadth, L/B ratio and panicle length. Similar reports were also given by Morales-ramos (1987), Sundaram *et al.* (1988),

Fig.3. Comparison of Genotypic coefficients of variation of fourteen characters in F_2 and F_3



X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}

X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio

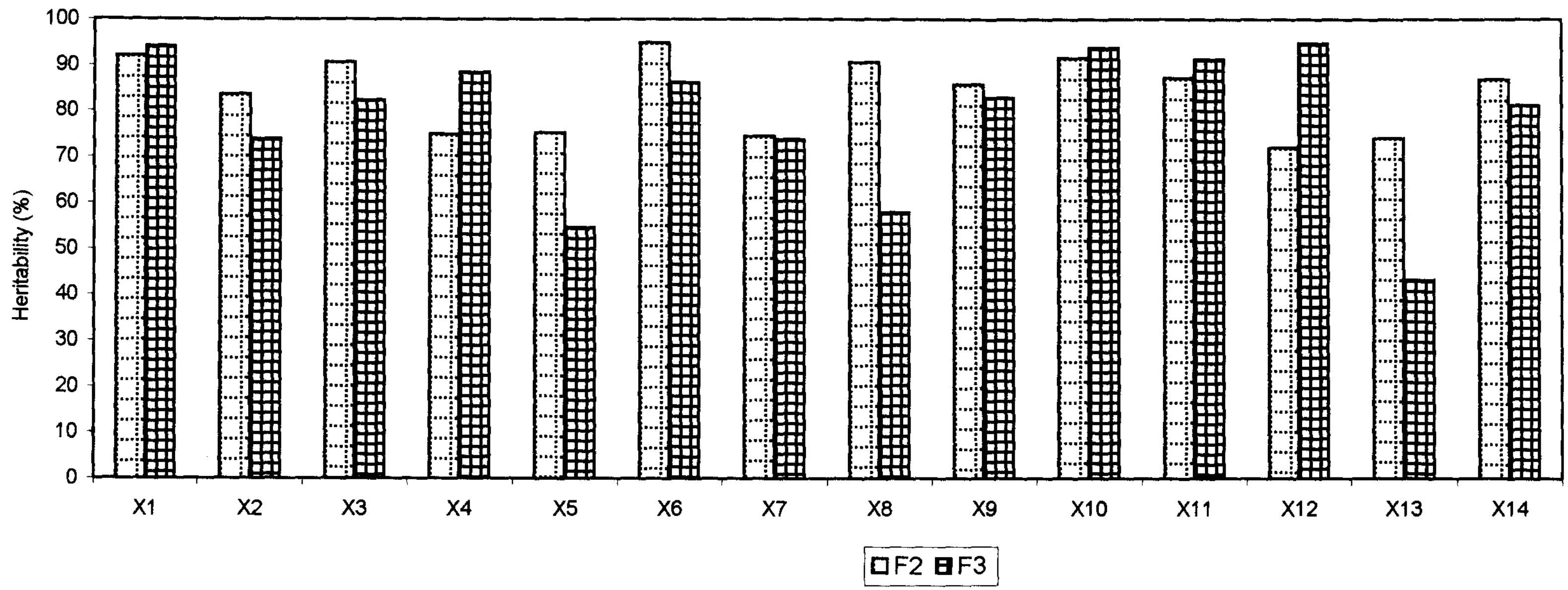
X11 - Thousand grain weight
X12 - Days to 50% flowering
X13 - Grain yield
X14 - Grain density

Marimuthu *et al.* (1990b), Singh *et al.* (1993), Regina *et al.* (1994) and Manomani *et al.* (1996) for plant height. Shamsuddin (1982) reported high heritability of 1000 grain weight and density. Reports of Marimuthu *et al.* (1990b), Roy *et al.* (1995) and Lalitha and Sreedhar (1996) for productive tillers plant^{-1}, days to 50% flowering, panicle length and 1000 grain weight; Reddy and Nerkar (1991), Santhalingam *et al.* (1992) and Yadav (1992) for number of effective tillers plant^{-1} and 1000 grain weight; Sreekumar *et al.* (1992) for 50% flowering days; Lokaprakash *et al.* (1992), Chaubey and Singh (1994), Paramasivam *et al.* (1995) and Govindarasu and Natarajan for 1000 grain weight; Chauhan and Chauhan (1994) and Reddy and De (1996) for grain breadth; Mishra *et al.* (1996) and Basavaraja *et al.* (1997) for total tillers hill^{-1}, also showed agreement with the findings of present investigation.

Moderate heritability was expressed by the characters number of grains panicle^{-1}, grain yield and grain length. Moderate heritability of yield was supported by the reports of Reddy and Nerkar (1991), Santhalingam *et al.* (1992), Yadav (1992) and Sreekumar *et al.* (1992). But in contrary to the results of present investigation, high variability of yield was reported by Sundaram *et al.* (1988), Chaubey and Singh (1994) and Manomani *et al.* (1996) and low heritability was noted by Basavaraja *et al.* (1997). Moderate heritability of grain length was also reported by Moeljopawiro (1986).

Comparing the heritability values of F_2 and F_3, it was evident that there was not much consistency in the heritability values of the characters studied. Grain yield showed a reduction in heritability from F_2 to F_3. In general, the heritability estimates tends to show a decreasing fashion, as reported also by Rao *et al.* (1986). A comparison of heritability estimates of F_2 and F_3 are shown in Fig.4.

Fig.4. Comparison of Heritability estimates of fourteen characters in F_2 and F_3



X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}

X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio

X11 - Thousand grain weight
X12 - Days to 50% flowering
X13 - Grain yield
X14 - Grain density

5.2.4. Genetic gain and genetic advance

Expected genetic advance showed moderate to high values for all the characters under study. Only grain length exhibited low GA. Highest expected genetic advance was observed for panicle bearing tillers plant^{-1} followed by L/B ratio, total tillers plant^{-1}, plant height at harvest, 1000 grain weight, tertiary branches panicle^{-1} and grain breadth. This suggests that these characters can be genetically improved through selection from a segregating population. A moderate level of expected GA was exhibited by secondary branches panicle^{-1}, number of grains panicle^{-1}, grain yield, grain density and panicle length. The low value of expected GA of grain length indicate little chance of genetic improvement through selection.

Reports similar to the results of present investigation were also reported by Shamsuddin (1982), Marimuthu *et al.* (1990b), Lokaprakash *et al.* (1992), Govindarasu and Natarajan (1995), Manomani *et al.* (1996) and Vanaja (1998) for 1000 grain weight; Basavaraja *et al.* (1997) and Vanaja (1998) for total tillers and panicle bearing tillers plant^{-1}; Sreekumar *et al.* (1992), Regina *et al.* (1994), Ganasan and Subramanian (1994) and Manomani *et al.* (1996) for plant height; Vanaja (1998) for plant height, tertiary branches and L/B ratio. Chauhan and Chauhan (1994) and Reddy and De (1995) reported high GA for grain breadth. Moderate expected GA was also reported by Vanaja (1998) for panicle length, secondary branches and duration to 50% flowering; Marimuthu *et al.* (1990b) for days to 50% flowering and panicle length; Sahu and Sahu (1990) for number of grains panicle^{-1} and grain yield. In contrast to the results observed, Vanaja (1998) reported high GA for yield and number of grains panicle^{-1} and moderate GA for grain breadth and length. High genetic advance for yield was reported by Shamsuddin (1982), Sundaram *et al.* (1988), Mishra *et al.* (1991) and Chaubey and Singh (1994).

Considering the coefficients of variation, heritability and expected genetic advance together for more reliable conclusion, a high heritability and genetic advance coupled with high GCV was observed for plant height at harvest, total tillers plant^{-1}, panicle bearing tillers plant^{-1} and L/B ratio. A high heritability, high expected genetic advance coupled with moderate GCV was exhibited by tertiary branches, 1000 grain weight and grain breadth. Hence the results indicated the role of additive gene action mainly governing the characters namely, plant height at harvest, tillers plant^{-1}, panicle bearing tillers plant^{-1}, tertiary branches panicle^{-1}, 1000 grain weight, L/B ratio and grain breadth. High heritability coupled with moderate to high genetic advance and moderate GCV, observed in the secondary branches panicle^{-1}, suggested that this character is also an important component of yield and is governed mainly by additive gene effects. The character panicle length exhibited high heritability and moderate to high genetic advance coupled with low to moderate GCV and the character grain density expressed high heritability coupled with moderate genetic advance and low GCV. Both these characters are governed mainly by additive genes but influence of environment reduced the variability. Duration to 50% flowering showed high heritability and moderate to low GA coupled with low GCV. This suggests environmental influence and the role of additive and dominance action controlling this trait. Both additive and non additive gene action controlling the characters namely, number of grains panicle^{-1} and grain yield, was evident from the moderate estimate of heritability and GA coupled with moderate GCV. For the character grain length, the estimate of heritability was moderate to high with low expected genetic advance and low GCV. This suggested that non-additive gene action mainly govern this trait. From the result, it is reflected that grain length and width are controlled by different genetic system. The chance of improvement of grain length through selection seems to be impossible due to low GCV and low GA.

Shamsuddin (1982) reported high heritability and GA for 1000 grain weight and Subramanian and Rathinam (1984b) suggested additive gene action for plant height, 1000 grain weight, grain width and L/B ratio. Sahu and Sahu (1990) reported the influence of environment on duration to 50% flowering and panicle length and moderate genetic gain of yield and number of grains panicle^{-1}, confirming the present results. Marimuthu *et al.* (1990b), Roy *et al.* (1995) and Lalitha and Sreedhar (1996) reported high heritability and GA for panicle bearing tillers plant^{-1} and high heritability with moderate to low GA for days to 50% flowering and panicle length. Chauhan and Chauhan (1994) and Reddy and De (1996) indicated high heritability and high to moderate GA for grain breadth, L/B ratio and 1000 grain weight. Basavaraja *et al.* (1997) reported high heritability with GA for total tillers and panicle bearing tillers plant^{-1}. Vanaja (1998) supported the role of additive gene action for number of total tillers plant^{-1}, plant height, number of tertiary branches and L/B ratio. High heritability, moderate GA and low GCV of panicle length and days to 50% flowering and the environmental influence on these characters were also observed by Vanaja (1998). High heritability with moderate GA and GCV of secondary branches panicle^{-1}, reported by Vanaja (1998), confirmed the result of present investigation. Contrasting to the results, Shamsuddin (1982) reported high heritability and GA for yield and grain number panicle^{-1}. Subramanian and Rathinam (1984b) reported additive gene action for grain length, grain number panicle^{-1} and dominance action for tiller number plant^{-1}. Deviating from the results, Sahu and Sahu (1990) reported poor genetic gain and low heritability for plant height and effective tillers. Chaubey and Singh (1994) and Paramasivam *et al.* (1995) reported that GA was highest for grain yield plant^{-1}. Chauhan and Chauhan (1994) and Reddy and De (1995) reported high heritability and GA for grain length and Govindarasu and Natarajan (1995) reported high heritability with high GA and less influence of environment on grain density. Kato (1989) reported that there was no clear evidence of dominance effect for grain breadth and that different genetic systems control grain length and width.

In general the characters namely, plant height at harvest, total tillers plant^{-1}, productive tillers plant^{-1}, secondary and tertiary branches, 1000 grain weight, L/B ratio and grain breadth are controlled by additive effects and provide good base for selection. The characters panicle length and grain density are also controlled by additive genes but are influenced by environment. In the character, duration to 50% flowering, non additive gene action plays the role along with the additive gene action and influence of environment prevails. Grain yield and number of grains panicle^{-1} are affected equally by additive and non-additive gene action. Non-additive (dominances and epistasis) genes control grain length which has little chance of improvement through selection because of its low GCV and low GA.

5.2.5. Correlation

In the present investigation correlation between yield and thirteen yield components in F_3 progenies were evaluated and results are discussed.

Among the thirteen characters, number of grains panicle^{-1} and grain density exhibited higher phenotypic correlation with yield than genotypic correlation. This confirms the environmental influence on these characters. Among the thirteen component characters, seven characters showed significant correlation with yield at both genotypic and phenotypic levels, which include panicle bearing tillers plant^{-1}, total tillers plant^{-1}, number of grains panicle^{-1}, tertiary branches panicle^{-1}, grain length, grain breadth and L/B ratio. Significant correlation, only at genotypic level, was exhibited by 1000 grain weight. Panicle length and plant height showed very low association with yield and absence of association for grain density, duration to 50% flowering and secondary branches were also noticed. Only genotypic correlation is discussed in detail. Genotypic correlations among different yield components in F_3 are shown in Fig.6.

Highest significant positive association with yield was expressed by grain length followed by L/B ratio, panicle bearing tillers plant^{-1}, total tillers plant^{-1}, tertiary branches panicle^{-1} and number of grains panicle^{-1}. Significant negative association was observed for grain breadth and 1000 grain weight with yield. This indicated that simultaneous selection on increased panicles, increased tillers, increased tertiary branches, increased number of grains panicle^{-1}, increased grain length , increased L/B ratio, reduced grain breadth and reduced 1000 grain weight would ultimately improve the grain yield. Eventhough panicle length and plant height showed negative correlation with yield, their correlation coefficient was insignificant. Reports of Prasad *et al.* (1988) also proved that contribution of days to 50% flowering, plant height and panicle length to yield was negligible. Mathew (1976) reported high correlation of tiller and panicle number with yield. Supporting evidents were also

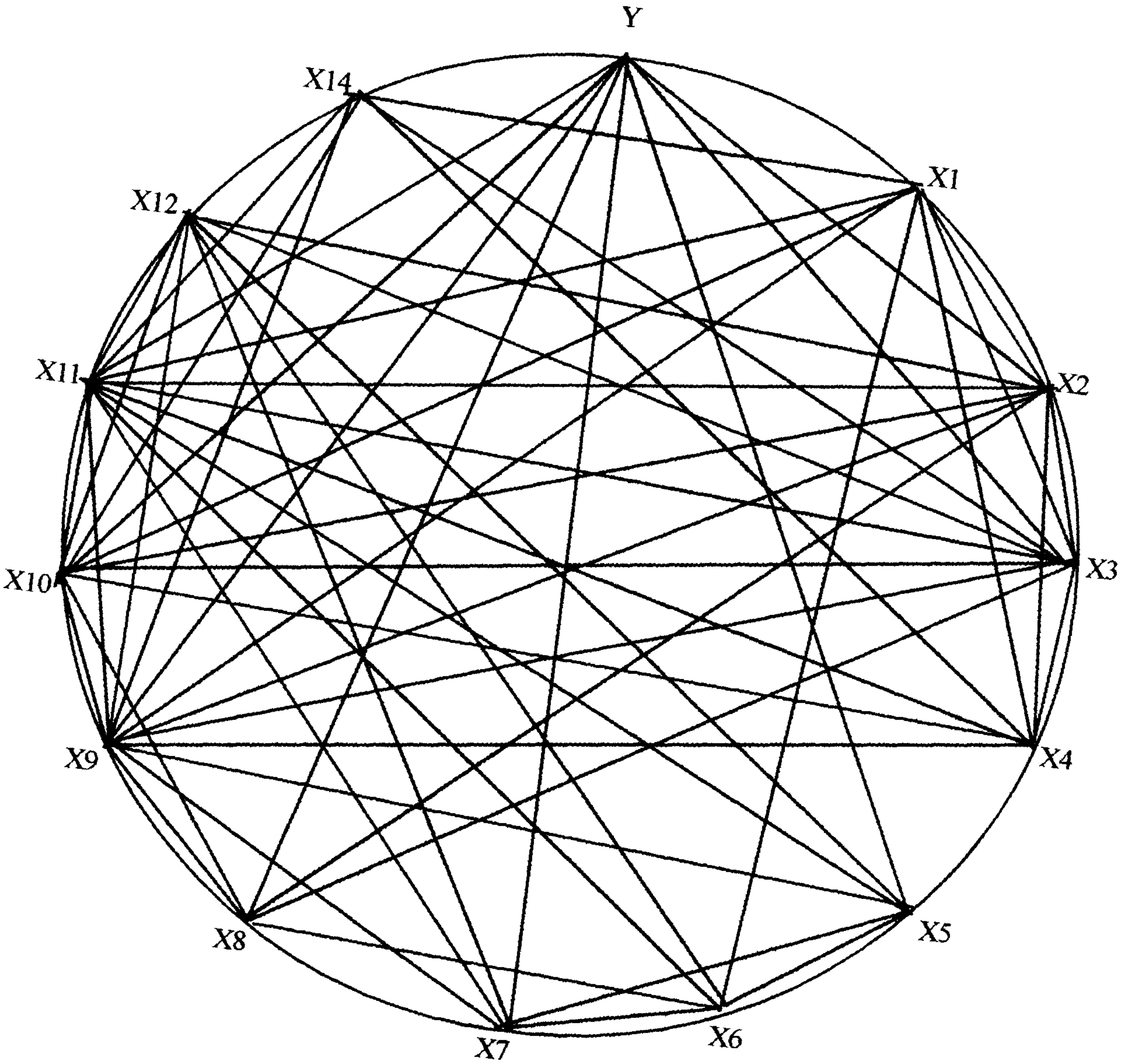


Fig.6. Genotypic correlation among different characters in F_3 generation

X1 - Plant height at harvest
X2 - Tiller number
X3 - Panicle bearing tillers
X4 - Panicle length
X5 - Number of grains panicle^{-1}
X6 - Secondary branches panicle^{-1}
X7 - Tertiary branches panicle^{-1}
X8 - Grain length
X9 - Grain breadth
X10 - L:B ratio
X11 - Thousand grain weight
X12 - Days to 50% flowering
X14 - Grain density
Y - Grain yield

Significant negetive correlation

Significant positive correlation

reported by Marimuthu *et al.* (1990a) and Reddy and Ramachandraiah (1990) for panicle number plant^{-1}, number of grains panicle^{-1} and secondary branches; Gomathinayagam *et al.* (1988) for grains panicle^{-1} and 1000 grain weight; Mishra *et al.* (1996) for total tillers hill^{-1} and number of grains panicle^{-1}; Sreekumar *et al.* (1992), Yadav (1992), Reddy and Nerkar (1992), Chaubey and Singh (1994), Rao *et al.* (1996) and Ganesan *et al.* (1996) for panicle bearing tillers plant^{-1}; Bai *et al.* (1992), Abd-el-samie and Hassan (1994), Sawant (1995), Yadav *et al.* (1995), Reddy *et al.* (1995), Yolanda and Das (1995) and Lalitha and Sreedhar (1996) for number of grains panicle^{-1} and productive tillers; Shi and Shen (1996) for grain length, breadth and L/B ratio; Morales-ramos (1987) and Vanaja (1998) for number of grains panicle^{-1} and 1000 grain weight and Vanaja (1998) for tertiary branches panicle^{-1}. Negative association of plant height with yield was also reported by Sivasubramanian and Madavamenon (1973), Mathew (1976), Reuber and Kisanga (1989) and Gupta *et al.* (1998). Slightly deviating from the results, Reddy and Ramachandraiah (1990) and Marimuthu *et al.* (1990a) reported highly significant positive correlation of plant height, panicle length and 1000 grain weight with yield. Similarly Gravois and Mcnew suggested negative correlation of productive tillers, with yield. Bai *et al.* (1992) reported positive correlation of panicle length and plant height and Shamsuddin (1982) reported positive correlation of 1000 grain weight and density and negative correlation of grain number panicle^{-1}, with yield. Chauhan and Chauhan (1994) indicated that there was no correlation for yield with grain length, breadth, L/B ratio and grain weight, which was contrary to the results of present investigation.

The highest significant positive association of grain length followed by L/B ratio, suggested the importance of long slender grains for improvement of yield. High correlation coupled with high heritability and GA indicate that L/B ratio can act as a good indicator of yield in yield trials in F_3. Strong negative correlation of grain breadth with yield confirms the possibility of developing high yielding genotype with longer, less bold or slender grains. Positive correlation of yield with tertiary branches and number of grains panicle^{-1} indicate compact panicle with more grain for high yielding genotypes. Significant negative correlation of 1000 grain weight with yield and L/B ratio and its positive association with grain breadth reveals that grain weight increase with boldness which in turn reduce the yield.

Panicle length, plant height, secondary branches panicle^{-1}, duration to 50% flowering and grain density exhibited insignificant association with yield. Though these characters showed absence of direct correlation with yield, indirect relation with yield is evident from their association with other characters like L/B ratio, panicle number and tiller number, which had high association with yield.

Correlation among the yield components revealed that selection based on high L/B ratio would bring correlated response of high number of tillers and panicles plant^{-1}, increased grain length, reduced grain breadth and grain weight, which would lead to increased yield. The increased duration, reduced height, shorter panicle and reduced density of grain along with the higher L/B ratio, is evident from the significant positive inter-correlation of L/B ratio with duration to 50% flowering and negative correlation with plant height, panicle length and grain density. Significant positive association of total tillers, panicle bearing tillers, grain length and L/B ratio among themselves and with yield reveal that if there are more tillers and panicles plant^{-1}, more longer and slender grains will be produced, which may ultimately increase the yield. In addition to this, selection for more tillers and panicles will bring correlated response of increased duration, shorter statured plants, shorter panicles with grains which are reduced in boldness, density and weight. Negative significant correlation of grain length with grain breadth and secondary branches panicle^{-1} indicated that selection for longer grains may reduce the secondary branches and boldness of grains. The correlation between length, breadth and L/B ratio was supported by Jun (1985) and Moeljopawiro (1986). Reports of Vanaja (1998) also supported that more tillers and panicles will produce slender grains. Negative association of 1000 grain weight and L/B ratio was suggested by Vanaja (1998) also.

Positive association between number of grains panicle^{-1}, tertiary branches panicle^{-1}, secondary branches panicle^{-1} and duration to 50% flowering indicate that compact panicles will produce more secondary branches and more grains with long duration to 50% flowering. Negative association of number of grains and tertiary branches panicle^{-1} with 1000 grain weight and grain breadth reveal that when number of grains and compactness of panicle increases, grains become more slender with reduced grain weight.

Heavier and bolder grains would be denser, was evident from the positive association existed between 1000 grain weight, grain breadth and grain density. Intense selection on heavier grains and higher grain breadth would simultaneously select for taller plants, longer panicles, denser grains, fewer tillers and panicles, reduced tertiary branches, reduced number of grains panicle^{-1} and reduced grains shape coupled with earliness. In addition to this, negative association of 1000 grain weight with secondary branches and negative association of grain breadth with length were also noticed.

Significant positive association between panicle length, plant height and grain density indicate that taller plants may produce longer panicle with denser grains. Eventhough there exist no association of these three characters with yield, indirect association is evident from the negative association with L/B ratio, tiller number and panicle number plant^{-1} and positive association with 1000 grain weight and grain breadth. Hence the results reveal that selection for shorter plant hight with shorter panicles and reduced grain density indirectly aid in yield improvement. Similarly indirect influence of secondary branches panicle^{-1} is evident from the positive association of this character with number of grains panicle^{-1} and tertiary branches and negative association with 1000 grain weight. But a positive association of secondary branches with tertiary branches panicle^{-1} and negative association with grain length, which had high positive correlation with yield, suggested that an intermediary number of secondary branches panicle^{-1} may indirectly improve the yield. Intercorrelation of duration to 50% flowering indicated that when number of days to 50% flowering increases a simultaneous increase in the characters namely, tiller and panicle number, tertiary and secondary branches, L/B ratio and number of grains and decrease in grain breadth and 1000 grain weight, was exhibited. Hence a long duration to 50% flowering favours the yield indirectly.

The results of correlation coefficient analysis were also supported by several workers. Reports of Marimuthu *et al.* (1990a) supported the positive intercorrelation between plant height and panicle length. Positive association of number of grains panicle^{-1} and number of tertiary branches, plant height and 1000 grain weight, grain breadth and 1000 grain weight was also reported by Vanaja (1998).

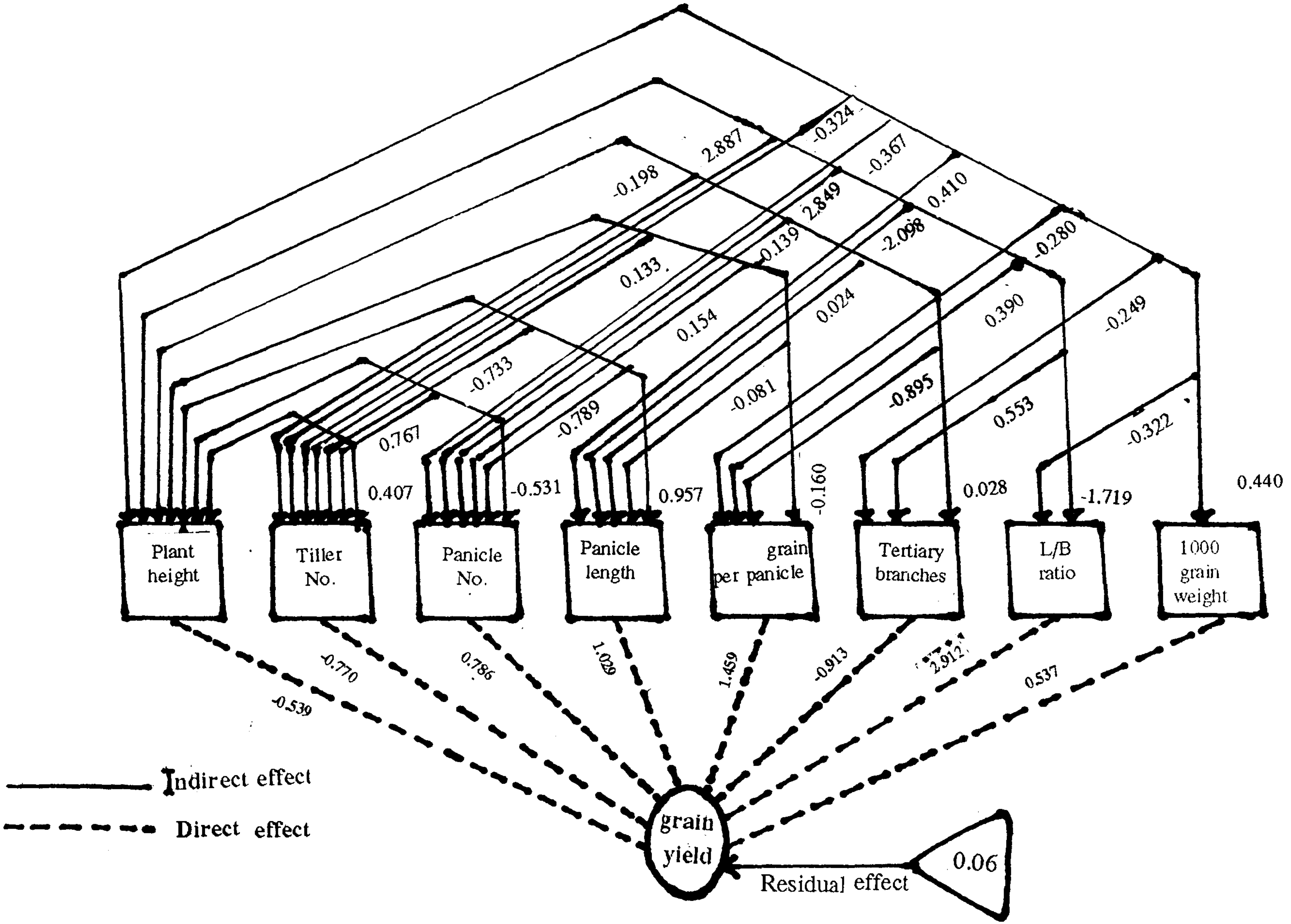
In general, the present investigation on F_3 generation of diverse crosses revealed that a strong correlation existed between yield and various characters which include positive association of L/B ratio, grain length, total tillers, panicle bearing tillers, tertiary branches panicle^{-1} and number of grains panicle^{-1} and negative association of grain breadth and 1000 grain weight. In addition to these characters, plant height, panicle length, secondary branches, duration to 50% flowering and grain density also showed indirect association with yield.

5.2.6. Path analysis

In the present investigation on F_3 population, a path coefficient analysis was performed, taking all the thirteen yield components. The cause and effect relationship is shown in Fig.8. The direct and indirect effects are discussed below.

The 99.6 per cent of variation existed in the grain yield was contributed by the yield components, which is evident from the residual effect (R = 0.06) of path analysis. Highest positive direct effect was exhibited by L/B ratio. Positive direct effects were also exhibited by the characters namely, total tillers plant^{-1}, panicle bearing tillers plant^{-1}, panicle length, number of grains panicle^{-1}, grain breadth, 1000 grain weight, duration to 50% flowering and grain density. High positive correlation and high positive direct effect of L/B ratio confirms the importance and usefulness of this character in assessing the yield. Comparing to the high positive direct effect,

Fig.8 Path diagram indicating the direct and indirect effects of the component characters on yield in F_3



slightly diminished correlation coefficient of L/B ratio with yield was exhibited because of the negative indirect effect exerted by panicle length, grain breadth, grain length and 1000 grain weight. A positive indirect effect was exerted on yield through panicle bearing tillers plant $^{-1}$ by L/B ratio. The results indicated that, in F_3, selection based on high L/B ratio is highly effective in increasing yield.

Second highest positive direct effect was exerted by number of grains panicle^{-1}. Negative indirect effects exerted on yield through secondary and tertiary branches panicle^{-1} and 1000 grain weight resulted in reduced correlation coefficient of number of grains to yield, comparing to its high positive direct effect. Positive significant correlation and high positive direct effect exerted by number of grains panicle^{-1} with yield suggest that selection for more number of grains panicle^{-1} is highly effective in improving the yield in F_3. Positive direct effect of number of grains panicle^{-1} was also reported by Prasad *et al.* (1988), Ramalingam *et al.* (1993), Sundaram and Palanisamy (1994) and Lalitha and Sreedhar (1996). But Subramaniam and Rathinam (1984a) and Vanaja (1998) reported negative direct effect of number of grains panicle^{-1}.

Panicle length exerted high positive direct effect on yield. Negative indirect effects through L/B ratio, panicle bearing tillers and plant height had led to insignificant negative correlation of panicle length with yield. Eventhough panicle length exhibited direct positive effect, its insignificant correlation and negative indirect effects exerted through important characters like panicle number and L/B ratio, indicate that length of panicle should be low, but not too low, for maximising the yield.

Grain breadth exerted a positive direct effect on yield. Highly significant negative correlation of grain breadth with yield was due to the negative indirect effects through the highly intercorrelated characters like L/B ratio, panicle number, plant height and number of grains panicle^{-1} . Though the effect of grain breadth on yield was positive, considering the negative indirect effects through various characters and negative correlation of grain breadth with yield together with the negative indirect effect through grain breadth on yield by characters like L/B ratio and panicle number, it can be indicated that grain breadth is an important yield component and medium boldness might be optimum to increase the yield.

High positive direct effect and high positive correlation of panicle bearing tillers indicated the importance of this character during selection. When panicle number increases, a simultaneous increase in L/B ratio is resulted, which increase the yield. This is evident from the high positive indirect effect through L/B ratio. Negtive indirect effects through tiller number, panicle length, grain length and grain breadth had led to the slightly diminished correlation coefficient of panicle number with yield compared to its high direct effect. Results revealed that, in F_3, productive tillers plant is highly reliable component and selection based on more number of panicle plant^{-1} will definitely result in higher yield. Positive direct effect of panicle bearing tillers plant^{-1} was supported by Prasad *et al.* (1988), Babu and Soundrapandian (1990), Gravois and Mcnew (1993), Chaubey and Singh (1994), Lalitha and Sreedhar (1996) and Basavaraja *et al.* (1997). Amrithadevarathinam (1990) reported positive direct effect of tiller number and yield.

The character, 1000 grain weight exhibited positive direct effect on yield. Negative correlation of 1000 grain weight with yield might be resulted due to highly negative indirect effects through L/B ratio, number of grains panicle^{-1}, panicle number and plant height. Hence, inspite of the positive direct effect, a reduced 1000 grain weight might be best for increasing yield, because of the undesirable indirect effects and negative significant correlation with yield.

Grain density exerted a low positive direct effect. An insignificant correlation with yield might be the result of negative indirect effect exerted through L/B ratio by grain density. This also suggest that grains with reduced density show high L/B ratio, which confirm the indirect influence of reduced density on yield.

The character, duration to 50% flowering exhibited the lowest direct effect on yield and lowest correlation with yield, which was insignificant, indicating that direct contribution of this character to yield is negligible. But indirect influence on yield was evident from high positive indirect effect exerted through L/B ratio and indirect effects through panicle number, grain breadth and panicle length, suggesting that long duration may increase the yield.

The character, tertiary branches panicle^{-1} showed highest negative direct effect on yield in F_3. Positive indirect effects on yield through number of grains panicle^{-1} and L/B ratio by tertiary branches panicle^{-1}, led to the significant positive correlation of tertiary branches with yield. The positive significant correlation and negative direct effect expressed by this character indicated that during selection, more weightage should be given on increased number of grains and high L/B ratio than the compactness of the panicle. This was further confirmed by the positive correlation of number of grains and L/B ratio with tertiary branches panicle^{-1}. Similar findings were also reported by Vanaja (1998). Though the direct effect of tertiary branches on yield was negative, an increase in the number of tertiary branches might result in higher yield because of the desirable indirect effects. But selection, based only on tertiary branches, may reduce the yield.

High negative direct effect was exterted also by total tillers plant^{-1}. High indirect positive effects through L/B ratio and panicle bearing tillers had led to highly significant positive correlation of total tillers with yield. Positive correlation with panicle bearing tillers and L/B ratio and positive indirect effects through them reveal that total tillers increase the yield through L/B ratio and panicle bearing tillers. Negative direct effect suggest that selection for plants with more number of tillers alone, might reduce the yield. But selection on plants with more number of tillers, all of which are productive, will increase the yield. Breeder should give more emphasis on panicle bearing tillers and L/B ratio than more number of tillers.

Grain length exerted negative direct effect on yield. The longer grains might be increasing the yield through the characters, L/B ratio and panicle number, which is evident from the high positive indirect effects through them on yield, which led to the highly significant positive correlation of grain length with yield. Hence, as in the case of total tillers, breeder should give more emphasis on L/B ratio and panicle number than the longer grains. The positive indirect effect through L/B ratio on yield by grain length was also reported by Jun (1985) and Moeljopawiro (1986).

Negative correlation of plant height with yield is the reflection of its negative direct effect on yield. Negative indirect effects through L/B ratio and panicle number combined with positive indirect effects through panicle length, grain breadth, 1000 grain weight and tiller number, led to the insignificant negative correlation of plant height with yield. Negative direct effect of plant height on yield and negative indirect effects through L/B ratio by plant height suggested that dwarf or semidwarf stature might increase the yield. Subramanian and Rathinam (1984a) reported a positive direct effect of 1000 grain weight, but deviating from the results, a positive direct effect was reported for plant height also. Chaubey and Singh (1994), Lalitha and Sreedhar (1996) and Basavaraja *et al.* (1997) also reported the same. Vanaja (1998) reported positive direct effect and negative correlation of 1000 grain weight to yield.

Secondary branches panicle^{-1} exerted negative direct effect on yield. The positive indirect effects through number of grains and grain length combined with negative indirect effects through L/B ratio and tertiary branches, reduced the high negative direct effect and led to insignificant negative correlation of secondary branches with yield. The result indicate that reduced number of secondary branches panicle^{-1} might be effective in increasing the yield.

Reports of several earlier workers also supported these findings. Positive direct effect of panicle length was also reported by Subramanian and Rathinam (1984a) and Gupta *et al.* (1998). The positive direct effects of number of grains panicle^{-1} and panicle length were also supported by Ramalingam *et al.* (1993) and Lalitha and Sreedhar (1996). Reports of Prasad *et al.* (1988) and Sundaram and Palanisamy (1994) confirmed the positive direct effect of number of grains panicle^{-1}. Abd-el-samie and Hassan (1994) reported that main contributors to yield were productive tillers and number of grains panicle^{-1}. Later Sawant (1995) and

Yadav *et al.* (1995) also reported the same. Deviating from the result, negative direct effect was observed for number of grains panicle^{-1} by Subramanian and Rathinam (1984a). According to Reddy and Ramachandraiah (1990), the highest direct contributors to yield was secondary branches panicle^{-1}. A positive direct effect of duration to 50% flowering was also noticed by Amrithadevarathinam (1990). But deviating from the result, Vanaja (1998) noticed negative direct effect for duration to 50% flowering and positive direct effect for tertiary branches panicle^{-1}.

In general, the correlation and path analysis studies conducted in F_3 generation revealed that during yield improvement programme, breeder should give emphasis for the characters L/B ratio, panicle bearing tillers, number of grains panicle^{-1}, grain breadth and 1000 grain weight. Indirect influence of secondary branches panicle^{-1}, plant height and panicle length was also confirmed. The character combination for higher yield include, semidwarf plant stature, higher number of productive tillers, higher number of grains, high L/B ratio of grain with reduced density and grain weight. Indirect influence of reduced secondary branches, compact panicle, intermediary panicle length and longer grains with medium boldness together with long duration to 50% flowering, was also revealed.

During path analysis in F_2 and F_3, it was evident that some characters like plant height, tiller number, secondary branches and grain length exhibited positive direct effects in F_2 and negative in F_3. The character, 1000 grain weight exhibited negative direct effect in F_2 and positive in F_3. The differences in the direct effects in F_2 and F_3 can be explained only based on the mean values of the characters in F_2 and F_3 populations in which study had done.

Direct and indirect effects of different characters vary with the population under study. For all the characters, there will be an optimum value for maximum yield. The character will exert a negative direct effect on yield, if the mean value of that character is higher than the optimum value, indicating that a reduction in mean value may increase the yield. Similarly if mean value of the character is lower than optimum value, an increase in the mean might increase the yield, as evidenced by the positive direct effect.

This can be further explained with reference to the mean values for the concerned characters in IR 36, in both F_2 and F_3 populations. IR 36 was identified as one of best accessions based on selection index and was present in both the experiments (F_2V_7 and F_3V_{103}). The mean values of IR 36 in F_2 and F_3 population can be compared to the optimum value to explain the differences in the direct effects of the characters namely, plant height, tiller number, secondary branches, grain length and 1000 grain weight. The population mean values of F_2 and F_3, mean values of IR 36 in F_2 and F_3 population and mean values of accession V_{82}, for these characters are presented in Table 14. The mean values of V_{82} can be considered as optimum value, or it can be near to optimum value, as V_{82} was ranked first based on selection index.

From the study it was revealed that emphasis on reduced plant height, increased tiller number, reduced secondary branches, increased grain length and reduced 1000 grain weight, ultimately increase the yield. This can be confirmed by comparing the F_2 and F_3 population mean values with the optimum value (mean value of V_{82}).

Table 14 Population mean of F_2 and F_3, mean values of IR 36 in F_2 and F_3 and mean values of accession V_{82} for the characters, plant height, total tillers, secondary branches, grain length and 1000 grain weight

Character	Mean		IR 36 (mean)		Mean
	F_2	F_3	F_2 V_7	F_3 V_{103}	V_{82}
Plant height (cm)	96.23	106.16	76.60	84.30	77.75
Tiller number plant^{-1}	9.59	13.34	13.40	24.80	19.85
Secondary branches panicle^{-1}	8.59	8.50	8.03	8.70	8.70
Grain length (mm)	8.20	8.46	8.97	9.90	9.00
1000 grain weight (g)	27.40	27.68	24.07	21.70	22.80

In the case of plant height the population mean of F_2 (96.23) and F_3 (106.16) is far above the optimum value and hence reduction in plant height increase the yield. The mean value of IR 36 in F_2 (76.6) is lower than optimum value (77.75) and that of IR 36 in F_3 (84.3) is higher than optimum value, which explains for the positive and negative direct effect of plant height in F_2 and F_3 respectively. Difference in the direct effects of F_2 and F_3 of other characters namely, tiller number, secondary branches and grain length can also be explained in the similar manner, as in plant height.

In the case of 1000 grain weight, comparison of the mean values of populations of F_2 (27.4) and F_3 (27.68) with the mean value of V_{82} (22.8), confirmed the role of reduced 1000 grain weight for increased yield. The mean value of IR 36 in F_2 (24.07) was higher than optimum value observed in V_{82} (22.8) and hence exerted a negative direct effect in F_2. But mean value of IR 36 in F_3 (21.7) was lower than optimum value, hence a further increase in the value of 1000 grain weight may increase the yield, as evidenced from the positive direct effect of 1000 grain weight on yield in F_3.

It is evident from the above facts that direct effects exerted by yield components on yield will depend upon the mean value in the population and the optimum value.

Results of evaluation of F_2 and F_3 can be summarised as follows:

Large variability and range of variation observed in F_2 and F_3 indicated the high scope of improvement for all the characters studied. But decreasing trend of

PLATE 6 SEGREGATION OBSERVED IN DIFFERENT CROSSES FOR PLANT HEIGHT

6A Plot with Tall plants

6B Plot with both Tall and dwarf plants

6C
Plots with mostely
dwarf plants

6D All plots with semidwarf plants

6E All plots with tall plants

PLATE 7 SEGREGATION FOR PLANT HEIGHT WITH IN THE PLOTS OF THE CROSS MATTATHRIVENI X MAHSURI

7A Plot with tall and dwarf plants 7B

7C plots with semidwarf plants

7D Plots with mostely dwarf plants

PLATE 8 SEGREGATION IN THE PANICLE CHARACTERISTICS

8A

8B

PLATE 9 DIFFERENCE IN THE PANICLE CHARACTERS OF FOUR SELECTED CROSSES

variability might be the result of increasing homozygosity from F_2 to F_3 generation. Higher value of PCV than GCV, in both generation, confirmed the role of environment on all the characters. All the characters showed moderate to high GCV and PCV in both generations, except panicle length, grain length and duration to 50% flowering. The character, grain density showed low GCV in F_3 generation. High heritability was noticed for all characters in both F_2 and F_3 , except grain yield, number of grains panicle^{-1} and grain length, which showed moderate heritability in F_3 generation. All characters exhibited moderate to high GA in both F_2 and F_3, but grain length exhibited low GA in F_3. Results of F_2 and F_3 indicated the effect of additive genes for plant height, total tillers, panicle bearing tillers, secondary and tertiary branches panicle^{-1}, 1000 grain weight, L/B ratio, grain breadth and grain density. Both additive and non additive gene action was noticed for duration to 50% flowering and non additive gene effects play role in deciding grain length, as evidenced by results of both F_2 and F_3 generation. Grain length and breadth were observed to be controlled by different genetic system. Results of F_2 indicated that additive gene effects controlled number of grains panicle^{-1} and grain yield, but F_3 results revealed that both additive and non additive genes control these characters. Similarly panicle length was observed to be controlled mainly by non additive gene action in F_2, while results of F_3 indicate that mostly additive gene action controlled this character. Correlation studies indicated that in both F_2 and F_3, positive correlation with yield was noticed for total tillers, productive tillers and tertiary branches and negative association with yield for 1000 grain weight, while duration to 50% flowering and panicle length exhibited absence of association in both generations.

In F_2, L/B ratio and grain length showed no association and number of grains panicle^{-1} showed negative association with yield, but these characters exhibited positive association with yield in F_3. Plant height, secondary branches and grain density showed negative association in F_2 but showed absence of association in F_3. But in both F_2 and F_3, all the characters exhibited either direct or indirect association with yield. Intercorrelation studies in F_2 and F_3 revealed importance of optimisation of characters in order to get higher yield. Path analysis in F_3 revealed importance of L/B ratio as an important component of yield. Path analysis in both F_2 and F_3 indicated that during yield improvement programmes in rice, breeder should give emphasis for semidwarf plants having more number of productive tillers and compact panicles, reduced number of secondary branches, more number of grains with high L/B ratio, reduced density and 1000 grain weight.

5.3. SELECTION INDEX

A better way to exploit genetic correlation with several traits having high heritability is to construct an index, called selection index, which combines information on all the characters associated with yield. Simultaneous selection model based on path analysis was developed by Hazel (1943). Selection indices involved discriminant function based on the relative importance of various characters. This technique provides information on yield components and thus aids in indirect selection for the improvement of yield. Hence a discriminant function analysis was carried out for isolating superior genotypes based on the genotypic correlation and direct effect of yield components on yield and eight simultaneous selection models were tried.

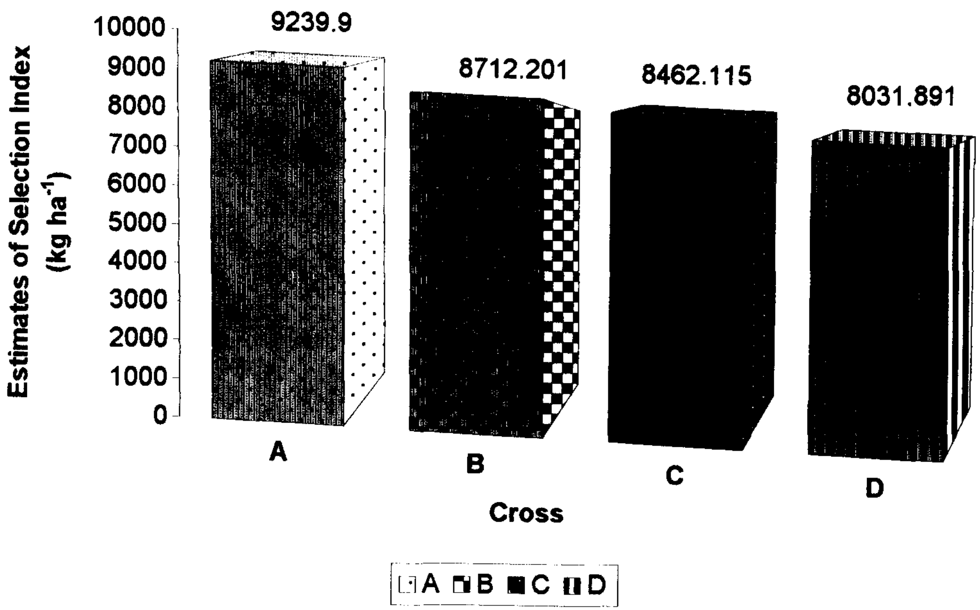
The selection index involving all the yield components, namely, yield ha^{-1}, plant height at harvest, total tillers $plant^{-1}$, panicle number $plant^{-1}$, panicle length, number of grains $panicle^{-1}$, secondary branches $panicle^{-1}$, tertiary branches $panicle^{-1}$, grain length, grain breadth, L/B ratio, 1000 grain weight, duration to 50% flowering and grain density, was observed to have maximum gain in efficiency (37%) over direct selection based on yield. But in order to formulate a selection index with minimum number of easily measurable characters, seven models were also tested. A model with yield ha^{-1} and four characters namely, total tillers $plant^{-1}$ (x_2), grain breadth (x_9), L/B ratio (x_{10}) and grain density (x_{14}), was selected for ranking 105 genotypes in F_3 and this model had 30.6 per cent gain in efficiency over direct selection based on yield alone. When ranking was done based on this model, it was found that first 9 ranks were allotted to the cross IR 36 x Mattathriveni and tenth rank was allotted to the parent, namely, IR 36. But based on yield alone, the cross, Vytilla 3 x Kaohsiung Sen Yu 338 was ranked first. The accession numbers, V_{14} and V_6, belong to the cross Vytilla 3 x Mattathriveni, got second and seventh rank respectively. Remaining seven ranks were allotted to accessions of cross, IR 36 x Mattathriveni. When both selection index and yield were considered, accession number V_{82}, belonging to the cross IR 36 x Mattathriveni, was found to be superior in performance.

Role of various yield components in formulating the selection indices were reported earlier also by several workers. Chalapathy (1978) and Sreekumar *et al.* (1992) reported that short statured plants having more number of panicle bearing tillers with shorter panicles and more number of grains, would increase yield and hence should be included in formulation of selection index. Importance of grain density and 1000 grain weight in formulation of indices were noticed by Shamsuddin (1982) and Govindarasu and Natarajan (1995). Considerable evidences were also given by Wu *et al.* (1987), Prasad *et al.* (1988), Mishra *et al.* (1991) and Reddy *et al.* (1995) for productive tillers and number of grains panicle^{-1}; Gravois and Mcnew (1993) and Chaubey and Singh (1994) for panicle number; Shamsuddin (1982), Subramanian and Rathinam (1984a) and Babu and Soundrapandian (1990) for panicle length and 1000 grain weight; Vivekanandan *et al.* (1992) and Manomani *et al.* (1996) for plant height and number of grains panicle^{-1}; Reddy and De (1996) for number of grains panicle^{-1}; Sreekumar *et al.* (1992) and Manomani *et al.* (1996) for days to flowering. Reports of Vanaja (1998) emphasised importance of days to 50% flowering, number of tertiary branches panicle^{-1} and number of grains panicle^{-1}.

In the present study, results of discriminant function analysis revealed that during yield improvement programme more emphasis should be given for the characters namely yield ha^{-1}, L/B ratio, grain breadth, grain density and total tillers plant^{-1}.

It is evident from the results that, in general, the cross IR 36 x Mattathriveni performed superior to all other crosses and parents. Order of superiority of different crosses in terms of higher estimates of selection index is presented in Fig.9. Vytilla 3 x Mattathriveni showed good performance followed by Vytilla 3 x Kaohsiung Sen Yu 338 and Mattathriveni x Mahsuri. Out of the five parents, IR 36, showed very good performance and that of Kaohsiung Sen Yu 338 was average followed by Mattathriveni. But ranks of Vytilla 3 and Mahsuri were lowest to all crosses and

Fig.9. Graphical representation of order of superiority of different crosses in terms of higher estimates of selection index



A - IR 36 x Mattathriveni
B - Vytilla 3 x Kaohsiung Sen Yu 338
C - Vytilla 3 x Mattathriveni
D - Mattathriveni x Mahsuri

PLATE 10 DIFFERENCE IN THE GRAIN CHARACTERISTICS OF SELECTED CROSSES

10A

10C

10B

10D

parents. IR 36 x Mattathriveni has all the desired ideotypic features as well as a high yield of 9.3 t ha^{-1}. The accession numbers 82 and 89 can be further used for development high yielding variety.

The present study strongly suggest that the plateau in rice productivity to a great extent could be overcome by trying a wide array of new crosses involving parents of diverse origin. This will further broaden the genetic base of high yielding rice varieties with adaptability to both biotic and abiotic stresses.

PLATE 11 SUPERIOR CROSS WITH DESIRABLE IDEOTYPIC FEATURES IDENTIFIED AMONG THE SELECTED CROSSES

11A Semidwarf plants with higher number of panicle bearing tillers and high yield

11B Higher number of panicles with higher number of grains and high L/B ratio of grain

Summary

6. SUMMARY

The present investigation of `Genetic analysis in F_2 and F_3 progenies of selected crosses of rice varieties of diverse origin' was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University during January, 1998 to January, 1999. The field trials were laid out at the Agricultural Research Station, Mannuthy of the Kerala Agricultural University.

The study was conducted with a view to understand the genetic architecture of yield and various yield contributing characters. Ultimate objective was to identify best genotype, among the four crosses, having economic characters recombined in suitable manner leading to maximum grain yield in Kerala condition.

The material consisted of seeds from four selected F_1 crosses, which were previously evaluated at Agricultural Research Station, Mannuthy. The crosses included Vytilla 3 x Mattathriveni, Vytilla 3 x Kaohsiung Sen Yu 338, Mattathriveni x Mahsuri and IR 36 x Mattathriveni. The parents of these crosses were of diverse origin. Seeds of crosses and parents were raised in plots laid out in RBD with three replication. Evaluation of F_2 generation was done during January to May 1998 and observation of fifteen characters, including colour of kernel, was taken. F_3 generation was raised during July to December 1998, with 105 genotypes laid out in RBD with two replications each. Observations of F_2 were repeated in F_3 also.

All the crosses showed good vigour and performance even under drought condition persisted from January to May. Diseases and pests were minimum except for slight susceptibility of Vytilla 3 and its crosses to bacterial leaf blight. Mahsuri was late flowering, hence was prone to severe rice bug infestation, which was the main cause for severe yield reduction in Mahsuri. All the crosses showed good segregation for all the characters studied. IR 36 x Mattathriveni exhibited uniform height and vigour.

Observations recorded in F_2 and F_3 were statistically analysed and the results are summarised as below:

1) There is ample scope of improvement through selection for all the characters under study, in both F_2 and F_3 generations, as evidenced by their high genetic variability and large range of variation.

2) Except for L/B ratio, all the characters showed decreased trend of variability from F_2 to F_3.

3) Generally PCV was higher than GCV for all the characters studied, in both F_2 and F_3 generations, indicating the environmental effects in the expression of characters.

4) In F_2 and F_3 generation, low GCV and PCV was observed for grain length, panicle length and duration to 50% flowering. In F_3 generation, grain density also showed low GCV and PCV.

5) Broad sense heritability estimates were higher in F_2 than F_3, in general. In F_2, all the characters showed high heritability. The characters, grain length,

grain yield and number of grains panicle^{-1} showed moderate heritability in F_3 and all other characters exhibited high heritability in F_3.

6) In F_2, all the characters showed moderate to high expected genetic advance, but grain length exhibited low genetic advance in F_3.

7) In both F_2 and F_3, the characters namely, plant height at harvest, total tillers plant^{-1}, productive tillers plant^{-1}, L/B ratio, 1000 grain weight, secondary branches panicle^{-1}, tertiary branches panicle^{-1} and grain breadth, exhibited higher values of heritability, genetic advance and genotypic coefficient of variation and hence provide great help in direct selection from phenotypic performance.

8) In F_2, panicle length was mostly influenced by non-additive gene effects. But in F_3, it was observed that both additive and non additive gene action influence this character. Duration to 50% flowering was governed by both additive and dominance effects in both F_2 and F_3.

9) Correlation studies in F_2 and F_3 revealed that positive correlation existed between yield and characters namely, total tillers, panicle bearing tillers and tertiary branches panicle^{-1}. Negative correlation was observed for yield with 1000 grain weight in both F_2 and F_3.

10) Grain length and L/B ratio showed high positive correlation with yield in F_3, but it showed no association with yield in F_2. Number of grains panicle^{-1} showed negative association with yield in F_2, but positive association in F_3. Character plant height, showed negative association with yield in F_2 but showed no association in F_3. Grain breadth showed absence of association in F_2, but negative association in F_3.

11) Panicle length and duration to 50% flowering exhibited absence of association with yield in both F_2 and F_3, which indicate that these traits can be recombined as desired.

12) From the inter correlation studies, in both F_2 and F_3, it was evident that optimisation of characters under selection is essential for maximising yield because of the association between characters which are positively associated with yield and characters which are negatively associated with yield.

13) Correlation study in F_2 and F_3 revealed that semidwarf plants with more number of tillers and panicles will produce compact panicles with long slender grains, which result in higher yield. The study also revealed that when the number of grains and compactness of panicle increases, grains become more slender with reduced grain weight

14) Correlation among various yield components suggested that taller plants will produce bolder, denser and heavier grains, but panicles and tillers will be lesser, thus reducing the yield.

15) Both in F_2 and F_3, characters selected for path analysis were counted for more than 99 percentage of variability.

16) Path analysis revealed that, in both F_2 and F_3, positive direct effect on yield was exerted by panicle length, panicle bearing tillers plant^{-1}, grain breadth and grain density. Tertiary branches exhibited negative direct effect in both F_2 and F_3.

17) The character L/B ratio was the most reliable yield component in improving yield in F_3.

18) Negative direct effect was exhibited by 1000 grain weight, duration to 50% flowering and number of grains panicle^{-1} in F_2, while in F_3 they exhibited positive direct effect. The characters plant height, total tillers plant^{-1}, secondary branches and the grain length showed positive direct effect in F_2 and negative direct effect in F_3.

19) Results of path analysis in F_2 and F_3 revealed that, for improving grain yield in rice, breeder should give emphasis on semidwarf plant stature, higher number of productive tillers, compact panicles, reduced number of secondary branches, longer grains with medium boldness, reduced density and grain weight. Path analysis in F_3 revealed that higher number of grains panicle^{-1} and high L/B ratio are highly effective in increasing the yield.

20) Discriminant function analysis revealed that selection index using minimum number of characters namely, yield ha^{-1}, total tillers plant^{-1}, L/B ratio, grain breadth and grain density, showed maximum efficiency over direct selection based on yield alone. Based on this model ranking of 105 genotypes in F_3 was done and found that IR 36 x Mattathriveni performed superior to all other crosses and parents. Based on both selection index and yield, accession number 82 followed by 89, belonging to IR 36 x Mattathriveni, were the best genotypes.

The study revealed that all the crosses are promising enough to draw superior segregants, the best among them being IR 36 x Mattathriveni. From the investigation, it was noticed that red kernel colour of Mattathriveni could be transferred to the cross IR36 x Mattathriveni. Kernel colour of IR36 x Mattathriveni was uniformly white in F_1 and it was segregated into white and red coloured kernels in F_2 and F_3. In accession number 89, which was identified as second best, based on selection index, one plant was observed to posses red coloured grains only. Such plants can be particularly selected from superior accessions identified in the study, for development of high yielding varieties in future.

The present investigation also suggested that trying of new crosses with parents of diverse origin, overcome the plateau observed in rice productivity, to a great extent, because the varieties developed by such crosses will have broad genetic base.

Based on the study, future line of research can be planned as below:

1) Screening of superior genotypes identified in the study, for pest and disease resistance and cooking qualities.
2) Development and release of variety with high yield, red kernel and preferable cooking qualities suited to Keralites.
3) Study of inheritance kernel colour in IR 36 x Mattathriveni, which was observed to segregate into white and red kernelled types in F_2 and F_3.

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Appendices

APPENDIX I

Mean performance of nine genotypes in F_2 for different qualitative and quantitative characters

Treatment No.	Plant height (cm)	Tiller No.	Panicle No.	Panicle length (cm)	No. of grains panicle^{-1}	Secondary branches	Tertiary branches	Grain length (mm)
V_1	100.48	8.67	8.08	25.05	73.18	6.17	17.01	8.34
V_2	103.29	6.52	6.17	25.15	67.51	5.96	14.16	8.2
V_3	84.73	9.41	9.03	25.75	106.68	8.88	26.6	7.68
V_4	70.2	12.6	12.49	22.27	81.81	7.32	23.31	8.99
V_5	113.77	9.09	9.03	27.3	93.82	6.92	21.63	8.07
V_6	83.53	11.5	11.43	26.6	115.0	9.32	27.93	7.67
V_7	76.6	13.44	13.05	23.56	89.67	8.03	27.5	8.97
V_8	96.67	10.73	10.4	27.2	79.33	11.07	35.67	8.0
V_9	136.8	4.3	1.0	23.96	134.2	13.6	25.5	7.97
Grand mean	96.23	9.59	8.96	25.2	93.46	8.59	24.37	8.21

Treatment No.	Grain breadth (mm)	L/B ratio	1000 grain weight (g)	Days to 50% flowering	Grain yield (kg ha^{-1})	Grain density (g ml^{-1})	Colour of kernel
V_1	3.31	2.52	27.03	75.0	5357.34	1.35	R
V_2	3.36	2.44	28.91	75.67	3714.79	1.35	R
V_3	3.36	2.3	22.83	82.67	6650.83	1.15	R
V_4	2.59	3.48	22.92	82.33	7331.57	1.2	W & R
V_5	3.6	2.24	28.0	78.33	7532.33	1.4	R
V_6	3.17	2.42	24.3	81.33	6981.81	1.22	R
V_7	3.0	2.99	24.07	84.0	7436.36	1.2	W
V_8	3.4	2.35	26.93	92.33	7198.22	1.35	W
V_9	2.75	2.9	20.81	94.33	1872.47	2.08	W
Grand mean	3.17	2.63	27.4	82.89	6008.41	1.37	

R - Red W - White

APPENDIX II

Treatment No.	Plant height (cm)	Tiller No.	Panicle No.	Panicle length (cm)	No. of grains $panicle^{-1}$	Secondary branches	Tertiary branches	Grain length (mm)
V1	109.4	11.6	8.7	25.25	113.6	7.55	20.8	8.55
V2	115.6	12.2	8.7	27.2	139.1	8.50	26.6	8.9
V3	115.65	9.55	7.55	26.05	123.85	8.05	22.7	9.0
V4	116.75	10.45	8.2	27	138.4	8.0	26.15	8.3
V5	120.25	9.35	7.5	28.65	128.1	8.45	24.2	9.0
V6	126.8	10.95	9.6	27.95	166.35	9.75	34.65	8.45
V7	113.9	11.65	9.1	26.05	151.8	8.05	24.95	8.75
V8	145.05	10.75	9.4	30.45	166.0	9.2	37.75	8.25
V9	123.3	11.1	9.9	30.15	137.5	9.2	39.85	8.3
V10	118.85	10.3	9.1	27.6	134.3	8.25	26.4	8.35
V11	138.9	12.2	10.25	28.85	114.95	7.70	22.2	8.6
V12	95.9	9.45	7.8	26.1	165.85	9.65	34.9	8.25
V13	139.3	10.5	9.7	28.2	164.0	9.45	34.45	8.45
V14	129.0	11.8	10.15	29.6	164.35	8.6	31.65	8.3
V15	128.45	11.4	8.1	28.75	142.25	8.85	28.45	8.35
V16	135.7	11.75	9.85	29.5	141.4	8.85	26.8	8.25
V17	139.45	10.35	8.4	27.9	134.5	8.25	26.1	8.2
V18	124.05	13.4	9.9	28.65	145.95	8.3	28.95	8.6
V19	93.95	12.6	9.15	25.9	133.4	8.6	26.75	8.25
V20	117.4	17.1	10.65	25.05	115.65	6.85	23.65	8.3
V21	122.8	15.1	10.95	26.45	109.05	6.80	23.6	8.35
V22	139.55	10.65	9.65	29.75	151.4	9.30	30.75	8.75
V23	112.7	12.35	9.95	24.25	116.25	7.5	23.7	8.1
V24	123.6	11.35	8.05	29.35	159.35	9.05	31.45	8.95
V25	142.15	9.95	8.25	29.85	156.75	9.05	31.25	8.6
V26	130.05	13.9	9.55	28.8	130.60	8.2	26.05	8.0
V27	128.85	12.3	8.2	28.2	120.2	7.7	23.85	8.0
V28	132.25	11.95	9.75	28	121.95	7.7	22.65	8.7

Contd....

Appendix II contd...

V29	134.2	11.07	8.35	28.4	145.25	7.7	29.22	8.0
V30	135.05	14	9.05	29.2	164.20	8.35	32.7	8.05
V31	128.15	10.75	8.05	27.5	120.70	7.45	21.8	8.3
V32	134.45	12.1	9.35	27.2	129.2	7.8	21.2	8.95
V33	129	11.75	8.05	27.95	121.5	7.8	22.25	8.4
V34	132.62	13.4	9.7	28.6	124.3	7.45	22.0	8.4
V35	132.35	11.3	9.1	28.05	127.15	7.4	23.45	8.4
V36	129.7	11.9	8.75	28.85	122.4	7.65	23.6	8.5
V37	133.25	11.35	8.67	28.4	125.6	7.8	22.0	8.75
V38	133.3	12.75	9.75	27.6	124.85	7.4	21.65	9.0
V39	132.6	10.55	8.65	27.65	120.0	7.55	22.65	8.65
V40	134.5	9.2	8.65	28.2	127.4	7.6	23.95	9.1
V41	129.85	11.9	9.7	27.95	121.75	7.3	22.0	8.65
V42	152.9	11.2	10.45	32.4	195.25	8.95	43.2	9.0
V43	133.7	12.55	9.2	28.1	125.1	7.75	23.25	8.7
V44	131.5	10.85	8.55	27.8	122.3	7.35	21.6	9.0
V45	139.25	12.2	9.15	28.5	123.1	7.75	22.75	8.5
V46	130.6	9.7	8.25	27.75	121.75	7.55	21.45	8.7
V47	131.45	10	7.85	27.5	127.0	7.58	22.4	9.25
V48	134.95	9.69	7.85	28.3	127.15	7.85	23.5	8.7
V49	131.4	9.3	7.35	27.8	122.1	7.8	23.15	9.05
V50	135.75	10.35	8.9	28.6	113.5	7.8	22.2	8.5
V51	142.65	12.3	10.6	30.95	138.35	8.65	31.05	8.05
V52	86.35	11.65	10.55	25.85	132.85	9.75	24.7	8.0
V53	140.5	11.65	9.8	30.45	159.0	8.5	35.4	8.4
V54	88.75	9.65	10.2	24.75	144.9	9.4	31.55	7.85
V55	84.65	13.5	12.2	25.05	134.0	9.2	22.55	8.0
V56	85.2	10.10	9.05	25.5	137.0	9.4	25.55	8.05
V57	85.55	11.45	9.85	25.45	133.95	9.55	19.45	8.0

Contd....

Appendix II contd...

V58	81.45	12.6	11.85	24.1	124.3	9.4	21.4	7.5
V59	84.5	12.25	10.9	24.75	132.3	9.35	22.75	8.1
V60	86.3	11.35	10.05	25.3	132.3	10.0	24.6	7.6
V61	80.6	10.05	9.35	24.3	130.35	9.25	23.1	7.6
V62	85.1	8.35	8.25	24.45	160.55	9.55	31.45	7.5
V63	80.95	10.6	9.7	24.75	133.35	9.4	23.95	7.6
V64	81.05	10.35	9.5	22.9	132.6	8.95	24.95	7.6
V65	80.65	10.3	10.1	23.35	141.05	8.65	28.5	7.5
V66	82.85	8	7.55	24.45	157.25	9.05	30.75	7.5
V67	83.1	10.05	9.45	24.25	141.05	9.85	24.25	7.5
V68	81.2	9.55	9.75	23.95	143.6	8.9	27.9	7.5
V69	85.05	8.9	8.2	24.35	157.65	9.65	31.35	7.5
V70	86	9.15	8.2	24.6	165.25	9.5	33.05	8.0
V571	84.05	11.85	11.1	25	138.7	9.35	25.05	8.0
V72	81.5	10	9.2	25.2	137.15	9.65	23.6	8.0
V73	82.85	10.2	9.2	25.8	134.75	9.3	24.8	8.0
V74	85.3	9.95	9	24.9	162.45	9.4	31.05	7.7
V75	81.8	11.9	10.95	25.75	134.05	9.3	24.7	8.0
V76	77.3	19.3	16.25	22.45	132.05	8.45	25.45	8.9
V77	74.3	18.1	15.6	22.4	131.95	8.6	24.7	9.05
V78	80.8	17.6	13.2	22.9	152.0	8.2	31.05	8.85
V79	83.15	17.25	14.15	22.1	150.5	7.95	31.8	8.95
V80	77	18.6	15.35	22.75	138.6	8.6	26.9	8.95
V81	77.75	19.4	16.2	22.6	138.65	8.45	29.55	8.9
V82	77.75	19.85	17.1	23.1	146.8	8.7	30.20	9.0
V83	76.5	18.35	16.1	22.7	147.65	8.55	29.1	8.9
V84	77.3	19.75	16.2	22.6	143.6	8.55	29.1	9.0
V85	83.05	18.75	14.45	22.55	158.45	8.15	33.95	9.0
V86	82.5	19.9	16	23.2	158.95	8.0	32.95	9.05

Contd....

Appendix II contd...

V87	82.2	19.15	14.7	22.75	154.25	7.85	32.5	9.15
V88	81.4	18.1	13.45	22.2	154.05	7.8	30.75	9.05
V89	74.6	18.6	15.85	22.45	126.35	8.25	23.65	9.35
V90	77.5	21.15	16.75	22.4	133.90	7.9	25.75	9.0
V91	74.95	22.15	19.04	22.75	121.8	8.2	23.6	9.0
V92	74.1	18.95	16.65	22.5	127.1	8.4	25.25	8.9
V93	82.85	18.95	16.85	22.25	154.0	8.35	30.9	9.05
V94	76.75	18.25	16.15	23.3	135.85	8.5	24.6	8.9
V95	78.45	18.1	13.75	22.45	143.0	8.15	29.85	8.85
V96	75.4	19	15.6	23.6	131.15	8.6	26.7	9.0
V97	82.3	20.55	17	22.6	152.15	8.05	32.0	8.8
V98	76.6	19.8	17.2	22.65	130.45	8.25	26.8	8.95
V99	82.05	19.5	16.15	22.05	145.2	7.95	31.5	8.9
V100	83.15	20.35	15.45	22.9	148.15	8.0	31.75	9.0
V101	145	17	7.9	26.8	205.9	12.9	52.4	7.0
V102	95.5	16.8	12.5	27.3	163.6	10.5	36.5	8.3
V103	83.5	24.8	21	23.4	137.0	8.7	27.92	9.9
V104	128.7	13.2	8.5	26.9	93.10	6.6	16.5	8.4
V105	90.7	9.9	7.8	25.8	143.4	9.6	30.9	7.9
Grand mean	106.16	13.34	10.91	25.97	138.82	8.50	27.19	8.46

Appendix II contd....

Treatment No.	Grain breadth (mm)	L/B ratio	1000 grain weight (g)	Days to 50% flowering	Grain yield (kg ha^{-1})	Grain density (g ml^{-1})	Colour of kernel
V1	3.4	2.51	32.25	75.0	5357.34	1.44	R
V2	3.3	2.7	32.15	78.5	6647.04	1.29	R
V3	3.0	3.0	36.5	75.0	5124.98	1.33	R
V4	3.2	2.6	32.15	74.0	5332.89	1.46	R
V5	3.5	2.57	32.85	80.0	5488.21	1.46	R
V6	3.1	2.72	31.85	74.0	7655.28	1.42	R
V7	3.15	2.78	31.15	74.5	6286.71	1.35	R
V8	3.0	2.75	27.0	69.5	6714.78	1.24	R
V9	3.25	2.57	30.65	75.0	7219.76	1.25	R
V10	3.25	2.59	31.0	71.5	5799.48	1.51	R
V11	3.05	2.82	32.5	78.5	6453.2	1.44	R
V12	3.0	2.85	28.35	78.0	5947.96	1.42	R
V13	3.0	2.82	29.0	77.0	6542.28	1.41	R
V14	3.2	2.6	33.3	77.5	8568.42	1.39	R
V15	3.1	2.7	32.15	75.0	5618.72	1.4	R
V16	3.1	2.66	30.15	75.0	6767.74	1.47	R
V17	3.05	2.69	27.65	75.0	5247.18	1.35	R
V18	3.05	2.82	30.35	75.0	6951.41	1.48	R
V19	3.1	2.66	27.85	70.0	5559.51	1.39	R
V20	3.0	2.77	28.3	73.5	5665.87	1.38	R
V21	3.05	2.74	29.0	75.0	5810.09	1.35	R
V22	3.55	2.47	32.8	75.0	7294.17	1.37	R
V23	3.15	2.57	31.65	75.0	6408.82	1.47	R
V24	3.25	2.76	28.45	82.0	5867.2	1.29	R
V25	3.0	2.87	28.5	75.0	6355.62	1.39	R
V26	3.0	2.67	32.1	75.0	5790.23	1.19	R
V27	3.0	2.67	34.25	75.0	5254.38	1.14	R
V28	3.0	2.9	32.85	82.5	5646.32	1.13	R

Contd....

Appendix II contd...

V29	3.0	2.67	29.0	87.0	5264.10	1.21	R
V30	3.0	2.68	28.5	80.0	6634.44	1.24	R
V31	3.15	2.65	34.75	75.0	5170.58	1.2	R
V32	3.35	2.7	34.3	75.0	6084.41	1.18	R
V33	3.25	2.59	32.65	75.0	4848.53	1.17	R
V34	3.30	2.56	32.5	74.0	5398.51	1.21	R
V35	3.25	2.59	34.2	74.0	5772.12	1.18	R
V36	3.30	2.58	34.75	74.0	5770.19	1.2	R
V37	3.4	2.58	34.5	74.0	5888.40	1.15	R
V38	3.3	2.75	34.5	75.0	5896.68	1.17	R
V39	3.9	2.22	35.15	75.0	5453.70	1.25	R
V40	3.2	2.85	33.9	79.0	5609.82	1.19	R
V41	3.25	2.66	34.05	79.0	5912.49	1.19	R
V42	3.0	3.0	27.3	79.0	9226.35	1.14	R
V43	3.3	2.64	34.05	75.0	5701.64	1.26	R
V44	3.35	2.72	32.75	75.0	4914.19	1.19	R
V45	3.2	2.66	33.65	75.0	5597.15	1.22	R
V46	3.3	2.64	34.0	80.0	5211.86	1.24	R
V47	3.35	2.78	33.8	75.0	5075.60	1.15	R
V48	3.5	2.51	34.15	75.0	5193.02	1.22	R
V49	3.5	2.63	34.65	80.0	4549.74	1.17	R
V50	3.5	2.46	33.4	82.0	4696.17	1.26	R
V51	3.0	2.68	23.8	81.0	5635.75	1.19	R
V52	3.0	2.67	24.8	74.5	5553.38	1.24	R
V53	3.0	2.8	27.4	80.0	6854.64	1.3	R
V54	3.0	2.62	24.0	74.0	5439.36	1.2	R
V55	3.0	2.67	24.8	75.0	6408.56	1.24	R
V56	3.0	2.68	24.35	74.0	5094.36	1.22	R
V57	3.0	2.67	24.65	74.0	5395.30	1.23	R

Contd....

Appendix II contd...

V58	3.0	2.52	24.15	76.5	6035.68	1.21	R
V59	3.0	2.7	24.3	76.0	5441.13	1.22	R
V60	3.0	2.55	24.7	75.0	5218.16	1.24	R
V61	3.0	2.53	23.65	75.0	4990.42	1.18	R
V62	3.0	2.5	24.5	75.0	4740.81	1.24	R
V63	3.0	2.53	24.95	76.5	4850.12	1.25	R
V64	3.0	2.53	25.55	75.0	4923.19	1.28	R
V65	3.0	2.5	23.7	75.0	5451.97	1.18	R
V66	3.0	2.5	24.15	78.0	4550.75	1.21	R
V67	3.0	2.5	23.45	77.5	4938.06	1.17	R
V68	3.0	2.5	24.25	75.5	5150.06	1.21	R
V69	3.0	2.5	22.35	77.5	4765.58	1.15	R
V70	3.0	2.67	24.05	80.5	5372.82	1.20	R
V71	3.0	2.67	24.25	75.0	6262.63	1.21	R
V72	3.0	2.67	25.05	76.0	4943.26	1.25	R
V73	3.0	2.67	24.35	77.0	5046.26	1.22	R
V74	3.0	2.67	24.2	77.0	5484.92	1.21	R
V75	3.0	2.67	23.9	77.0	5206.41	1.19	R
V76	2.1	4.27	24.15	84.0	7581.17	1.24	R &W
V77	2.0	4.53	22.85	85.0	6898.59	1.2	W
V78	2.15	4.12	23.8	78.5	6637.91	1.19	R &W
V79	2.05	4.37	22.6	75.0	6266.83	1.22	R &W
V80	2.05	4.37	22.45	79.0	6546.93	1.18	R &W
V81	2.1	4.27	23.80	75.0	7605.97	1.19	R &W
V82	2.0	4.50	22.8	79.0	8301.06	1.2	W
V83	2.15	4.16	24.2	80.5	8238.32	1.24	R &W
V84	2.0	4.5	22.3	84.0	8087.01	1.17	W
V85	2.0	4.5	22.7	79.0	7734.65	1.18	W
V86	2.15	4.23	22.25	79.0	7346.75	1.2	R &W

Contd....

Appendix II contd...

V87	2.0	4.57	22.65	78.0	7122.16	1.16	W
V88	2.0	4.53	21.55	78.0	5804.05	1.13	W
V89	2.05	4.56	23.9	78.0	7321.78	1.19	R &W
V90	2.1	4.3	22.3	83.0	6918.34	1.17	R &W
V91	2.0	4.5	21.8	86.5	6306.75	1.12	W
V92	2.1	4.24	23.45	89.0	6512.52	1.21	R &W
V93	2.0	4.53	21.65	84.0	6354.13	1.14	W
V94	2.1	4.25	25.0	84.0	7366.52	1.25	R &W
V95	2.1	4.21	23.4	79.0	5941.90	1.17	R &W
V96	2.0	4.5	22.7	79.0	6378.51	1.16	W
V97	2.2	4.0	22.25	82.0	6872.53	1.17	R &W
V98	2.05	4.37	23.5	78.0	7366.51	1.17	R &W
V99	2.1	4.25	22.5	83.0	6683.75	1.18	R &W
V100	2.0	4.5	20.9	75.0	6698.77	1.16	W
V101	3.0	2.33	19.45	106.0	3639.19	1.30	W
V102	3.2	2.65	26.6	87.0	6499.07	1.27	W
V103	2.0	4.95	21.7	84.0	5938.0	1.21	W
V104	3.4	2.48	34.35	78.0	4116.27	1.14	R
V105	3.1	2.55	25.9	79.0	4346.11	1.30	R
Grand mean	2.87	3.07	27.67	77.75	6003.77	1.24	

GENETIC ANALYSIS IN F_2 AND F_3 PROGENIES OF SELECTED CROSSES OF RICE VARIETIES OF DIVERSE ORIGIN

By

K. V. FASEELA

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

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Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR
Kerala, India

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ABSTRACT

The research project `Genetic Analysis in F_2 and F_3 Progenies of Selected Crosses of Rice Varieties of Diverse Origin' was carried out in the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period January to December, 1998. The major objectives of the study were to understand the various genetic parameters of characters under study, identification of yield components and formulation of selection model so as to isolate promising lines having desirable ideotypic features from the segregating generations. The high yielding varieties developed from such lines will have a broad genetic base as the parents of selected crosses are of diverse origin.

Components of heritable variation revealed that the characters showed decreased trend of variability from F_2 to F_3. PCV was higher than GCV in both generations for all the characters studied. Low PCV and GCV were observed for grain length, panicle length and duration to 50% flowering in both generations, while grain density showed low PCV and GCV in F_3 only. In general, broad sense heritability estimates were observed to be higher in F_2 than F_3. The characters, plant height at harvest, total tillers plant^{-1}, L/B ratio, 1000 grain weight, secondary branches panicle^{-1} and tertiary branches panicle^{-1} provided great help in direct selection from phenotypic performance, as they exhibited higher values of genotypic coefficient of variation, heritability and expected genetic advance. The

character, grain length showed little scope of improvement through selection due to low GCV and GA.

Correlation studies in F_2 and F_3 revealed that positive correlation existed between yield and component characters, namely, total tillers, panicle bearing tillers and tertiary branches panicle^{-1}. Negative correlation was observed for 1000 grain weight with yield in both the generations. Panicle length and duration to 50% flowering exhibited absence of association with yield in F_2 and F_3, which indicate that these traits can be recombined as desired. In F_3, L/B ratio and grain length exhibited positive correlation and grain breadth exhibited negative correlation, with yield, while these characters showed absence of association with yield in F_2. Plant height and number of grains panicle^{-1} exhibited negative association with yield in F_2 where as number of grains panicle^{-1} exerted positive association with yield in F_3 and plant height showed absence of association with yield in F_3.

Genotypic correlation among different yield components in F_2 and F_3 revealed that semidwarf plants with higher number of productive tillers produced grains with higher L/B ratio and lesser grain weight, which in turn increased the yield. The study also showed that, when number of grains and compactness of panicles increase, grains become more slender with reduced grain weight.

Study of path coefficient analysis revealed that all the characters influenced the yield directly or indirectly through some other traits. The correlation and path analysis study suggested that during selection, breeder should give emphasis on semidwarf plant stature, higher number of productive tillers, compact panicles, reduced number of secondary branches, high L/B ratio of grains with reduced density and weight.

A selection model was formulated consisting of the characters, namely, yield ha^{-1}, total tillers $plant^{-1}$, L/B ratio, grain breadth and grain density. Using this model, ranking of 105 genotypes in F_3 was done and identified that the accessions, V_{82} and V_{89}, belonging to IR 36 x Mattathriveni, were the best genotypes. Study revealed that all the four crosses namely, Vytilla 3 x Mattathriveni, Vytilla 3 x Kaohsiung Sen Yu 338, Mattathriveni x Mahsuri and IR 36 x Mattathriveni, were promising enough to derive superior segregants, the best among them being IR 36 x Mattathriveni.

The plants with red kernel, identified in F_3 of the cross IR 36 x Mattathriveni, can be used for the development of high yielding varieties with red kernel and preferable cooking qualities suited to Keralites, as well as resistance to biotic and abiotic stresses. This investigation also suggested that crosses from parents of diverse origin will broaden the genetic base of the varieties to be developed in future and will help to break the yield plateau in rice.