CONVERGENT BREEDING FOR NEW PLANT TYPE IN RICE (*Oryza sativa* L.)

BY

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THESIS

submitted in partial fulfilment of the requirement for the degree of

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2005

DECLARATION

I hereby declare that this thesis entitled **"Convergent breeding for new plant type in rice (*Oryza sativa* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Convergent breeding for new plant type in rice (*Oryza sativa* L.)"** is a record of work done independently by **Mrs. Divya Satheesh**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Dedicated to my Husband and little love Devika

INTRODUCTION

1. INTRODUCTION

Rice is the single most important food crop of the world and a primary food source for more than one third of the world's population. Rice occupies the largest area among all the crops grown in India, having an area of 43 million hectares with a production of 78 million tons.

Major increase in rice production had occurred during the last 35 years due to large scale adoption of high yielding semidwarf varieties and improved technology. World's rice production doubled from 257 million tons in 1965 to 520 million tons in 1990 with present production of 599 million tons. This has to be further increased to 800 million tons to meet the demand in 2025. Major increase in area planted to rice are unlikely and hence the increased demand for rice will have to be met from less land with less water, less labour and less pesticides (Khush, 1995).

Quantum jump in yield potential of rice during the 1960's was primarily due to the modification of plant type from low tillering tall varieties to high tillering semidwarf varieties. Effective partitioning of total dry matter production and increasing harvest index was achieved as a result of this. After the green revolution which occurred through this modified plant type, a significant improvement in yield was not possible during the past 40 years. Attempts to increase yield potential have not given promising results and research works were mostly concentrated on improving the adaptability by incorporating pest and disease tolerance and other components of adaptability.

To break the yield potential barrier, further modification of the present high yielding plant type was proposed and this new plant type concept considers combination of traits that directly or indirectly results in high yield expression. To achieve this plant type, characters present in different varieties and their gene action are to be studied and desirable characters are to be combined through convergent breeding. The major components of the proposed modifications were low tillering capacity, long panicles with more than 200 grains, short stature, thick and sturdy stem, vigorous root system, 120-130 days growth duration and harvest index of 0.6 (Khush, 1996). This plant type as such could not be adopted under Kerala conditions due to varied agroecological situations prevailing in the state. In the present study a set of varieties having high degree of expression of different characters and adaptability to Kerala condition is used for analyzing their combining ability, heterosis, character association and gene action involved.

Combining ability analysis provides useful information in selection of parents in terms of performance of their hybrids. Combining ability analysis also elucidates the nature and magnitude of various types of gene action involved in the expression of quantitative traits. Correlation and path analysis reveal the strength of relationship among group of characters and their direct and indirect influence on grain yield.

In order to formulate efficient breeding programmes for improvement of yield, it is essential to characterize the nature and mode of gene action that determine yield and its components. The success of any plant breeding programme depends to a greater extend on understanding the genetic architecture of the population handled by the breeder. Hence the present study was undertaken with the following objectives.

1. To identify donor parents for evolving an ideal plant type through combining ability analysis for grain yield and its component characters.
2. To determine the nature of gene action involved in the expression of quantitative traits.
3. To determine the heterotic effects for different characters.
4. To determine the phenotypic and genotypic correlations between yield and yield components.
5. To find out the direct and indirect effect of different yield contributing characters on grain yield.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is the only major cereal crop that is consumed largely by human beings. More than 90 per cent of the world's rice is grown and consumed in Asia where 60 per cent of the earth's people live (Khush, 1997). Genetic improvement of economic traits is a continuous one and the efforts are always to make the better, the best. A clear understanding of the gene action involved, character association, heterosis, breeding and selection methods of targetted characters are necessary in rice breeding programme and should be secured fairly in advance. The available literature on grain yield and selected component characters in rice are reviewed below under the following headings.

1. New plant type
2. Combining ability analysis
3. Heterosis
4. Phenotypic and genotypic correlation
5. Path analysis

2.1 NEW PLANT TYPE

Plant physiologists proposed increased photosynthetic efficiency and greater sink size as possible approaches to increase yield potential (Yoshida *et al.*, 1972). However photosynthetic capacity has not resulted in higher grain yield (Mc Donald *et al.*, 1974). To break the apparent yield potential barrier scientists proposed further modifications of the present high yielding plant type that would support a significant increase in rice yield potential (Janoria, 1989).

Kim and Vergara (1991) proposed low tillering capacity of the plant for increasing grain yield potential and he suggested the optimum number of tillers as five. Lu *et al.* (1991) studied the yielding potential and related characteristics of rice ideotypes and found that varieties, which correspond to the rice ideotype, gave higher yields than those of the curve, slant and erect type.

Janoria (1994) evaluated novel rice lines based on a new ideotype and found high yield potential of the prototype lines as a result of very heavy panicles, reduced number of tiller number and less leafy canopy. Akita *et al.* (1996) conducted field experiments to examine factors related to the yield potential of two new plant type (NPT) lines developed by IRRI. The NPT lines which are tropical *japonica* lines where compared for seven yield components and found that yield of the NPT lines were lower due to increase in dry weight after heading. Panicle number of the NPT lines was low. Spikelet number per panicle was high. No lodging was observed in NPT lines. Sink size was calculated by multiplying filled grain weight by spikelet number. The results indicated that NPT lines may not always be high yielding accompanied by an effective grain sink.

Bentota *et al.* (1997) evaluated the genetic architecture of twelve quantitative characters using the basic generations and F_3 families from two crosses, chosen at random from IRRI's New Plant Type (NPT) programme (*japonica* x *javanica*) with the objective of increasing the genetic yield potential to 13-15 t/ha of direct seeded, irrigated crop in low land tropics. The genes controlling the characters in cross I displayed mainly additive or additive and dominance effects, except for two related characters, tiller number and panicle number. The results showed that characters in both crosses were heritable except for harvest index in cross I. An assessment of the potential of these crosses showed that while it should be relatively easy to achieve the NPT targets for six characters in both crosses, this is unlikely for proportion of filled spikelets, grain yield and harvest index with one cycle of in breeding.

Puckridge and Salisberry (1997) explained that yields in tropical rainfed rice fields are far below the potential. Many breeders consider the ideotype approach offers no real advantage for yield improvement, but at least a conceptual ideotype is necessary in optimizing the design of phenotypes to make efficient use of the environment. The predominant yield potential improvements so far have been in the patterns of partitioning and the timing of development, not in the efficiency of the major metabolic and assimilatory processes. They found the lacking of convincing evidences of improvements for photosynthesis, respiration, translocation and growth rate. They suggested more input and integration towards ideotype approach and selection of traits on physiological evidence.

Ramesh and Singh (1998) conducted a green house experiment to investigate the contribution of different tillers in a plant towards grain yield and also evaluated the ideotype of a low tillering rice for increasing yield potential. Among four rice cultivars IR 36 and Pusa Basmati-1 had earlier and longer tillering period compared with Saket-4 and Basmati 370. Per cent effective tillers was higher in low tillering cultivars than in high tillering ones. Based on spikelet number and grain weight of panicle, the panicles on the first formed ten tillers in a plant (main culm, first five to six primary tillers and the first two to three secondary tillers) were larger than other panicles. These top ten tillers were characterized by early initiation, early flowering, longer growth duration, heavier culm and greater flag leaf area. Panicles from primary tillers were larger than those from secondary and tertiary tillers. Reduced tillering generally resulted in larger and heavier panicles with an increase in the number of panicle branches, spikelets and grain weight, compared to the corresponding tillers in plants with unrestricted tillering. The results suggest the critical number of tillers for a low tillering rice ideotype must be around ten.

Kumar *et al.* (1999) studied a set of new plant type rice breeding lines of extra early, early and medium duration for yield and yield attributing characters during kharif (Jun.-Nov.) and rabi (Dec.-May) seasons. He found that grain yield of NPT lines were either significantly superior or at par with the corresponding semi dwarf check varieties. The NPT lines had much higher grain number per panicle, much lower tiller number per plant and more plant height than the semi dwarf checks.

Peng *et al.* (1999) explored several approaches to break the yield barrier of about 10 t/ha in the tropics since the breeding for population improvement with in the *indica* germplasm had started. These approaches include development of a new plant type (NPT) with low tillering capacity and large from tropical *japonica* germplasm and exploitation of heterosis through inter varietal and inter subspecific hybrids. Hybrid rice between *indica* varieties increased yield potential by about nine per cent under the tropical conditions. The higher yield potential of *indica* x *indica* hybrids compared with *indica* in bred cultivars was attributed to greater biomass production rather than harvest index. New plant type breeding has not yet improved yield potential due to poor grain filling and low biomass production. Factors that cause poor grain filling and low biomass production of the NPT lines have been identified. Selecting parents with good grain filling traits, introduction of *indica* genes into NPT's tropical japonica are expected to improve the performance of the NPT lines. Further enhancement in yield potential may be possible from use of inter subspecific heterosis between *indica* and NPT lines.

Khush (2002) estimated that we will have to produce 50 per cent more rice to satisfy the growing demand for food., This increased demand will have to be met from less land, with less water, less labour and less chemicals. Thus the challenges of rice improvement are to develop varieties with higher potential more durable resistance to diseases and insects and higher level of tolerance to abiotic stresses. Approaches to increase yield potential are population improvement, ideotype breeding, heterosis breeding, wide hybridization, genetic engineering and molecular breeding.

2.2 COMBINING ABILITY ANALYSIS

Combining ability analysis gives useful information regarding selection of parents interms of performance of their hybrids. Sprague and Tatum (1942) defined the term general combining ability (GCA) as the performance of a line or population in several hybrid combinations and specific combining ability (SCA) was used to designate those effects in specific combinations which significantly departed from what could be expected on the basis of average performance of the lines involved. GCA is due to additive genetic effects and SCA is due to dominance deviation and epistatic interactions. Further, combining ability analysis elucidates the nature and magnitude of various types of gene actions involved in the expression of quantitative traits (Dhillon, 1975).

Rojas and Sprague (1952) examined combining ability over years in corn and found that SCA was constantly greater than GCA and concluded that SCA not only involved dominance and epistasis but a considerable amount of genotype and environmental interactions. Griffings (1956) expressed that GCA involved both additive and additive x additive interaction.

Genetics of harvest index and its components were studied following line x tester approach by Sharma *et al.* (1987). Thirty cross combinations (3 x 10) along with parental traits were studied for 16 characters. Analysis of variance indicated the existence of significant variation among F_1 and parents for all 16 characters. Combining ability analysis shared both additive and non additive types of gene action playing significant role in controlling the expression of all characters under study. The exception was economical yield for which only non-additive gene action was found to be significant. For days to flowering, plant height, second leaf length, number of ear bearing tillers per plant, grain length and width, additive type of gene action was important, whereas for the remaining characters viz., harvest index, economical yield and biological yield, non additive type of gene action seems to be playing significant role. Similar results of importance of both additive and non additive gene action for the characters, days to flowering, plant height, panicle length, number of grains per panicle, number of spikelets per panicle, sterility percentage, 1000 grain weight and yield with preponderance of non additive gene action for the remaining characters were reported by Manuel and Palanisamy (1989).

Peng and Virmani (1990) studied combining ability for grain yield, dry matter, harvest index, plant height and days to flowering, using line x tester analysis involving seven maintainers and eleven restorer lines. General combining ability and specific combining ability variances were significant for yield, dry matter, days to flowering, and plant height. For harvest index, only SCA variance was significant implying that the first four traits are controlled by both additive and dominant gene action. The harvest index however is primarily controlled only by dominant gene action. Significant *gca* effects for the five traits were observed in the parents and good general combiners for each of the characters could be identified. High *gca* effect for yield of a specific line was found associated with high *gca* effect for dry matter production or harvest index (HI). High *gca* effects for yield mostly was associated with high *gca* effect for plant height and days to flower, though in some cases the high *gca* effect was related with low *gca* effect for plant height and days to flower.

Lokaprakash *et al.* (1991) revealed importance of both additive and non additive gene actions for the characters plant height, panicle length, productive tillers per plant, number of spikelets per panicle, 1000 grain weight, harvest-index and grain yield with preponderance of non additive gene action for all the characters except for plant height.

Yuan *et al.* (1995) evaluated eight varieties and their 15 hybrids and found dry plant weight, panicle number, grain weight per panicle weight and number of grains per panicle having significant correlation with grain weight per plant. Rao *et al.* (1996) revealed IR58025A and IR62829A were good general combiners for grains per panicle, spikelet fertility, grain yield per plant and per day productivity after analysis of five lines and four testers in a line x tester design. Ramalingam *et al.* (1997) observed Mahsuri and Kasturi as good general combiners for yield and other important traits in line x tester analysis. Fine grained varieity Mahsuri was found to be the best general combiner for all the characters except 1000 grain weight and length of grain with late maturity under transplanted and direct seeded condition. Thus Mahsuri was suggested for developing fine grain varieties with late to mid late maturity suitable for both conditions. The best specific combination involved the parents with high x high, high x low and low x low *gca* effects.

Vivekanandhan and Giridharan (1997) derived the importance of additive gene action for 100 grain weight, grain length, breadth and grain thickness from data on six yield related traits in eight parents and their 15 progeny from a line x tester (5x3) cross. Based on the *per se* performance and *gca* effects, ADT 39 and improved white ponni were the best parents for improvement of grain traits besides grain yield. Importance of both additive and non additive gene actions for the characters plant height, panicle length, productive tillers per plant, number of spikelets per panicle, 1000 grain weight, harvest index and grain yield with preponderance of non additive gene action for all the characters except for plant height were reported by Ganesan *et al.* (1997) in a line x tester analysis.

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

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

Geetha (1998) found significant variances due to GCA and SCA for eight quality related traits in six rice parents and their, 30 hybrids. The higher values for GCA variance indicated the predominance of additive gene action for these traits. IR50 and ADT 41 were good general combiners for a number of traits studied. Geetha *et al.* (1998) derived information on combining ability from data on 12 yield related traits in parents and F_1 progeny of a diallel cross involving six cultivars and indicated a predominance of additive gene action for all the characters studied.

Rosamma (1998) reported Kanchana and Aiswarya as good combiners for different yield contributing interaction. Perraju and Sarma (1999) crossed three newly developed genetic male sterile lines and eight testers in a line x tester design and found lines GMS 35, GMS 33 and tester IR 36 were good combiners for grain yield, while IR 36 and Swarnaprabha among testers showed good general combining ability for grains per panicle. Among the hybrids the best-performance for grain yield and specific combining ability effects and heterosis were noticed for GMS 35 and IR 36. Selvarani and Rangasamy (1999) found predominance of nonadditive gene action for all the traits except leaf area index in a line x tester evaluation.

Shanmugavalli *et al.* (1999) evaluated seven very early rice genotypes (ovule parents) and seven short duration testers (pollen parents). Crosses in line x tester design and found the lines AS 18696, AS 13744 and the testers IR 50 and ADT 36 as good general combiners recording higher yield.

Yadav *et al.* (1999) reported NDR 358 as the best general combiner for all the traits except days to 50 per cent flowering and plant height. Jhona 349 was the best general combiner for earliness. The female line IR 58025A was a good general combiner for grain yield per plant. The promising combinations for grain yield per plant were also identified by them.

Janardhanam *et al.* (2000) evaluated eight strains of rice crossed in a 4x4 line x tester design along with 16 hybrids and found significant variance for all traits except for number of productive tillers per plant. Three parents were good combiners for plant height and number of grains per panicle, two for plant yield and one for number of spikelets per panicle.

Selvi *et al.* (2001) tested 42 hybrids and seven parents for combining ability of grain yield and physiological characters. Among the parents CO43 was the best general combiner for leaf temperature, flag leaf area, dry matter production and harvest index.

Babu and Reddy (2002) evaluated sixteen hybrids generated by crossing four lines with four testers along with their parents and found significant additive gene action for plant height, panicle length, 1000 grain weight, grain length and grain breadth. Non additive gene action was found to be controlling days to 50 per cent flowering whereas both additive and non additive gene action were found to be significant for productive tillers per plant, grains per panicle and grain yield per plant.

Sundar and Thiyagarajan (2002) evaluated 64 hybrids generated by crossing four cytoplasmic genic male sterile lines and 16 testers. Among female parents IR 58025A was a good general combiner for panicle length, filled grains per panicle, spikelet fertility and grain yield per plant. The male parent IR 21567-18-3R was a good general combiner for all the characters except panicle length.

Most of the crosses with significant standard heterosis for yield were found to show heterosis for more than one component (Sharma and Mani, 1990). Heterosis in yield was mostly due to simultaneous heterosis for yielding components like panicles per plant, grains per panicle, panicle length and grain weight. Standard heterosis percentage varied from -59 to 34 for grain yield, -40 to 58 for dry matter, -36 to 20 for harvest index, -27 to 19 for days to flowering and -21 to 27 for plant height.

Patel *et al.* (1994) evaluated 10 yield components in 30 F_1 hybrids from line x tester crosses of 13 rice genotypes. Estimates of heterotic effects were highest for days to 50 per cent flowering, grains per panicle and yield per plant, whereas days to maturity, panicle length and harvest index had the least heterotic effect.

Ramalingam *et al.* (1994) studied five cytoplasmically male sterile genotypes and five testers in a line x tester design and the resultant 25 hybrids showed, significantly high heterosis for production of tillers. In all crosses except IR 58025 x IR 24, IR 58025 A x ARCII 353, IR 62829 A x IR 24, IR 62829 A x IR 29733, ear length in seven crosses, filled grains per ear in two crosses, 100 grain weight in all crosses and grain yield in five crosses. The mean outcrossing percentage was high in V 20 A and IR 58025 A.

Ali and Khan (1995) evaluated four rice cultivars and their six G_1 hybrids and found significant positive heterosis for all the characters except plant height, percentage filled spikelets and spikelet density. Heterobeltiosis was significant and positive over the better parental value in most of the crosses for number of tillers per plant, panicle weight and grain yield per plant. Zhang *et al.* (1995) found that of the eight characters studied, only three characters showed standard heterosis while relative heterosis was observed in all characters. Standard heterosis for grain yield ranged from -36.8 to 33.6 per cent with a mean of -2.4 per cent. Reddy and Nerkar (1995) observed highly significant and positive heterosis for grain yield over mid parent and better parent in four hybrids. Such high grain yield heterosis was due to additive heterotic effect of one or more component traits.

Yuan *et al.* (1995) evaluated eight varieties and their 15 hybrids and found grain number per panicle and number of filled grains had greatest heterosis. Rao *et al.* (1996) revealed significant heterotic effect over both better and standard parent with respect to number of productive tillers per panicle in the cross Pushpa A x ARC 11353.

Standard heterosis over HKR 126 (standard check) evaluated in 22 rice hybrids was significant for all the four traits studied. It was both negative and positive for grain yield per plant (-0.57 to 54.75%), panicles per plant (-14.84 to 89.14%) and grains per panicle (-16.04 to 43.28%), and negative for 1000 grain weight (-34.55 to -5.82%). Six hybrids showed positive and significant standard heterosis for all traits except 1000 grain weight (Panwar and Dhaka, 1998).

Selvarani and Rangasamy (1999) evaluated ten rice genotypes and their 24 F_1s evolved from crossing in a line x tester (4 x 6) fashion. They found the hybrid IR 50 and TNAU 801793 had the highest heterosis estimates for grain yield, leaf area index, dry matter production and harvest index.

Sathya *et al.* (1999) made a study to assess one nature and extent of heterosis, heterobeltiosis and standard heterosis for yield and its components in a line x tester design. The hybrids such as IR 62829 x IR 50, IR 62829 A x AS 90043 and IR 58025 A x AS 89090 were adjudged best for exploitation of heterosis based on standard heterosis pertaining to grain yield per plant. The two former cross combinations showed significant standard heterosis for productive tillers per plant in addition to heterosis for grain yield. Seetharamiah *et al.* (1999) evaluated ten rice hybrids and observed that plant height and panicle length did not play significant role in expression of heterosis. Negative heterosis was observed for test weight ranging from -45.6 to -28.2 per cent while hybrid MTUHR 2003 exhibited highest standard heterosis of 157.4 per cent for grain yield.

Gomez *et al.* (2003) assessed the combining ability for 12 quantitative characters in rice under drought conditions through line x tester analysis involving ten drought resistant local land races and three high yielding testers. They concluded that all the characters studied were governed by additive gene action except harvest index.

Vanaja *et al.* (2003) evaluated 28 rice hybrids and revealed the importance of both additive and non additive gene effects in governing yield and most of the yield components with preponderance of non additive gene action for most of the yield components. Additive gene action was found important for 1000 grain weight, second upper most internodal length and height of plant at harvest. Vytilla-3, Mahsuri, Mattatriveni and Karthika were identified as good general combiners.

2.3 HETEROSIS

The biological phenomenon in which an F_1 hybrid of two genetically dissimilar parents shows increased vigour over parents is referred to as heterosis. The term heterosis was first coined by Shull (1908) and commonly standard heterosis is more important in plant breeding.In rice heterosis was first observed by Jones (1926), who noticed some F_1 hybrids with more culms and higher yield than parents.

Rangasamy and Natarajamoorthy (1988) reported that straw yield showed standard heterosis of upto 134 per cent while standard heterosis for grain yield reached a maximum of only eight per cent, and all combinations had high standard heterosis for tiller number.

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

Annadurai and Nadarajan (2001) evaluated 35 rice hybrids and reported that with respect to productive tillers per plant, none of the hybrids showed positive standard heterosis while 12 hybrids showed positive standard heterosis for grains per panicle, six for 1000 grain weight and nine for grain yield per plant.

Janardhanam *et al.* (2001) studied eight parental rice cultivars as lines and ADT 36, IR 20, IR 50, and MDU 5 as tester and 16 hybrids derived from 8 x 4 design. They found highly significant variation among genotypes for all traits except the number of productive tillers. Plant height, number of grains per panicle and single plant yield which showed significant values of relative heterosis, heterobeltiosis and standard heterosis were considered as important selection criteria for high yield.

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

Kumar and Singh (2002) studied 27 rice hybrids and found significant heterosis for grain yield in all crosses. Singh *et al.* (2002) studied 36 hybrids produced from crossing between two wild abortive cytoplasmic male sterile lines and 18 genotypes of rice in line x tester design and found 38-50 per cent of the hybrids exhibiting significant and positive heterobeltiosis and standard heterosis for grain yield per plant. Heterosis for grain yield, was mainly due to heterosis of ear bearing tillers per plant, 1000 grain weight, number of fertile grains per panicle, biological yield and harvest index.

Banumathy *et al.* (2003) evaluated 100 rice hybrids and reported that top yielding hybrids exhibited significant standard heterosis over CORH 2 and ADTRH1. High standard heterosis for productive tillers and 1000 grain weight also resulted in increased grain yield in some cross combinations. 25 aromatic rice hybrids developed by line x tester mating design were evaluated for standard heterosis over standard variety Pusa Basmati. The study revealed that heterosis for grain yield was mainly because of simultaneous manifestation of heterosis for tiller number, grains per panicle and test weight (Krishnaveni and Sobharani, 2003).

Alum *et al.* (2004) studied genetic basis of heterosis in mid parent, standard cultivar and better parent for 11 quantitative traits in 17 parental lines and their ten selected hybrids in rice (*Oryza sativa* L.). Significant heterosis was observed for plant height, days to flag leaf initiation, days to first panicle initiation, days to 100 per cent flowering, panicle length, flag leaf length, days to maturity, number of fertile spikelets per panicle, number of effective tillers per hill and 1000 grain weight. Both positive and negative inbreeding depression were found in many crosses for the studied traits but none was found significant. Selection of good parents was found to be the most important for developing high yielding hybrid rice cultivars.

Rathika *et al.* (2004) found that the hybrid RP 6784-690-39-14 x RP-825-24-7 expressed significant standard heterosis for all the seven characters studied. Standard heterosis for 64 rice hybrids estimated over two hybrids viz., CORH-2 and ADTRH-1 by Sundar and Thiyagarajan (2004) revealed that 37 hybrids recorded negative standard heterosis over CORH-2 for days to 50 per cent flowering and ten hybrids showed significant positive heterosis over CORH-2 while 15 hybrids recorded significant positive standard heterosis for productive tillers per plant.

2.4 PHENOTYPIC AND GENOTYPIC CORRELATIONS

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

Correlation studies undertaken by Gomathinayagam *et al.* (1988) reported that duration and plant height were correlated significantly with grain yield in upland rice varieties. There was significant but negative correlation between grain yield and total tillers.

Lu *et al.* (1988) reported that grain yield per hill was positively correlated with biomass, harvest index, grains per panicle, filled grains per panicle, fertility and plant height and negatively with panicles per hill. Prasad *et al.* (1988) reported positive and significant association of grain yield per plant and total spikelets per panicle, followed by fertile grains per panicle and 100 grain weight and negative significant correlation with sterility. Plant height and flag leaf length showed positive and significant correlation with days to flowering and panicle length respectively.

Manuel and Palanisamy (1989) observed significant positive correlation of grain yield with days to 50 per cent flowering, plant height, flag leaf area, panicles per plant, panicle length and number of grains per panicle from the evaluation of 15 hybrids and their parents. Cai *et al.* (1989) reported that grain yield was positively correlated with panicle numbers, floret number per panicle, fertile florets and 1000 grain weight. Biological yield and dry matter production before and after heading had very significant positive effects on grain yield.

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

Mehetre *et al.* (1994) reported that grain yield per m^2 was positively and significantly correlated with straw yield per m^2 and filled grains per panicle, while it was negatively and significantly correlated with days to 50 per cent flowering and maturity. Plant height was significantly and positively correlated with straw yield per

m^2, panicle length and filled grains per panicle, while it was significantly and negatively correlated with productive tillers per m^2.

Chen *et al.* (1997) evaluated 60 F_1 hybrids and their 11 parents and found grain yield per plant was significantly correlated with fertility, while fertility and effective tillers were negatively correlated with grains per panicle, 1000 seed weight, plant height and heading data. Choudhury and Das (1997) observed significant positive correlations for days to 50 per cent flowering, day to maturity, plant height, grains per panicle and panicle length with yield.

Paul and Sarmah (1997) evaluated seven quantitative characters in 13 diverse genotypes and found yield was positively correlated with days to maturity, plant height and filled grains per panicle, and negatively with false grains per panicle. Reddy *et al.* (1997) studied 36 genotypes of lowland rice and found grain yield per hill was positively correlated with number of ear bearing tillers (EBT) per hill, number of spikelets per panicle, number of grains per panicle and panicle weight.

Kennedy and Rangasamy (1998) evaluated hybrids derived from three CMS lines and cold tolerant testers and reported that the direction of phenotypic and genotypic correlation coefficients was the same, but their magnitude varied. Generally, genotypic correlation coefficients were higher than the corresponding phenotypic ones. It was concluded that simultaneous selection for traits such as days to 50 per cent flowering (early), productive tillers, spikelets sterility, harvest index and 1000 grain weight may serve to increase grain yield. Kumar *et al.* (1998) observed high positive correlation of grain yield with plant height, panicle length, spikelet fertility and 1000 grain weight.

Luzikihupi (1998) evaluated 36 rice cultivars for yield and other components and revealed that grain yield per plant is positively correlated with all the characters except percent unfilled grains and days to 50 per cent flowering. Santhakumar *et al.* (1998) reported days to 50 per cent flowering, total tillers per hill, effective tillers per hill and spikelet fertility showed positive correlation with grain yield in dry and wet season after evaluating 34 rice genotypes in dry, wet and winter seasons. In winter season, grain yield was positively correlated with flag leaf length, spikelet fertility and 1000 grain weight.

Balan *et al.* (1999b) after evaluating 15 salt tolerant rice genotypes found positive correlation for harvest index and straw yield with seed yield. Days to 50 per cent flowering recorded the highest positive direct effect on seed yield followed by harvest index.

El Hissewy and Bastawisi (1999) studied root characters in three rice crosses like root length, thickness, dry weight, root to shoot ratio and found root length was positively correlated with root thickness, root dry weight and root to shoot ratio. Root thickness was closely related to both root weight and root to shoot ratio.

Meenakshi *et al.* (1999) worked out genotypic and phenotypic correlations for yield and physiological characters in rainfed rice and found productive tillers per plant, grains per panicle, dry matter production and harvest index were positively correlated with grain yield. Thakur *et al.* (1999) studied correlation among grain yield and its attributing traits in an F_2 population in rice and suggested that grain yield had a positive correlation with plant height, tillers per plant, panicle weight, biological yield and harvest index. Nehru *et al.* (2000) reported that the number of productive tillers directly correlated with grain yield. Genotypic correlation coefficients were in general higher than that of corresponding phenotypic ones. Grain yield showed positive significant correlation with plant height, days to 50 per cent flowering at genotypic level and number of spikelets per panicle, yield and harvest index at both genotypic and phenotypic levels (Shivani and Ramareddy, 2000).

Bhandarkar *et al.* (2002) revealed yield per plant had positive significant association with days to 50 per cent flowering, maturity, plant height, number of total grains per panicle and number of filled grains per panicle through correlation analysis of 52 early duration genotypes of rice. Of the 20 factors related to plant morphology, only plant height and leaf angle were two most important factors, which were highly correlated with grain yield (Pan *et al.*, 2003).

In a field experiment conducted with 21 rice hybrids, it was observed that grain yield had significant correlation with productive tillers per plant, 1000 grain weight, panicle length and harvest index (Raju *et al.*, 2003). Grain yield exhibited a very strong positive correlation with harvest index and also significantly correlated with dry matter per hill, productive tillers per plant and grains per panicle (Shirame and Muley, 2003).

Estimation of correlation in 20 selected rice genotypes by Khediker *et al.* (2004) revealed that genotypic correlation was slightly higher than respective phenotypic correlations for most of characters. High phenotypic and genotypic correlation for head rice recovery and grain yield per plant was shown by productive tillers per plant and for grain yield per plant by spikelet density. Raju *et al.* (2004) studied simple correlation coefficients in 21 crosses and found that plant height, productive tillers per plant and 1000 grain weight had significant correlation with grain yield per plant.

2.5 PATH COEFFICIENT ANALYSIS

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

Lu *et al.* (1988) reported that, direct effect of yield related characters on grain yield was positive except for filled grains per panicle. Paramasivan and Rangasamy (1988) suggested that the selection for grain yield could be efficient if it is based on plant height, tiller number, panicle length, grain number per panicle and grain weight as these characters fulfilled both the requirements of genotypic association with yield and path coefficient analysis.

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

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

Gravois and McNew (1992) identified positive direct effects for both panicle number and panicle weight on rice yield, with panicle weight exhibiting larger direct effects on yield than panicle number.

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

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

Choudhury and Das (1997) reported that direct effects of panicle length, days to maturity, grains per panicle and plant height are high and positive. Selection for a late maturing plant having a long panicle with more number of grains may be indicative for breeding high yielding deep water rice varieties. Paul and Sarmah (1997) evaluated seven quantitative characters in 13 diverse genotypes and through path analysis revealed that length of panicle had the highest positive direct effect on yield.

Rao *et al.* (1997) evaluated twenty genotypes of rice for eight yield components and found all correlation coefficients were genetically significant but phenotypically productive tillers per plant showed a significant association with 1000 grain weight and straw yield per plant. Path coefficient analysis indicated that productive tillers per plant had the highest direct effect on grain yield, followed by plant height, panicle length and flag leaf area.

Reddy *et al.* (1997) evaluated 36 genotypes of low land rice through path analysis and found the importance of number of grains per panicle, panicle weight and number of ear bearing tillers (EBT) per hill in selection programmes to improve grain yield in low land rice.

Kumar *et al.* (1998) evaluated 34 cold tolerant rice genotypes and observed high direct effect of spikelets fertility and moderate direct effects of plant height, panicle length and 1000 grain weight to yield.

Luzikihupi (1998) identified number of filled grains per panicle, number of panicles per plant and 1000 grain weight to be important characters that influence grain yield through evaluation of 36 rice cultivars and found number of filled grains per panicle had a significant negative indirect effect through number of panicles per plant and 1000 grain weight. Begali *et al.* (1999) reported that panicle weight exerted maximum positive direct effect, followed by number of grains per panicle and harvest index on grain yield per plant. Panicle weight showed high positive indirect effect through harvest index and number of grains.

Path coefficients for five characters in salt tolerant genotypes were estimated by Balan *et al.* (1999a). Days to 50 per cent flowering recorded the highest positive direct effect on seed yield followed by harvest index. Meenakshi *et al.* (1999) evaluated the path coefficients for yield and physiological characters in rainfed rice. The result indicated dry matter production as the most important character because its higher positive direct effect, followed by harvest index. Sarawagi *et al.* (2000) reported a greater contribution of harvest index, fertile spikelets per panicle, biological yield and plant height to grain yield from the character association studies in rain fed low land rice genotypes.

Shivani and Ramareddy (2000) found that plant height had negative direct effect on grain yield per plant, while days to 50 per cent flowering had showed positive direct effect on yield and positive indirect effect via productive tillers per plant, yield and harvest index. Grains per panicle has direct positive significant correlation with grain yield. Data on path coefficient analysis of Kavitha and Reddi (2001) revealed that the characters, filled grains per panicle, dry matter production per plant and harvest index exhibited a high positive direct effect coupled with positive significant correlation with grain yield per plant.

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

Path coefficient analysis in 20 scented rice genotypes by Khediker *et al.* (2004) revealed that the test weight had the high positive direct effect in grain yield per plant, followed by productive tillers per plant, days to 50 per cent flowering and spikelet density. Days to 50 per cent flowering had indirect positive effect on grain yield via spikelet density, productive tillers per plant and panicle length.

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

MATERIALS AND METHODS

3. MATERIALS AND METHODS

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

3.1 MATERIALS

Ten rice varieties were selected as parents and hybridization between selected lines and testers were conducted. Four rice varieties having one or few of the characters required for the ideotype were selected as testers and six popular high yielding varieties as lines in this programme. Details of parents selected as lines and testers are given in Table 1.

3.2 METHODS

Line x Tester hybridization was conducted with six lines and four testers already selected from the ongoing programme at Agricultural Research Station, Mannuthy. The whole programme can be divided into two experiments.

3.2.1 Experiment I

Hybridization and production of F1 seeds.

Hybridization between selected lines and testers was conducted during kharif 2003. Six lines and four testers were raised separately during June 2003 at Agricultural Research Station, Mannuthy (Plate 1). Since there were long duration,

Plate 1. Raising parents for hybridization

medium duration and short duration varieties, sowing was staggered so as to get synchronized flowering. Sowing was again repeated after ten days in order to enable crossing for a long period to get enough F_1 seeds. Hybridization between six lines and four testers were effected during September to November of the year 2003. For emasculation 'wet cloth' method was followed (Plate 2). Mature F_1 and parental seeds were harvested, sundried and stored separately. Seeds were obtained from all 24 cross combinations.

3.2.2 Experiment II

Evaluation of parents and hybrids

Seeds of twenty four F_1 hybrids and ten parents were sown separately during June 2004. Details of the cross combinations used for the study are presented in Table 2.

Twenty five days old seedlings of all cross combinations and parents were transplanted to the main field in two rows with ten plants in each row . Spacing of 15 cm was adopted between plants and 30 cm between rows. The cultural practices followed for experiment crop was as per the Package of Practices Recommendation of the Kerala Agricultural University. Following observations were recorded from all the plants and data were subjected to different statistical analysis for estimating combining ability, heterosis, phenotypic and genotypic correlations and path analysis.

OBSERVATIONS RECORDED

1. Days to flowering

Number of days were counted from the date of sowing to the day when 50 per cent flowers opened in the panicle.

Plate 2. Panicles covered with butter paper cover after hybridization

2. Number of tillers at active tillering stage

Total number of tillers present in each plant was counted at active tillering stage.

3. Number of tillers at panicle initiation stage.

Total number of tillers present in each plant was counted at panicle initiation stage

4. Number of tillers at flowering stage.

Total number of tillers present in each plant was counted at flowering stage.

5. Number of productive tillers per plant

Number of panicle bearing tillers per plant were counted at the time of maturity.

6. Plant height

Height of plants were measured in centimeters from the surface of the soil to the tip of the longest panicle at the time of harvest.

7. Stem thickness

Thickness of the stem from the basal portion of the tiller was measured in centimeters at the time of harvest.

8. Flag leaf area

Area of flag leaf was calculated by measuring length and maximum width of the flag leaf and using the formula, k.l.b. where K = 0.65 (the constant used at maturity state; l = length of flag leaf, b = maximum width of flag leaf.

9. Panicle length

Length of the main panicle was measured in centimeters from the panicle base to the tip of the top most spikelet.

10. Grains per panicle

The number of grains from three panicles from each plant was counted and their mean value was taken.

11. Panicle weight

The weight of three panicles from each plant was recorded in grams and their mean value was taken as panicle weight of the plant.

12. Chaff per cent

The number of chaffy grains in the main panicle was counted and expressed as per cent over the total number of grains in the main panicle.

13. 1000 grain weight

Thousand well filled whole grains were selected randomly and weight was recorded in grams.

14. Grain density

Volume of known weight of seeds were measured by water displacement method and expressed as gram per ml.

15. Grain thickness

Thickness of 10 randomly selected grains in the main panicle was measured and expressed in millimeters.

16. Grain yield

Grains harvested from each plant was weighed after normal drying and the weight was expressed in grams.

17. Straw yield

Straw yield in gram per plant was recorded.

18. Total dry matter

Sum total of the weight of normally dried grains, straw and root of each plant expressed in grams.

19. Harvest Index

The proportion of economic yield reported over biological yield, using the formula (Donald and Hamblin, 1976).

Economic yield (grain yield) / Biological yield (grain + straw yield)

20. Root weight per plant

Roots separated from each plant after harvesting was washed thoroughly and weighed after drying and weight was expressed in grams.

21. Root to shoot ratio

It is the ratio of root weight to the shoot weight .

22. Root volume

Volume of normally dried roots were calculated by water displacement method and is expressed in ml.

23. Root length

Root length was measured in centimeters from the base of the stem to the root tip.

3.3 STATISTICAL ANALYSIS

The data collected from the present study were analysed by using various biometrical techniques.

3.3.1 Analysis of variance

The data collected on 34 genotypes for all the biometrical traits were subjected to an analysis of variance (Panse and Sukhatme, 1964).

Source	*df*	Expected mean square
Block (b)	(b-1)	$\sigma^2e + g.\ \sigma^2b$
Genotype (g)	(g-1)	$\sigma^2e + b.\sigma^2g$
Error	(b-1) (g-1)	σ^2e
Total	(bg-1)	

3.3.2 Combining ability analysis

The data for all the biometrical traits were subjected to analysis of variance appropriate for line x tester crossing design (Kempthorne, 1957). The mean squares due to different sources of variation were obtained and the genetic expectations were also worked out using the following analysis of variance.

3.3.2.1 Analysis of variance for combining ability

Source	*df*	Mean square	Expected mean square
Replication	(r-1)		
Lines	(l-1)	M_1	EMS+r(COV.F.S-2COV.H.S.) + rt(COV.H.S.)
Testers	(t-1)	M_2	EMS+r(COV.F.S.-2COV.H.S.)+rl(COV.H.S.)
L x T interaction	(l-1) (t-1)	M_3	EMS+r(COV. F.S.-2COV.H.S.)
Error	(r-1) (lt -1)	M_4	EMS

Where,

r - number of replications

l - number of lines

t - number of testers

EMS - error mean square

From the genetic expectations of the mean squares, the covariances of full sibs (COV.F.S.) and half-sibs (COV.H.S.) were estimated as given below.

$$\text{COV.H.S.} = \frac{1}{r[2lt-l-t]}\left[\frac{(l-1)M_1+(t-1)M_2}{l+t-2} - M_3\right]$$

$$\text{COV.F.S.} = \frac{(M_1-M_4)+(M_2-M_3)+(M_3-M_4)}{3r} + \frac{6r.COV.H.S.-r(l+t)COV.H.S.}{3r}$$

From the covariance values, general and specific combining ability variances were computed as given below.

GCAvarience = (σ^2 GCA) = COV.H.S.

SCA varience = (σ^2 SCA) = COV.F.S.-2.COV.H.S.

GCA varience for lines and testers and SCAvarience for the hybrids were calculated as follows.

$$\sigma^2 \, GCA_{(lines)} = \frac{M_1 - M_3}{rt}$$

$$\sigma^2 \, GCA_{(testers)} = \frac{M_2 - M_3}{rl}$$

$$\sigma^2 \, SCA_{(hybrids)} = \frac{M_3 - M_4}{r}$$

3.3.2.2 Estimation of combining ability effects

Both the gca and sca of an ijkth observation was arrived at using the mathematical model given below.

X_{ijk} = $\mu + g_i + g_j + S_{ij} + e_{ijk}$ where,

μ = Population mean

g_i = gca of $_i$th line

g_j = gca of $_j$th tester

S_{ij} = sca of $_{ij}$th hybrid

e_{ijk} = error associated with $_{ijk}$th observation

i = represents ith line

j = represents jth tester

k = represents kth replicate

General combing ability effects of parents and specific combining ability effects of hybrids were estimated as given below.

$$\text{Mean} = \frac{X_{...}}{rlt}$$

i. *gca* effect of lines

$$g_i = \frac{X_{i..}}{rt} - \frac{X_{...}}{rlt}$$

ii. *gca* effect of testers

$$g_j = \frac{X_{.j.}}{rl} - \frac{X_{...}}{rlt}$$

iii. *sca* effect of hybrids

$$s_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{rt} - \frac{X_{.j.}}{rl} - \frac{X_{...}}{rtl}$$

Where,

$X_{...}$ = Total of all hybrids over 'r' number of replications

$X_{i..}$ = Total of $_i$th line over 't' testers and 'r' replications

$X_{.j.}$ = Total of $_j$th tester over 'l' lines and 'r' replications

$X_{ij.}$ = Total of the hybrid between $_i$th line and $_j$th tester over 'r' replications

Test of significance of combining ability effects

i. S.E. of *gca* of lines $= \sqrt{\frac{EMS}{rt}}$

ii. S.E. of *gca* of testers = $\sqrt{\frac{EMS}{rl}}$

iii. S.E. of *sca* of hybrids = $\sqrt{\frac{EMS}{r}}$

Where,

S.E. - Standard error

EMS - Error mean square

$$t = \frac{\text{Parameter}}{\text{S.E.}}$$

The calculated t value was compared with table t value at error degrees of freedom to test the significance.

3.3.3 Estimation of heterosis

Magnitude of heterosis for all hybrids were estimated over mid parent, better parent and standard check as given below.

i. Relative heterosis (d_i)

The superiority / inferiority of F_1 over the mid-parental value was estimated as follows.

$$d_i = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

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

MP - mid-parental value

ii. Heterobeltiosis (d_{ii})

Heterosis of F_1 over better parent was obtained as follows

$$d_{ii} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{BP}$ - mean value of better parent

iii. Standard heterosis (d_{iii})

Superiority / inferiority of F_1 over the standard or check was calculated as given below

$$d_{iii} = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

Where,

$\overline{SV}$ - mean value of the standard variety.

Jyothi was taken as the standard variety (Plate 4).

3.3.4. Correlation

The association between yield and component traits, and among themselves were computed based on per se performance as genotypic and phenotypic correlation coefficients (Goulden, 1952).

3.3.5 Path coefficient analysis

Path coefficient analysis as applied by Dewey and Lu (1959) was used to partition the genotypic correlation coefficient into components of direct and indirect

Plate 4. Jyothi - the standard check variety

effects. By keeping yield as dependent variable and the other traits as independent variables, simultaneous equations, which express the basic relationship between path coefficients, were solved to estimate the direct and indirect effects.

Table 1. Details of parents selected for crossing

Varieties	Parentage	Origin
LINES		
Mattatriveni (Ptb 45)	Annapoorna x Ptb-15	India (Kerala)
Gouri (MO-20)	Hybrid derivative of Bhadra x Mutant of orpandy	India (Kerala)
Jyothi (Ptb-39)	Ptb10 x IR-8	India (Kerala)
Kanchana (Ptb-50)	IR36 x Pavizham	India (Kerala)
Uma (MO-16)	MO-6 x Pokkali	India (Kerala)
Aiswarya (Ptb-52)	Jyothi x BR-51	India (Kerala)
TESTERS		
Swarnaprabha (Ptb-43)	Bhawani x Triveni	India (Kerala)
Mahsuri	Taichung65 x Mayangebos	Malaysia
Ponmani	Pankaj x Jaganath	India(Tamilnadu)
Ptb-15	Selection from Kavungin poothala	India (Kerala)

Table 2. Details of F_1 generations raised during June 2004

Sl. No.	Combinations	Designation
1	Mattatriveni x Swarnaprabha	C_1
2	Gouri x Swarnaprabha	C_2
3	Jyothi x Swarnaprabha	C_3
4	Kanchana x Swarnaprabha	C_4
5	Uma x Swarnaprabha	C_5
6	Aiswarya x Swarnaprabha	C_6
7	Mattatriveni x Mahsuri	C_7
8	Gouri x Mahsuri	C_8
9	Jyothi x Mahsuri	C_9
10	Kanchana x Mahsuri	C_{10}
11	Uma x Mahsuri	C_{11}
12	Aiswarya x Mahsuri	C_{12}
13	Mattatriveni x Ponmani	C_{13}
14	Gouri x Ponmani	C_{14}
15	Jyothi x Ponmani	C_{15}
16	Kanchana x Ponmani	C_{16}
17	Uma x Ponmani	C_{17}
18	Aiswarya x Ponmani	C_{18}
19	Mattatriveni x Ptb-15	C_{19}
20	Gouri x Ptb-15	C_{20}
21	Jyothi x Ptb-15	C_{21}
22	Kanchana x Ptb-15	C_{22}
23	Uma x Ptb-15	C_{23}
24	Aiswarya x Ptb-15	C_{24}

RESULTS

4. RESULTS

Six lines viz. Mattatriveni, Gouri, Jyothi, Kanchana, Uma and Aiswarya were crossed to four testers viz. Swarnaprabha, Mahsuri, Ponmani and Ptb-15 and the resultant twenty four hybrids were evaluated for combining ability, heterosis and character association to have an effective selection of parents and hybrids and to understand the gene action involved (Plate 3).

Experimental results on (i) combining ability analysis (ii) mean performance and heterosis (iii) correlation and (iv) path analysis are furnished here under.

4.1 ANALYSIS OF VARIANCE

The estimates of variance for twenty three characters studied are presented in Table 3. The analysis of variance showed highly significant difference among the genotypes for all the characters studied.

4.2 COMBINING ABILITY ANALYSIS

The combining ability analysis for the twenty three traits revealed highly significant difference between lines, testers and for line x tester interaction. Variance due to SCA were predominant for all the characters studied (Table 4). The ratio of variance due to GCA and SCA ranged from –1.96 to 0.65. Dominance variance was high for all the characters studied except grain yield.

Plate 3. Evaluation of parents and hybrids

Table 3. Analysis of variance for different characters in a 6 x 4 line x tester analysis

Source	df	Days to flowering	Total no. of tillers at active tillering stage	Total no. of tillers at active panicle initiation	Total no. of tillers at flowering stage	No. of productive tillers per plant	Plant height	Stem thickness	Flag leaf area	Panicle length	Grains per panicle	Panicle weight
Replication	2	0	1.69	0.25	0.62	1.66	1.12	0.069	1.94	2.56	2.25	0.02
Parents	9	2197.2**	4.50**	4.37	7.33**	6.77**	2546.58**	0.126**	44.97**	21.40**	3052.33**	0.83**
Females	5	77.6**	5.02*	2.40	7.57**	5.42*	242.09**	0.092**	24.09**	1.57	583.39**	0.54**
Males	3	3875.0**	3.89	4.31	5.64*	7.86**	3930.89**	0.18**	74.77**	29.89**	5419.33**	1.18**
Females Vs males	1	7762.8**	3.76	14.45*	11.25*	1.03	9916.08**	0.13*	59.97**	95.05**	8296.03**	1.18**
Hybrids	23	75.43**	5.00**	3.93**	3.80**	5.07**	238.23**	0.33**	139.01**	5.73**	2956.73**	0.54**
Par Vs Hybrids	1	5578.55**	101.72**	92.89*	133.83**	105.09**	7289.13**	6.60**	1227.54**	12.38**	5100.41**	1.60**
Error	66	0.04	2.01	2.17	1.89	1.72	2.84	0.023	3.04	1.00	4.26	0.05

Source	df	Chaff per cent	1000 grain weight	Grain density	Grain thickness	Grain yield per plant	Straw yield per plant	Total dry matter per plant	Harvest index	Root weight per plant	Root to shoot ratio	Root volume	Root length
Replication	2	6.13	1.85	0.03	0.002	337.60	3.08	1.94	1.84	0.22	0.009	1.09	0.28
Parents	9	1001.70**	42.53**	5.30**	0.04**	48.02	181.37**	345.09**	98.11**	27.25**	0.06**	59.19**	26.51**
Females	5	753.28**	13.76**	2.80**	0.004**	43.23	42.14**	112.82**	96.89**	27.83**	50.04**	12.57**	12.48**
Males	3	1368.11**	72.82**	11.18**	0.05**	34.15	405.97**	675.67**	118.10**	3.99*	0.11**	24.60**	13.09**
Females Vs males	1	1144.59**	95.48**	0.19	0.23**	113.60	203.73**	514.78**	44.20**	94.18**	0.05**	396.05**	136.94**
Hybrids	23	608.43**	19.03**	4.42**	0.007**	531.52**	88.09**	97.94**	179.80**	122.41**	0.27**	83.64**	26.22**
Par Vs Hybrids	1	12882.97**	0.35	1.71**	0.009**	451.61	0.37	125.51**	101.50**	3414.35**	4.45**	2202.60**	532.65**
Error	66	5.21	1.06	0.06	0.0005	364.82	1.55	3.54	5.89	1.31	0.006	1.65	0.75

* Significant at 5%

** Significant at 1%

Table 4. Analysis of variance for combining ability and estimates of variances in a 6 x 4 line x tester analysis

Source	Mean square											
	df	Days to flowering	Number of tillers at active tillering stage	Number of tillers at panicle initiation	Number of tillers at flowering stage	Number of productive tillers per plant	Plant height	Stem thick-ness	Flag leaf area	Panicle length	Grains per panicle	Panicle weight
Replication	2	0.0208	0.875	0.014	0.60	1.06	0.44	0.032	3.65	1.85	2.77	0.0027
Females	5	219.95**	6.49	6.22	3.81	7.92	299.71	0.41	181.72	7.26	5435.58	1.20*
Males	3	28.24	8.199*	1.87	0.53	4.46	209.31	0.43	42.01	5.15	2925.24	0.391
Female x Male	15	36.70**	3.88	3.59	4.44**	4.24**	223.52**	0.284**	144.18**	5.34**	2136.74**	0.36**
Error	46	0.0571	2.32	2.52	2.31	1.88	2.46	0.023	2.89	0.82	4.17	0.060
σ^2 gca		5.83	0.23	0.03	-0.15	0.13	2.07	0.01	-2.15	0.06	136.25	0.03
σ^2 sca		12.21	0.52	0.36	0.71	0.79	73.68	0.09	47.09	1.51	710.85	0.10
σ^2 A		11.65	0.46	0.06	-0.30	0.26	4.13	0.02	-4.31	0.12	272.49	0.06
σ^2 D		12.22	0.52	0.36	0.71	0.79	73.68	0.09	47.09	1.51	710.86	0.10
σ^2 gca/ σ^2 sca		0.48	0.44	0.08	-1.36	0.17	0.03	0.11	0.06	0.04	0.19	0.3

Source	Mean square											
	df	Chaff per cent	1000 grain weight	Grain density	Grain thickness	Grain yield per plant	Straw yield per plant	Total dry matter per plant	Harvest index	Root weight per plant	Root to shoot ratio	Root volume	Root length
Replication	2	1.29	0.191	0.0004	-0.0000068	514.26	3.18	0.68	2.72	1.16	0.0097	1.99	0.274
Females	5	1329.63*	34.55	4.56	0.0075	627.68	145.05	128.82	379.35*	110.87	0.176	185.62*	66.21**
Males	3	255.65	5.63	8.51	0.0054	476.33	85.54	68.35	210.61	59.06	0.545	4.10	30.26
Female x Male	15	438.59**	16.54**	3.56**	0.0078**	510.51	69.61**	93.56**	107.12**	138.92**	0.24**	65.56**	12.09**
Error	46	4.21	0.84	0.046	0.00028	514.72	1.56	2.13	6.04	1.61	0.008	2.06	1.03
σ^2 gca		23.6	0.24	0.20	0.00008	2.77	3.05	0.34	12.52	-3.60	0.0079	1.95	2.41
σ^2 sca		144.8	5.23	1.17	0.0022	-1.41	22.68	30.47	33.7	45.78	0.08	21.17	3.69
σ^2 A		47.21	0.47	0.40	0.00	5.53	6.09	0.67	25.05	-7.19	0.02	3.91	4.82
σ^2 D		144.79	5.23	1.17	0.00	-1.40	22.69	30.48	33.69	45.77	0.08	21.17	3.69
σ^2 gca/ σ^2 sca		0.16	0.05	0.2	0.04	-1.96	0.134	0.011	0.37	-0.08	0.1	0.09	0.65

* Significant at 5%

** Significant at 1%

4.3 COMBINING ABILITY EFFECTS

4.3.1 Days to flowering

General combining ability effects ranged from -4.4 (Mattatriveni) to 6.6 (Gouri) for the lines and from -1.62 (Swarnaprabha) to 1.43 (Ptb-15) for the testers. Four lines and one tester recorded significant negative *gca* effects and two lines and one tester recorded significant positive *gca* effects.

The *sca* effects of hybrids ranged between -7.88 (Uma x Swarnaprabha) and 6.12 (Mattatriveni x Swarnaprabha). Out of the 24 hybrids twelve recorded positive significant *sca* while eleven recorded negative significant *sca* (Table 5).

4.3.2 Number of tillers at active tillering stage

The range of *gca* of lines was from -1.04 (Aiswarya) to 0.88 (Kanchana) and of testers from -0.74 (Ptb-15) to 0.65 (Ponmani). One line showed significant positive *gca* and no testers had significant positive *gca*. One line(Aiswarya) and one tester (Ptb-15) showed significant negative *gca.*

The *sca* of hybrids ranged between -2.24 (Aiswarya x Swarnaprabha) and 1.51 (Gouri x Swarnaprabha). Among the 24 hybrids only one recorded negative significant *sca* (Table 6).

4.3.3 Number of tillers at panicle initiation stage

General combining effects of the lines exhibited a range from -0.86 (Aiswarya) to 1.06 (Kanchana) and of testers between -0.25 (Ptb-15) and 0.47 (Swarnaprabha). None of the lines and testers showed significant positive or negative *gca.*

Table 5. Combining ability effects of parents and hybrids for days to flowering

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	6.12**	-1.26**	-4.26**	-0.60**	-4.4**
Gouri	-0.88**	1.74**	1.74**	-2.60**	6.6**
Jyothi	2.12**	-0.26	-1.26**	-0.60**	-1.4**
Kanchana	-0.62**	-2.01**	1.99**	0.65**	-2.65**
Uma	-7.88**	1.40**	1.40**	5.07**	3.93**
Aiswarya	1.12**	0.40**	0.40**	-1.93**	-2.07**
gca of Males	-1.62**	0.10	0.10	1.43**	

SE(gi) of lines = 0.07

SE(gj) of testers = 0.06

SE(sij) of lines x testers = 0.14

* Significant at 5%
**Significant at 1%

Table 6. Combining ability effects of parents and hybrids for number of tillers at active tillering stage

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	0.93	0.82	-0.57	-1.18	0.12
Gouri	1.51	-0.60	-0.65	-0.26	0.54
Jyothi	0.10	-0.68	-0.74	1.32	-0.71
Kanchana	-0.49	-0.93	1.35	0.07	0.88*
Uma	0.18	0.07	0.01	-0.26	0.21
Aiswarya	-2.24*	1.32	0.60	0.32	-1.04*
gca of Males	0.49	-0.40	0.65	-0.74*	

SE(gi) of lines = 0.44

.SE(gj) of testers = 0.36

SE(sij) of lines x testers = 0.88

* Significant at 5%
**Significant at1%

The *sca* of hybrids ranged between -1.42 (Uma x Ptb-15) and 1.58 (Jyothi x Ptb-15). No significant positive or negative *sca* was recorded (Table 7).

4.3.4 Number of tillers at flowering stage

The *gca* effects ranged from -0.85 (Aiswarya) to 0.65 (Kanchana) among the lines and from -0.24 (Mahsuri) to 0.15 (Ptb-15) among the testers. None of the parents recorded significant positive or negative *gca.*

Specific combining ability effects ranged from -1.76 (Aiswarya x Swarnaprabha) to 1.85 (Kanchana x Ponmani). Two different hybrid combinations recorded significant positive *sca* effect and significant negative *sca* effect (Table 8).

4.3.5 Number of productive tillers per plant

The *gca* of lines ranged from -0.61 (Aiswarya and Jyothi) to 1.56 (Kanchana) and of testers from -0.47 (Ptb-15) to 0.64 (Ponmani). Kanchana recorded high significant positive *gca* effect among lines and Ponmani recorded high positive significant *gca* effect among testers.

Specific combining ability effects of hybrids ranged from -1.44 (Uma x Ptb-15) to 1.89 (Jyothi x Ptb-15).Among twenty four hybrid combinations only two recorded positive significant *sca* effects (Table 9).

4.3.6 Plant height

The *gca* of lines ranged from -5.01 (Jyothi) to 8.65 (Aiswarya) and of testers from -4.07 (Ptb-15) to 4.26 (Mahsuri). Two lines and one tester showed highly

Table 7. Combining ability effects of parents and hybrids for number of tillers at panicle initiation

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-0.22	0.67	0.72	-1.17	-0.11
Gouri	0.03	-0.08	-1.03	1.08	0.64
Jyothi	0.53	-0.92	-1.19	1.58	-0.19
Kanchana	-0.06	-1.17	0.89	0.33	1.06
Uma	0.86	0.75	-0.19	-1.42	-0.53
Aiswarya	-1.14	0.75	0.81	-0.42	-0.86
gca of Males	0.47	-0.08	-0.14	-0.25	

SE(gi) of lines = 0.46

.SE(gj) of testers = 0. 37

SE(sij) of lines x testers = 0.92

* Significant at 5%
**Significant at 1%

Table 8. Combining ability effects of parents and hybrids for number of tillers at flowering stage

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	0.90	0.24	-0.65	-0.49	0.49
Gouri	0.90	-0.10	-1.65	0.85	0.15
Jyothi	0.15	-1.18	-0.74*	1.76*	-0.43
Kanchana	-0.26	-0.26	1.85*	-1.32	0.65
Uma	0.07	0.74	0.18	-0.99	-0.01
Aiswarya	-1.76*	0.57	1.01	0.18	-0.85
gca of Males	0.10	-0.24	-0.01	0.15	

SE(gi) of lines = 0.44

SE(gj) of testers = 0.36

SE(sij) of lines x testers = 0.88

* Significant at 5%
**Significant at1%

significant positive *gca* effect and three lines and one tester showed negative significant *gca* effect.

Specific combining ability effects ranged from -17.51 (Gouri x Ptb-15) to 11.26 (Uma x Ponmani). Ten hybrid combinations recorded significant positive *sca* effect and seven recorded significant negative *sca* effects (Table 10).

4.3.7 Stem thickness

The general combining ability effects ranged from -0.18 (Mattatriveni) to 0.28 (Aiswarya) for the lines and from -0.19 (Ptb-15) to 0.16 (Mahsuri) for the testers. Among the lines two of them recorded positive significant *gca* effects and three recorded negative significant *gca* effects. One tester showed positive significant *gca* effect while another tester showed negative significant *gca* effect.

Among the hybrids the *sca* effects ranged between -0.48 (Mattatriveni x Mahsuri) and 0.52 (Aiswarya x Ptb-15). Five hybrid combinations exhibited significant positive *sca* effects and five recorded significant negative *sca* effects (Table 11).

4.3.8 Flag leaf area

The range of *gca* of lines was between -6.44 (Uma) and 4.36 (Jyothi) and for testers from -1.62 (Ptb-15) to 1.69 (Mahsuri). Among the six lines and four testers, two lines and two testers recorded highly significant *gca* effects while two lines and two testers exhibited negative significant *gca* effects.

The *sca* effects of hybrids ranged from -11.36 (Jyothi x Mahsuri) and 13.95 (Jyothi x Ptb-15). Out of twenty four hybrids eight recorded positive significant *sca* effects and ten recorded negative significant *sca* effects (Table 12).

Table 9. Combining ability effects of parents and hybrids for number of productive tillers per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-1.19	1.03	-0.14	0.31	-0.03
Gouri	0.81	-0.64	-1.14	0.97	-0.36
Jyothi	-0.28	-0.72	-0.89	1.89*	-0.61
Kanchana	-0.44	0.78	0.94	-1.28	1.56**
Uma	1.72*	-0.72	0.44	-1.44	0.06
Aiswarya	-0.61	0.28	0.78	-0.44	-0.61
gca of Males	-0.31	0.14	0.64*	-0.47	

SE(gi) of lines = 0.40

SE(gj) of testers = 0.32

SE(sij) of lines x testers = 0.79

* Significant at 5%
**Significant at 1%

Table 10. Combining ability effects of parents and hybrids for plant height

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-1.49	4.4**	-3.99**	1.07	-0.51
Gouri	3.60**	8.15**	5.76**	-17.51**	2.4**
Jyothi	-0.65	0.24	-3.82**	4.24**	-5.01**
Kanchana	0.10	6.32**	-10.40**	3.99**	-1.43**
Uma	-6.57**	-5.68**	11.26**	0.99	-4.10**
Aiswarya	5.01**	-13.43**	1.18	7.24**	8.65**
gca of Males	0.15	4.26**	-0.35	-4.07**	

SE(gi) of lines = 0.45

SE(gj) of testers = 0.37

SE(sij) of lines x testers = 0.91

* Significant at 5%
**Significant at 1%

4.3.9 Panicle length

The general combining ability effects *(gca)* ranged from -0.72 (Uma) to 1.11 (Mattatriveni) for the lines and from -0.67 (Ptb-15) to 0.61 (Mahsuri) for the testers. Among the six lines and four testers two lines and one tester showed highly positive significant *gca* effect and one line and one tester showed highly negative significant *gca* effects.

Specific combining ability effects of hybrid combinations ranged from -1.83 (Gouri x Ptb-15) to 2.17 (Mattatriveni x Ponmani). Out of 24 hybrids three recorded negative significant *sca* effects and five recorded positive significant *sca* effects (Table 13).

4.3.10 Grains per panicle

The range of *gca* of lines was between -23.90 (Gouri) and 24.68 (Mattatriveni) and for testers between -13.49 (Ptb-15) and 14.62 (Swarnaprabha). Among the six lines and four testers three lines and two testers showed highly positive significant *gca* effects and another three lines and two testers showed highly negative significant *gca* effect.

The *sca* effects of hybrids ranged from -40.76 (Aiswarya x Ponmani) to 36.49 (Mattatriveni x Ponmani). Out of 24 hybrids eleven hybrids recorded highly significant positive *sca* effect and eleven hybrids recorded highly significant negative *sca* effects (Table 14).

4.3.11 Panicle weight

The *gca* for lines ranged from -0.32 (Gouri) to 0.43 (Mattatriveni) and for testers from -0.18 (Ptb-15) to 0.18 (Swarnaprabha). Two lines and one tester

Table 11.Combining ability effects of parents and hybrids for stem thickness

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	0.18*	-0.48**	-0.01	0.31**	-0.18**
Gouri	0.07	0.15	0.15	-0.37**	-0.04**
Jyothi	-0.07	0.07	0.11	-0.11	0.17**
Kanchana	-0.10	0.48**	-0.15	-0.23**	-0.17**
Uma	-0.12	0.19*	0.06	-0.12	-0.05
Aiswarya	0.05	-0.40**	-0.17*	0.52**	0.28**
gca of Males	0.07	0.16**	-0.04	-0.19**	

SE(gi) of lines = 0.45

SE(gj) of testers = 0.37

SE(sij) of lines x testers = 0.91

* Significant at 5%
**Significant at 1%

Table 12. Combining ability effects of parents and hybrids for flag leaf area

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-2.76**	-2.36*	6.50**	-1.38	3.69**
Gouri	2.23*	6.23**	-3.01**	-5.46**	-1.23*
Jyothi	4.24**	-11.36**	-6.83**	13.95**	4.36**
Kanchana	1.16	2.56**	-2.58**	-1.13	-0.22
Uma	-2.96**	8.77**	-0.90	-4.92**	-6.44**
Aiswarya	-1.91	-3.84**	6.82**	-1.07	-0.16
gca of Males	-0.91*	1.69**	0.83*	-1.62**	

SE(gi) of lines = 0.49

SE(gj) of testers = 0.40

SE(sij) of lines x testers = 0.98

* Significant at 5%
**Significant at 1%

Table 13. Combining ability effects of parents and hybrids for panicle length

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-1.22*	-0.94	2.17**	0.00	1.11**
Gouri	-0.39	0.89	1.33*	-1.83**	-0.39
Jyothi	-0.97	1.31*	-0.92	0.58	0.86**
Kanchana	0.69	-0.03	0.08	-0.75	-0.47
Uma	0.61	-0.78	-1.00	1.17*	-0.72**
Aiswarya	1.28*	-0.44	-1.67**	0.83	-0.39
gca of Males	-0.11	0.61**	0.17	-0.67**	

SE(gi) of lines = 0.26

SE(gj) of testers = 0.21

SE(sij) of lines x testers = 0.52

*Significant at 5%
**Significant at 1%

Table 14. Combining ability effects of parents and hybrids for grains per panicle

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-39.79**	36.49**	33.65**	-30.35**	24.68**
Gouri	-23.21**	-1.60	9.90**	14.90**	-23.90**
Jyothi	-1.38	-3.10**	-12.93**	17.40**	23.93**
Kanchana	23.21**	-19.85**	6.65**	-10.01**	-15.32**
Uma	12.38**	-3.68**	3.49**	-12.18**	-15.49**
Aiswarya	28.79**	-8.26**	-40.76**	20.24**	6.10**
gca of Males	14.62**	-7.32**	6.18**	-13.49**	

SE(gi) of lines = 0.59

SE(gj) of testers = 0.48

SE(sij) of lines x testers = 1.18

* Significant at 5%
** Significant at 1%

showed significant positive *gca* effects and three lines and one tester showed significant negative *gca* effect.

The *sca* of hybrids ranged from -0.55 (Mattatriveni x Swarnaprabha) to 0.55 (Gouri x Mahsuri). Four hybrids showed positive significant *sca* and four showed negative significant *sca* effect (Table 15).

4.3.12 1000 grain weight

Out of the six lines and four testers tested, the *gca* effects ranged from -1.22 (Uma and Aiswarya) to 3.24 (Jyothi) among the lines and -0.56 (Swarnaprabha) to 0.76 (Ponmani) among the testers. Three lines and one tester showed significant negative *gca* effect and one line and one tester showed significant positive *gca* effect.

The variation for *sca* effect was from -3.95 (Aiswarya x Swarnaprabha) to 3.95 (Aiswarya x Ptb-15). Seven hybrid combinations recorded significant positive *sca* effect while six had significant negative *sca* effects (Table 16).

4.3.13 Grain density

The *gca* effects of lines ranged between -1.08 (Mattatriveni) and 0.59 (Kanchana). The variation was from -0.62 (Ptb-15) to 0.97 (Swarnaprabha) among the testers. Results presented in Table 17 indicated significant negative *gca* effect for two lines and two testers while three lines and one tester showed significant positive *gca* effect.

Among the hybrids tested, the *sca* effect ranged from -1.72 (Mattatriveni x Swarnaprabha) to 1.98 (Kanchana x Swarnaprabha). Eleven hybrids exhibited significant positive *sca* effects and nine hybrids recorded significant negative *sca* effects.

Table 15. Combining ability effects of parents and hybrids for panicle weight per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-0.55**	0.17	0.50**	-0.12	0.43**
Gouri	-0.36**	0.55**	-0.18	-0.01	-0.32**
Jyothi	0.05	0.09	-0.14	0.00	0.34**
Kanchana	0.01	-0.21	0.13	0.07	-0.22**
Uma	0.53**	-0.29*	-0.19	-0.05	-0.21**
Aiswarya	0.32*	-0.30*	-0.13	0.11	-0.03
gca of Males	0.18**	-0.03	0.03	-0.18**	

SE(gi) of lines = 0.07

SE(gj) of testers = 0.06

SE(sij) of lines x testers = 0.14

* Significant at 5%
**Significant at 1%

Table 16. Combining ability effects of parents and hybrids for 1000 grain weight

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	0.84	1.22*	-0.39	-1.67**	-0.98**
Gouri	-0.32	-3.57**	2.86**	1.04*	-0.02
Jyothi	0.99	2.14**	-0.60	-2.52**	3.24**
Kanchana	2.10**	0.15	-0.25	-2.00**	0.19
Uma	0.34	-0.51	-1.04*	1.21*	-1.22**
Aiswarya	-3.95**	0.57	-0.57	3.95**	-1.2**
gca of Males	-0.56**	-0.21	0.76**	0.01	

SE(gi) of lines = 0.27

SE(gj) of testers = 0.22

SE(sij) of lines x testers = 0.53

* Significant at 5%
**Significant at 1%

4.3.14 Grain thickness

Among the females, *gca* effect was between -0.03 (Mattatriveni) to 0.03 (Gouri) and among the males it was from -0.02 (Mahsuri) to 0.02 (Ponmani). Three lines and one tester showed positive significant gca effects while another three lines and two testers showed significant negative *gca* effects.

The specific combining ability of the hybrid combination ranged between -0.08 (Gouri x Swarnaprabha) and 0.07 (Gouri x Ponmani). Among the 24 hybrids eight hybrids exhibited negative significant *sca* effects and seven hybrids exhibited positive significant *sca* effects (Table 18).

4.3.15 Grain yield

General combining ability effects of the lines ranged from -7.3 (Gouri) to 13.56 (Mattatriveni) and of the testers from -4.13 (Ptb-15) to 7.45 (Mahsuri). Only Mattatriveni (13.56) showed highly significant positive *gca* effect.

Among the hybrids the *sca* effects ranged between -18.12 (Mattatriveni x Ptb-15) to 38.62 (Mattatriveni x Mahsuri). Only Mattatriveni x Mahsuri combination exhibited highly significant positive *sca* effect (Table 19).

4.3.16 Straw yield

Among the lines tested, the *gca* effects ranged from -4.18 (Jyothi) to 4.58 (Uma) and among testers the *gca* effects ranged from -2.80 (Ponmani) to 2.00 (Swarnaprabha). Three lines and one tester exhibited highly significant negative *gca* effects while two lines and two testers showed significant positive *gca* effects.

Table 17. Combining ability effects of parents and hybrids for grain density

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-1.72**	0.53**	0.59**	0.60**	-1.08**
Gouri	1.21**	-0.90**	0.16	-0.46**	0.35**
Jyothi	-1.34**	0.55**	0.54**	0.25*	0.44**
Kanchana	1.98**	-0.17	-0.77**	-1.03**	0.59**
Uma	0.78**	-0.86**	-0.17	0.24	-0.02
Aiswarya	-0.90**	0.86**	-0.35**	0.39**	-0.27**
gca of Males	0.97**	-0.28**	-0.08	-0.62**	

SE(gi) of lines = 0.07

SE(gj) of testers = 0.05

SE(sij) of lines x testers = 0.13

* Significant at 5%
**Significant at 1%

Table 18. Combining ability effects of parents and hybrids for grain thickness

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-0.03*	0.06**	-0.01	-0.02	-0.03**
Gouri	-0.08**	0.02	0.07**	-0.01	0.03**
Jyothi	0.05**	-0.03*	-0.02	0.00	0.02**
Kanchana	0.03*	-0.06**	0.06**	-0.03*	0.01*
Uma	0.05**	0.00	-0.06**	0.00	-0.02**
Aiswarya	-0.03*	0.02	-0.04**	0.05**	-0.01*
gca of Males	0.00	-0.02**	0.02**	-0.01*	

*Significant at 1%
**Significant at 1%

SE(gi) of lines = 0.01

.SE(gj) of testers = 0.004

SE(sij) of lines x testers = 0.01

Table 19. Combining ability effects of parents and hybrids for grain yield per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-13.15	38.62**	-7.35	-18.12	13.56**
Gouri	1.17	-7.52	2.38	3.97	-7.3
Jyothi	4.65	-4.28	1.09	-1.46	-1.88
Kanchana	5.72	-9.21	0.12	3.38	-2.28
Uma	1.72	-9.14	3.43	3.98	-3.65
Aiswarya	-0.11	-8.47	0.33	8.25	1.55
gca of Males	-2.44	7.45	-0.88	-4.13	

SE(gi) of lines = 6.55

SE(gj) of testers = 5.35

SE(sij) of lines x testers = 13.1

*Significant at 5%
**Significant at 1%

Table 20. Combining ability effects of parents and hybrids for straw yield per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-2.56**	-2.08**	0.01	4.63**	-2.86**
Gouri	2.35**	1.93**	5.05**	-9.32**	3.43**
Jyothi	-0.43	-2.96**	1.00	2.39**	-4.18**
Kanchana	3.09**	7.3**	-6.11**	-4.28**	-1.37**
Uma	-2.63**	-4.08**	0.84	5.87**	4.58**
Aiswarya	0.18	-0.11**	-0.78	0.71	0.40
gca of Males	2.00**	1.42**	-2.80**	-0.63	

SE(gi) of lines = 0.36

SE(gj) of testers = 0.29

SE(sij) of lines x testers = 0.72

* Significant at 5%
**Significant at 1%

Out of 24 hybrids the *sca* effects ranged from -9.32 (Gouri x Ptb-15) to 7.3 (Kanchana x Mahsuri). Nine hybrids recorded negative significant *sca* effects and eight hybrids recorded positive significant *sca* effects (Table 20).

4.3.17 Total dry matter

The *gca* effects for lines ranged from -3.36 (Jyothi) to 4.56 (Aiswarya) and for testers ranged from -2.19 (Ptb-15) to 2.14 (Swarnaprabha). Four lines and two testers exhibited significant negative *gca* effects and two lines and two testers exhibited significant positive *gca* effects.

sca effects of the hybrids ranged between -8.36 (Kanchana x Ponmani) and 7.44 (Uma x Ptb-15). Out of 24 hybrids nine hybrids showed significant negative *sca* effect and eight hybrids exhibited positive significant *sca* effects (Table 21).

4.3.19 Harvest Index

General combining ability effects ranged from -8.7 (Gouri) to 5.76 (Jyothi) for the lines and from -2.12 (Mahsuri) to 5.10 (Ponmani) for the testers. Two lines and three testers recorded significant negative *gca* effects and four lines and one tester showed significant positive *gca* effects.

The *sca* of hybrids ranged between -9.46 (Mattatriveni x Ptb-15) and 9.46 (Gouri x Ptb-15). Among 24 hybrids, six showed negative significant *sca* effects and seven hybrids showed positive significant *sca* effects (Table 22).

Table 21. Combining ability effects of parents and hybrids for total dry matter

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-2.47**	-3.03**	5.97**	-0.47	-2.53**
Gouri	1.03	2.47**	4.81**	-8.31**	-1.36**
Jyothi	1.69*	0.81	-0.86	-1.64	-3.36**
Kanchana	5.86**	5.97**	-8.36**	-3.47**	-0.86**
Uma	-3.56**	-5.44**	1.56	7.44**	3.56**
Aiswarya	-2.56**	-0.78	-3.11**	6.44**	4.56**
gca of Males	2.14**	1.03**	-0.97**	-2.19**	

SE(gi) of lines = 0.42

SE(gj) of testers = 0.34

SE(sij) of lines x testers = 0.84

* Significant at 5%
**Significant at 1%

Table 22. Combining ability effects of parents and hybrids for harvest index

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	2.6	1.21	5.65**	-9.46**	2.18**
Gouri	-3.82**	-0.54	-5.10**	9.46**	-8.74**
Jyothi	4.01**	5.62**	-0.93	-8.71**	5.76**
Kanchana	-0.49	-7.88**	3.24*	5.12**	2.26**
Uma	0.85	1.79	-0.76	-1.88	-5.07**
Aiswarya	-3.15*	-0.21	-2.10	5.46**	3.60**
gca of Males	-1.18*	-2.12**	5.10**	-1.79**	

* Significant at 5%
**Significant at 1%

SE(gi) of lines = 0.71

SE(gj) of testers = 0.58

SE(sij) of lines x testers = 1.42

4.3.19 Root weight per plant

The range of *gca* of lines was between -4.37 (Mattatriveni) to 4.06 (Gouri) and of testers between -1.78 (Swarnaprabha) to 2.50 (Ponmani). Two lines and one tester showed significant positive *gca* effect. Two lines and two testers exhibited significant negative *gca* effects.

The *sca* of hybrids ranged between -7.66 (Mattatriveni x Swarnaprabha) to 12.46 (Aiswarya x Swarnaprabha). Among the 24 hybrids nine hybrids exhibited positive significant *gca* effects and another eleven hybrids recorded negative significant *sca* effects (Table 23).

4.3.20 Root to shoot ratio

The *gca* effects of lines ranged between -0.11 (Mattatriveni and Uma) to 0.15 (Kanchana) and of testers from -0.19 (Swarnaprabha) to 0.21 (Ponmani). Two lines and two testers recorded significant positive *gca* effects. Three lines and two testers showed significant negative *gca* effects.

The *sca* of hybrid combination ranged between -0.57 (Kanchana x Mahsuri) and 0.41 (Kanchana x Ponmani). Among 24 hybrids nine exhibited significant negative *sca* effects and seven exhibited significant positive *sca* effects (Table 24).

4.3.21 Root volume

Out of the six lines and four testers the *gca* effects of lines were between -3.29 (Aiswarya) to 6.41 (Gouri) and of testers were between -0.55 (Ptb-15) and 0.49 (Mahsuri). Three lines showed negative significant *gca* effect and two recorded

Table 23. Combining ability effects of parents and hybrids for root weight per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-7.66**	7.61**	-3.77**	3.83**	-4.37**
Gouri	-5.22**	4.89**	2.93**	-2.6**	4.06**
Jyothi	-6.03**	0.75	3.46**	1.83*	0.06
Kanchana	10.14**	-8.88**	-2.13**	0.87	-0.21
Uma	-3.69**	-0.71	4.57**	-0.17	2.52**
Aiswarya	12.46**	-3.66**	-5.05**	-3.75**	-2.06**
gca of Males	-1.78**	-0.66*	2.50**	-0.07	

SE(gi) of lines = 0.37

.SE(gj) of testers = 0.30

SE(sij) of lines x testers = 0.73

* Significant at 5%
**Significant at 1%

Table 24. Combining ability effects of parents and hybrids for root to shoot ratio

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-0.17**	0.37**	-0.14**	-0.06	-0.11**
Gouri	-0.16**	0.07	-0.15**	0.24**	0.01
Jyothi	-0.20**	0.18**	0.05	-0.03	0.14**
Kanchana	0.11*	-0.57**	0.41**	0.06	0.15**
Uma	0.03	0.13*	0.07	-0.23**	-0.11**
Aiswarya	0.40**	-0.18**	-0.25**	0.03	-0.07*
gca of Males	-0.19*	-0.09*	0.21*	0.06*	

SE(gi) of lines = 0.03

.SE(gj) of testers = 0.02

SE(sij) of lines x testers = 0.05

* Significant at 5%
**Significant at 1%

Table 25. Combining ability effects of parents and hybrids for root volume per plant

Female parents	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-3.70**	3.25**	0.02	0.43	-3.16**
Gouri	-0.60	0.35	6.65**	-6.40**	6.41**
Jyothi	-3.52**	-2.57**	-0.14	6.24**	-2.33**
Kanchana	7.09	-0.86	0.44	-6.68**	0.72
Uma	-2.27**	0.88	-2.79**	4.19**	3.08**
Aiswarya	3.00**	-1.05	-4.18**	2.23**	-3.29**
gca of Males	-0.23	0.49	0.29	-0.55	

SE(gi) of lines = 0.41

.SE(gj) of testers = 0.34

SE(sij) of lines x testers = 0.83

* Significant at 5%
**Significant at 1%

Table 26. Combining ability effects of parents and hybrids for root length per plant

Female parents.	*sca* of hybrids with each male parent				*gca* of females
	Swarnaprabha	Mahsuri	Ponmani	Ptb-15	
Mattatriveni	-1.16**	-2.60**	3.24**	0.52	-1.37**
Gouri	1.95**	-2.43**	1.58**	-1.10	0.23
Jyothi	-1.55**	0.87	-0.32	1.00	2.06**
Kanchana	0.62	3.25**	-3.01**	-0.86	-0.08
Uma	-0.63	0.60	-0.66	0.69	-3.67**
Aiswarya	0.78	0.31	-0.85	-0.24	2.83**
gca of Males	1.91**	-0.32	-0.73**	-0.87**	

SE(gi) of lines = 0.29

.SE(gj) of testers = 0.24

SE(sij) of lines x testers = 0.59

* Significant at 5%
**Significant at 1%

significant positive *gca* effects. While no testers recorded any positive or negative significant *gca* effects.

The variation for *sca* effect was from -6.68 (Kanchana x Ptb-15) to 7.09 (Kanchana x Swarnaprabha). Eight hybrid combinations showed significant negative *sca* effects and six hybrids recorded significant positive *sca* effects (Table 25).

4.3.22 Root length

The *gca* effects of lines ranged between -3.67 (Uma) to 2.83 (Aiswarya). The variation was from -0.87 (Ptb-15) to 1.91 (Swarnaprabha) among the testers. Results presented in Table 26 indicated significant negative *gca* for two lines and two testers and significant positive *gca* for another two lines and one tester.

Among the hybrids tested the *sca* effect ranged between -3.01 (Kanchana x Ponmani) and 3.25 (Kanchana x Mahsuri). Out of twenty four,five hybrids recorded negative significant *sca* effects and four hybrids recorded positive significant *sca* effects.

4.4 MEAN PERFORMANCE AND HETEROSIS OF PARENTS AND HYBRIDS

4.4.1 Days to flowering

Mean performance of lines ranged from 75 (Aiswarya) to 86 days (Gouri and Uma). In testers days to flowering ranged from 80 (Swarnaprabha) to 160 days (Ptb-15). Among the hybrids flowering duration ranged from 68 (Mattatriveni x Ponmani) to 87 days (Uma x Ptb-15). All the hybrids expressed lesser duration compared to the parents (Table.27).

Table 27. Mean performance of hybrids and parents for different quantitative characters

Sl. No.	Genotypes	Days to flowering	Number of tillers at active tillering stage	Number of tillers at panicle initiation	Number of tillers at flowering stage	Number of productive tillers per plant	Plant height (cm)	Stem thick-ness (cm)	Flag leaf area (cm^2)	Panicle length (cm)	Grains per panicle	Panicle weight/ plant (g)
1	Mattatriveni x Swarnaprabha	76.67	11.67	11.00	12.67	8.67	95.00	3.4	41.67	21.67	80.00	2.67
2	Gouri x Swarnaprabha	80.67	12.67	12.00	12.33	10.33	103.00	3.43	41.73	21.00	48.00	2.10
3	Jyothi x Swarnaprabha	75.67	10.00	11.67	11.00	9.00	91.33	3.5	49.33	21.67	117.67	3.17
4	Kanchana x Swarnaprabha	71.67	11.00	12.33	11.67	11.00	95.67	3.13	41.67	22.00	103.00	2.57
5	Uma x Swarnaprabha	71.00	11.00	11.67	11.33	11.67	86.33	3.23	31.33	21.67	92.00	3.10
6	Aiswarya x Swarnaprabha	74.00	7.33	9.33	8.67	8.67	110.67	3.73	38.67	22.67	130.00	3.07
7	Mattatriveni x Mashuri	71.00	10.67	11.33	11.67	11.67	105.00	2.83	44.67	22.67	134.33	3.17
8	Gouri x Mashuri	85.00	9.67	11.33	11.00	11.00	111.67	3.60	48.33	23	47.67	2.80
9	Jyothi x Mashuri	75.00	8.33	9.67	9.33	9.33	96.33	3.73	36.33	24.67	94.00	3.00
10	Kanchana x Mashuri	72.00	9.67	10.67	11.33	11.33	106.00	3.80	45.67	22.00	38.00	2.13
11	Uma x Mashuri	82.00	10.00	11.00	11.67	11.67	91.33	3.63	45.67	21.00	54.00	2.07
12	Aiswarya x Mashuri	75.00	10.00	10.67	10.67	10.67	96.33	3.37	39.33	21.67	71.00	2.23

Contd.

Table 27. continued

Sl. No.	Genotypes	Days to flowering	Number of tillers at active tillering stage	Number of tillers at panicle initiation	Number of tillers at flowering stage	Number of productive tillers per plant	Plant height (cm)	Stem thick-ness (cm)	Flag leaf area (cm^2)	Panicle length (cm)	Grains per panicle	Panicle weight (g)
13	Mattatriveni x Ponmani	68.00	10.33	11.33	11.00	11.00	92.00	3.10	52.67	25.33	145.00	3.57
14	Gouri x Ponmani	85.00	10.67	10.33	9.67	9.67	104.67	3.40	38.23	23.00	72.67	2.13
15	Jyothi x Ponmani	74.00	9.33	9.33	10.00	10.00	87.67	3.59	40.00	22.00	97.67	2.83
16	Kanchana x Ponmani	76.00	13.00	12.67	13.67	13.67	84.67	2.97	39.67	21.67	78.00	2.53
17	Uma x Ponmani	82.00	11.00	10.00	11.11	11.33	103.67	3.30	35.13	20.33	74.67	2.23
18	Aiswarya x Ponmani	75.00	10.33	10.67	11.33	11.33	106.33	3.40	49.13	20.60	52.00	2.47
19	Mattatriveni x Ptb 15	73.00	8.33	9.33	11.33	10.00	93.33	3.27	42.33	22.33	61.33	2.73
20	Gouri x Ptb 15	82.00	9.67	12.33	12.33	10.33	77.67	2.73	33.33	19.00	58.00	2.10
21	Jyothi x Ptb 15	76.00	10.00	12.00	12.67	11.00	92.00	3.20	58.33	22.67	108.33	2.77
22	Kanchana x Ptb 15	76.00	10.33	12.00	10.67	10.00	95.33	2.73	38.67	20.00	41.67	2.27
23	Uma x Ptb 15	87.00	9.33	8.67	10.33	8.33	89.67	2.97	28.67	21.67	39.33	2.17
24	Aiswarya x Ptb 15	74.00	8.67	9.33	10.67	8.67	108.67	3.93	38.80	21.67	93.33	2.50
25	Swarnaprabha	80.00	7.33	7.67	7.67	6.33	130.00	2.53	42.83	24.33	60.67	2.37

Contd.

Table 27. continued

Sl. No.	Genotypes	Days to flowering	Number of tillers at active tillering stage	Number of tillers at panicle initiation	Number of tillers at flowering stage	Number of productive tillers per plant	Plant height (cm)	Stem thickness (cm)	Flag leaf area (cm^2)	Panicle length (cm)	Grains per panicle	Panicle weight (g)
26	Mashuri	90.00	8.67	8.67	9.67	9.33	137.67	2.87	34.33	24.67	127.67	3.50
27	Ponmani	120.00	8.00	9.00	8.00	7.67	97.67	2.93	31.10	21.33	38.67	2.20
28	Ptb 15	160.00	6.00	6.33	6.33	5.67	185.33	2.43	34.71	29.00	114.33	2.20
29	Mattatriveni	79.00	7.67	9.33	9.00	8.33	99.33	2.77	29.57	21.00	57.00	2.27
30	Gouri	86.00	8.33	9.00	9.00	8.00	90.33	2.77	35.00	20.77	31.00	1.40
31	Jyothi	76.00	6.33	9.00	7.33	6.69	97.00	2.93	28.93	20.33	36.67	2.30
32	Kanchana	76.00	9.67	10.33	11.33	10.33	94.67	2.67	34.67	21.00	64.67	2.37
33	Uma	86.00	9.67	10.33	10.67	9.67	115.00	3.13	34.07	22.33	60.00	2.00
34	Aiswarya	75.00	7.67	8.00	7.67	7.67	107.00	2.70	35.76	21.77	59.00	2.63
35	Mean of testers	112.50	7.50	7.92	7.92	7.25	137.67	2.69	32.87	24.83	85.33	2.57
36	Mean of lines	79.67	8.22	9.33	9.17	8.44	100.56	2.83	41.64	21.20	51.39	2.16
37	Mean of hybrids	76.57	10.12	10.86	11.18	10.19	96.85	3.33	41.64	21.89	80.49	2.60
38	General mean	81.34	9.48	10.25	10.44	9.54	102.30	3.17	39.40	22.11	75.92	2.52

Contd.

Table 27. continued

Sl. No.	Genotypes	1000 grain weight (g)	Grain density (g/ml)	Grain thickness (mm)	Grain yieldper plant(g)	Straw yieldper plant (g)	Total dry matter (g)	Harvest index	Root weight per plant (g)	Root to shoot ratio	Root volume (ml)	Root length (cm)
1	Mattatriveni x Swarnaprabha	23.83	0.79	1.88	21.73	24.97	46.62	0.47	14.00	0.56	15.07	14.97
2	Gouri x Swarnaprabha	23.63	1.22	1.89	15.20	36.17	51.33	0.29	24.87	0.69	27.73	19.67
3	Jyothi x Swarnaprabha	28.20	0.98	2.00	24.10	25.77	50.00	0.52	20.07	0.78	16.07	18.00
4	Kanchana x Swarnaprabha	26.27	1.32	1.97	24.77	32.10	56.67	0.44	35.97	1.10	28.30	18.03
5	Uma x Swarnaprabha	23.10	1.14	1.96	19.40	32.33	51.67	0.38	24.87	0.77	22.73	13.20
6	Aiswarya x Swarnaprabha	18.83	0.95	1.90	22.77	30.97	53.67	0.42	36.43	1.17	21.63	21.10
7	Mattatriveni x Mashuri	24.57	0.89	1.94	83.40	24.87	45.00	0.44	30.40	1.20	22.73	11.30
8	Gouri x Mashuri	20.73	0.89	1.97	16.40	35.17	51.07	0.32	36.10	1.02	29.40	13.07
9	Jyothi x Mashuri	29.70	1.04	1.90	25.07	22.67	48.00	0.52	27.97	1.27	17.73	18.20
10	Kanchana x Mashuri	24.67	0.98	1.85	19.73	35.73	55.67	0.35	18.07	0.52	21.07	18.43
11	Uma x Mashuri	22.60	0.85	1.89	18.43	30.30	48.67	0.38	28.97	0.96	26.60	12.20
12	Aiswarya x Mashuri	23.70	1.00	1.93	24.30	30.10	54.33	0.44	21.43	0.68	18.30	18.40

Table 27. continued

Sl. No.	Genotypes	1000 grain weight (g)	Grain density (g/ml)	Grain thickness (mm)	Grain yield per plant (g)	Straw yield per plant (g)	Total dry matter per plant (g)	Harvest index	Root weight per plant (g)	Root to shoot ratio	Root volume (ml)	Root length (cm)
13	Mattatriveni x Ponmani	23.93	0.91	1.91	29.10	22.73	52.00	0.56	22.17	0.99	19.30	16.73
14	Gouri x Ponmani	28.13	1.01	2.05	17.97	34.07	52.00	0.34	37.30	1.10	35.50	16.67
15	Jyothi x Ponmani	27.93	1.06	1.96	22.10	22.40	44.33	0.53	33.83	1.43	19.97	16.60
16	Kanchana x Ponmani	25.23	0.94	2.02	20.73	18.10	39.44	0.54	27.99	1.80	22.17	11.77
17	Uma x Ponmani	23.03	0.94	1.87	22.67	31.00	53.67	0.42	37.40	1.20	22.73	10.53
18	Aiswarya x Ponmani	23.53	0.90	1.91	24.77	25.20	30.00	0.50	23.20	0.92	14.97	16.83
19	Mattatriveni x Ptb 15	21.90	0.86	1.88	15.07	29.53	44.33	0.34	27.20	0.92	18.87	13.87
20	Gouri x Ptb 15	25.57	0.90	1.95	16.30	21.87	37.67	0.42	29.20	1.33	21.60	13.83
21	Jyothi x Ptb 15	25.27	0.98	1.94	16.30	25.97	42.33	0.38	29.63	1.20	25.50	17.77
22	Kanchana x Ptb 15	22.73	0.86	1.90	20.73	22.10	43.00	0.49	28.40	1.30	14.20	13.77
23	Uma x Ptb 15	24.53	0.93	1.90	19.97	38.20	58.33	0.34	30.10	0.75	28.83	11.73
24	Aiswarya x Ptb 15	27.30	0.92	1.96	29.43	28.87	58.33	0.50	21.93	1.05	20.53	17.30
25	Swarnaprabha	28.03	1.00	1.93	19.20	25.20	44.33	0.43	18.50	0.84	12.73	11.83

continued

T able 27 continued

Sl. No.	Genotypes	1000 grain weight (g)	Grain density (g/ml)	Grain thickness (mm)	Grain yield per plant (g)	Straw yield per plant (g)	Total dry matterper plant (g)	Harvest index	Root weight per plant (g)	Root to shoot ratio	Root volume (ml)	Root length (cm)
26	Mashuri	21.27	0.77	1.70	25.97	48.87	74.67	0.34	17.83	0.94	19.63	12.30
27	Ponmani	16.17	0.77	1.90	18.63	25.20	44.33	0.43	15.83	0.63	17.17	12.30
28	Ptb 15	23.43	1.17	1.69	22.33	26.50	45.33	0.50	16.97	0.64	16.07	16.30
29	Mattatriveni	25.43	0.93	1.98	14.53	25.07	39.60	0.37	17.63	0.75	10.33	11.07
30	Gouri	24.53	0.99	1.93	11.20	24.17	35.27	0.31	11.87	0.49	6.17	5.30
31	Jyothi	26.87	0.97	1.97	19.87	23.73	43.60	0.45	13.40	0.57	8.30	8.40
32	Kanchana	29.00	1.09	1.96	19.43	26.40	46.07	0.42	10.73	0.41	8.63	10.20
33	Uma	22.77	0.79	2.02	20.03	33.50	53.40	0.38	17.20	0.50	8.30	8.20
34	Aiswarya	26.60	0.92	2.03	20.30	23.87	44.33	0.46	11.17	0.51	12.17	9.77
35	Mean of testers	22.23	0.93	1.80	21.53	31.44	52.17	0.42	17.28	0.63	16.40	13.18
36	Mean of lines	25.87	0.95	1.98	17.56	26.12	43.71	0.40	13.67	0.34	8.98	8.82
37	Mean of hybrids	24.54	0.97	1.93	23.71	28.38	49.53	0.43	23.81	1.03	22.15	15.58
38	General mean	24.50	0.96	1.92	22.41	28.34	48.81	0.42	24.08	0.89	19.15	14.11

continued

The values of relative heterosis, heterobeltiosis and standard heterosis are presented in Table 28. All hybrids expressed negative values for relative heterosis, which ranged from -38.91 (Mattatriveni x Ptb-15) to -2.81 (Gouri x Swarnaprabha). Heterobeltiosis ranged from -0.14 (Mattatriveni x Ponmani) to 0.01 (Gowri x Swarnaprabha, Uma x Ptb-15 and Aiswarya x Ptb-15). Standard heterosis, taking Jyothi as check variety ranged from -11.84 (Jyothi x Swarnaprabha) to 14.47 (Uma x Ptb-15).

4.4.2 Number of tillers at active tillering stage

The mean value for lines ranged from 6.33 (Jyothi) to 9.67 (Kanchana and Uma) and from 6.00 (Ptb-15) to 8.67 (Mahsuri) for testers. Almost all hybrids performed better than their parents and their values ranged between 7.33 (Aiswarya x Swarnaprabha) and 13.00 (Kanchana x Ponmani) (Table 27).

For number of tillers at active tillering stage the relative heterosis ranged from -2.22 (Aiswarya x Swarnaprabha) to 62.16 (Jyothi x Ptb-15). For heterobeltiosis, the range was from -3.52 (Uma x Ptb-15) to 57.98 (Jyothi x Ptb-15). The range for standard heterosis was from 15.80 (Aiswarya x Swarnaprabha) to 105.37 (Kanchana x Ponmani). All the hybrids expressed highly positive values for the standard heterosis (Table 29).

4.4.3 Number of tillers at panicle initiation

Mean performance of lines ranged from 8.00 (Aiswarya) to 10.33 (Kanchana and Uma) and for testers from 6.33 (Ptb-15) to 9.00 (Ponmani). Among the hybrids the value ranged from 8.67 (Uma x Ptb-15) to 12.67 (Kanchana x Ponmani)(Table 27).

Table 28. Expression of heterosis in 24 F_1 hybrids in rice for days to flowering

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-3.56	-0.03	0.88	-15.98	-0.10	-6.58	-31.66	-0.14	-10.53	-38.91	-0.08	-3.95
Gowri	-2.81	0.01	6.14	-3.41	-0.01	11.84	-17.48	-0.01	11.84	-33.33	-0.05	7.89
Jyothi	-2.99	-.004	-11.84	-9.64	-0.01	-1.32	-24.49	-0.03	-2.63	-35.59	0	0
Kanchana	-8.12	-8.12	-5.70	-13.25	-0.05	-5.26	-22.45	0	0	-35.59	0	0
Uma	-14.46	-0.113	-6.58	-6.82	-0.05	7.89	-20.39	-0.05	7.89	-29.27	0.01	14.47
Aiswarya	-4.52	-0.01	-2.63	-9.09	0	-1.32	-23.08	0	-1.32	-37.02	0.01	-2.63

di- relative heterosis   dii- heterobeltiosis   diii- standard heterosis

Table 29. Expression of heterosis in 24 F_1 hybrids in rice for number of tillers at active tillering stage

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	55.56	0.52	84.36	30.61	0.23	68.56	31.91	0.29	63.19	21.95	8.60	31.60
Gowri	61.70	0.52	100.16	13.73	0.12	52.76	30.61	0.28	68.56	34.88	16.01	52.76
Jyothi	46.34	0.36	57.98	11.11	-0.04	31.60	30.23	16.63	47.39	62.16	57.98	57.98
Kanchana	29.41	0.14	73.78	5.45	0	52.76	47.17	34.44	105.37	31.91	0.07	63.19
Uma	29.41	0.14	73.78	9.09	0.03	57.98	24.53	13.75	73.78	19.15	-3.52	47.37
Aiswarya	-2.22	0.04	15.80	22.45	0.153	57.98	31.91	29.13	63.19	26.83	13.04	36.97

di- relative heterosis   dii- heterobeltiosis   diii- standard heterosis

Relative heterosis ranged from 3.45 (Uma x Ponmani) to 60.87 (Gouri x Ptb-15) and were positive for all the hybrids. Heterobeltiosis ranged between -3.19 (Uma x Ponmani) and 37 (Gouri x Ptb-15). For standard heterosis, the range was from -3.67 ((Uma x Ptb-15) to 40.78 (Kanchana x Ponmani) (Table 30).

4.4.4 Number of tillers at flowering stage

The number of tillers at flowering stage ranged from 6.33 (Ptb-15) to 9.67 (Mahsuri) for lines and from 7.33 (Jyothi) to 10.67 (Uma) for testers. Among the hybrids the value ranged from 8.67 (Aiswarya x Swarnaprabha) to 13.67 (Kanchana x Ponmani) (Table 27).

Studies on heterosis for number of tillers at flowering presented in Table 31 revealed high positive mid parent heterosis with the range between 7.94 (Kanchana x Mahsuri) and 85.37 (Jyothi x Ptb-15). Heterobeltiosis was negative for two hybrids and positive for the rest. The range was from -5.83 (Kanchana x Ptb-15) to 72.85 (Jyothi x Ptb-15). Standard heterosis over Jyothi ranged from 18.28 (Aiswarya x Swarnaprabha) to 86.49 (Kanchana x Ponmani).

4.4.5 Number of productive tillers per plant

The mean performance of testers ranged from 5.67 (Ptb-15) to 9.33 (Mahsuri) and for lines from 6.67 (Jyothi) to 10.33 (Kanchana). Hybrids had a better expression of the character than their parents with mean values ranging from 8.33 (Uma x Ptb-15) to 13.33 (Kanchana x Ponmani) (Table 27).

Results presented in Table 32 indicated positive relative heterosis for all hybrids with the range between 1.75 (Uma x Mahsuri) and 78.38 (Jyothi x Ptb-15). Heterobeltiosis ranged between -13.86 (Uma x Ptb-15) and 65.00 (Jyothi x Ptb-15).

Table 30. Expression of heterosis in 24 F_1 hybrids in rice for total number of tillers at panicle initiation

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	29.41	17.90	22.22	25.93	21.44	25.89	23.94	21.44	25.89	19.15	0	3.67
Gowri	44.00	33.33	33.33	28.30	25.84	25.89	14.81	14.81	14.78	60.87	37.00	37.00
Jyothi	40.00	29.63	29.63	9.43	7.41	7.41	3.67	3.70	3.70	56.52	33.33	33.33
Kanchana	37.04	3.29	37.00	12.28	3.29	18.56	31.03	3.29	40.78	44.00	16.17	33.33
Uma	29.63	12.97	29.63	15.79	6.49	22.22	3.45	-3.19	11.11	4.00	16.07	-3.67
Aiswarya	19.15	16.63	3.67	28.00	23.07	18.56	25.49	18.56	18.56	30.23	16.63	3.67

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 31. Expression of heterosis in 24 F_1 hybrids in rice for total number of tillers at flowering stage

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	52.00	40.78	72.85	25.00	20.68	59.21	29.41	22.22	50.07	47.83	25.89	54.57
Gowri	48.00	37.00	68.21	17.86	13.75	50.07	13.76	7.44	31.92	60.87	37.00	68.21
Jyothi	46.67	43.42	50.07	9.80	27.29	27.29	30.43	25.00	36.43	85.37	72.85	72.85
Kanchana	22.81	3.00	59.21	7.94	0	54.57	41.38	20.65	86.49	20.75	-5.83	45.57
Uma	23.64	6.19	54.57	14.75	9.37	59.21	21.43	6.19	54.57	21.57	-3.19	40.93
Aiswarya	13.04	13.04	18.28	23.08	10.34	45.57	44.68	41.63	54.57	52.38	39.11	45.57

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Standard heterosis ranged between 24.89 (Uma x Ptb-15) and 99.85 (Kanchana x Ponmani).

4.4.6 Plant height

Among the female parents the plant height varied from 90.33 (Gouri) to 115 cm(Uma) and in the male parents the range was between 97.67 (Ponmani) and 185.33 cm (Ptb-15). In the hybrids the plant height ranged between 84.67 (Kanchana x Ponmani) and 111.67 cm(Gouri x Mahsuri)(Table 27).

Out of 24 hybrids evaluated the relative heterosis ranged between -43.65 (Gouri x Ptb-15) to 11.35 (Gouri x Ponmani). Heterobeltiosis ranged between -24.93 (Gouri x Swarnaprabha) and 23.62 (Gouri x Mahsuri). Standard heterosis in comparison with Jyothi ranged between -19.93 (Gouri x Ptb-15) and 15.12 (Gouri x Mahsuri) Table 33).

4.4.7 Stem thickness

Mean performance for stem thickness ranged from 2.67 (Kanchana) to 3.13 cm (Uma) for lines and from 2.43 (Ptb-15) to 2.93 cm (Ponmani) for testers. All the hybrids expressed greater mean value for stem thickness compared to their parents. Among hybrids the mean performance ranged between 2.73 (Gouri x Ptb-15 and Kanchana x Ptb-15) and 3.93 cm(Aiswarya x Ptb-15) (Table 27).

The values of relative heterosis, heterobeltiosis and standard heterosis are presented in Table 34. All hybrids expressed positive values for relative heterosis and heterobeltiosis, which ranged from 0.59 (Mattatriveni x Mahsuri) to 53.25 (Aiswarya x Ptb-15) in case of relative heterosis and from 2.17 (Mattatriveni x Mahsuri) 61.73 (Aiswarya x Ptb-15) for heterobeltiosis. Standard heterosis ranged from -6.83 (Kanchana x Ptb-15) to 34.13 (Aiswarya x Ptb-15).

Table 32. Expression of heterosis in 24 F_1 hybrids in rice for total number of productive tillers per plant

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	18.18	4.08	29.99	28.30	21.44	69.87	33.33	28.09	59.97	42.86	20.05	49.93
Gowri	44.19	29.13	54.87	7.69	0	39.88	19.15	16.63	39.88	51.22	29.13	54.87
Jyothi	38.46	35.00	35.00	12.50	-3.54	35.00	30.23	21.64	40.00	78.38	65.00	65.00
Kanchana	32.00	6.49	65.00	28.81	22.65	89.96	48.15	29.04	99.85	25.00	-3.19	49.93
Uma	45.83	20.68	74.96	1.75	0	44.98	30.77	17.17	69.87	8.70	-13.86	24.89
Aiswarya	23.81	13.04	29.99	17.65	7.18	49.93	43.48	43.48	65.00	30.00	13.04	29.99

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 33. Expression of heterosis in 24 F_1 hybrids in rice for plant height

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-17.15	-4.36	2.06	-11.39	5.71	8.25	-6.60	-7.38	-5.15	-34.43	-6.04	-3.78
Gowri	-6.51	14.03	6.19	-2.05	23.62	15.12	11.35	7.17	7.91	-43.65	-14.02	-19.93
Jyothi	-19.53	-5.85	-5.84	-17.90	-0.69	-0.69	-9.93	-10.24	-9.62	-34.83	-5.15	-5.15
Kanchana	-14.84	1.06	-1.37	-8.75	11.97	9.28	-11.96	-13.31	-12.71	-31.90	6.97	-1.72
Uma	-29.52	-24.93	-11.00	-27.70	-30.58	-5.85	-2.51	-9.85	6.88	-40.29	-22.03	7.56
Aiswarya	-6.61	-3.43	14.09	-21.25	3.43	-0.69	3.91	-6.26	9.62	-25.66	1.56	12.03

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

4.4.8 Flag leaf area

The mean performance for flag leaf area ranged from 28.93 (Kanchana) to 35.00cm^2(Gouri and Jyothi) in lines and from 31.10 (Ponmani) to 42.83cm^2 (Swarnaprabha) in testers. For hybrids the mean value ranged from 28.67 (Uma x Ptb-15) to 58.33 cm^2(Jyothi x Ptb-15)(Table 27).

The relative heterosis ranged from -19.14 (Uma x Swarnaprabha) to 73.63 (Mattatriveni x Ponmani). For better parent heterosis the range was from -26.85 (Uma x Swarnaprabha) to 69.36 (Mattatriveni x Ponmani). The standard heterosis on comparison with Jyothi ranged from -18.09 (Uma x Ptb-15) to 66.67(Jyothi x Ptb-15) (Table 35).

4.4.9 Panicle length

From the values for mean performance presented in Table 27the mean of lines ranged from 20.33 (Jyothi) to 22.33 cm(Uma) and for testers from 21.33 (Ponmani) to 29.00cm (ptb-15)(Plate 5). Among the hybrids the value ranged from 19.00 (Gouri x Ptb-15) to 25.33cm (Mattatriveni x Ponmani).

Here relative heterosis ranged from -23.64 (Gouri x Ptb-15) to 19.69 (Mattatriveni x Ponmani). Heterobeltiosis ranged between -34.48 (Gouri x Ptb-15) and 18.75 (Mattatriveni x Ponmani). For standard heterosis the range was from -6.54 (Gouri x Ptb-15) to 24.59 (Mattatriveni x Ponmani (Table 36)(Plate 6 and Plate 7).

4.4.10 Grains per panicle

The grains per panicle ranged from 31.00 (Gouri) to 64.67 (Kanchana) in lines and from 38.67 (Ponmani) to 127.67 (Mahsuri) in testers. Among the hybrids

Plate 5. Earheads of parents used in the programme

Plate 6. Mattatriveni x Ponmani - a promising hybrid

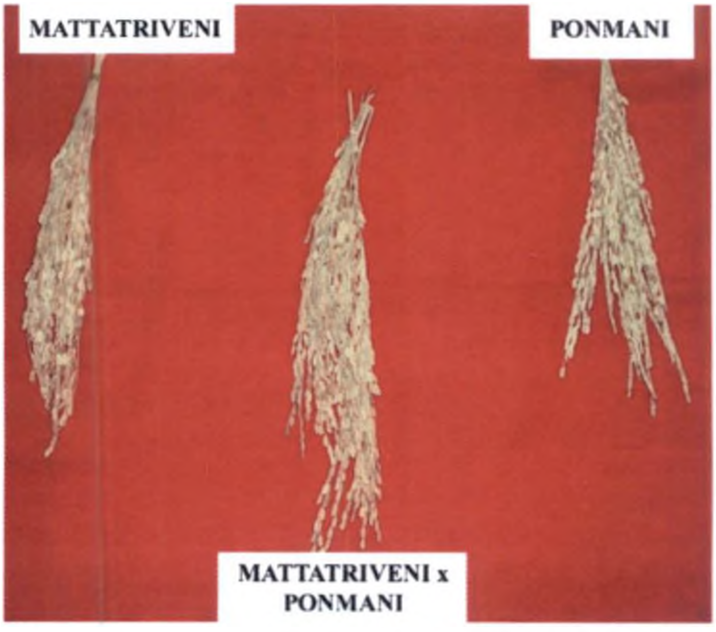


Plate 7. Earheads of Mattatriveni, Ponmani and Mattatriveni x Ponmani

Table 34. Expression of heterosis in 24 F_1 hybrids in rice for stem thickness

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	28.30	34.39	16.04	0.59	2.17	-3.41	8.77	11.91	5.80	25.64	34.57	11.60
Gowri	29.56	35.57	17.06	27.81	29.96	22.87	19.30	22.74	16.04	5.13	12.35	6.83
Jyothi	28.05	38.34	19.32	28.74	29.97	27.27	21.59	21.59	21.59	19.25	31.69	9.09
Kanchana	20.51	38.34	6.83	37.35	42.32	29.69	5.95	11.24	1.37	7.19	12.35	-6.83
Uma	14.12	27.67	10.24	21.11	26.49	23.89	8.79	12.63	12.63	6.59	22.22	1.37
Aiswarya	42.68	47.43	27.27	20.96	24.81	15.02	20.71	25.93	16.04	53.25	61.73	34.13

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 35. Expression of heterosis in 24 F_1 hybrids in rice for flag leaf area

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	15.10	-2.71	19.06	39.80	30.12	27.63	73.63	69.36	50.49	31.61	21.74	20.94
Gowri	7.24	-2.57	19.23	39.42	38.09	38.09	15.68	9.23	9.23	-4.44	-4.77	-4.77
Jyothi	26.77	15.18	40.95	4.81	3.81	3.81	21.03	14.29	14.29	67.22	66.67	66.67
Kanchana	16.12	-2.71	19.06	44.36	33.03	30.49	32.15	27.56	13.34	21.40	11.22	10.49
Uma	-19.14	-26.85	-10.49	32.37	31.73	30.49	6.84	1.33	0.37	-17.43	-17.54	-18.09
Aiswarya	0.56	-9.71	10.49	15.01	14.56	12.37	50.79	44.20	40.37	12.74	11.59	10.86

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 36. Expression of heterosis in 24 F_1 hybrids in rice for panicle length

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-4.41	-10.93	6.59	-0.73	-8.11	11.51	19.69	-18.75	24.59	-10.67	-23.00	9.84
Gowri	-6.87	-13.69	3.30	1.25	-6.77	13.13	9.26	7.83	13.13	-23.64	-34.48	-6.54
Jyothi	-2.99	-10.93	6.59	9.63	0	21.31	5.60	3.14	8.20	-8.11	-21.83	11.48
Kanchana	-2.94	-9.58	8.20	-3.65	-10.82	8.20	2.36	1.59	6.59	-20.00	-31.03	-1.62
Uma	-7.14	-10.93	6.59	-10.64	-14.88	3.30	-6.87	-8.96	0	-15.58	-25.28	6.59
Aiswarya	-1.66	-6.82	11.51	-6.68	-12.16	6.59	-7.19	-8.13	-1.62	-14.64	-25.28	6.59

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 37. Expression of heterosis in 24 F_1 hybrids in rice for grains per panicle

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	35.98	31.86	118.16	45.49	5.22	266.32	203.14	154.4	295.42	-28.40	-46.36	67.25
Gowri	4.73	-20.83	30.90	-39.92	-62.66	30.00	108.61	87.92	98.17	-20.18	-49.27	58.17
Jyothi	141.78	93.95	220.91	14.40	-26.37	156.36	159.29	152.6	166.36	43.49	-5.25	195.45
Kanchana	64.36	59.27	180.88	-60.49	-70.24	3.63	50.97	20.61	112.71	-53.45	-63.55	13.64
Uma	52.49	51.64	150.89	-42.45	-57.70	47.26	51.35	24.45	103.63	-54.88	-65.60	7.25
Aiswarya	116.27	114.27	254.51	-23.93	-44.39	93.62	6.48	-11.86	41.81	7.69	-18.37	154.51

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

the value ranged from 38.00 (Kanchana x Mahsuri) to 145 (Mattatriveni x Ponmani) (Table 27).

Studies on heterosis for grains per panicle presented in Table 37 exhibited the range for relative heterosis from -60.49 (Kanchana x Mahsuri) to 203.14 (Mattatriveni x Ponmani). Heterobeltiosis ranged between -70.24 (Kanchana x Mahsuri) and 154.39 (Mattatriveni x Ponmani). Standard heterosis over Jyothi ranged from 3.63 (Kanchana x Mahsuri) to 295.42 (Mattatriveni x Ponmani).

4.4.11 Panicle weight

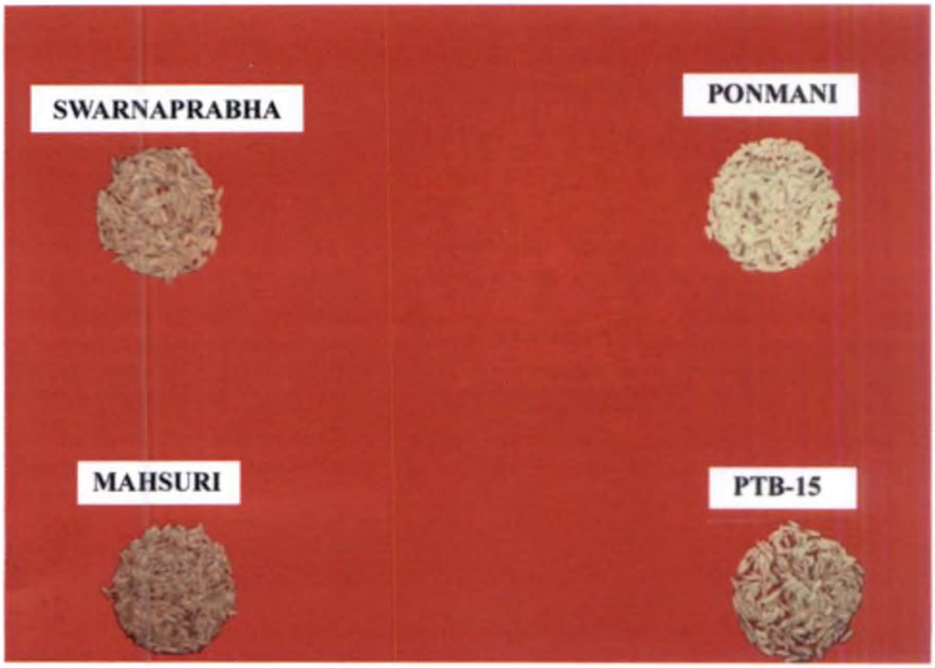
The mean performance of lines ranged from 1.40 (Gouri) to 2.63g (Aiswarya) and of testers from 2.20 (Ponmani and Ptb-15) to 3.50 g (Mahsuri). In case of hybrids the mean performance ranged from 2.07 (Uma x Mahsuri) to 3.57g (Mattatriveni x Ponmani) (Table 27).

Results presented in Table 38 revealed the range of relative heterosis from -27.27 (Kanchana x Mahsuri) to 59.70 (Mattatriveni x Ponmani). Heterobeltiosis ranged between -40.86 (Uma x Mahsuri) and 57.27 (Mattatriveni x Ponmani). Standard heterosis ranged between -10.00 (Uma x Mahsuri) and 55.22 (Mattatriveni x Ponmani).

4.4.12 1000 grain weight

The mean of lines ranged from 22.77 (Uma) to 29.00g (Kanchana) and for testers from 16.17 (Ponmani) to 28.03g(Swarnaprabha)(Plate 8). Among the hybrids the value ranged from 18.83 (Aiswarya x Swarnaprabha) to 29.70g (Jyothi x Mahsuri).(Table 27)(Plate 9a and 9b).

Relative heterosis ranged from -31.06 (Aiswarya x Swarnaprabha) to 38.25 (Gouri x Ponmani). Heterobeltiosis ranged between -32.82 (Aiswarya x



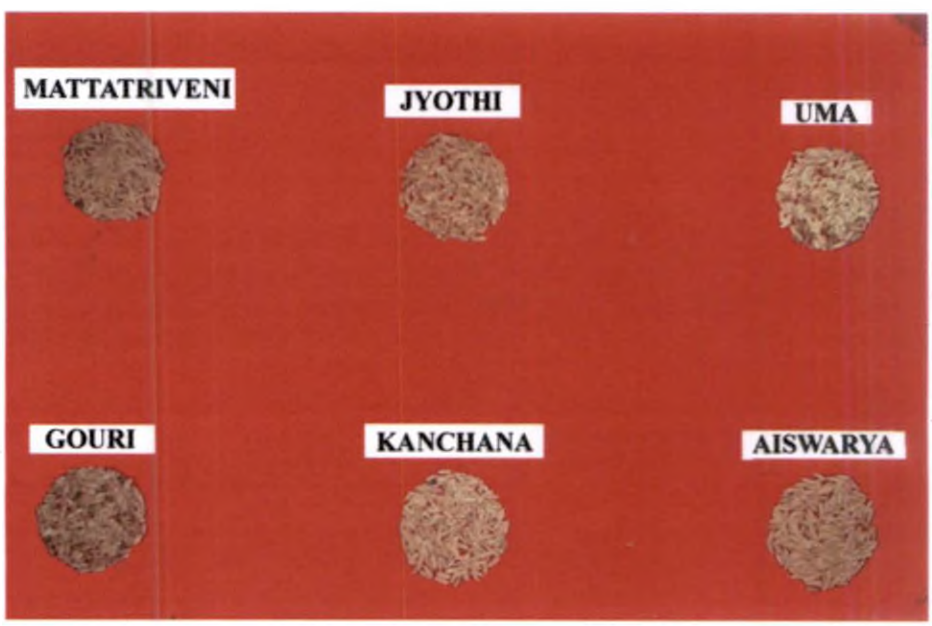
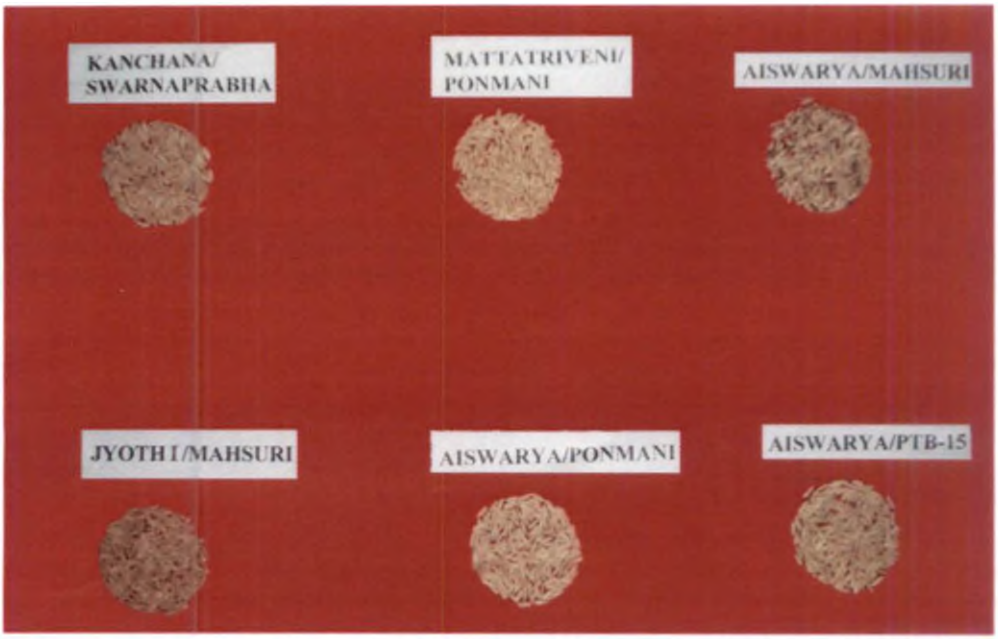


Plate 8. Grains of testers and lines used in the programme



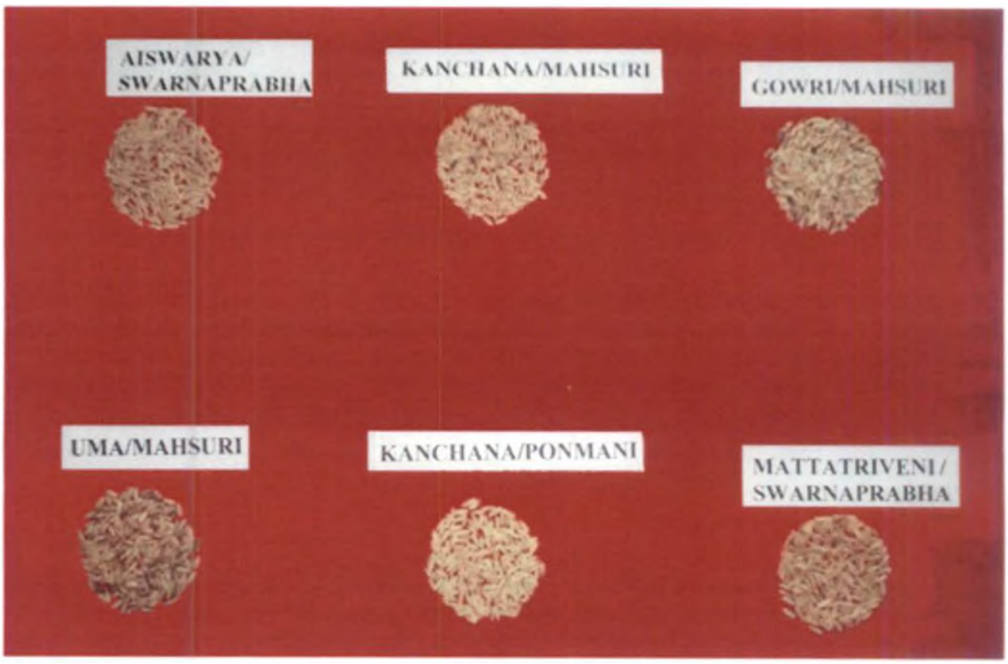
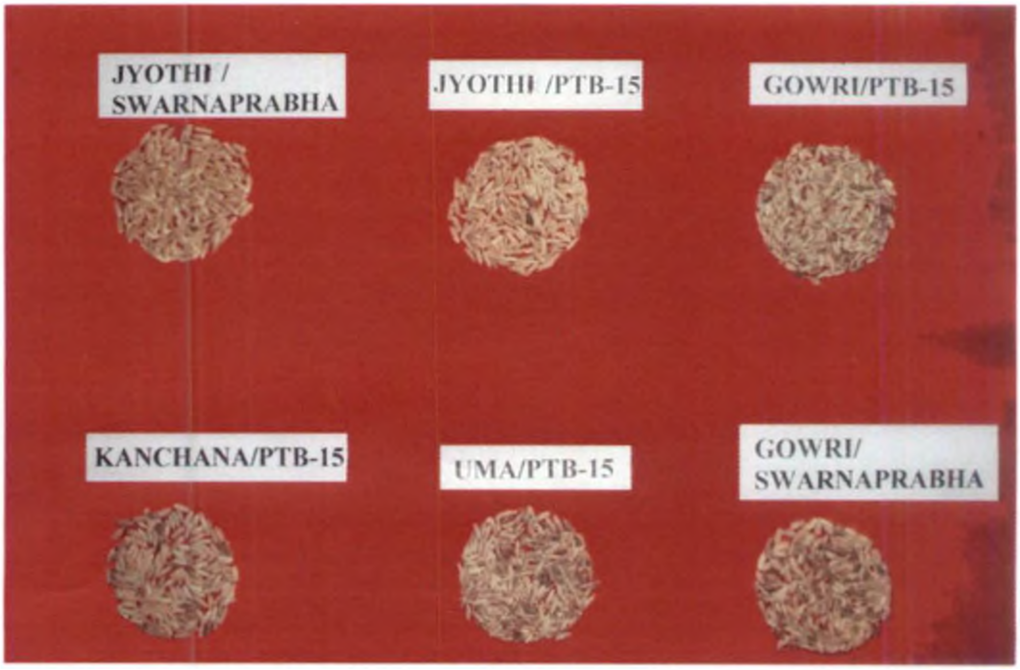


Plate 9a. Grains of hybrids



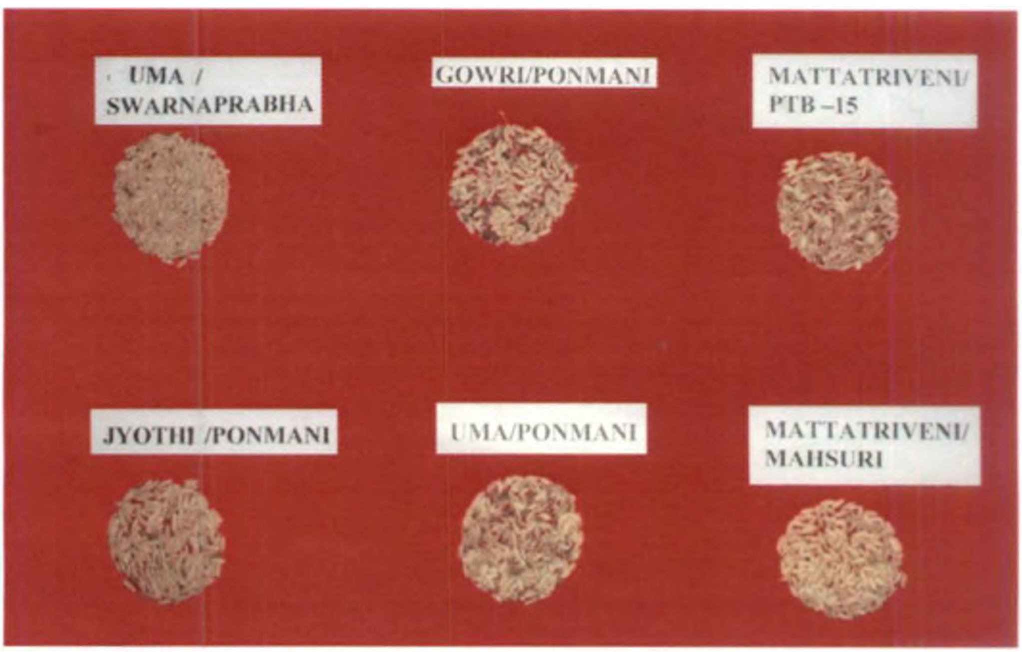


Plate 9b. Grains of hybrids

Table 38. Expression of heterosis in 24 F_1 hybrids in rice for panicle weight

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	15.11	12.66	16.09	9.83	-9.40	37.83	59.70	57.27	55.22	22.39	20.26	18.70
Gowri	11.50	-11.39	-8.70	14.29	-0.2	21.74	18.52	-3.18	-7.39	16.67	-4.55	-8.70
Jyothi	35.71	33.76	37.68	3.45	-14.29	30.43	25.93	23.19	23.19	22.96	20.29	20.29
Kanchana	8.45	8.45	11.74	-27.27	-39.14	-7.39	10.95	6.75	10.00	-0.73	-4.22	-1.30
Uma	41.98	30.80	34.78	-24.85	-40.86	-10.00	6.35	1.36	-3.04	3.17	-1.36	-5.65
Aiswarya	22.67	16.73	33.48	-27.17	-36.29	-3.04	2.07	-6.61	7.39	3.45	-4.94	8.70

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 39. Expression of heterosis in 24 F_1 hybrids in rice for 1000 grain weight

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-10.85	-14.98	-11.31	5.21	-3.38	-8.56	15.06	-7.36	-10.94	-10.37	-13.88	-18.50
Gowri	-10.08	-15.70	-12.06	-9.46	-15.49	-22.85	38.25	14.68	4.69	6.60	4.24	-4.84
Jyothi	2.73	0.61	4.96	23.41	10.53	10.55	29.82	3.97	3.97	0.46	-5.96	-5.96
Kanchana	-7.89	9.41	-2.23	-1.86	-14.93	-8.19	11.73	-0.13	-6.10	-13.29	21.62	-15.41
Uma	-9.06	-17.59	-14.03	2.65	-0.75	-15.89	18.32	1.14	-14.29	6.20	4.69	-8.71
Aiswarya	-31.06	-32.82	-11.80	-0.97	-10.90	-11.80	10.05	-11.54	-12.43	9.13	2.63	1.60

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Swarnaprabha) and 21.62 (Kanchana x Ptb-15). For standard heterosis the range was from -22.85 (Gouri x Mahsuri) to 10.55 (Jyothi x Mahsuri) (Table 39).

4.4.13 Grain density

Among the female parents the grain density ranged from 0.79 (Uma) to 1.09 g\ml(Kanchana) and in the male parents the range was between 0.76 (Mahsuri) and 1.17g\ml (Ptb-15). In the hybrids grain density ranged between 0.79 (Mattatriveni x Swarnaprabha) and 1.32g\ml (Kanchana x Swarnaprabha) (Table 27).

Out of 24 hybrids the relative heterosis ranged between -23.49 (Kanchana x Ptb-15) and 27.04 (Gouri x Swarnaprabha). Heterobeltiosis ranged from -26.50 (Mattatriveni x Ptb-15) to 21.71 (Kanchana x Swarnaprabha). Standard heterosis in comparison with Jyothi ranged between -18.87 (Mattatriveni x Swarnaprabha) and 36.39 (Kanchana x Swarnaprabha) (Table 40).

4.4.14 Grain thickness

The mean value ranged from 1.93 (Gouri) to 2.03 mm(Aiswarya) for lines and from 1.69 (Ptb-15) to 1.93mm (Swarnaprabha) for testers. For hybrids the range was from 1.85 (Kanchana x Mahsuri) to 2.05mm (Gouri x Ponmani) (Table 27).

For grain thickness the relative heterosis ranged from -4.26 (Uma x Ponmani) to 8.46 (Gouri x Mahsuri). For heterobeltiosis, the range was from -9.01 (Aiswarya x Ponmani) to 6.22 (Gouri x Ponmani). The range of standard heterosis taking Jyothi as check was from -6.09 (Kanchana x Mahsuri) to 5.08 (Uma x Ponmani) (Table 41).

Table 40. Expression of heterosis in 24 F_1 hybrids in rice for grain density

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-18.62	-21.85	-18.87	4.93	-4.31	-8.56	6.61	-1.51	-5.88	-17.97	-26.50	-11.34
Gowri	22.54	21.45	26.08	1.14	-10.40	-8.56	14.07	2.32	4.43	-16.98	-23.33	-7.53
Jyothi	-1.18	-2.98	0.69	20.00	7.22	7.22	20.68	9.28	9.28	-8.72	-16.50	0.69
Kanchana	26.43	21.71	36.39	6.31	-9.56	1.34	0.71	-13.25	-2.78	-23.49	-26.24	-11.03
Uma	27.04	13.51	17.84	9.64	7.57	-12.06	19.41	18.92	-2.78	-5.26	-20.51	-4.12
Aiswarya	-1.38	-5.66	-2.06	18.81	8.70	3.09	5.47	-2.17	-7.22	-11.96	-21.37	-5.15

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 41. Expression of heterosis in 24 F_1 hybrids in rice for grain thickness

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-4.01	-5.05	-4.57	5.16	-2.02	-1.52	-1.55	-3.54	-3.05	2.09	-5.05	-4.57
Gowri	-1.73	-1.73	-4.06	8.46	2.07	0	7.41	6.22	4.06	7.73	1.04	-1.02
Jyothi	2.74	1.52	1.52	3.27	-3.89	-3.89	1.12	-0.84	-0.84	6.00	-1.52	-1.52
Kanchana	1.54	2.97	0	1.28	-5.61	-6.09	4.58	3.06	2.54	4.20	-3.06	-3.89
Uma	-0.42	-2.97	-0.84	1.88	-6.44	-4.06	-4.26	-7.43	5.08	2.61	-5.94	-3.89
Aiswarya	-3.96	-6.40	-3.89	3.31	-6.40	-2.03	-2.89	-9.01	-3.05	5.46	-3.45	-0.84

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

4.4.15 Grain yield

From the values presented in Table 27, the mean grain yield of lines ranged from 11.20 (Gouri) to 20.30g(Aiswarya) and for testers from 18.63 (Ponmani) to 25.97g (Mahsuri). Among the hybrids the value ranged from 15.07 (Mattatriveni x Ptb-15) to 83.40g (Mattatriveni x Mahsuri).

Here relative heterosis ranged from -22.75 (Jyothi x Ptb-15) to 311.85 (Mattatriveni x Mahsuri). The better parent heterosis had a range from -36.85 (Gouri x Mahsuri) to 221.40 (Mattatriveni x Mahsuri). For standard heterosis the range was from -24.16 (Mattatriveni x Ptb-15) to 319.73 (Mattatriveni x Mahsuri) (Table 42).These results showed that the particular cross Mattatriveni x Mahsuri expressed maximum heterosis on grain yield.

4.4.16 Straw yield

Mean performance of lines ranged from 23.73 (Jyothi) to 33.50g (Uma). In testers straw yield ranged from 25.20 (Swarnaprabha and Ponmani) to 48.87g (Mahsuri). For the hybrids the range was between 18.10 (Kanchana x Ponmani) and 38.20 (Uma x Ptb-15) (Table 27).

The values of relative heterosis, heterobeltiosis and standard heterosis are presented in Table 43. The relative heterosis ranged from -37.56 (Jyothi x Mahsuri) to 46.52 (Gouri x Swarnaprabha). Heterobeltiosis had a value between -53.61 (Jyothi x Mahsuri) and 43.53 (Gouri x Swarnaprabha). Standard heterosis on comparison with Jyothi ranged from -7.84 (Gouri x Ptb-15) to 60.98 (Uma x Ptb-15).

4.4.17 Total dry matter

Mean performance of total dry matter in Table 27 ranged between 35.27 (Gouri) and 53.4 g (Uma) in case of lines and between 44.33 (Swarnaprabha and

Table 42. Expression of heterosis in 24 F_1 hybrids in rice for grain yield

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	28.85	13.18	9.36	311.85	221.40	319.73	75.48	56.20	46.45	-18.26	-32.51	-24.16
Gowri	0	-20.83	-23.50	-11.75	-36.85	-17.46	20.45	-3.54	-9.56	-2.78	-27.00	-17.97
Jyothi	23.38	21.31	21.31	9.38	-3.47	26.17	14.81	11.24	11.24	-22.75	-27.00	-17.95
Kanchana	28.21	27.41	24.66	-13.07	-24.03	-0.70	8.93	6.69	4.33	-0.72	-7.17	4.33
Uma	-1.10	-3.15	-23.65	-19.86	-29.63	0	17.24	13.18	14.09	-5.74	-10.57	0.50
Aiswarya	15.27	12.17	14.59	5.04	-6.43	22.29	27.23	22.02	24.66	38.08	31.80	48.11

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 43. Expression of heterosis in 24 F_1 hybrids in rice for straw yield

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-0.66	-9.13	5.23	-32.73	-49.11	4.80	-9.55	-9.92	-4.21	14.54	11.43	24.44
Gowri	46.52	43.53	52.42	-3.70	-28.05	48.21	38.01	35.20	43.57	-13.68	-17.47	-7.84
Jyothi	5.31	2.26	8.57	-37.56	-53.61	-4.49	-8.45	-11.11	-5.62	3.38	-2.00	9.41
Kanchana	24.42	21.59	35.27	-5.05	-26.89	50.57	-29.84	-31.44	23.73	-16.45	-16.60	-6.87
Uma	10.16	-3.49	36.24	-26.43	-37.99	27.69	5.62	-7.46	30.64	27.33	14.03	60.98
Aiswarya	26.22	22.90	30.51	-17.23	-38.41	26.84	2.72	0	6.19	14.63	8.94	21.66

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Ponmani) and 74.67g (Mahsuri) in case of testers. For hybrids the range was from 37.67 (Gouri x Ptb-15) to 58.33g (Uma x Ptb-15 and Aiswarya x Ptb-15).

The results presented in Table 44 exhibited a range from -24.00 (Uma x Mahsuri) to 30.65 (Gouri x Ponmani) for relative heterosis and a range between -39.73 (Mattatriveni x Mahsuri) and 28.68 (Aiswarya x Ptb-15) for heterobeltiosis. For standard the values lied between -13.60 (Gouri x Ptb-15) and 33.78 (Uma x Ptb-15 and Aiswarya x Ptb-15).

4.4.18 Harvest Index

The mean performance of lines ranged from 0.31 (Gouri) to 0.46 (Aiswarya) and for testers 0.34 (Mahsuri) to 0.50 (Ptb-15). The value ranged from 0.29 (Gouri x Swarnaprabha) to 0.56 (Mattatriveni x Ponmani) for the hybrids (Table 27).

The relative heterosis for harvest index ranged between -21.37 (Uma x Ptb-15) and 41.18 (Mattatriveni x Ponmani). For heterobeltiosis the range was from -31.55 (Mattatriveni x Ptb-15) to 31.24 (Mattatriveni x Ponmani). Standard heterosis on comparison with Jyothi ranged from -35.30 (Gouri x Swarnaprabha) to 23.54 (Mattatriveni x Ponmani) (Table 45).

4.4.19 Root weight per plant

Mean value for root weight per plant presented in Table 27 showed a range between 10.73 (Kanchana) and 17.63 (Mattatriveni) in case of lines and from 15.83 (Ponmani) to 18.5 (Swarnaprabha) in case of testers. For hybrids mean value had a range between 14.00 (Mattatriveni x Swarnaprabha) and 37.40 (Uma x Ponmani).

Table 44. Expression of heterosis in 24 F_1 hybrids in rice for total dry matter

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	11.20	5.28	7.04	-21.24	-39.73	3.21	23.91	17.30	19.27	4.40	-2.21	1.67
Gowri	28.98	15.79	17.73	-6.00	-30.80	18.51	30.65	17.30	19.27	-6.53	-16.90	-13.60
Jyothi	13.72	12.79	14.68	-18.83	-35.72	10.09	0.83	0	1.68	-4.80	-6.62	-2.91
Kanchana	25.37	23.01	29.98	-7.79	-25.45	27.68	-12.98	-14.63	-9.79	-5.91	-6.66	-1.38
Uma	5.73	-3.24	18.51	-24.00	-34.82	11.63	9.82	5.06	23.10	18.16	9.23	33.78
Aiswarya	21.05	21.07	23.10	-8.68	-27.24	24.61	12.78	12.78	14.68	30.11	28.68	33.78

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 45. Expression of heterosis in 24 F_1 hybrids in rice for harvest index

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	17.45	9.04	2.96	24.88	20.89	-2.21	41.18	31.24	23.54	-21.24	-31.55	-24.99
Gowri	-20.86	-31.47	-35.30	-3.55	-7.75	-30.13	-7.21	-19.55	-24.27	3.70	-15.44	-7.35
Jyothi	17.25	13.97	13.97	31.38	15.44	15.44	20.45	16.91	16.91	-19.30	-22.83	-15.44
Kanchana	2.58	2.03	-3.66	-7.83	-16.54	-22.06	26.27	25.78	18.40	5.80	-2.01	7.37
Uma	-6.38	-11.99	-16.90	4.63	0	-16.90	5.39	-0.80	-6.62	-21.39	-30.88	-24.27
Aiswarya	-4.65	-7.98	-6.62	10.37	-3.63	-2.21	12.03	7.98	9.57	5.23	1.33	11.03

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

The results presented under Table 46 indicated a range from -22.51 (Mattatriveni x Swarnaprabha), the only negative relative heterosis value to 169.31 (Gouri x Ponmani). For heterobeltiosis a range between -24.32 (Mattatriveni x Swarnaprabha) and 135.63 (Gouri x Ponmani) was seen. On comparison with Jyothi the range of standard heterosis whose values were all positive was from 4.48 (Mattatriveni x Swarnaprabha) to 179.10 (Uma x Ponmani).

4.4.20 Root to shoot ratio

The mean values for lines ranged from 0.41 (Kanchana) to 0.75 (Mattatriveni) and for testers from 0.63 (Ponmani) to 0.94 (Mahsuri). The results in Table 27 showed a range between 0.52 (Kanchana x Mahsuri) and 1.80 (Kanchana x Ponmani) among the hybrids.

Results presented in Table 47 indicated a range from -29.41 (Mattatriveni x Swarnaprabha) to 248.39 (Kanchana x Ponmani) for relative heterosis and from -44.68 (Kanchana x Mahsuri) to 185.71 (Kanchana x Ponmani) for heterobeltiosis. For standard heterosis the range was from -8.77 (Kanchana x Mahsuri) to 215.79 (Kanchana x Ponmani).

4.4.21 Root volume

Here the mean value was from 6.17 (Gouri) to 12.17 (Aiswarya) for lines and from 12.73 (Swarnaprabha) to 19.63 (Mahsuri) for testers. The results in Table 27 showed a range from 14.2 (Kanchana x Ptb-15) to 35.5 (Gouri x Ponmani) in case of hybrids for root volume.

The three heterosis estimates in Table 48 showed a range from 2.05 (Aiswarya x Ponmani) to 204.29 (Gouri x Ponmani) for relative heterosis and from -12.81 (Aiswarya x Ponmani) to 122.31 (Kanchana x Swarnaprabha) in case of

Table 46. Expression of heterosis in 24 F_1 hybrids in rice for root weight per plant

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-22.51	-24.32	4.48	71.43	70.50	126.87	32.47	25.75	65.45	57.23	54.28	102.99
Gowri	63.78	34.43	85.60	143.10	102.47	169.40	169.31	135.63	178.36	102.54	72.07	117.91
Jyothi	25.81	8.49	49.75	79.08	56.87	108.71	131.47	113.71	152.49	95.17	74.60	121.14
Kanchana	146.07	94.43	168.43	26.49	1.35	34.85	110.54	76.69	108.73	105.05	67.35	111.94
Uma	39.31	34.43	85.60	65.37	62.48	116.19	126.44	117.44	179.10	76.20	75.00	124.63
Aiswarya	145.62	96.92	171.87	47.82	20.19	59.93	71.85	46.56	73.13	55.92	29.23	63.66

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 47. Expression of heterosis in 24 F_1 hybrids in rice for root to shoot ratio

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	-29.41	-33.33	-1.75	113.65	27.66	110.53	44.17	32.00	73.68	31.89	22.67	61.40
Gowri	3.00	17.86	21.05	134.48	8.51	78.95	96.43	74.60	92.98	134.60	107.81	133.33
Jyothi	10.90	-7.14	37.65	168.55	35.11	123.53	140.22	126.98	152.94	98.35	87.50	111.76
Kanchana	76.47	30.95	92.98	33.62	-44.68	-8.77	248.39	185.71	215.79	147.62	103.13	128.00
Uma	14.43	-8.33	35.09	118.25	2.13	68.42	113.02	90.48	110.53	31.20	17.19	31.58
Aiswarya	72.84	39.29	105.26	54.14	-27.60	19.30	61.88	46.03	61.40	82.66	64.06	84.21

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 48. Expression of heterosis in 24 F_1 hybrids in rice for root volume

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	30.64	18.38	81.57	51.72	15.79	173.86	40.36	12.41	132.53	42.93	17.42	127.35
Gowri	193.47	117.83	234.10	127.91	49.77	254.22	204.29	106.76	327.71	94.30	34.41	160.24
Jyothi	52.77	26.24	93.57	26.97	-9.68	113.65	56.81	16.31	140.56	109.30	58.68	207.23
Kanchana	164.90	122.31	240.96	49.06	7.34	153.86	71.83	29.12	167.11	14.98	-11.64	71.08
Uma	116.16	78.55	173.86	90.45	35.51	220.48	78.53	32.38	173.86	136.94	79.65	247.83
Aiswarya	73.76	69.91	160.60	15.09	-6.78	120.48	2.05	-12.81	80.36	45.45	27.75	147.35

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

Table 49. Expression of heterosis in 24 F_1 hybrids in rice for root length

Testers	Swarnaprabha			Mahsuri			Ponmani			Ptb-15		
Lines	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Mattatriveni	30.71	26.54	78.21	-3.28	8.13	34.52	43.22	36.02	99.17	1.34	-14.91	65.12
Gowri	129.57	66.27	134.17	48.48	6.26	55.60	89.39	35.53	98.45	28.09	-15.15	64.64
Jyothi	77.92	52.16	114.29	75.85	47.97	116.67	60.39	34.96	97.62	43.86	9.02	111.51
Kanchana	63.69	52.41	114.64	63.85	49.84	119.40	4.59	-4.31	40.12	3.90	-15.52	63.93
Uma	31.78	11.58	57.14	19.02	-0.81	45.24	2.76	-14.39	25.36	-4.22	-28.04	39.64
Aiswarya	95.37	78.36	151.19	66.77	49.59	119.05	52.57	49.59	100.36	32.74	6.01	105.95

di- relative heterosis dii- heterobeltiosis diii- standard heterosis

heterobeltiosis. Standard heterosis ranged from 71.08 (Kanchana x Ptb-15) to 327.71 (Gouri x Ponmani).

4.4.22 Root length

Root length of lines ranged from 5.30 (Gouri) to 11.07 cm(Mattatriveni) and of testers from 11.83 (Swarnaprabha) to 16.3 cm (Ptb-15). Among hybrids the range was from 10.53 (Uma x Ponmani) to 21.10 cm(Aiswarya x Swarnaprabha) (Table 27).

The results presented in Table 49 showed a range from -4.22 (Gouri x Ptb-15) to 129.57 (Gouri x Swarnaprabha) for relative heterosis. Heterobeltiosis ranged from -28.04 (Uma x Ptb-15) to 78.36 (Aiswarya x Swarnaprabha). For standard heterosis taking Jyothi as check variety the range was between 25.36 (Uma x Ponmani) and 151.19 (Aiswarya x Swarnaprabha).

4.5 CORRELATION STUDIES

Genotypic and phenotypic correlation coefficients were estimated based on genotypic and phenotypic variances and covariances. The correlation coefficients between grain yield and other biometrical traits and inter correlation among them are furnished separately for parents and hybrids in Table 50 and Table 51 respectively.

4.5.1 Correlation between grain yield and its components traits in parents

Highest significant positive correlation with grain yield at genotypic (0.85) and phenotypic level (0.75) was recorded by panicle weight followed by total dry matter (0.81). Other characters which recorded significant positive correlation with grain yield were plant height (0.61), panicle length (0.59), grains per panicle

(0.78), straw yield (0.66), root volume (0.71) and root length (0.61). Characters viz. chaff per cent (-0.55) and grain thickness (-0.54) recorded negative significant correlation with grain yield.

Number of days from sowing to flowering was highly correlated with plant height (0.73), panicle length (0.77), root volume (0.55) and root length (0.71) at both genotypic and phenotypic level. This character showed negative significant correlation with number of tillers at active tillering, panicle initiation, flowering and harvest stages. This character also showed negative significant correlation with grain characters such as 1000 grain weight and grain thickness.

Number of tillers at active tillering stage showed highly significant positive correlation with number of tillers at panicle initiation, flowering and harvesting stages at genotypic and phenotypic levels. But this character showed high negative significant correlation with harvest index (-0.75) and root to shoot ratio (-.68) at genotypic level. Number of tillers at panicle initiation showed highly significant positive correlation with number of tillers at flowering and harvesting stages along with stem thickness at both genotypic and phenotypic level. This character was significantly and negatively correlated with plant height (-0.91 and -0.59) and panicle length (-0.91 and -0.6). At genotypic level characters like flag leaf area (-0.58), grains per panicle (-0.52), harvest index (-0.67), root to shoot ratio (-0.52), root volume (-0.61) and root length (-0.76) were significantly and negatively correlated with tiller number at panicle initiation.

Number of tillers at flowering stage was significantly positively correlated at both levels with productive tillers at harvesting stage (0.99 and 0.95) only. This character showed significant negative genotypic correlation with harvest index (-0.70) and root to shoot ratio (-0.62). Number of productive tillers per plant showed highly significant positive correlation (0.60) at genotypic level to stem thickness only. This character showed negative significant correlation with flag leaf area and root to shoot ratio at both levels.

Table 50a. Genotypic correlation matrix of parents

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.00**																						
2	-0.52*	1.00**																					
3	-0.73**	0.89**	1.00**																				
4	-0.53*	1.01**	1.00**	1.00**																			
5	-0.53*	0.996**	0.98**	0.99**	1.00**																		
6	0.73**	-0.51	-0.91**	-0.47	-0.51	1.00**																	
7	-0.39	0.66**	0.92**	0.52	0.60**	-0.58*	1.00**																
8	-0.026	-0.36	-0.58*	-0.43	-0.57*	-0.39	-0.25	1.00**															
9	0.77**	-0.48	-0.91**	-0.47	-0.54*	1.03**	-0.63**	0.41	1.00**														
10	0.44	-0.07	-0.52*	-0.03	0.03	0.82**	-0.37	0.06	0.83**	1.00**													
11	-0.096	-0.016	-0.21	0.034	0.17	0.30	-0.04	0.01	0.29	0.69**	1.00**												
12	-0.41	0.21	0.50	0.07	0.03	-0.63**	0.72**	0.19	-0.66**	-0.79**	-0.51	1.00**											
13	-0.54*	-0.09	0.04	0.11	-0.02	-0.11	-0.48	0.22	-0.16	-0.12	-0.08	-0.21	1.00**										
14	0.28	-0.49	-0.50	-0.32	-0.46	0.33	-0.87**	0.099	0.36	0.06	-0.34	-0.52	0.63**	1.00**									
15	-0.71**	0.34	0.69**	0.32	0.29	-0.78**	0.41	-0.11	-0.82**	-0.82**	-0.43	0.68**	0.39	-0.13	1.00**								
16	0.27	-0.13	-0.36	-0.12	-0.002	0.61**	-0.009	0.16	0.59*	0.78**	0.85**	-0.55*	-0.17	-0.18	-0.54*	1.00**							
17	0.0009	0.44	0.13	0.41	0.50	0.32	0.33	0.03	0.33	0.72**	0.71**	-0.28	-0.35	-0.55*	-0.66*	0.66**	1.00**						
18	0.01	0.35	0.06	0.33	0.44	0.37	0.34	0.06	0.36	0.75**	0.84**	-0.35	-0.31	-0.54*	-0.54*	0.81**	0.98**	1.00**					
19	0.43	-0.75**	-0.67**	-0.70**	-0.69**	0.42	-0.55*	0.13	0.39	0.11	0.10	-0.37	0.18	0.52*	-0.05	0.40	-0.44	-0.21	1.00**				
20	0.33	-0.22	-0.33	-0.195	-0.27	0.54*	0.005	0.38	0.55*	0.45	0.27	-0.02	-0.39	-0.29	-0.43	0.32	0.43	0.41	-0.10	1.00**			
21	0.17	-0.68**	-0.52*	-0.62**	-0.77**	0.18	-0.45	0.43	0.19	-0.22	-0.27	0.19	0.08	0.25	0.11	-0.298	-0.51	-0.49	0.28	0.52*	1.00**		
22	0.55*	-0.26	-0.61**	-0.35	-0.23	0.59*	-0.195	0.07	0.62**	0.69**	0.71**	-0.47	-0.60**	-0.28	-0.75**	0.71**	0.53*	0.62**	0.23	0.52*	0.05	1.00**	
23	0.71**	-0.496	-0.76**	-0.46	-0.43	0.78**	-0.58*	0.02	0.82**	0.70**	0.48	-0.69**	-0.26	0.23	-0.68**	0.61**	0.19	0.29	0.57*	0.53*	0.33	0.80**	1.00**

* Significant at 5 per cent

** Significant at 1 per cent

Table 50b. Phenotypic correlation matrix of parents

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.00*																						
2	-0.35	1.00*																					
3	-0.48	0.70*	1.00*																				
4	-0.45	0.88*	0.71*	1.00*																			
5	-0.41	0.88*	0.70*	0.95*	1.00*																		
6	0.73*	-0.35	-0.59*	-0.39	-0.38	1.00*																	
7	-0.30	0.29	0.52*	0.36	0.41	-0.44	1.00*																
8	-0.02	-0.32	-0.43	-0.42	-0.52*	0.33	-0.27	1.00*															
9	0.70*	-0.31	-0.60*	-0.35	-0.32	0.93*	-0.48	0.34	1.00*														
10	0.44	-0.05	-0.35*	-0.02	0.03	0.81*	-0.29	0.06	0.77*	1.00*													
11	-0.09	0.09	-0.07	0.08	0.20	030	0.0097	-0.03	0.24	0.66*	1.00*												
12	-0.40	0.12	0.33	0.05	0.01	-0.62*	0.58*	0.16	-0.59*	-0.79*	-0.49	1.00*											
13	0.52*	-0.04	0.002	0.07	-0.01	-0.12	-0.37	0.20	-0.08	-0.12	-0.06	-0.196	1.00*										
14	0.28	-0.39	-0.36	-0.30	-0.39	0.32	-0.72*	0.09	0.32	0.06	-0.33	-0.51	0.60*	1.00*									
15	-0.69*	0.23	0.43	0.21	0.19	-0.75*	0.32	-0.11	-0.74*	-0.79*	-0.38	0.64*	0.39	-0.12	1.00*								
16	0.25	0.03	-0.19	-0.006	0.05	0.57*	-0.03	0.09	0.51	0.73*	0.75*	-0.52*	-0.15	-0.16	-0.51	1.00*							
17	0.0009	0.34	0.10	0.37	0.41	0.32	0.29	0.002	0.28	0.71*	0.68*	-0.29	-0.33	-0.53*	-0.53*	0.61*	1.00*						
18	0.01	0.29	0.05	0.29	0.34	0.36	0.19	0.03	0.31	0.72*	0.78*	-0.35	-0.29	-0.48	-0.506	0.797*	0.94*	1.00*					
19	0.40	-0.40	-0.37	-0.44	-0.40	0.39	-0.28	0.07	0.35	0.11	0.09	-0.33	0.16	0.43	-0.08	0.43	-0.40	-0.197	1.00*				
20	0.32	-0.11	-0.19	-0.12	-0.14	0.53*	0.07	0.31	0.47	0.43	0.27	-0.01	-0.35	-0.29	-0.41	0.28	0.42	0.37	-0.07	1.00*			
21	0.17	-0.42	-0.33	-0.47	-0.52*	0.17	-0.29	0.39	0.18	-0.21	-0.23	0.19	0.11	0.22	0.099	-0.25	-0.49	-0.48	0.31	0.53*	1.00*		
22	0.54*	-0.16	-0.41	-0.28	-0.15	0.58*	-0.18	0.05	0.58*	0.68*	0.66*	-0.45	-0.56*	-0.27	-0.72*	0.65*	0.52*	0.60*	0.20	0.50	0.04	1.00*	
23	0.71*	-0.33	-0.49	-0.37	-0.30	0.77*	-0.44	0.01	0.72*	0.69*	0.45	-0.68*	-0.25	0.22	-0.66*	0.57*	0.18	0.28	0.54*	0.53*	0.33	0.781*	1.00*

* Significant at 1 per cent

At both levels plant height was highly positively and significantly correlated with panicle length, grains per panicle (0.82 and 0.81), root weight per plant (0.54 and 0.53), root volume (0.59 and 0.58) and root length (0.78 and 0.77). This character showed negative significant correlation at genotypic and phenotypic level for chaff per cent (-0.63 and -0.62) and grain thickness (-0.78 and -0.75).

Stem thickness showed only significant correlation with chaff per cent at both levels and showed negative significant correlation at genotypic level with panicle length (-0.63), harvest index (-0.55) and root length (-0.58). This character showed phenotypic and genotypic negative significant correlation with grain density (-0.87 and -0.72). Flag leaf area did not show significant correlation with any of the characters under study. Panicle length was positively and significantly correlated at both levels with grains per panicle (0.83 and 0.77), root volume (0.62 and 0.58) and root length (0.82 and 0.72). The characters showed negative significant correlation with chaff per cent (-0.66 and -0.59) and grain thickness (-0.82 and -0.74) at genotypic and phenotypic levels.

Grains per panicle was significantly and positively correlated with panicle weight (0.69 and 0.66), straw yield (0.72 and 0.71), total dry matter (0.75 and 0.78), root volume (0.69 and 0.65) and root length (0.70 and 0.69) at genotypic and phenotypic levels. But this character was negatively correlated with chaff per cent (-0.79 and -0.79) and grain thickness (-0.82 and -0.79) at both levels.

Panicle weight was significantly and positively correlated with straw yield (0.71 and 0.68), total dry matter (0.84 and 0.78) and root volume (0.71 and 0.66) at both levels. Positive significant correlation was indicated by chaff per cent at both levels for grain thickness and for root length negatively significant correlation (-0.69 and -0.68) was exhibited. For 1000 grain weight positive and highly significantly correlation was seen for grain density (0.63 and 0.60) at both levels and this character was significantly negatively correlated with root volume (-0.60 and -0.56) at both levels.

Grain density exhibited negative significant correlation with straw yield and total dry matter at genotypic level and only with straw yield at phenotypic level. This character showed only positive significant genotypic correlation with harvest index (0.52). Grain thickness was negatively but significantly correlated with straw yield, total dry matter, root volume and root length at both levels. Straw yield was positively and significantly correlated with total dry matter (0.98 and 0.94) and root volume (0.53 and 0.52) at both levels.

Total dry matter showed positive significant correlation at both genotypic and phenotypic levels with root volume (0.62 and 0.60). Harvest index showed positive significant correlation with root length (0.57 and 0.54) at both levels. Root weight per plant showed positive significant correlation with all other root characters at both phenotypic and genotypic levels. Root volume showed significantly and positively significant correlation with root length (0.80 and 0.78) at both genotypic and phenotypic levels respectively.

4.5.2 Correlation between grain yield and its component traits in hybrids

Highest positive and significant genotypic correlation with grain yield was recorded by panicle weight followed by grains per panicle. Other characters like plant height (0.76), panicle length (0.73), 1000 grain weight (0.49), harvest index (0.89) and root to shoot ratio (0.43) also showed significant positive genotypic correlation with grain yield in case of hybrids. Characters viz. number of tillers at flowering stage (-0.71), stem thickness (-0.83), chaff per cent (-1.35), grain density (-0.47), straw yield (-0.84), root volume (-0.43) and root length (-0.78) recorded negative significant correlation with grain yield.

Towards number of days to flowering chaff per cent (0.62 and 0.61) and root volume (0.56 and 0.54) were positively and significantly correlated at genotypic and phenotypic level. Straw yield (0.40), root weight per plant (0.39) and root volume

Table 51a. Genotypic correlation matrix - Hybrids

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.00**																						
2	0.12	1.00**																					
3	-0.19	1.04**	1.00**																				
4	-0.02	0.98**	0.79**	1.00**																			
5	-0.44**	0.67**	0.70**	0.66**	1.00**																		
6	0.03	-0.27	-0.514**	-0.59**	-0.20	1.00**																	
7	0.04	-0.58**	-0.79**	-0.64**	-0.43*	0.55**	1.00**																
8	-0.30	0.07	0.57**	0.44**	0.23	0.21	0.61**	1.00**															
9	-0.36	-0.41*	-0.39*	-0.69**	-0.23	0.20	0.28	0.34	1.00**														
10	-0.60**	-0.19	0.05	-0.27	-0.04	-0.02	0.02	0.29	0.61**	1.00**													
11	-0.65**	-0.31	0.05	-0.32	-0.09	-0.02	0.04	0.36	0.76**	0.87**	1.00**												
12	0.62**	0.23	0.12	0.28	0.079	0.20	0.15	0.04	-0.35	-0.60**	-0.65**	1.00**											
13	-0.05	0.04	-0.003	-0.11	-0.11	-0.29	0.08	-0.06	0.17	0.19	0.02	-0.30	1.00**										
14	-0.17	0.33	0.36	-0.08	0.25	-0.04	0.09	-0.16	0.095	0.13	-0.001	0.19	0.31	1.00**									
15	0.12	0.30	0.45**	0.02	0.04	-0.17	-0.13	-0.004	0.09	0.26	0.16	-0.13	0.47**	0.27	1.00**								
16	-0. 14	0.08	-0.24	-0.71**	0.14	0.76**	-0.83**	0.28	0.73**	1. 05**	1.4**	-1.35**	0.49**	-0.47**	0.16	1.00**							
17	0.40*	-0.13	-0.44**	-0.35	-0.19	0.46**	0.35	-0.19	0.005	-0.38*	-0.38*	0.70**	0.31	0.32	-0.15	-0.84**	1.00**						
18	0.04	-0.25	-0.68**	-0.71**	-0.29	0.55**	0.52**	-0.15	0.24	-0.01	-0.08	0.23	-0.07	0.33	-0.12	-0.26	0.74**	1.00**					
19	-0.53**	0.0008	0.03	-0.14	0.007	-0.24	-0.05	0.12	0.15	0.52**	0.50**	-0.80**	0.43*	-0.15	0.15	0.89**	-0.83**	-0.23	1.00**				
20	0.39*	-0.22	-0.21	-0.51**	-0.08	0.15	-0.15	-0.21	0.05	0.06	-0.08	0.17	-0.11	0.23	0.31	0.06	0.18	-0.02	-0.26	1.00**			
21	-0.0007	0.04	0.26	0.05	0.27	-0.25	-0.34	-0.08	-0.002	0.25	0.13	-0.35	-0.20	-0.05	0.48	0.43**	-0.63**	-0.56**	0.44**	0.58**	1.00**		
22	0.56**	0.21	0.03	-0.009	0.007	0.16	0.002	-0.11	0.17	-0.14	-0.32	0.57**	0.02	0.38*	0.40*	-0.43*	0.63**	0.29	-0.67**	0.61**	0.04	1.00**	
23	-0.34	-0.37*	-0.10	-0.56**	-0.25	0.29	0.54**	0.30	0.31	0.27	0.15	0.0006	0.19	0.44**	-0.0009	-0.78**	0.10	0.30	0.10	-0.21	-0.27	-0.12	1.00**

* Significant at 5 per cent
** Significant at 1 per cent

Table 51b. Phenotypic correlation matrix of hybrids

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.00*																						
2	0.064	1.00*																					
3	-0.08	0.52*	1.00*																				
4	-0.01	0.60*	0.66*	1.00*																			
5	-0.27	0.46*	0.49*	0.56*	1.00*																		
6	0.03	-0.14	-0.21	-0.26	-0.09	1.00*																	
7	-0.34	-0.26	-0.32	-0.29	-0.23	0.49*	1.00*																
8	-0.29	0.04	0.18	0.17	0.12	0.20	0.15	1.00*															
9	-0.29	-0.13	-0.13	-0.15	-0.046*	0.18	0.28	0.26	1.00*														
10	-0.59*	-0.09	0.03	-0.10	-0.03	-0.02	0.01	0.28	0.49*	1.00*													
11	-0.57*	-0.13	-0.03	-0.10	-0.02	-0.008	0.04	0.31	0.51*	0.74*	1.00*												
12	0.61*	0.13	0.07	0.14	0.07	0.19	0.13	0.04	-0.30	-0.59*	-0.54*	1.00*											
13	-0.05	0.09	-0.17	-0.02	-0.05	-0.26	-0.08	-0.05	0.17	0.18	0.02	-0.28	1.00*										
14	-0.17	0.18	0.13	-0.04	0.16	-0.03	0.08	-0.15	0.095	0.13	-0.03	0.18	0.295	1.00*									
15	0.12	0.18	0.26	0.04	0.02	-0.16	-0.12	0..004	0.09	0.25	0.08	-0.13	0.43	0.26	1.00*								
16	-0.22	0.03	0.05	0.09	0.16	0.17	-0.15	0.09	0.12	0.30	0.24	-0.21	0.009	-0.08	0.004	1.00*							
17	0.39	-0.049	-0.23	-0.18	-0.15	0.44	0.31	-0.17	0.008	-0.37	-0.32	0.67*	-0.26	0.31	-0.15	-0.13	1.00*						
18	0.04	-0.15	-0.31	-0.31	-0.21	0.53*	0.44	-0.14	0.17	-0.01	-0.07	0.22	-0.06	0.31	-0.13	0.02	0.73*	1.00*					
19	-0.50*	-0.03	-0.003	-0.003	0.03	-0.23	-0.06	0.099	0.13	0.50*	0.37	-0.76*	0.36	-0.15	0.15	0.19	-0.79*	-0.21	1.00*				
20	0.38	-0.11	-0.21	-0.21	-0.03	0.14	-0.12	-0.21	0.03	0.06	-0.06	0.17	-0.11	0.22	0.27	-0.007	0.17	-0.01	-0.24	1.00*			
21	-0.004	-0.002	0.04	0.04	0.16	-0.23	-0.29	-0.09	0.007	0.23	0.09	-0.34	0.19	-0.03	0.38	0.08	-0.61	-0.54*	0.42	0.56*	1.00*		
22	0.54*	0.12	-0.03	-0.03	-0.01	0.15	0.005	-0.098	0.11	-0.13	-0.28	0.55*	0.003	0.35	0.37	-0.06	0.60	0.26	-0.63*	0.59*	0.03	1.00*	
23	-0.33	-0.21	-0.25	-0.25	-0.21	0.29	0.49	0.26	0.24	0.25	0.12	0.003	0.18	0.42	-0.03	-0.13	0.10	0.29	0.09	-0.20	-0.24	-0.11	1.00*

* Significant at 1 per cent

(0.56) were genotypically positively correlated with number of days to flowering. Characters like grains per panicle (-0.60 and -0.59), panicle weight (-0.65 and 0.57) and harvest index (-0.53 and -0.50) were significantly and negatively correlated with days to flowering. Number of tillers at active tillering stage was positively and significantly correlated with number of tillers at panicle initiation (1.04 and 0.52), flowering (0.98 and 0.60) and harvesting stages (0.67 and 0.46) at both levels. This character showed negative significant correlation with stem thickness (-0.58), panicle length (-0.41) and root length (-0.37) at genotypic level.

Number of tillers at panicle initiation had a significant positive correlation with number of tillers at flowering (0.79 and 0.66) and number of total productive tillers (0.70 and 0.49) at harvesting stage for both genotypic and phenotypic levels. For flag leaf area (0.57) and grain thickness (0.45) this character showed significant positive genotypic correlation and for plant height (-0.51), stem thickness (-0.79), panicle length (-0.39), straw yield (-0.44) and total dry matter (-0.68) this characters showed negative significant correlation at genotypic level. Number of tillers at flowering stage exhibited significant positive correlation for number of productive tillers at harvest (0.66 and 0.56) at both levels. For plant height (-0.59), stem thickness (-0.64), panicle length (-0.69), total dry matter (-0.71), root weight per plant (-0.51) and root length, negative significant correlation was observed at genotypic level.

Number of productive tillers per plant at harvesting stage showed significant negative genotypic correlation for stem thickness (-0.43). For plant height significant positive genotypic correlation was found for stem thickness (0.55), straw yield (0.46) and total dry matter (0.55). Total dry matter was the only character for which positive and significant phenotypic correlation was observed for this character. Towards stem thickness, flag leaf area (0.61), total dry matter (0.52) and root length (0.54) showed significant positive genotypic correlation. Root length exhibited significantly positive phenotypic correlation with stem thickness. Flag leaf area showed significant positive correlation with number of tillers at panicle initiation (0.57) and flowering (0.44) stages at genotypic level.

Panicle length recorded significant positive correlation with grains per panicle (0.61 and 0.49) and panicle weight (0.76 and 0.51) at both genotypic and phenotypic levels. Grains per panicle expressed significant positive correlation for panicle weight (0.87 and 0.74) and harvest index (0.52 and 0.50) at both levels and expressed significant negative correlation with chaff per cent (-0.60 and -0.59).

Panicle weight showed significantly positive genotypic correlation with harvest index (0.50) and significantly negative genotypic and phenotypic correlation with chaff per cent (-0.65 and -0.54). Chaff per cent was significantly positively correlated with straw yield (0.70 and 0.67) and root volume (0.67 and 0.55) at both levels. This character was significantly negatively correlated with harvest index (-0.80 and -0.76) at both levels.

1000 grain weight was significantly and positively correlated with grain thickness (0.47) and harvest index (0.43) at genotypic level. Grain density was positively and significantly correlated with root volume (0.38) and root length (0.44) and significantly negatively correlated with grain yield (-0.47) at genotypic level.

Grain thickness was significantly positively correlated with only root volume (0.40) at genotypic level. Here straw yield exhibited significant positive correlation with total dry matter (0.74 and 0.73) and root volume (0.63 and 0.60) at both levels. This character expressed negative significant correlation with harvest index and root to shoot ratios. Total dry matter expressed significant negative correlation with root to shoot ratio (-0.56 and -0.54) at both levels. Harvest index also exhibited significant negative correlation for root to shoot ratio and root volume at both levels.

Root weight per plant showed significant positive correlation with root to shoot ratio (0.58 and 0.56) and root volume (0.61 and 0.59) at both levels. Root volume showed significantly and positively correlation with number of days to flowering, chaff per cent, grain density, grain thickness, straw yield and with root weight per plant. Root length also showed significant positive correlation with stem thickness and grain density.

4.6 PATH ANALYSIS

Path analysis was carried out separately in parents and hybrids using significant genotypic correlation of ten characters viz. plant height, panicle length, grains per panicle, panicle weight, chaff per cent, grain thickness, straw yield, total dry matter, root volume and root length with grain yield in parents and 14 characters namely number of tillers at flowering stage, plant height, stem thickness, panicle length, grains per panicle, panicle weight, chaff per cent, 1000 grain weight, grain density, straw yield, harvest index, root to shoot ratio, root volume and root length with grain yield in hybrids.

4.6.1 Direct and indirect effects of traits on grain yield in parents

4.6.1.1 Direct effects

Total dry matter registered maximum positive direct effect of 0.96 on grain yield for parents (Table 52) followed by panicle weight (0.67) and panicle length (0.60). Plant height (0.38), grain thickness (0.039) and root length (0.26) also recorded positive direct effects on yield. Grains per panicle (-1.27) recorded maximum negative direct effect followed by root volume (-0.30) and chaff per cent (-0.29) on grain yield.

4.6.1.2 Indirect effects

Path analysis carried out in parents (Table 52) revealed that plant height exhibited positive indirect effects through panicle length (0.56), total dry matter

Table 52. Direct and indirect effects of traits on grain yield in parents

Characters	Plant height	Panicle length	Grains/ panicle	Panicle weight	Chaff %	Grain thickness	Straw yield	Total dry matter	Root volume	Root length
Plant height	**0.38**	0.56	-1.03	0.20	0.18	-0.03	-0.02	0.34	-0.17	0.20
Panicle length	0.35	**0.60**	-0.97	0.16	0.17	-0.03	-0.02	0.30	-0.17	0.19
Grains/panicle	0.31	0.46	**-1.27**	0.45	0.23	-0.03	-0.04	0.69	-0.20	0.18
Panicle weight	0.11	0.15	-0.84	**0.67**	0.14	-0.01	-0.04	0.75	-0.20	0.12
Chaff %	-0.24	-0.35	0.99	-0.33	**-0.29**	0.03	0.02	-0.33	0.13	-0.18
Grain thickness	-0.28	-0.44	1.00	-0.25	-0.19	**0.039**	0.03	-0.49	0.21	-0.17
Straw yield	0.12	0.17	-0.90	0.46	0.08	-0.02	**-0.06**	0.90	-0.15	0.05
Total dry matter	0.14	0.19	-0.92	0.53	0.099	-0.020	-0.06	**0.96**	-0.18	0.07
Root volume	0.22	0.35	-0.86	0.45	0.13	-0.03	-0.03	0.57	**-0.30**	0.20
Root length	0.29	0.44	-0.87	0.30	0.19	-0.03	-0.01	0.27	-0.23	**0.26**

Diagonal values (bold) denote direct effects

(0.34), panicle weight (0.20) and root length (0.20). This character exerted high negative indirect effects through grains per panicle (-1.03), root volume and straw yield. Panicle length registered high positive indirect effects on yield through plant height (0.35), total dry matter (0.30) and root length (0.19). Negative indirect effect was through grains per panicle (-0.97), root volume (-0.17) and straw yield.

Grains per panicle exerted maximum positive indirect effect on yield through total dry matter (0.69). High positive indirect effects were also exerted through panicle length (0.46), panicle weight (0.45) and plant height (0.31). High negative indirect effect was exerted through root volume, and straw yield. Panicle weight exhibited maximum positive indirect effect through total dry matter (0.75) followed by panicle length, and root length.

Chaff per cent showed maximum positive in direct effect through grains per panicle on grain yield and maximum negative indirect effects through panicle length, panicle weight and total dry matter. Grain thickness registered maximum positive indirect effect through grains per panicle (1.00) followed by root volume. This character showed high negative indirect effects on yield through total dry matter, panicle length and panicle weight.

Straw yield showed maximum positive indirect effect on grain yield through total dry matter (0.90) followed by panicle weight (0.46) and panicle length. High negative indirect effect was exhibited through grains per panicle (-0.90) followed by root volume and grain thickness.

Total dry matter registered high positive indirect effects through panicle weight (0.53), panicle length, root length and plant height. High negative indirect effects was exhibited through grains per panicle (-0.92) and root volume. Root volume exerted high positive indirect effect on yield through total dry matter, panicle weight, panicle length, plant height and root length. This character showed high negative indirect effect on yield through grains per panicle. Root length exerted maximum positive indirect effect through panicle length and maximum negative indirect effect through grains per panicle and root volume. Positive indirect effect was also exerted through panicle weight and total dry matter.

4.6.2 Direct and indirect effects of traits on grain yield in hybrids

4.6.2.1 Direct effects

Grains per panicle recorded maximum positive direct effect of 2.80 on grain yield for hybrids in Table 53 followed by plant height 2.54 and 1000 grain weight 1.39. Panicle length (0.18), chaff per cent (1.06) and grain density (0.43) also exhibited positive direct effect on grain yield. Root length (-2.30) recorded maximum negative direct effect followed by straw yield (-1.9) and stem thickness (-1.46) on grain yield. Number of tillers at flowering, panicle weight, harvest index, root to shoot ratio, and root volume also recorded negative direct effect on yield.

4.6.2.2 Indirect effects

Path analysis carried out in Table 53 revealed that number of tillers at flowering exerted positive indirect effects through root length (0.57), stem thickness (0.42), straw yield (0.33), panicle weight, chaff per cent, harvest index and root volume. Negative indirect effect was exerted through plant height (-0.65), grains per panicle, 1000 grain weight, panicle length, grain density and root to shoot ratio. Plant height registered maximum indirect effect through number of tillers at flowering (0.31). Positive indirect effect was also recorded through panicle length, panicle weight, harvest index and root to shoot ratio. Negative indirect effect was exerted through stem thickness. 1000 grain weight, straw yield, root volume and root length.

Stem thickness exerted maximum indirect effect through plant height (1.26) on grain yield. This character also recorded positive indirect effect through number of tillers at flowering, panicle length, grains per panicle, 1000 grain weight, grain density, harvest index and root to shoot ratio on grain yield. Negative indirect

Table 53. Direct and indirect effects of traits on grain yield in hybrids

Characters	No. of tillers at flowering	Plant height	Stem thickness	Panicle length	Grains/ panicle	Panicle weight	Chaff %	1000 grain weight	Grain density	Straw yield	Harvest index	Root to shoot ratio	Root volume	Root length
No. of tillers at flowering	**-1.19**	-0.65	0.42	-0.03	-0.29	0.03	0.15	-0.03	-0.02	0.33	0.003	-0.04	0.03	0.57
Plant height	0.31	**2.54**	-0.73	0.03	-0.04	0.003	0.20	-0.36	-0.01	-0.84	0.24	0.25	-0.16	-0.66
Stem thickness	0.34	1.26	**-1.46**	0.05	0.04	-0.01	0.14	0.11	0.03	-0.58	0.06	0.32	-0.05	-1.13
Panicle length	0.18	0.45	-0.40	**0.18**	1.38	-0.18	-0.32	0.24	0.04	-0.02	-0.13	-0.007	-0.12	-0.56
Grains/ panicle	0.12	-0.04	-0.02	0.09	**2.80**	-0.27	-0.62	0.25	0.06	0.70	-0.52	-0.25	0.14	-0.58
Panicle weight	0.12	-0.02	-0.05	0.09	2.07	**-0.36**	-0.57	0.02	-0.01	0.61	-0.39	-0.10	0.30	-0.28
Chaff %	-0.16	0.48	-0.20	-0.06	-1.65	0.20	**1.06**	-0.39	0.08	-1.29	0.80	0.37	-0.59	0.006
1000 grain weight	0.02	-0.66	-0.12	0.03	0.50	-0.005	-0.30	**1.39**	0.13	0.50	-0.38	-0.20	-0.003	-0.42
Grain density	0.05	-0.09	0.11	0.02	0.36	0.010	0.19	0.41	**0.43**	-0.59	0.16	0.04	-0.38	-0.97
Straw yield	0.21	1.12	-0.45	0.001	-1.03	0.12	0.72	-0.36	0.13	**-1.9**	0.84	0.66	-0.65	-0.24
Harvest index	0.004	-0.58	0.09	0.02	1.38	-0.14	-0.80	0.49	-0.06	1.51	**-1.06**	-0.45	0.68	-0.20
Root to shoot ratio	-0.05	-0.58	0.43	0.001	0.65	-0.03	-0.36	0.26	-0.015	1.16	-0.44	**-1.09**	-0.03	0.54
Root volume	0.03	0.38	-0.007	0.02	-0.37	0.10	0.58	0.004	0.15	-1.15	0.67	-0.04	**-1.07**	0.26
Root length	0.30	0.72	-0.72	0.04	0.70	-0.04	0.003	0.25	0.18	-0.20	-0.09	0.26	0.12	**-2.30**

Diagonal values (bold) denote direct effects

effects were exerted through root length (-1.13), straw yield (-0.58), root volume and panicle weight.

Panicle length registered maximum positive indirect effect through grains per panicle (1.38). Positive indirect effects was also exerted through plant height, 1000 grain weight and grain density. Negative indirect effect was exerted through stem thickness, panicle weight, chaff per cent, straw yield, harvest index, root volume and root length. Grains per panicle exerted positive indirect effects through number of tillers at flowering stage, panicle length, 1000 grain weight, grain density, straw yield and root volume while negative indirect effects through plant height, stem thickness, panicle weight, chaff per cent, harvest index, root to shoot ratio and root length.

Panicle weight recorded positive indirect effects through grains per panicle (2.07), panicle length, straw yield, root volume, 1000 grain weight etc. and negative indirect effects through harvest index, chaff per cent, grain density, root length etc. chaff per cent exerted high positive indirect effects through plant height, panicle weight, harvest index, root to shoot ratio etc. This character exhibited high negative indirect effects through grains per panicle (-1.65), straw yield (-1.29), panicle length, root volume and 1000 grain weight.

1000 grain weight registered high positive indirect effects through grains per panicle (0.50), straw yield (0.50) and panicle length while high negative indirect effects through plant height, root length, harvest index and chaff per cent. Grain density exhibited high positive indirect effects on yield through 1000 grain weight (0.41), grains per panicle, harvest index and high negative indirect effects on yield through root length (-0.97), straw yield, root volume and plant height. Straw yield recorded high positive indirect effect through plant height (1.12), number of tillers at flowering, panicle weight, harvest index and chaff per cent. This character showed high negative indirect effect on yield through grains per panicle (-1.03), stem thickness, 1000 grain weight, root volume and root length.

Harvest index recorded high positive indirect effect through straw yield (1.51), grains per panicle and root volume and high negative indirect effects through chaff per cent and plant height. Root to shoot ratio exhibited high positive indirect effect through straw yield (1.16) followed by grains per panicle and root length and showed high negative indirect effect through plant height.Root volume showed high positive indirect effect through harvest index(0.67) followed by plant height, root length etc. and high negative indirect effect through straw yield. Root length exerted high positive indirect effect through plant height (0.72) followed by grains per panicle and root to shoot ratio and high negative indirect effect through stem thickness and straw yield.

DISCUSSION

5. DISCUSSION

Yield components play an important role in many crop breeding programmes. Plant breeders always aim to improve the crop productivity by seeking selection for appropriate yield components. It is frequently of interest to identify parents which contribute towards yield.

Varietal breeding programme in the context of agricultural production is an important factor of technological progress. Superiority of improved type is caused by certain specific gene combinations and how rapidly these specific gene combinations can be marshaled in a single plant or variety depends upon the system through which the genes in the material available are mobilized. Results obtained after the evaluation of ten parents and 24 hybrids from line x tester mating design are discussed here under.

5.1 EVALUATION OF PARENTS

Combining ability effects of parents have been used for evaluating the ability of parents to transmit desirable traits to their off spring. In the present study combining ability of ten parents and 24 hybrid combinations were analysed through line x tester analysis. The analysis of variance for combining ability revealed that variance due to lines, testers and line x tester interaction were significant for the characters studied, indicating the presence of adequate variability in the experimental material.

5.1.1 GCA : SCA variance

Success in breeding for quantitative traits depends upon gene action involved for the trait concerned and the nature of gene effects controlling the characters. If additive variance is greater, then the chance of fixing superior

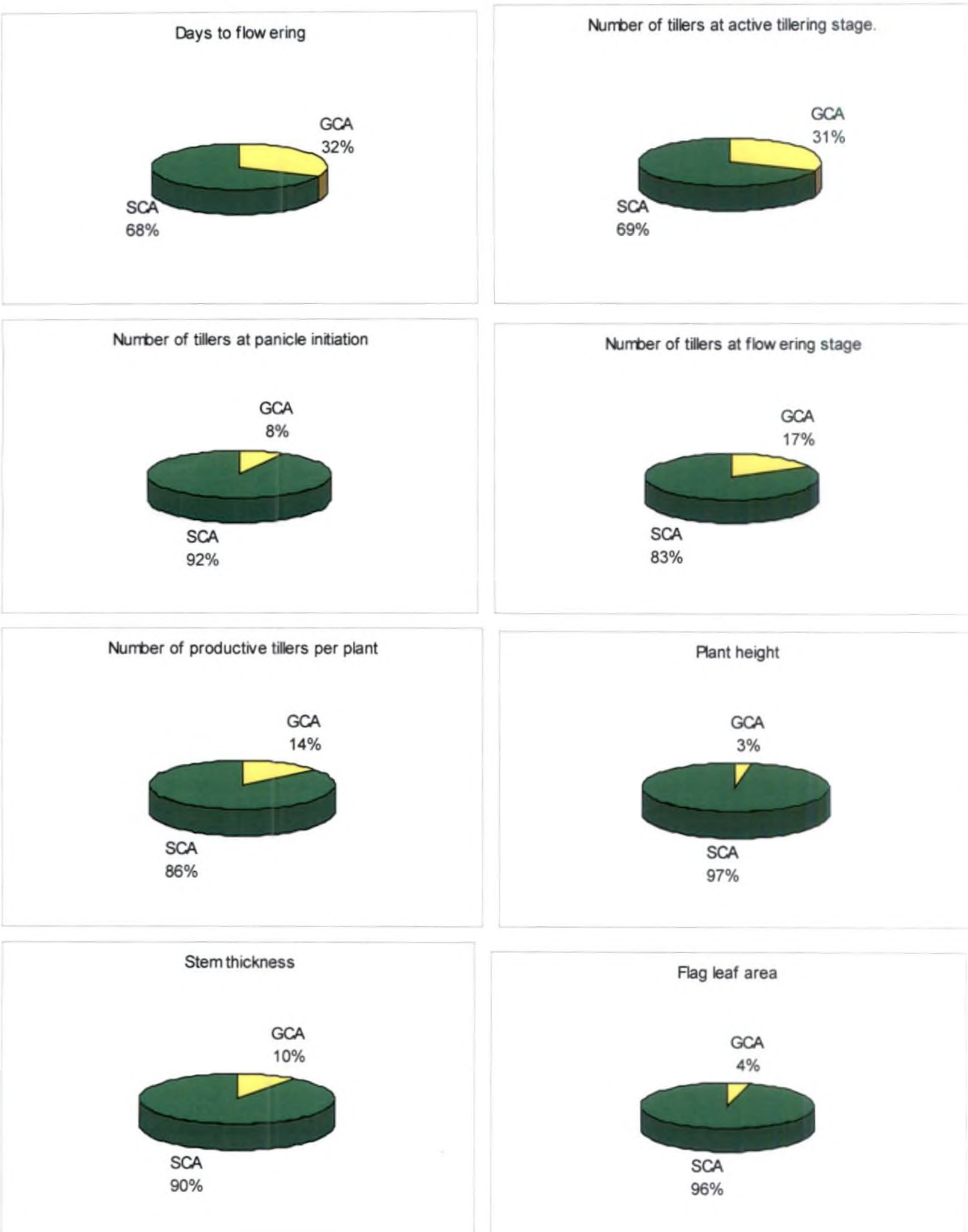


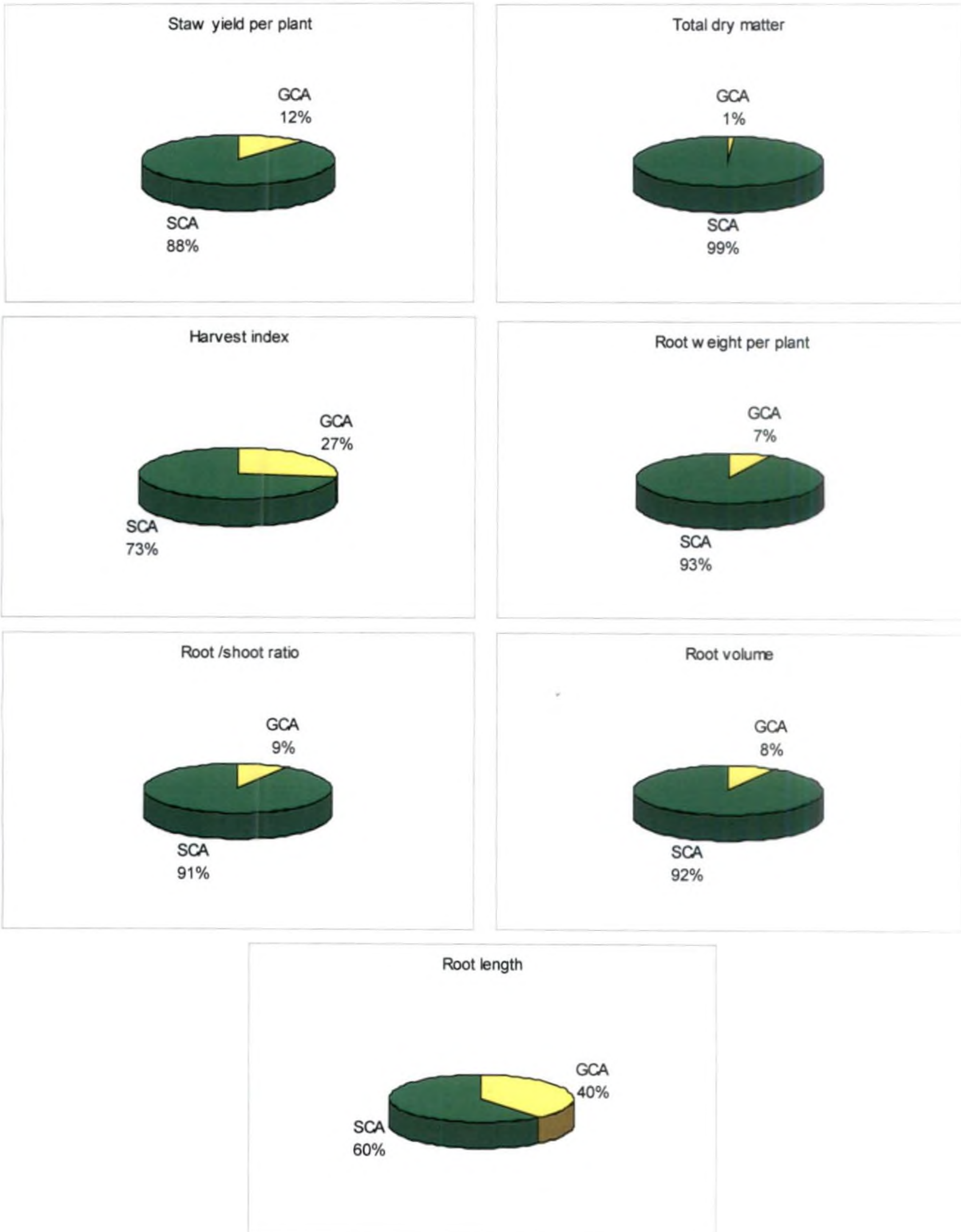
Fig. 1. Magnitude of GCA and SCA variance for different characters

Contd.

Fig. 1. continued

Contd.

Fig. 1. continued



genotypes in the early segregating generations will be great. If non additive varience is predominant, then the selection will have to be postponed to later generations, and appropriate breeding techniques adopted to sieve the material for obtaining useful genotypes (Panse, 1942).

In the present study the magnitude of SCA variance was more than GCA variance for all the characters studied except grain yield per plant, suggesting predominance of non additive genetic variance for these traits (Fig 1). Eventhough grain yield per plant exhibited high GCA variance, there was no significant difference among males, females or male x female interaction with respect to this character. An assessment of the potential of different crosses by Bentota *et al.* (1997) showed that it was easy to achieve the NPT targets for six characters while this is unlikely for proportion of filled spikelets, grain yield and harvest index with one cycle of breeding. GCA/SCA ratio was observed to be more than one for number of tillers at flowering stage indicating influence of additive gene action. For the rest of the characters GCA/SCA ratio was lesser than one indicating the influence of non additive gene action. Similar results were reported by Lokaprakash *et al.* (1991),Selvarani and Rangasamy(1999) and Gomez *et al.* (2003). However, according to Pethani and Kapoor (1984), the nature of gene action varies with the material, the analytical procedure used and the environment under which the test is carried out.

5.1.2 Mean performance and *gca* effects

Mean performance of the parents for different traits were evaluated along with their *gca* effects (Table 54). Among the ten parents studied Mattatriveni exhibited significant positive *gca* effects for panicle weight, grain yield, panicle length and grains per panicle and highly significant negative *gca* effects for days to flowering. Analysis of mean performance also showed same trend indicating that Mattatriveni can be used in the production of new plant type considering these

Table 54. Parents with desirable mean performance and *gca* effects

Sl. No.	Characters	Parents with superior mean performance	Parents having high *gca* effects
1	*Days to flowering	Aiswarya Jyothi Kanchana Mattatriveni Swarnaprabha	Mattatriveni Kanchana Aiswarya Swarnaprabha Jyothi
2	Number of tillers at flowering stage	Kanchana Uma Mahsuri Gouri Mattatriveni	Kanchana Mattatriveni Gouri Ptb 15 Swarnaprabha
3	Total number of productive tillers per plant	Kanchana Uma Mahsuri Mattatriveni Gouri	Kanchana Ponmani Mahsuri Uma Mattatriveni
4	Panicle length	Ptb 15 Mahsuri Swarnaprabha Uma Aiswarya	Mattatriveni Jyothi Mahsuri Ponmani Swarnaprabha
5	Grains per panicle	Mahsuri Ptb 15 Kanchana Swarnaprabha Uma	Mattatriveni Jyothi Swarnaprabha Ponmani Aiswarya
6	Panicle weight per plant	Mahsuri Aiswarya Kanchana Jyothi Mattatriveni	Mattatriveni Jyothi Swarnaprabha Ponmani Aiswarya Mahsuri
7	1000 grain weight	Kanchana Swarnaprabha Jyothi Aiswarya Mattatriveni	Jyothi Ponmani Kanchana Ptb 15 Gouri
8	Plant height	Ptb 15, Mahsuri, SwarnaPrabha, Uma, Aiswarya.	Aiswarya, Mahsuri, Gouri, Swarnaprabha, Mattatriveni

Contd.

Table 54. continued

Sl. No.	Characters	Parents with superior mean performance	Parents having high *gca* effects
9	Grain density	Ptb 15 Kanchana Swarnaprabha Gouri Jyothi	Swarnaprabha Kanchana Jyothi Gouri, Uma
10	Grain yield	Mahsuri Ptb 15 Aiswarya Uma Jyothi	Mattatriveni Mahsuri Aiswarya Ponmani Jyothi
11	Total dry matter	Mahsuri Uma Kanchana Ptb 15 Ponmani Swarnaprabha Aiswarya	Aiswarya Uma Swarnaprabha Mahsuri Kanchana
12	Harvest index	Ptb 15 Aiswarya Jyothi Swarnaprabha Ponmani	Jyothi Ponmani Aiswarya Kanchana Mattatriveni Swarnaprabha
13	Root to shoot ratio	Mahsuri Swarnaprabha Mattatriveni Ptb 15 Ponmani	Ponmani Kanchana Jyothi Ptb 15 Gouri
14	Root weight per plant	Swarnaprabha Mahsuri Mattatriveni Uma Ponmani	Gouri Uma Ponmani Jyothi Kanchana
15	Root length	Ptb 15 Ponmani Mahsuri Swarnaprabha Mattatriveni	Aiswarya Jyothi Swarnaprabha Gouri Mahsuri

*High negative *gca* effects are considered.

characters. Based on mean performance Kanchana was identified as best parent for characters namely thousand grain weight, number of tillers at flowering and number of productive tillers per plant. Among the lines Gouri and among the testers Ponmani exhibited high mean performance and positive significant *gca* effects for root characters like root weight per plant, root to shoot ratio and root volume. In the highly lateritic soils of Kerala, root characters also should be given due consideration and these varieties assume importance while breeding for improvement of root characters. Significant *gca* effect and high mean performance for 1000 grain weight and harvest index was shown by Jyothi.

Among the testers Swarnaprabha recorded high *gca* effects for characters viz., panicle weight, grain density, grains per panicle, total dry matter, root length and negative high *gca* effect for days to flowering. Perraju and Sarma (1999),reported high *gca* effects for grains per panicle in Swarnaprabha. Mean performance of Ptb 15 for characters viz., panicle length, harvest index, grain density and grain yield were superior but absence of significant *gca* effect for these characters indicated the inability of the variety to transfer these characters to the hybrids. This variety also showed negative significant *gca* effect for stem thickness and plant height. Similarly Mahsuri showed superior mean performance for panicle and grain characters such as panicle length, grains per panicle, panicle weight, grain yield and total dry matter, but significant *gca* effect was shown only for panicle length and total dry matter. Thus it can be seen that different varieties exhibited superior performance and significant *gca* effects for different characters. Virmani *et al.* (1981), Peng and Virmani (1991) and Padmavathi *et al.* (1997) also reported different varieties to have high *gca* effect for different characters.

5.1.3 Correlation and path analysis

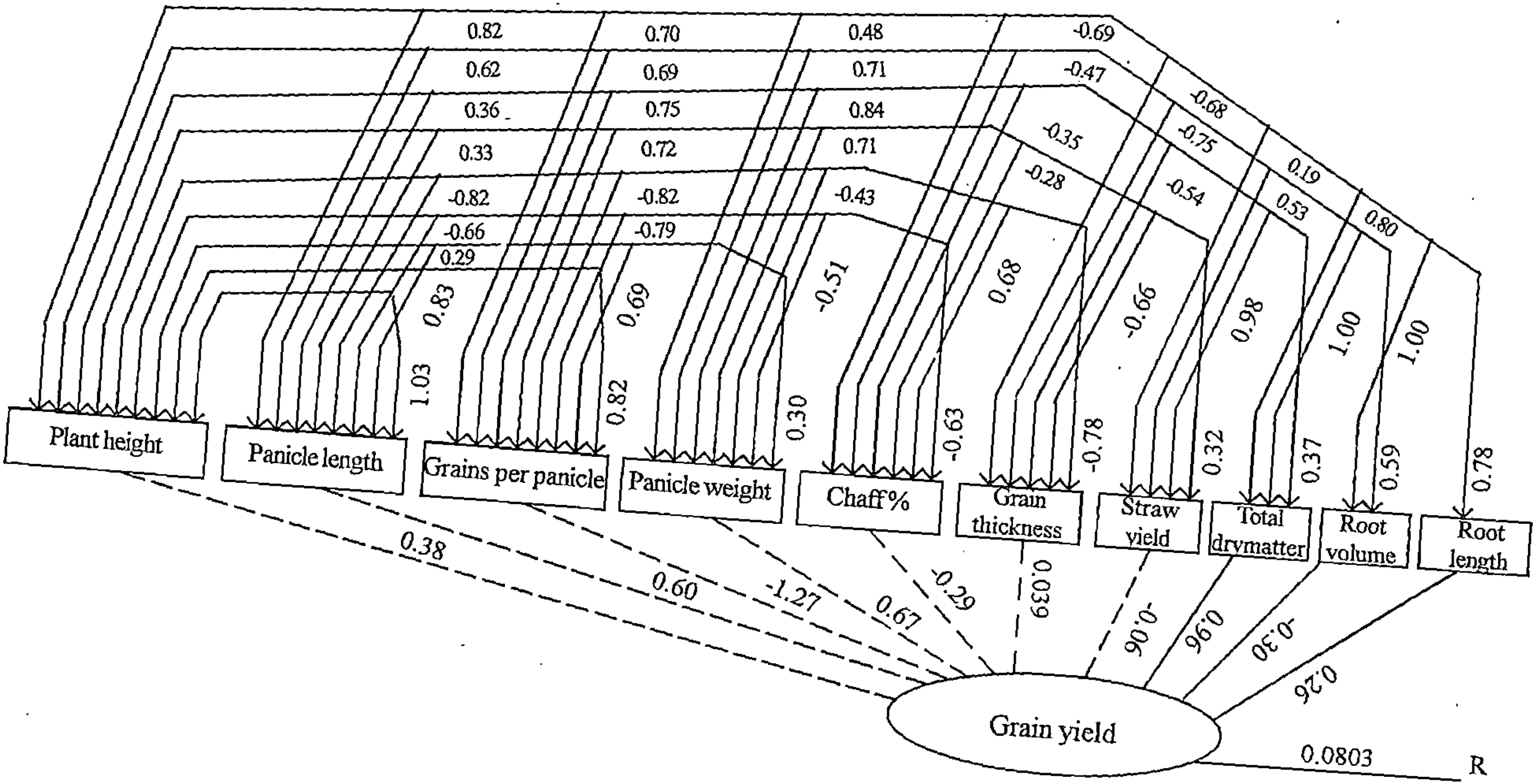
Correlation provides information on the nature and extent of relationship between characters. When the breeder applies selection pressure for a trait, the population being improved for that trait is also improved in respect of all other characters associated with it. Thus correlation, facilitates simultaneous improvement of two or more characters. The estimates of the genotypic and phenotypic correlation coefficients between different characters indicate the extent and direction of association. Genotypic correlation between two or more characters may result from pleiotropic effects of genes or linkages of genes governing the inheritance of characters. Phenotypic correlation on the other hand is determined by genotypic and environmental effects. Sometimes correlation coefficients may not be due to the direct effect of the characters, but due to the indirect effects through other characters. Hence in order to identify the direct and indirect effect of the variabilities path analysis was conducted.

In the present study genotypic correlation coefficients were higher than phenotypic correlation coefficients for all the characters studied. Low phenotypic correlation might be due to the masking or modifying effect of the environment in genetic association between characters. Kennedy and Rangasamy (1998), Nehru *et al.* (2000) and Khediker *et al.* (2004) reported similar results from their studies in rice.

Characters viz., panicle weight and total dry matter showed significant positive association with grain yield at genotypic and phenotypic levels. Meenakshi *et al.* (1999) reported similar results for total dry matter and Mehetre *et al.* (1994) identified negative correlation for panicle weight with grain yield. Other characters viz., plant height, panicle length, grains per panicle, straw yield, root volume and root length also showed positive correlation with grain yield indicating that improvement of these characters can result in increased grain yield. Similar results were reported by Prasad *et al.* (1988), Manual and Palanisamy (1989) and El Hissewy and Bestawisi (1999).

Inter correlation studies among characters revealed that there was significant correlation between plant height and root characters viz., root weight per plant, root volume and root length revealing that an active root system is associated

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



with better shoot characters. Panicle length exhibited positive correlation with grains per panicle which inturn was significantly and positively correlated with panicle weight, straw yield, total dry matter, root volume and root length indicating that improvement in panicle length can lead to improvement of above characters. Kumar *et al.* (1998) and Chaubey and Richharia (1993) also reported similar results.

Characters viz., panicle weight, panicle length, plant height and root length which recorded significant positive correlation also recorded positive direct effect on grain yield revealing improvement of these characters can directly increase grain yield. Grains per panicle and root volume which registered significant positive correlation recorded negative direct effect on grain yield indicating their contribution through other characters (Fig.7). Grains per panicle expressed its indirect effect through panicle length, panicle weight, total dry matter and plant height. Root volume showed positive indirect effect through plant height, panicle length, panicle weight, total dry matter and root length.

5.2 EVALUATION OF HYBRIDS

The basic idea of hybridization in convergent breeding programme is to combine favourable genes present in different parents into a single genotype. In the evolution of new plant type parents with high mean performance and *gca* effect for desirable characters will be hybridized and superior segregants in the subsequent generations will be selected. Back crossing with desirable parents also will have to be conducted for incorporating specific traits. As an initial step in convergent breeding programme for evolution of new plant type, hybrids obtained from a line x tester mating design were evaluated for their performance based on the mean, heterosis and *sca* effects (Table 55).

5.2.1 Mean performance, *sca* effects and heterosis

Superior hybrids for different characters with respect to mean performance, *sca* effect and heterosis are listed in Table 55 . It was found that parents with high *gca* effects produced hybrids with superior performance in most of the cases. Mattatriveni which exhibited significant negative *gca* effect for days to flowering produced hybrids with early flowering habit (Mattatriveni x Mahsuri and Mattatriveni x ptb-15). Negative heterosis for the character was also expressed by Mattatriveni x Ponmani and Mattatriveni x Mahsuri. Mattatriveni x Ponmani expressed significant negative *sca* effect. Kanchana, which also exhibited significant negative *gca* effect for this character produced hybrids(Kanchana x Mahsuri and Kanchana x Swarnaprabha) with early flowering character. Eventhough Uma, which showed significant positive *gca* effect for days to flowering, its cross with the tester Swarnaprabha (which had high negative significant *gca* for the character) showed maximum negative significant *sca* value for days to flowering and was the hybrid combination which showed shortest flowering duration.

Hybrid combinations Mattatriveni x Ponmani and Mattatriveni x Mahsuri expressed higher *per se* performance, high *sca* effect and standard heterosis for panicle length, grains per panicle and panicle weight per plant (Fig 2,3,4,5,6). Mattatriveni and Jyothi which expressed high *gca* values for panicle characters produced hybrids with high *per se* performance and heterosis. Among the testers Mahsuri expressed high *gca* value for panicle length and crosses with this parent (Jyothi x Mahsuri, Gouri x Mahsuri and Mattatriveni x Mahsuri) expressed superior performance and high standard heterosis with Jyothi x Mahsuri alone expressing significant superior *sca* effect (Plate 10 and Plate 11). Reports of Padmavathi *et al.* (1997),Yadav *et al.* (1999) and Janardhanam *et al.* (2000) also revealed the fact that parents with high *gca* effects produce better performing hybrids .Swarnaprabha with high significant *gca* value for grains per panicle, panicle weight per plant, grain

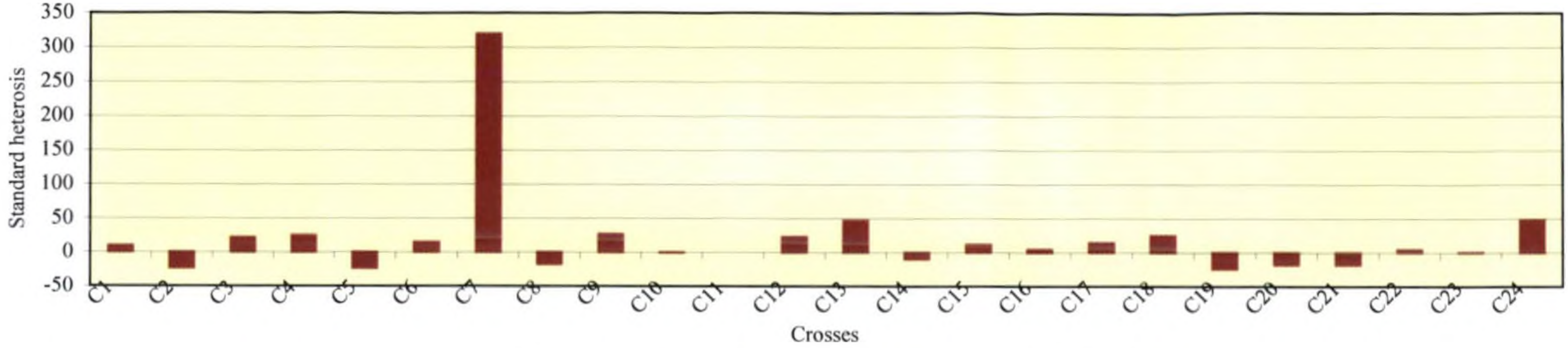


Fig. 2. Standard heterosis for grain yield in 24 hybrid combinations

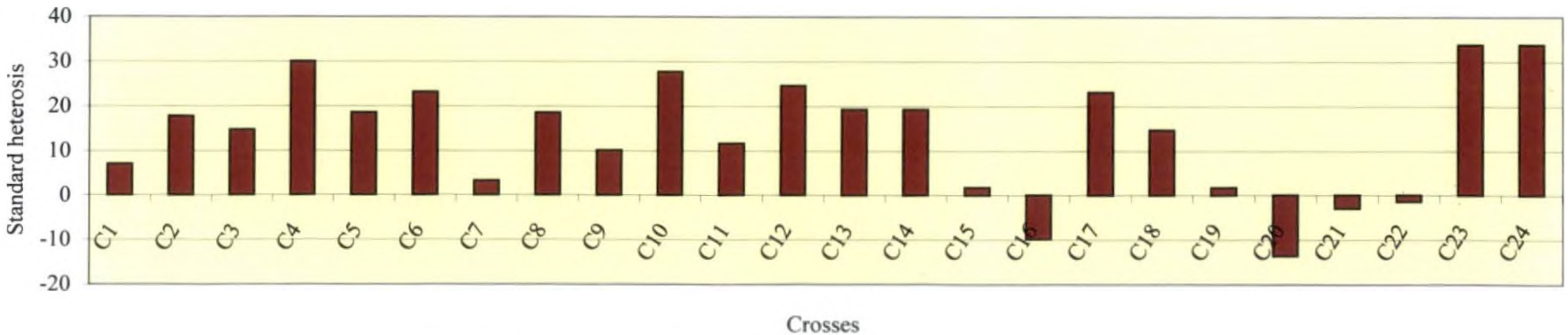


Fig. 3. Standard heterosis for total dry matter in 24 hybrid combinations

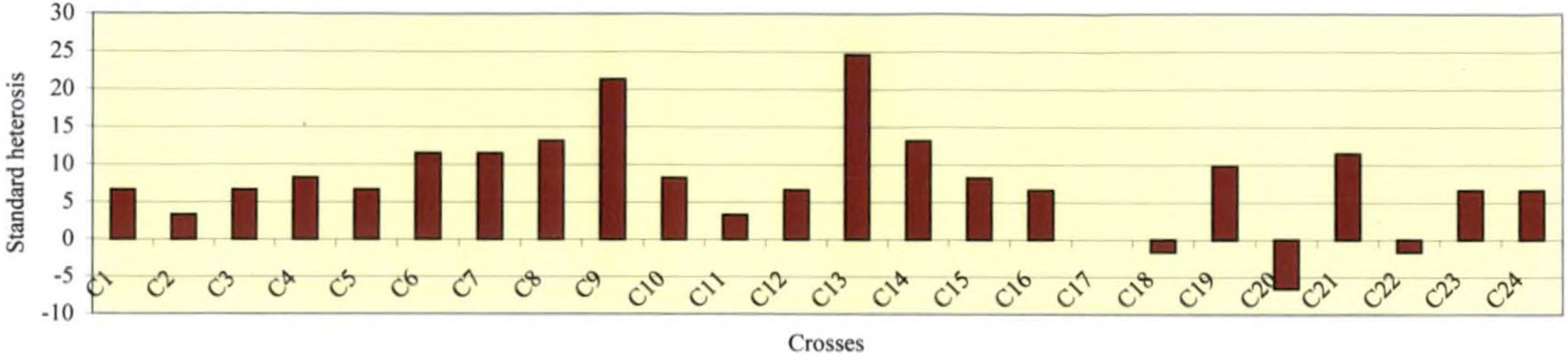


Fig. 4. Standard heterosis for panicle length in 24 hybrid combinations

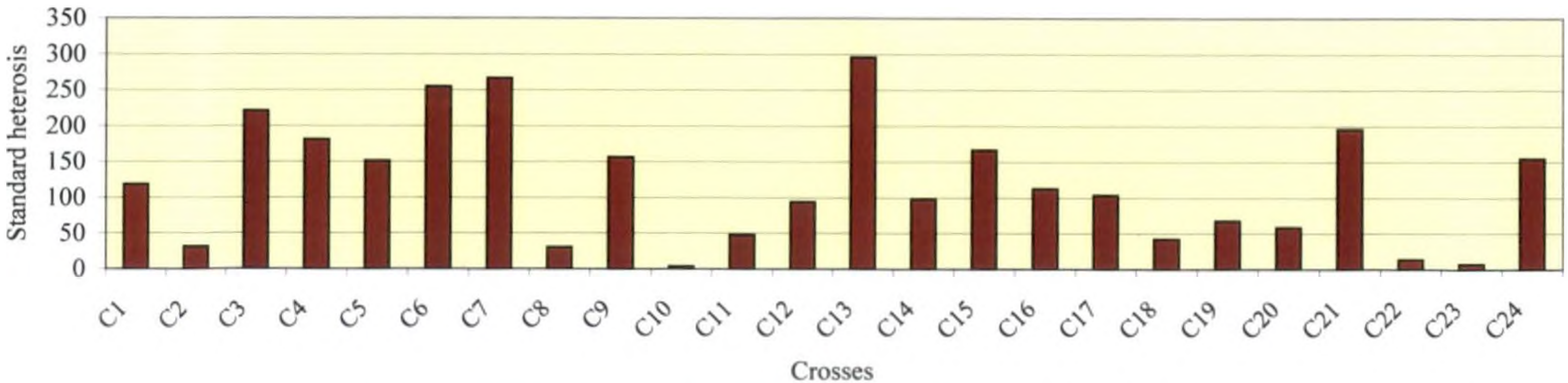


Fig. 5. Standard heterosis for grains per panicle in 24 hybrid combinations

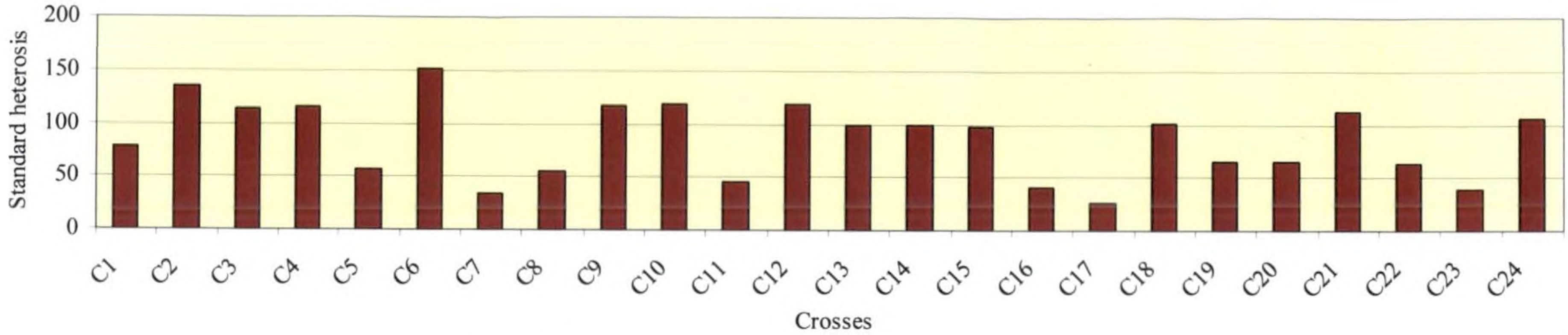


Fig. 6. Standard heterosis for root length in 24 hybrid combinations

Combinations	Designation	Combinations	Designation
Mattatriveni x Swarnaprabha	C_1	Mattatriveni x Ponmani	C_{13}
Gouri x Swarnaprabha	C_2	Gouri x Ponmani	C_{14}
Jyothi x Swarnaprabha	C_3	Jyothi x Ponmani	C_{15}
Kanchana x Swarnaprabha	C_4	Kanchana x Ponmani	C_{16}
Uma x Swarnaprabha	C_5	Uma x Ponmani	C_{17}
Aiswarya x Swarnaprabha	C_6	Aiswarya x Ponmani	C_{18}
Mattatriveni x Mahsuri	C_7	Mattatriveni x PTB-15	C_{19}
Gouri x Mahsuri	C_8	Gouri x PTB-15	C_{20}
Jyothi x Mahsuri	C_9	Jyothi x PTB-15	C_{21}
Kanchana x Mahsuri	C_{10}	Kanchana x PTB-15	C_{22}
Uma x Mahsuri	C_{11}	Uma x PTB-15	C_{23}
Aiswarya x Mahsuri	C_{12}	Aiswarya x PTB-15	C_{24}

Plate 10. Earhead of Mahsuri

Plate 11. Earheads of Jyothi, Mahsuri and Jyothi x Mahsuri

Table 55. Hybrids with desirable mean performance, *sca* effects and standard heterosis

Sl. No.	Characters	Hybrids with superior *per se* performance	Hybrids with high *sca* effect	Hybrids with high standard heterosis
1	*Days to flowering	Uma x Swarnaprabha Mattatriveni x Mahsuri Kanchana x Swarnaprabha Kanchana x Mahsuri Mattatriveni x Ptb 15	Uma x Swarnaprabha Mattatriveni x Ponmani Gouri x Ptb15 Kanchana x Mahsuri Aiswarya x Ptb 15	Jyothi x Swarnaprabha Mattatriveni x Ponmani Uma x Swarnaprabha Mattatriveni x Mahsuri Kanchana x Swarnaprabha
2	Number of tillers at flowering stage	Kanchana x Ponmani Mattatriveni x Swarnaprabha Jyothi x Ptb 15 Gouri x Swarnaprabha Gouri x Ptb 15	Kanchana x Mahsuri Jyothi x Ptb 15 Aiswarya x Ponmani Mattatriveni x Swarnaprabha Gouri x Swarnaprabha	Kanchana x Ponmani Mattatriveni x Swarnaprabha Jyothi x Ptb 15 Gouri x Swarnaprabha Gouri x Ptb 15
3	Total number of productive tillers per plant	Kanchana x Ponmani Kanchana x Mahsuri Uma x Swarnaprabha Uma x Ponmani Mattatriveni x Mahsuri	Jyothi x Ptb 15 Uma x Swarnaprabha Mattatriveni x Mahsuri Gouri x Ptb 15 Kanchana x Ponmani	Kanchana x Ponmani Kanchana x Mahsuri Uma x Swarnaprabha Mattatriveni x Mahsuri Uma x Ponmani
4	Panicle length	Mattatriveni x Ponmani Jyothi x Mahsuri Aiswarya x Swarnaprabha Gouri x Mahsuri, Jyothi x Swarnaprabha Gouri x Ponmani Mattatriveni x Mahsuri	Mattatriveni x Ponmani Gouri x Ponmani Jyothi x Mahsuri Aiswarya x Mattatriveni Uma x Ptb 15	Mattatriveni x Ponmani Jyothi x Mahsuri Gouri x Mahsuri Gouri x Ponmani Mattatriveni x Mahsuri
5	Grains per panicle	Mattatriveni x Ponmani Mattatriveni x Mahsuri Aiswarya x Swarnaprabha Jyothi x Swarnaprabha Jyothi x Ptb 15	Mattatriveni x Mahsuri Mattatriveni x Ponmani Aiswarya x Swarnaprabha Kanchana x Swarnaprabha Aiswarya x Ptb 15	Mattatriveni x Ponmani Mattatriveni x Mahsuri Aiswarya x Swarnaprabha Jyothi x Swarnaprabha Jyothi x Ptb 15

*High negative *sca* effects are considered

Contd.

Table 55. continued

Sl. No.	Characters	Hybrids with superior *per se* performance	Hybrids with high *sca* effect	Hybrids with high standard heterosis
6	Panicle weight per plant	Mattatriveni x Ponmani Mattatriveni x Mahsuri Jyothi x Swarnaprabha Uma x Swarnaprabha Jyothi x Mahsuri	Gouri x Mahsuri Uma x Swarnaprabha Mattatriveni x Ponmani Aiswarya x Swarnaprabha Mattatriveni x Mahsuri	Mattatriveni x Ponmani Mattatriveni x Mahsuri Jyothi x Swarnaprabha Uma x Swarnaprabha Aiswarya x Swarnaprabha
7	1000 grain weight	Jyothi x Mahsuri Jyothi x Swarnaprabha Gouri x Ponmani Jyothi x Ponmani Aiswarya x Ptb 15	Aiswarya x Ptb 15 Gouri x Ponmani Kanchana x Swarnaprabha Mattatriveni x Mahsuri Uma x Ptb 15	Jyothi x Mahsuri Jyothi x Swarnaprabha Gouri x Ponmani Jyothi x Ponmani Aiswarya x Ptb 15
8	Grain density	Kanchana x Swarnaprabha Jyothi x Swarnaprabha Gouri x Ponmani Jyothi x Ponmani Aiswarya x Ptb 15	Kanchana x Swarnaprabha Gouri x Swarnaprabha Aiswarya x Mahsuri Uma x Swarnaprabha Mattatriveni x Ptb 15	Kanchana x Swarnaprabha Gouri x Swarnaprabha Uma x Swarnaprabha Jyothi x Ponmani Jyothi x Mahsuri
9	Grain yield	Mattatriveni x Mahsuri Aiswarya x Ptb 15 Mattatriveni x Ponmani Kanchana x Swarnaprabha Aiswarya x Ponmani	Mattatriveni x Mahsuri Aiswarya x Ptb 15 Kanchana x Swarnaprabha Jyothi x Swarnaprabha Uma x Ptb 15	Mattatriveni x Mahsuri Aiswarya x Ptb 15 Mattatriveni x PonmaniJyothi x Ponmani,Jyothi x Mahsuri, KanchanaxSwarnaprabha,Aiswarya x Ponmani

Contd.

*High negative *sca* effects are considered

Table 55. continued

Sl. No.	Characters	Hybrids with superior *per se* performance	Hybrids with high *sca* effect	Hybrids with high standard heterosis
10	Total dry matter	Aiswarya x Ptb 15 Uma x Ptb 15 Kanchana x Swarnaprabha Kanchana x Mahsuri Aiswarya x Mahsuri	Uma x Ptb 15 Aiswarya x Ptb 15 Kanchana x Mahsuri Mattatriveni x Ponmani Kanchana x Swarnaprabha	Uma x Ptb 15 Aiswarya x Ptb 15 Kanchana x Swarnaprabha Kanchana x Mahsuri Aiswarya x Mahsuri
11	Harvest Index	Mattatriveni x Ponmani Kanchana x Ponmani Jyothi x Ponmani Jyothi x Mahsuri Jyothi x Swarnaprabha	Gouri x Ptb 15 Mattatriveni x Ponmani Jyothi x Mahsuri Aiswarya x Ptb 15 Kanchana x Ptb 15	Mattatriveni x Ponmani Kanchana x Ponmani Jyothi x Ponmani Jyothi x Mahsuri Jyothi x Swarnaprabha
12	Root to shoot ratio	Kanchana x Ponmani Jyothi x Ponmani Gouri x Ptb 15 Jyothi x Mahsuri Mattatriveni x Mahsuri Uma x Ponmani	Kanchana x Ponmani Mattatriveni x Mahsuri Aiswarya x Swarnaprabha Gouri x Ptb 15 Jyothi x Mahsuri	Kanchana x Ponmani Jyothi x Ponmani Gouri x Ptb 15 Jyothi x Mahsuri Kanchana x Ptb 15
13	Root weight per plant	Uma x Ponmani Gouri x Ponmani Aiswarya x Swarnaprabha Gouri x Mahsuri Kanchana x Swarnaprabha	Aiswarya x Swarnaprabha Kanchana x Swarnaprabha Mattatriveni x Mahsuri Gouri x Mahsuri Uma x Ponmani	Uma x Ponmani Gouri x Ponmani Aiswarya x Swarnaprabha Gouri x Mahsuri Kanchana x Swarnaprabha
14	Plant height	Gouri x Mahsuri,Aiswarya x Swarna prabha,Aiswarya x Ptb15,Aiswarya x Ponmani,Kanchana x Mahsuri.	Uma x Ponmani, Gouri x Mahsuri, Aiswarya x Ptb 15,Jyothi x Mahsuri, Gouri x Ponmani	Gouri x Mahsuri,Aiswarya x Swarna prabha,Aiswarya x Ptb 15,Aiswarya x Ponmani,Kanchana x Mahsuri,
15	Root length	Aiswarya x Swarnaprabha, Gouri x Swarnaprabha Kanchana x Mahsuri Aiswarya x Mahsuri Uma x Mahsuri	Kanchana x Mahsuri, Mattatriveni x Ponmani, Gouri x Swarnaprabha, Gouri x Ponmani, Jyothi x Ptb 15	Aiswarya x Swarnaprabha, Gouri x Swarnaprabha, Kanchana x Mahsuri Aiswarya x Mahsuri Jyothi x Mahsuri

density and total dry matter produced hybrids with high mean performance, high heterosis and highly significant *sca* effect indicating that the variety can be used for the improvement of above characters.

Ponmani, which expressed high *gca* effects for root characters produced hybrids with high *per se* performance, standard hererosis and *sca* effect for these characters.

Mattatriveni x Mahsuri recorded highest grain yield among the hybrids. It also expressed high standard heterosis and significant positive *sca* value for grain yield. This cross also expressed superior performance for grain and ear head characters.

Eventhough most of the hybrids expressed superior performance, high heterosis and high *sca* effects for different characters, only one hybrid recorded superior performance and significant *sca* effect for grain yield indicating that improvement in grain yield is possible only through combination of characters in different varieties through hybridization followed by selection in segregating population and back crossing with specific parents.

5.2.2 Correlation and path analysis

The efficiency of selection depends on the direction and magnitude of association between yield and its components. Grain yield is a complex character and its expression depends upon the interaction of different yield parameters. Keeping this in view, the present study was undertaken to know the degree and direction of association between yield and its contributing characters in the hybrids.

In hybrids, panicle weight, grains per panicle, plant height, panicle length, 1000 grain weight, harvest index and root to shoot ratio recorded significant positive correlation with grain yield. Similar results were reported by Rangasamy and Natarajamoorthy (1988), Choudhury and Das (1997) and Reddy *et al.* (1997).

Characters viz., straw yield, root volume and root length which exhibited significant positive correlation with yield in parents recorded negative significant correlation in hybrids showing different characters are associated with grain yield in parents and hybrids.

Grains per panicle recorded highest positive direct effect on grain yield as against the negative direct effect recorded by this character in parents indicating the improvement of number of grains per panicle can increase grain yield in F_1 and segregating generations. Indirect effect of this character through 1000 grain weight was also high. Other characters which recorded direct effect on grain yield in the F_1 generation are plant height, 1000 grain weight, panicle length and grain density. Eventhough negative correlation along with negative direct effect was expressed by root length, root volume and straw yield their indirect contribution through plant height, harvest index and grains per panicle were high.

Since improvement in yield contributing characters alone can result in higher yield expression, final selection of characters exhibiting high mean performance and combining ability effects will have to be based on character association studies also.

Characters viz., panicle weight, panicle length, grains per panicle, 1000 grain weight, total dry matter, plant height, grain density and root length expressed positive direct effect on grain yield. Varieties viz., Mattatriveni, Jyothi, Mahsuri, Swarnaprabha and Ponmani which expressed high *gca* effect for these characters can be used in the production of new plant type through convergent breeding. Hybrids involving these parents expressed high mean performance, standard heterosis and *sca* effect for most of the above characters. Stable performance of these varieties was also reported by Prasad *et al.* (2001).

SUMMARY

6. SUMMARY

To achieve high productivity, moulding the genotypes to desirable levels through hybridization and selection is needed. Choice of parents which can neck well to produce superior offsprings is essential for making rapid success in crop improvement programme. Among different methods to assess the combining ability line x tester is a systematic method to provide useful information on the nature of inheritance of yield and component characters. It also helps in identifying the superior parents and cross combinations likely to yield better genotypes.

The present investigation on " Convergent breeding for new plant type in rice (*Oryza sativa* L.)" was conducted under the Department of Plant Breeding and Genetics ,College of Horticulture, Kerala Agricultural University, Vellanikkara and Agricultural Research Station, Mannuthy using six lines viz. Mattatriveni, Gouri, Jyothi, Kanchana, Uma and Aiswarya and four testers viz., Swarnaprabha, Mahsuri, Ponmani and ptb-15. Line x tester analysis was used to identify donor parents for evolution of an ideal plant type, and to determine the nature of gene action involved in expression of quantitative traits.

- The results obtained are summarized as follows.

- There was significant difference between varieties for all the characters studied, suggesting that wide variability existed among the varieties ensuring successful selection of desirable parents.

- Consistently higher magnitude of SCA compared to GCA as revealed by GCA/SCA ratio, suggested the preponderance of non additive gene action for almost all characters.

- Mattatriveni and Swarnaprabha exhibited high negative *gca* values for days to flowering and high positive *gca* values for panicle and grain characters indicating these varieties can be used as general combiners for the above characterers.

- Gouri and Ponmani exhibited high positive significant *gca* effect for root characters like root weight per plant, root to shoot ratio and root volume indicating that these varieties can be used in the production of new plant type considering these characters.

- Parents with high *gca* effects produced hybrids with superior performance.

- Based on *per se* performance and *gca* effects Mattatriveni, Kanchana, Jyothi, Gouri, Swarnaprabha, Mahsuri and Ponmani were identified as best parents which can be utilized in the convergent breeding programme aimed at substantial increase in yield.

- Mattatriveni x Mahsuri and Mattatriveni x Ponmani expressed high *sca* effect and standard heterosis for grain yield, panicle length, grains per panicle and panicle weight per plant. These hybrids were identified as superior combinations based on per se performance, *sca* effects and standard heterosis and they can be further utilized in the evolution of new plant type.

- Yield contributing characters such as panicle weight, grains per panicle, plant height, panicle length, 1000 grain weight, harvest index and root to shoot ratio had significant positive correlation with grain yield. Grain yield can be improved through selection considering the above characters.

- Path analysis revealed positive direct effect of characters viz., plant height, panicle length, panicle weight, grain thickness, total dry matter and root length. Characters having high correlation but negative direct effect exhibited indirect effect through other characters.

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* Originals not seen

CONVERGENT BREEDING FOR NEW PLANT TYPE IN RICE (*Oryza sativa* L.)

BY

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study on "Convergent breeding for new plant type in rice (*Oryza sativa* L.) was carried out under the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara. This study was carried out for 23 characters in six lines and four testers, and their hybrids developed through a line x tester mating design and was aimed at identification of donor parents for the development of new plant type, and evaluation of the nature of gene action involved in the expression of quantitative traits. In the experiment combining ability, heterosis, character association and gene action involved were estimated.

The analysis of variance was significant for almost all the traits under study. Combining ability analysis revealed constantly higher magnitude of SCA variance compared to GCA variance suggesting the preponderance of non additive gene action. Based on mean performance and gca effects Mattatriveni, Kanchana, Jyothi, Gouri ,Swarnaprabha, Mahsuri and Ponmani were identified as best parents which can be utilized in the crossing programme for the development of rice varieties having high yield potential. Among the hybrids Mattatriveni x Ponmani and Mattatriveni x Mahsuri were identified as superior cross combinations based on mean performance, sca effects and standard heterosis and they can be exploited in the creation of new plant type.

Characters viz., panicle weight, panicle length, grains per panicle, plant height, 1000 grain weight, total dry matter, grain density and root length which showed significant positive correlation also recorded positive direct effect on grain yield revealing improvement of these characters can directly increase grain yield. Varieties which can be used as donor parents for these characters were identified. Since combination of desirable characters cannot be achieved through one generation of breeding further evaluation and back crossing with specific donor parents is suggested as future line of work.