GENETIC DIVERGENCE AND SELECTION PARAMETERS IN BASMATI RICE

By

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THESIS

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DECLARATION

I here by declare that this thesis entitled "**GENETIC DIVERGENCE AND SELECTION PARAMETERS IN BASMATI RICE**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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SREEEJAYA, K.C.

Dedicated to

my

Family

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Introduction

1. INTRODUCTION

Aromatic rices enjoy a unique place in the world rice market and they are highly priced. The leading aromatic rice in world trade is Basmati, produced mainly in North-Western parts of Indian subcontinent. Like any other traditional tall variety, Basmati rices are also tall, low yielding and photosensitive. With the introduction of high yield potential to the Basmati rice a number of high yielding Basmati rice varieties were evolved.

Even with the introduction of high yielding rice varieties in the rice farming scenario, Kerala farmers are finding it difficult the rice farming as profitable. One of the main problems is the low return. The Basmati rice types are very often getting 3-4 times higher unit value than the ordinary rice varieties. The high yielding Basmati rice varieties evolved in various rice research stations located in north and north-western parts of India offers ample scope for testing adaptability for Kerala rice farming eco-system. A scientific and systematic evaluation of these varieties/cultivars is a pre-requisite for selection of suitable ones, if any, to Kerala conditions and to derive back ground genetic informations for their further genetic improvement.

It is well established that exploitation of hybrid vigor and success in getting desirable segregants in rice breeding programme depends to a large extent on the degree of genetic divergence between parents chosen. The programme envisages to study the genetic divergence among 38 cultures of Basmati rice evolved at various rice research centres in India. They are grouped into clusters based on D^2 analysis .

Selection of superior genotypes will be effective only if genetic variability exists in the material chosen for yield improvement. A search for variability available in the group is conducted and the genotypes having the desirable characters are selected for cultures/varieties with increased yield potential and requisite qualities.

An estimation of association existing among yield contributing components and qualities is carried out by measuring its genetic correlations. An assessment of the merit of each character by analysing the direct and indirect effect of each character towards final yield coupled with quality is carried out for selecting suitable lines.

For selecting suitable genotypes for a highly heterogeneous mass population selection should always be based on minimum number of characters. An analysis of descriminant function based on such more reliable and effective characters is carried out to ensure a maximum concentration of the desired genes in the plants selected. Finally programme is aimed to select high yielding quality Basmati rice genotypes adaptable to Kerala ecosystem.

Review of Literature

2. REVIEW OF LITERATURE

An overview of works concluded in rice, especially of Basmati rice, in the aspects of genetic variability, heritability, correlation studies, path analysis, genetic advance, expected genetic gain, genetic divergence, quality parameters and selection index is presented here under.

2.1 Genetic variability

Genetic variability study using 48 low land rice cultivars of U.P. were carried out. Grains/panicle, plant height, leaf length, days to flowering and leaf angle showed a wide range of phenotypic variation. The phenotypic coefficient of variability ranged from 5.7 for days to flowering to 45.09 for leaf angle (Maurya *et al.*, 1986).

In a variability study using 98 upland rice cv.s, the phenotypic coefficient of variability was higher than the genotypic coefficient of variation and it ranged from 7.51 for days to 50% flowering to 39.32 for tillers/plant (Singh *et al*,1986).

Information on genotypic and phenotypic coefficients of variability is derived from data on 7 yield-related traits in 25 genotypes of early upland rice grown under four different environments. Highest genotypic and phenotypic coefficients of variation were recorded for number of grains per panicle (Reddy, 1992).

According to the data presented on genetic variation for fourteen genotypes from different thum (shifting cultivation) fields of the hills of Assam, highest genotypic coefficient of variation was observed for panicles/m^2 followed by 100 -grain weight and grain yield/plant (Sarma and Roy, 1993).

Genetic variance was determined for ten quantitative traits on nine genotypes grown during 1989. Genotypic variance was high for gains/panicle followed by plant height, days to 50% flowering, seedling height and flag leaf length (Kumar *et al.* , 1994).

As per the data recorded on 15 yield components of 16 cultivars of rice and their 72 F_1 grown under irrigated and rainfed conditions, sterility showed the highest level of variability (Sarawgi and Soni, 1994).

Variability and character correlations was derived from data on 14 quality characters in 22 rice genotypes, 17 lines selected from the popular scented dwarf variety Madhuri and five promising scented varieties (Madhuri, Dubraj, Chinoor, Kalimuch - 64 and Basmati - 370). The highest coefficient of variation was observed for 100 -grain weight and length : breadth ratio and for cooking traits the highest variation was recorded for proportionate change (negatively) breadth-wise expansion, water absorption percentage and for length-wise elongation (Sarawgi *et al,* 1994).

In the data on eight yield components in 75 genotypes and their hybrids, the genotypes showed a wide range of variation for all the measured characters. High coefficients of variation were observed for grains/panicle, grain yield/plant and plant heights (Sawant and Patil, 1995).

Morpho-agronomic characterization of 88 long, slender scented Basmati rice germplasms collected from northern India (U.P and Haryana) revealed significant variability in leaf length, culm length, culm number and panicle length (Patra and Dhua, 1996).

2.2 Genetic Divergence

Mahalanobis D^2 statistic was employed to assess the nature of genetic divergence in relation to low temperature tolerance and high yielding capabilities in a collection of 25 rice strains. Data were recorded on nine agronomic characters and the 25 strains were then grouped into twelve clusters. The clustering pattern revealed that the characters building up low temperature tolerance capability were more related to the geographical origin of the variety or its specific ecological condition, while yield and yield attributes exercised profound effect on genetic diversity irrespective of the origin of the variety (Chatterjee *et al.*, 1978).

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

Thirtynine scented rice varieties from India and four from Afghanistan were analysed using Mahalanobis D^2 statistic. The varieties were grouped into five clusters. Clustering pattern was not related to geographical distribution, and the four varieties from Afghanistan fell into three different clusters (Ratho, 1984).

Seventy five strains comprising *indica* (ARC and non-ARC), *japonica*, *ponlai* and *javanica* rice were grouped into thirteen clusters using D^2 statistic. Sixty seven ARC strains showed high order of genetic diversity, indicating the importance of the north-eastern region of India as a rich source of diverse centered rice germplasm and in tracing the centre of origin of cultivated rice. Genetic drift and selection pressure were inferred to have played a great role in bringing about genetic divergence among the strains. Two characters, viz. 100 grain weight and number of grains per panicle, were the highest contributors to D^2 value (De *et al.* , 1988).

Genetic diversity in 23 upland rice varieties was determined using Mahalanobis D^2 analysis. Using Tocher's techniques genotypes were grouped in six clusters. Clustering pattern failed to reveal any relationship between geographic divergence and genetic variability. Several clusters were highly divergent and use of these genotypes in breeding programs may result in a large degree of heterosis. (Anandakumar and Subramanian, 1989). Similar results of absence of parallelism between geographical distribution and genetic diversity was reported by Biswal (1990) and Rangel *et al.* (1991).

Varieties originating from IRRI (21 varieties), India (3), Korea (1), Sri Lanka (1) and Vietnam (6) were subjected to cluster analysis based on plant height, days to 50% flowering, panicle length, grains/panicle, unfilled grain percentage, effective tillers/plant, grain weight and grain yield. Five clusters were produced by Tocher's method. Plant height and days to 50% flowering contributed the most to divergence (Buu and Tuan, 1989).

Genetic divergence, using Mahalanobis D^2 statistic was worked out in 30 traditional upland rice varieties from nine states of India including the Northeastern Region. Based on 10 agromorphological characters, these varieties were grouped into six clusters. No parallelism was observed between geographic diversity and genetic diversity. Characters like number of secondary branches per panicle, yield/ plant and number of fertile grains/panicle had sizeable contribution to total divergence. These characters could, therefore, form the basis for selection of parents from distantly placed clusters to obtain high heterotic combinations (Sinha *et al.* ,1991).

Genetic divergence was studied for yield and its eleven component traits in 28 early rice varieties (*Oryza sativa* L.) under direct seeded and transplanted conditions. The strains were grouped into five and six clusters in direct seeded and transplanted conditions, respectively. There is no relationship between geographical distribution and genetic divergence (De *et al.* ,1992).

Genetic divergence for bacterial blight resistance, grain yield and nine yield related traits was studied in 99 diverse genotypes using multivariate D^2 analysis. Genotypes were grouped into 16 clusters. Since the 51 genotypes in cluster one were of different origin, no association between ecogeographical distribution and genetic diversity was indicated. Genetic divergence was controlled mainly by panicles/plant, grains/panicle, grain yield/plant, spikelets/panicle and bacterial blight severity (Roy and Panwar, 1993).

The nature and magnitude of genetic divergence was assessed in 28 genotypes of rainfed rice using Mahalanobis D^2 statistics. The population was grouped into five clusters. The geographical diversity has not been found related to genetic diversity (Vivekanandan and Subramanian, 1993).

2.3 Heritability, Genetic advance and Genetic gain

According to the analysis of data from 53 ecotypically diverse varieties, heritability estimates for all traits were high, ranging from 98.04% (grain yield/plant) to 86.94%. High genetic advance associated with a high coefficient of variation was obtained for 100- grain weight and volume, number of grains per panicle and grain yield/plant. Individual selection for rachilla number/panicle, 100 grain weight and volume and panicle length resulted in genetic advance for grain yield/plant, suggesting that grain yield improvement might be obtained through selection for these traits (Shamsuddin, 1982).

Amrithadevarathinam, (1983) observed that coefficients of variation, heritability, expected genetic advance were high for grain yield, total tillers/m^2, productive tillers/m^2 and days to flowering in the study using 162 accessions, breeding lines and varieties from inland and abroad.

Heritability was moderate for grain and straw yields in the study of 10 yield components of 10 varieties according to Subramaniam and Rathinam (1984a).

Grain yield showed high heritability and genetic advance in the F_3 and F_4 of the (K 35-3 X K 184 and Pusa 33 X K 35-3) two crosses of upland paddy (Jangale *et al.* 1985).

High heritability and high genetic advance were detected for kernel length, kernel length : breadth ratio, plant height, grains/panicle, test weight and panicle length (all H values > 70%). These traits are regarded as useful for selection criteria in lowland rice, in the opinion of Maurya *et al.* (1986).

In a study by Singh *et al.* (1986) using 98 upland rice cultivars of India, heritability was highest for days to 50 % flowering (95.1%) followed by plant height (94.3 %) and seedling height (93 %).

High heritabilities (90.3, 86.7 and 81.9 %) and positive genetic advance (29.2, 8.6and 43.9 %) were detected for plant height, days to flowering and 1000- grain weight respectively in a study of the F_2 generation of selected crosses of rice (Dhanraj *et al.*, 1987).

The best 10 of 24 lines were evaluated at Los Palacios (Spain) in cold season for obtaining early varieties. In this study the characters number of panicles/m^2, number of grains/panicles and 1000- grain weight showed sufficient heritability for effective selection (Morales, 1987).

Alfonso *et al.* (1988) reported that growth period and 1000- grain weight showed highest heritability in two years study using eleven genotypes of rice in rainy season. There was moderate heritability for yield in the dry season.

Heritability and genetic advance were studied in 82 populations of rice by Vishwakarma *et al.* (1989). Heritability was moderate for grain yield and low for number of tillers. Genetic advance was high in grains/panicle and medium to low in grain yield, test weight and number of tillers.

Information on heritability and genetic variance was derived from data on eight yield components in 28 cultivars of rice grown during 1979 by Lokanathan *et al.* (1991). Values for expected genetic advance ranged from 32.3% (panicle weight) to 69.4 % (plant height). Plant height also showed high values of heritability (94.2%) indicating high potential for selection.

Chauhan *et al.* (1992) studied 45 varieties and elite lines of indica rice under rainfed conditions and data recorded on 12 quality traits. Grain length, alkali-digestion value, length-breadth ratio of grain, and grain breadth showed consistent high heritabilities of above 75 %, with grain breadth and alkali digestion value also giving high values for genetic advance. Low values for genetic advance were recorded for hulling and milling recovery.

Among the eight characters studied in 3 crosses of rice, panicle weight, 100 - seed weight and number of fertile spikelets per panicle recorded high heritability coupled with moderate to high genetic advance, indicating that they are governed by additive gene action and thus offer greater scope for further improvement through selection (Lokaprakash *et al.*, 1992).

Information on heritability and genetic advance is derived from data on seven yield - related traits in 25 genotypes of early upland rice grown under different environments. All the traits exhibited moderate to high estimates of heritability ranging from 67.9% for grain yield/hill to 99.5%. for days to 50% flowering. Plant height and number of grains/panicle showed high estimates of genetic advance along with high estimates of heritability (Reddy, 1992).

High heritability and genetic advance were found for panicles/m^2, grains/panicle, 100 - grain weight and percentage sterility in the data presented for 14 genotypes of jhum rice, by Sarma and Roy (1993).

Plant height showed high heritability in the narrow sense when five yield components were studied in eight diverse cultivars of rice (Singh *et al.*, 1993).

Twenty rice varieties were evaluated for eight yield traits by Chaubey and Singh (1994). Heritability was high in all traits, but was highest for total number of spikelets followed by grain yield/plant and 100- grain weight. Genetic advance as a percentage of the mean was highest for grain yield/plant followed by panicle weight and total number of spikelets.

Heritability was derived from data on ten quantitative traits in nine genotypes grown during 1989. High heritability coupled with high to moderate genetic advance was observed for grains/panicle, grain yield/plant, flag leaf length, plant height, straw weight/plant, seedling height, days to 50% flowering and leaves/plant (Kumar *et al.*, 1994).

Sixteen cultivars of rice and their 72 F_1s were grown under irrigated and rainfed conditions and data recorded on fifteen yield components by Sarawgi and Soni (1994). Heritability estimates were high for plant height, grain length, 100- seed weight, spikelet density, days to 50 % flowering, panicle length and fertile spikelets/panicle.

Estimates of variability, heritability and genetic advance were high for high density grains/panicle and 1000- grain weight, in 20 advanced breeding lines of rice (Govindarasu and Natarajan, 1995).

High heritability estimates were obtained for bacterial blight severity, plant height, spikelets/panicle and grains/panicle, from data on eleven characters in 99 genotypes of rice when studied by Roy *et al.* (1995).

Information on heritability is derived from data on eight yield components in 75 genotypes of rice and their hybrids. High values of heritability coupled with high expected genetic advance were observed for the characters grains/panicle, plant height, grain yield/plant and 1000- grain weight (Sawant and Patil, 1995).

Data from trials of ten scented rice genotypes over four seasons indicated high heritability estimates for all characters except number of tillers per hill, panicle length and number of chaffs per panicle indicating better scope for selection. However, genetic advance was low for most of the traits (Mishra *et al.*, 1996).

2.4 Phenotypic and Genotypic correlations

Grain yield was positively correlated with total tillers and productive tillers, and negatively correlated with plant height and days to ripening in a study of 162 accessions, breeding lines and varieties of upland rice (Amirthadevarathinam, 1983).

In the analysis of data from 53 ecotypically diverse varieties all traits except grain number/panicle were positively and significantly genotypically correlated with grain yield/plant (100 grain weight and volume, rachilla number/plant, panicle length) (Shamsuddin, 1982).

A highly significant correlation was found between protein content/grain and 1000-grain weight when studied in eighteen rice cultivars by Ahmad and Chughtai (1982).

Cooking quality was positively and significantly correlated with amylose content when six high yielding varieties of rice were evaluated by Madan *et al.*, 1984. Of the ten characters studied in 3 F_2 indica rice hybrids, grain yield/plant was highly correlated with height and grain set percentage (Yang, 1986).

Ten characters were studied in 26 varieties of rice. Grain yield was positively correlated with number of grains per panicle and productive tillers ; these characters had the highest direct effects on yield. Height was only positively correlated with yield under poor and optimum fertilizer conditions (Hegde, 1987).

Number of grains/panicle was the character most closely correlated with yield, followed by 1000 grain weight, days to 100 % flowering, number of panicles/m^2 and days to 50 % flowering when the best ten lines of rice were studied by Morales (1987).

Studies of yield correlations in ten tall varieties and 22 of intermediate height showed that in the former only straw yield/plant was positively correlated with height, while in the latter, total number of grains/ear, number of filled grains/ear, straw yield/plant were positively correlated with height, thus increasing height would lead to corresponding yield increases (Sun, 1987).

Negative correlations observed between yield and each of the traits fleet number, 1000- grain weight and weight/panicle in 1983 were not found in 1984 when estimated for ten yield related characters in 17 entries (Zhang *et al.*, 1987).

Parents and hybrids from a complete diallel involving 7 varieties were evaluated by Kalaimani and Kadambavanasundaram (1988) and from the analysis grain yield was correlated with tillers/plant, grains/panicle and 100 grain weight.

The grain yield/hill was positively correlated with harvest index, grains/ panicle, filled grains/panicle, fertility and plant height and negatively with panicles/ hill, when eight yield-related characters were analysed in five conventional rice cultivars and three hybrids (Lu *et al.*, 1988).

Grain yields and yield components of five different rice cultivars were studied by Taniyama *et al.* (1988). In the study it was noted that yield depended mainly on number of spikelets/panicle and percentage of ripened grains. Panicle length, 1000-grain weight and area of four uppermost leaves had no effect on grain yield.

Yield/plant was highly and significantly correlated with grain number/panicle, panicle length, grain density on panicle and days to heading where panicle number / plant was negatively correlated with grain yield. These observations were made when ten yield related characters were investigated in 59 high yielding cultivars and breeding lines of japonica rice (Zeng and Wang, 1988).

In 1985, 25 varieties were tested for grain quality using the following criteria : hulling, milling and head rice recovery ; grain length and breadth; alkali value; elongation ratio. Although L/B ratio was inversely associated with head rice recovery there was no association between L/B ratio and elongation ratio. The lowest alkali spreading value was in Basmati 370 (Malik, 1989).

Grain yield was positively correlated with 1000-grain weight and number of grains/panicle, when six crosses and five parental rice genotypes were compared by Mirza *et al.* (1992).

Grain yield exhibited positive genotypic and phenotypic correlation with plant height, number of productive tillers and grain number, the latter two characters having major influences on yield. This information was got from data on eight characters in 40 rice genotypes (Ragarathinam and Raja, 1992).

Genetic correlations provide useful information to plant breeders for developing selection schemes. Yield was positively correlated with panicle weight and negatively correlated with panicle number in a study by Gravois and Mc new (1993), using F_1 hybrids and 16 parents of rice. Panicle weight was negatively correlated with panicle number in a genetic correlation study of rice.

Correlation studies in 37 genotypes of upland rice during 1991 indicated that grain yield/plant was positively and significantly correlated with straw yield/plant and filled grains/panicle (Mahajan *et al.,* 1993).

Plant height, panicles/m^2, panicle length and grains/panicle were significantly and positively correlated with grain yield. The highest positive direct effect on grain yield was observed for spikelets/panicle followed by panicles/m^2 and panicle height. This information was obtained from an investigation of 14 genotypes of rice by Sarma and Roy (1993).

Genotypic correlations were greater than phenotypic correlations for all the traits when eight yield related traits were studied in 20 rice varieties. Grain yield/ plant was positively correlated with number of ear-bearing tillers, plant height and panicle weight.Positive correlations were noted between panicle length and plant height. panicle length and number of spikelets and plant height and number of spikelets. Panicle weight was positively correlated with primary branches number of spikelets and 100 - grain weight (Chaubey and Singh, 1994).

Seventy five rice cultivars were studied for test weight, length and breadth of polished kernels. Correlation indicated that weight of grain was influenced more by length than that of L/B ratio of kernels (De *et al.*, 1994).

Grain length breadth ratio and water absorption were significantly correlated with grain elongation in two crosses of rice as reported by Deosarkar and Nerkar (1994).

In a study of fourteen varieties in a yield trial by Paul and Nanda (1994), panicle density and number of filled grains/panicle showed a significant positive correlation with yield.

Hundred- grain weight showed significant positive correlation with length and breadth of grain and normalised grain weight, according to Sarawgi *et al.* (1994).

The percentage of high density grains was significantly and positively associated with 1000 - grain weight, milling and head-rice recovery. Grain length and breadth were not individually associated with 1000 grain weight but their product showed significant association. This was reported by Sarkar *et al.* (1994) from the data recorded for a number of yield and quality characters in twelve rice cultivars including nine aromatic cultivars.

High density grains/panicle was significantly and positively correlated with number of spikelets/panicle and high density grain index when 20 advanced breeding lines of rice were studied by Govindarasu and Natarajan (1995).

Grain yield was positively associated with days to 50% flowering, spikelets/panicle and milling percentage when eleven characters were studied in 99 genotypes of rice by Roy *et al.* (1995).

Number of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield when data from trials of 10 scented rice genotypes were analysed by Mishra *et al.* (1996).

2.5 Path analysis

Path analysis of yield components in upland rice showed that total tillers and days to flowering made a positive direct contribution to grain yield (Amrithadeavarathinam, 1983).

Grain : straw ratio exerted the highest direct effect on yield, followed by straw yield, panicle length, plant height and 100-grain weight, when path analysis was carried out in rice by Subramanian and Rathinam (1984b).

Path coefficient analysis of upland rice by Awasthi and Berthakur (1986) revealed that panicle length, 1000-grain weight and fertile grains per panicle had direct. positive effects on grain yield per plant.

A study by Hegde (1987) showed that grain yield was positively correlated with number of grains/panicle and productive tillers and these characters had the highest direct effects on yield. Height was positively correlated with yield only under poor and optimum fertilizer conditions.

Analysis of data on yield/plant and ten related traits from 74 diverse genotypes indicated that number of ear-bearing tillers makes the largest direct positive contribution to yield, followed by grain number/panicle. Grain length/breadth ratio and 100 grain weight also directly influenced yield. Plant height influenced yield directly, but not via the two major yield components (Sinha and Banerjee, 1987).

Path analysis of rice grain yield and components of yield under saline conditions were carried out by Buu and Truong (1988). They found out that number of filled grains per panicle and sterility percentage had the greatest direct effects on yield and are recommended as selection criteria under saline conditions.

Path analysis of yield and yield components in conventional and hybrid rice by Lu *et al.* (1988) showed that the direct effect of yield-related characters on grain yield was positive except for filled grains/panicle and the indirect effect was negative except for filled grains/panicle. Biomass, harvest index, grains/panicle, filled grains/panicle, fertility, plant height, 1000-grain weight and fertile panicles/hill were the yield-related characters studied.

Direct and indirect associations between yield components were assessed in eleven advanced breeding lines during 1987. Path analysis suggested the importance in yield, in order, of filled grains/panicle, plant height, plant density and tillers/plant. Relationships between filled grains/panicle and plant height, plants/m^2 and tillers/plant were negative suggesting a compromise needed in selecting for the optimum combination of these characters (Reuben and Katuli, 1989).

Path analysis of main economic characters in ten genotypes of japonica rice showed that the number of filled grains/panicle had the greatest direct effect on grain weight/plant, followed by that of 1000-grain weight and effective panicles/plant. The indirect effect of panicle length to grain weight/plant via filled grains per panicle was also important (Bao, 1989).

Informations on yield correlations is derived from data on eleven characters in 50 lines and ten varieties by Panwar *et al.* (1989). They found that the spikelet number was the main component affecting yield directly.

Path analysis in fixed cultures of rice by Sardana *et al.* (1989) showed that panicles/m^2, panicle length, days to 50 % flowering, days to maturity and plant height were the most important characters contributing to yield.

Path analysis of rice grain yield under rainfed lowland conditions indicated that number of productive tillers had high direct effects on grain yield while panicle length and flowering duration had moderate direct effects. The effect of plant height was slightly negative (Ibrahim *et al.*, 1990).

Data on character association and path analysis are presented from yield trials with 48 lowland rice cultivars from Uttar Pradesh. Test weight, grain breadth, numbers of grains/panicle and number of internodes were the most important components of yield (Singh *et al.* , 1990).

Path analysis of red rice (*Oryza sativa* L.) competition with cultivated rice indicated that the number of panicles/plant and florets/panicle were the most important yield components determining the responses of fecundity and grain yield to competition. The direct effects of rice and red rice densities on panicles/plant and florets /panicles were always negative. In contrast, the effects of density on percent filled florets and grain weight varied from positive to negative and were relatively small, implying that they were determined primarily by density independent factors (Pantone *et al.*, 1992).

Path analysis in 80 indica rice varieties indicated that panicle weight made the highest contribution to grain yield (Chaubey and Richharia, 1993).

Path analysis studies by Gravois and Mc new (1993) revealed 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.

According to Mahajan *et al.* (1993) path analysis of 37 genotypes of upland rice revealed that filled grains/panicle exerted a positive direct effect on yield, hence it is considered as the most important yield contributing character.

Sarma and Roy (1993) also reported that spikelets/panicle had highest positive direct effect on yield followed by panicles/m^2 and plant height.

The greatest direct positive effects on grain yield were recorded for number of ear-bearing tillers followed by plant height, 100-grain weight and total number of spikelets. The results indicated the importance of number of ear-bearing tillers as a selection criterion for rice hybridisation programmes. The study was carried out by Chaubey and Singh (1994) using twenty rice varieties.

Path coefficient analysis in rice by Marwat *et al.* (1994) found that productive tillers, panicle length and 1000- grain weight had the highest direct effect on grain yield per plant.

Paul and Nanda (1994) studied 14 varieties of rice and path analysis in the study showed that panicle number/m^2 had the largest direct positive effect on yield. The direct effect of number of filled grains/panicle, although negative, was counter-balanced by an indirect effect of panicle number/m^2. The direct positive effect of 1000-grain weight on yield was high but negated by the indirect effects of all other yield components. To obtain high yields and good milling quality, it appeared that adequate panicle density and optimum grain number/panicle must be achieved. An appropriate number of panicles/m^2 is seen as the basis of high yields.

Eleven early rice varieties were studied for ten quantitative characters, during 1984-85 at Ambasamudram. Grains per panicle had the highest positive direct effect on yield and highest positive indirect effect via productive tillers, panicle weight and grain weight (Sundaram and Palanisamy, 1994).

Study of eight F_2 progeny and their nine parents grown at three plant densities revealed that number of panicle - bearing tillers had the greatest direct effect on yield, followed by 1000- seed weight (Yadav *et al.*, 1995).

2.6 Quality Parameters

The 1000- grain weight, total protein content and amylose contents were studied in 18 rice cultivars. Neither the transplanting date nor fertilizer rates affected grain amylose contents (Ahmad and Chughtai, 1982).

Khan and Ali (1985) studied four varieties of rice. Among them Basmati 370 took least time for water absorption and cooking. Volume expansion ratio, water absorption ratio and elongation ratio on cooking were highest in Basmati 370. Cooked grain of Basmati 370 was partially separated and showed a strong aroma, while that of the other varieties was moderately sticky, with a weak aroma.

Thirteen aromatic rice lines were compared to Basmati 370 (B 370) with respect to the milling and cooking qualities. Basmati 370 had 7.7 mm long grains. Six lines equalled or exceeded Basmati 370 in amylose content (r 19.0 percent). Grain elongation ratio was higher in s 41 than in B 370 (Nagi *et al.*, 1989).

Rani and Srinivasan (1989) reported more than double grain elongation during cooking in 20 varieties including Basmati lines. They had also the typical beaded appearance of cooked grains.

Effect of time of transplanting on grain yield and quality traits were studied in four Basmati-type varieties of rice, viz Basmati 370, Kasturi, Pusa Basmati 1 and Haryana Basmati 1. Late planting in August slightly improved quality traits such as hulling, milling and head-rice recovery (Rao *et al.*, 1996).

Breakage of grain during milling was evaluated in 102 traditional aromatic varieties received from IRRI by Yadav and Singh (1989). Varieties were classified into four groups (slender, medium, bold and round) on the basis of grain length/width ratio. The similarity in range of variation in all four groups in hulling and milling percentages suggested that these characters are independent of grain shape. However, head rice recovery increased with a decrease in length/width ratio. High hulling (over 75 per cent) and milling (over 69.8 per cent) percentages and head rice recovery (over 65.4 per cent) were observed in Basmati Surbh 161 and Basmati 370 A (slender), Basmati 106-12 (medium) Basmati 2B and Xiang Geng Dao (bold) and Ambemohar 159 (round).

Awning, pigmentation, length : breadth (L/B) ratio and 1000- grain weight were measured in 43 traditional scented rice varieties in 1988. Of these thirteen had awns and 23 were pigmented. Grain length ranged from 5.7 to 9.9 mm, breadth from 1.8 to 3.0 mm and L/B ratio from 2.4 to 4.3. A range of 8.4 to 25.5 g was recorded for 1000- grain weight (Sarma *et al.*, 1990).

Ali *et al.* (1991) reported that milling and cooking quality decrease with early or late transplanting and the best transplanting dates were 1 and 16 July for Basmati 370 and Basmati 385, respectively.

Ali *et al.* (1993a) reported that threshing on the day of harvest gave the highest head rice recovery and the lowest broken rice, in rice CV KS 282 (medium grain) and Basmati 385 (fine grain). Mode of beating (bund, steel drum or wooden log) did not affect milling recovery.

It is reported that high recoveries of total milled and head rice, and good cooking quality, were obtained from harvesting at 20-23 per cent grain moisture content. Delaying harvesting to lower moisture content decreased head rice recovery but had little effect on milled rice or cooking quality (Ali *et al.*, 1993b).

The cooking and eating qualities of 5 indica rice cultivars are discussed in the report of Deosarkar and Nerkar (1993). In decreasing order of cooking and eating quality the cultivars were : Basmati 370 > Karnal local > Punjab 1 > IET 8573 > Prabhavati.

Rice cv. Basmati 370 was grown in pots of Daska (traditional rice growing area) and Multan (not a traditional area), in soils from each area. Pots were also transferred between the two areas at panicle initiation or panicle emergence. Grain size and composition were unaffected by treatment, but cooking quality and aroma were highest in rice grain grown in the Daska soil and environment throughout growth (Sagar and Ali, 1993).

Field trials at Velezzo and Garbagha, N. Italy, with rice cv. A 301 and eleven aromatic lines showed that A 301 and two Basmati lines were the most promising and had high contents of 2- acetyl-1 pyrroline, the compound responsible for the aroma (Bocchi *et al.* 1995).

Seventy volatile compounds were identified in cooked fragrant and non fragrant rice in a study by Widjaja *et al.* (1996). Many other compounds were also contributing to the total aroma profile. Basmati had the high amount of 2-phenyl ethanol and the lowest content of n-hexanal among all the rice types examined whilst it has the highest popcorn-like aroma.

Experiments were conducted to find out whether there is a difference in presence of aroma at different stages of growth of various plant parts of scented rice varieties ; the plant parts studied are undifferentiated callus, plumule, seminal roots, lamina at tillering and post-tillering phases, lemma, palea, androecium, pollen, gynoecium, adult root with four scented and two non scented varieties. It was found that scent is present in all the plant parts irrespective of age or growth phase (Mohanty *et al.*, 1991).

Ten aromatic rice germplasm which were collected from Orissa and Bihar were evaluated at NBPGR for determining their agromorphological and physico-chemical characteristics. Results indicated that in eastern India scented varieties are mostly medium slender having high head rice recovery with around 20 per cent amylose content and excellent elongation ratio with pleasant appealing aroma on cooking. Variability in quality characters exists as Jubaraj having highest Kernel length after cooking (9.8 mm) and Makarkanda and Balshabhog having highest elongation ratio. 1.86 (Malik *et al.*, 1994).

2.7 Selection indices

Based on data on ten yield characters in 30 lines of upland rice, Deosarkar *et al.*(1989) reported that selection should be based on plant height, 1000-grain weight and grains/ panicle.

Grain weight/plant (y), effective panicles/plant (x_1), filled grains/panicle (x_2), panicle length (x_3) and 1000-grain weight (x_4), were studied in ten genotypes of japonica rice. Out of eight selection indices established,the selection index for yield expressed by the relation $Y=0.3895\ y + 0.0971\ x_1 + 0.1412\ x_2 + 0.2890 x_3 + 0.558\ x_4$ would produce the highest expected genetic gain (3.37) and relative efficiency (158%). It concluded that selection for filled grains/panicle, grain weight/plant, panicle length and bow-like panicle could be effective for improving yield (Bao, 1989).

It is suggested by Mirza *et al.* (1992) that panicle length, number of grains/ panicle and number of panicle/plant should be used as selection criteria for improving yield in rice. But Murthy *et al.* (1992) recommended the following traits for increasing grain yield in rice.: high leaf area at crop stages (45 and 60 days after sowing), leaf photo synthesis rate, total leaf weight and harvest index.

Of the seven yield related characters studied in 25 genotypes of early upland rice grown under different environments, days to 50% flowering,plant height, panicle length and 1000-grain weight showed consistency over the different environments for most of the genetic parameters estimated. So these traits are suggested as selection criteria (Reddy, 1992).

Gravois and Mcnew (1993) reported that selection for increased yield via panicle weight or panicle number alone would be ineffective. A selection index that included selection for both increased panicle weight and panicle number to increase yield was estimated to be 91% as effective on selecting for yield directly.

The results of Chaubey and Singh (1994) indicated the importance of number of ear-bearing tillers as a selection criterion for rice hybridization programmes.

Paul and Nanda (1994) reported that to obtain high yields and good milling quality it appeared that adequate panicle density and optimum grain number/panicle must be achieved. An appropriate number of panicle/m^2 is seen as the basis of high yields. Selection indices were constructed on this assumption.

Paramasivan and Rangasamy (1988) suggested that the selection for grain yield can be efficient if it is based on plant height, tiller number, panicle length, grain number per panicle and grain weight since these characters fulfilled both the requirements of genotypic association with yield and path coefficient analysis. Maximum weightage was given for these characters during analysis.

Materials and Methods

3. MATERIALS AND METHODS

The present study was envisaged to estimate the genetic diversity in a collection of advanced breeding lines of basmati rice and to formulate selection parameters for isolating genetically improved lines. The study was conducted in the Department of Plant breeding and Genetics, College of Horticulture, Vellanikkara, during 1996-97. Field trials were laid out at Agricultural Research Station, Mannuthy of Kerala Agricultural University. During the trial period the total annual rainfall was 2621 mm., the highest monthly rainfall being 979 mm in July, maximum temperature was recorded in October (32.4^{0}C) and minimum of 21.8^{0}C in July; average sunshine hours ranged from 2.9 in July to 8.6 in October. The soil is laterite loam with a pH 5.62 - 6.1 and it is located at 10 ^{0} 32'N and 76 ^{0} 10' E with an elevation of 1.5m at MSL.

3. 1.1 Materials:

Thirty eight basmati rice cultures collected from All India Coordinated Rice Improvement Project Centre, Mannuthy constituted the materials for the experiment. The particulars of genotypes used for this study are given in Table 1.

3. 1. 2 Methodology

Germinated Seeds of 38 basmati cultures/varieties were sown in the wet nursery beds during June 1996. Twenty five days old seedlings were transplanted at a spacing of 20cm x15cm with a plot size of 5.4m x 1.6m constituting 8 rows of 36 hills. All Package of Practices recommendations of Kerala Agricultural University. (KAU,1993) for short duration rice varieties were adopted while raising the crop. The experiment was laid out in randomised block design with three replications.

Observation on yield, 10 yield attributes and 21 qualitative attributes were recorded for ten randomly selected tagged plants from each plot after leaving the

Table 1 Advanced breeding lines of Basmati rice used

Entry No.	IET. No.	Designation	Cross combination	Grain Type
V_1	13540	UPR 1071-21-1-1	---	LS
V_2	13548	RP 3238-33-15-7 -1	Pusa Basmati-1/ IET 8585	LS
V_3	13549	RP-ST-328	Selection from Basmati composite	LS
V_4	13550	HKR 90-421	HAU 5-298-2/Pusa 167	LS
V_5	13551	HKR 90-404	IET 7313/HBC 143	LS
V_6	13552	HKR 90-403	IET 7313/HBC 143	LS
V_7	13553	HKR 90-413	HAUS-298-2/Pusa 167	LS
V_8	13554	HKR 90-414	----do----	LS
V_9	13845	BK 843-2	IET 10364/Local Basmati	LS
V_{10}	13846	BK 843-7	--- do ---	LS
V_{11}	13850	NDR 6017	Saket 4/T 1	LS
V_{12}	13852	HKR 91-405	HKR 212/Basmati 370	LS
V_{13}	13853	HKR 91-406	HKR 118/Karnal local	LS
V_{14}	13854	HKR 91-408	HKR 118/Karnal local	LS
V_{15}	13856	RP 3138-42-11-7-1	Pusa Basmati. 1/Phalghuna	LS
V_{16}	13857	RP 3138-42-11-7-4	Pusa Basmati.1/Phalghuna	LS
V_{17}	13858	RP 3138-78-20-9-2	--- do ---	LS
V_{18}	13859	RP 3138-78-25-11-4	--- do ---	LS
V_{19}	14128	HKR 92-401	HKR 237/Taraori Basmati	LS
V_{20}	14129	RP 3121-14-70-2	RP 2695/Pusa Basmati.1	LS
V_{21}	14130	RP 3138-56-11-9-3	Pusa Basmati-1/Phalghuna	LS
V_{22}	14131	RP 3138-60-9-6-6	--- do ---	LS
V_{23}	14132	UPR-BS-92-4	--- do ---	LS
V_{24}		Tarori Basmati check		
V_{25}		Pusa Basmati .1 Check	----	
V_{26}	13549	RP-ST-328 composite	Selection from Basmati	LS
V_{27}	14129	RP 3121-14-10-2	RP 2695/pusa Basmati 1	LS
V_{28}	14131	RP-3138-60-9 6-6	Pusa Basmati 1/Phalguna	LS
V_{29}	14132	UPR - BS- 92-4	----	---
V_{30}	14707	HKR 93-401	IR 50/Tarori Basmati	LS
V_{31}	14708	HKR 93-402	IR 50/Tarori Basmati	LS
V_{32}	14709	HKR 93-403	IR 50/Tarori Basmati	LS
V_{33}	14720	88-H5-1-1-2	BR 4-10/PAK Basmati	LS
V_{34}	14721	88-H5-2-B-4	BR 4-10/PAK Basmati	LS
V_{35}		Tarori Basmati Check		
V_{36}		Pusa Basmati 1 Check		
V_{37}	Mannuthy	Culture 385	Selection from Punjab Basmati	LS
V_{38}	Mannuthy	Culture 386	---do---	LS

border rows. Observations on these 32 characters were taken as per the standard evaluation system suggested by Shouichi *et al.* (1976), IRRI, (1995) and Directorate of Rice Research (1995). Observations recorded are given below.

3.1.2.1 Characters

1. Number of days to panicle initiation

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

2. Number of days to 50 per cent flowering.

Number of days were counted from date of germination to about 50 per cent flowering stage of the plants in a plot.

3. Height of plant at harvest.

Plant height was measured in centimeters from ground level to tip of tallest panicle about one week prior to harvest. In case of awned varieties, height was measured excluding the awns.

4. Total number of tillers.

Total number of tillers in each plant was counted after 50 percent of flowering.

5. Number of panicle bearing tillers.

Number of panicle bearing tillers was recorded prior to harvest.

6. Number of days to harvest

Number of days from germination to grain ripening.(when 85 per cent of grains in a panicle were matured) was recorded.

7. Number of panicles/m^2

One square metre area was marked out in each plot and actual counts on panicles were made.

8. Number of spikelets/panicle

Ten panicles from each plot were taken at random and number of spikelets were counted and average worked out.

9. Length of panicle

Mean value of ten panicle lengths in centimeters taken at random from each plot was recorded, excluding awns.

10. Number of grains/panicle

Number of filled grains were counted from ten randomly selected panicles from each plot and mean value was recorded.

11. Thousand grain weight

1000 grains were taken at random from each plot and weighed and recorded in grams.

12. Kernel length

Kernel length of five randomly selected kernels from each plot was measured in mm by graphic method and mean value worked out.

13. Kernel breadth

Kernel breadth of five randomly selected kernels from each plot was measured in mm by graphic method and mean value worked out.

14. L/B ratio of kernel

L/B ratio of kernel was found out from the mean value of kernel lengths and breadths already calculated.

15. Awnness

Awning was graded as follows

0 absent

1 short and partly awned

5 short and fully awned

7 long and partly awned

9 long and fully awned

16. Lemma and palea pubescence

Lemma and palea pubescence was graded as follows

1 glabrous

2 hairs on lemma keel

3 hairs on upper portion

4 short hairs

5 long hairs(velvety)

17. Grain yield

The entire plants from each plot were harvested discarding border rows and the yield was expressed in kg/ ha.

18. Hulling percentage.

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

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

19. Milling percentage

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

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

Cooking quality : -

Amylose content and alkali spreading value are the important characters in determining the cooking quality of rice (Ghosh and Govindaswami, 1972). About 25 g rice kernel was cooked for quality studies.

20. Amylose content.

Amylose content was calculated using the standard procedure taking pure amylose as standard. 100 mg of parboiled milled rice was powdered. One ml of distilled ethanol was added to the sample. 10 ml of 1 N NaOH was added to this and was kept overnight. The volume was made upto 100 ml. 2.5 ml of the extract was taken and 20 ml of distilled water and three drops of phenolphthalein were added. Then 0.1 N HCl was added drop by drop until the pink colour just disappeared. To this 1 ml of Iodine reagent was added and made up to 50 ml and the colour developed was read at 590 nm using spectrophotometer. 0.2, 0.4, 0.6, 0.8 and 1 ml of the standard amylose solution was taken and developed the colour as in the case of sample. Using the standard graph the amount of amylose present in the sample was calculated.One ml of iodine was taken and diluted to 50 ml for a blank (Sadasivam and Manickam, 1992).

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

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

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

21. Alkali spreading value

Six milled rice kernels were placed in 100 ml. 1.7 percent KOH in a shallow container (petriplate). The kernels were so arranged that they did not touch each other. They were allowed to stand for 23 hours at 30^0 C. The appearance and disintegration of the kernels were rated visually after incubations, based on the following numerical scale (IRRI, 1980)

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

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

A rating of 1 to 2 was classified as high final gelatinization temperature, 3, high intermediate, 4 to 5, intermediate (70 - 74^0 C); and 6 to 7, low final gelatinization temperature (< 70^0 C).

22. Kernel elongation ratio

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

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

23. Presence of aroma in precooked and cooked grains

24. Kernel appearance

25. Kernel elongation

26. Cohesiveness

27. Taste

28. Tenderness on touching

29. Tenderness on chewing

30.Overall acceptability

Observations 23-30 were scored by a panel of 5 members as per the evaluation system of Directorate of Rice Research, Hyderabad.

31. pH content

About 10g of finely powdered samples taken from each plot were used to read pH values using pH meter.

32. Susceptibility to bacterial blight and other pest and disease.

The Basmati crop was not much affected by any pest or diseases except slight rice bug attack.

3.1.3 Statistical analysis

The data were subjected to the following statistical analysis.

3.1.3.1 Estimation of selection parameters:

3.1.3.1.1 Components of heritable variation

a) Variability

Variability existing in the various characters under observation was estimated as per the procedure suggested by Burton (1952). Then estimate of PCV and GCV were classified as, less than 10 per cent = low; 10-20 per cent = moderate and greater than 20 per cent = high

b) Heritability

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

$$H^2 = \frac{Vg}{Vp} \times 100$$ where,

H^2 = Heritability (in broad sense) expressed in percentage.

Vg = Genotypic variance

Vp = Phenotypic variance

Phenotypic variance (Burton, 1952).

Vp = Vg + E where,

Vp = phenotypic variance

Vg = genotypic variance

E = error mean square

Genotypic variance (Burton, 1952)

$$Vg = \frac{V - E}{r} \quad \text{where,}$$

Vg = Genotypic variance

E = Error mean square

V = varietal mean square

r = no. of replications

The heritability was catagorised as 60-100 per cent = high; 30-60 per cent = moderate; less than 30 per cent = low

C) Genetic advance

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

$$GA = \frac{Vg}{vp} \times Vp \times k \quad \text{where,}$$

GA = Genetic advance

Vg = Genotypic variance

Vp = Phenotypic variance

K = intensity of selection or standerdised selection differential

K = 2.06 in the case of 5 per cent selection in large samples (Allard, 1960)

d) Genetic gain

Expected genetic gain under selection (Johanson *et al.* 1955)

$$GG = \frac{GA}{X} \times 100 \quad \text{where}$$

GG = Genetic gain

GA = Genetic advance

X = Mean

Genetic gain was categorised as more than 20 per cent = high; 10-20 per cent = moderate and less than 10 per cent = low

3.1.3.1.2 Phenotypic and genotypic correlations

Phenotypic and genotypic correlation coefficients multiple correlation between yield and various yield components and among themselves were found out (Rangasamy, 1995).

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

Association analysis based on genetic correlations of components with yield will not give a true picture of the relative merits or demerits of each of the components to final yield. Hence an assessment of the merit of each character by analyzing the direct and indirect effects of the same towards final yield is of immense value for yield improvement.

Path coefficient analysis suggested by Wright (1921) was applied to study the cause and effect relationship in a system of correlated variables.

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

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

3.1.3.2 Mahalanobis D^2 analysis

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

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

Results

4. RESULTS

Observations recorded from ten plants selected at random in each of the thirty eight genotypes of Basmati rice on eleven yield and yield attributes and twentyone important qualitative characters were statistically analysed and presented in the following pages.

4.1 Variability in Basmati rice genotypes.

Results pertaining to analysis of variance of different characters of the Basmati rice genotypes indicated that all the genotypes differed significantly at 1% level except for four characters for which the genotypes differed at 5% level. The abstract of analysis of variance is presented in Table 2. Range expressed as (R), mean (M), percentage of mean (%) for different characters are presented in Table 3. Table 4 gives phenotypic, genotypic and environmental variances, heritability, genetic advance and genetic gain for twenty different characters.

The results reveal the presence of high amount of variability in the material studied. There exists a wide gap between the maximum and minimum values with respect to each of the traits studied.

A further scrutiny of the results revealed the following.

Number of days to panicle initiation:

The mean for numbers of days to panicle initiation of the basmati rice genotypes under study varied from 68 to 75 with a mean of 69.92. Most of the genotypes recorded minimum number of days to panicle initiation while only two genotypes showed maximum days for panicle initiation (Variety11 and variety 37). This character showed comparatively low PCV (3.39), GCV (3.45) and low ECV of 0.04, indicating a low amount of environmental effect on this character. A comparatively high amount of heritability (H^2= 0.980) also indicated a predominant genotypic influence for this character (Table 4) A genetic advance of 4.92 days is indicated (low genetic gain 7.036 %) for selection.

Table 2 Abstract of analysis of variances for different characters

Sl No.	Characters	Mean Square Values: Genotypes df=37	Error df=74	C.V. (%)
1.	Number of days to panicle initiation	17.593**	0.117	0.49
2.	Number of days to 50% flowering	34.850**	0.000	0.00
3.	Height of plant at harvest	609.870**	28.662	4.79
4.	Total number of tillers	7.892*	8.159	21.42
5.	Number of panicle bearing tillers	7.892**	8.159	19.34
6.	Number of panicles/m^2	10014.964**	1878.679	14.16
7.	Number of spikelets/ panicle	1080.263**	190.380	16.07
8.	Length of panicle	7.933**	1.278	4.48
9.	Thousand grain weight	11.169**	3.089	7.42
10.	Kernel length before cooking	0.676**	0.003	0.65
11.	Awnness	39.440**	0.732	18.94
12.	Pubescence(Lemma & Palea)	0.924**	-0.000	0.00
13.	pH of raw grain	0.038**	0.000	0.08
14.	Number of grains/panicle	377.412**	143.831	22.75
15.	Kernel breadth	0.051**	0.000	0.05
16.	L/B ratio	0.268**	0.000	0.06
17.	Number of days to harvest	1.310*	1.062	0.87
18.	Kernel appearance	0.117**	0.001	0.72
19.	Cohesiveness	0.118**	0.000	0.00
20.	Tenderness on touching	0.308**	0.001	0.69
21.	Tenderness on chewing	0.368**	0.000	0.35
22.	Taste	0.175**	0.000	0.31
23.	Aroma	0.274**	0.000	0.03
24.	Elongation	0.533**	0.007	2.62
25.	Overall acceptability	0.322**	0.000	0.16
26.	Amylose content	8.503**	0.017	0.87
27.	Milling percentage	20.014**	8.365	4.57
28.	Hulling percentage	10.441**	4.303	2.75
29.	Alkali value	0.604*	0.417	11.29
30.	Kernel elongation after cooking	5.102*	0.007	0.68
31.	Elongation ratio	0.080**	0.000	3.49
32.	Yield	298627.711**	151483.760	22.61

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

Table 3 Range (R), mean (M), percentage of magnitude of the range over mean (%) of different characters

Sl. No.	Characters	R	M	Percentage of magnitude of the R over M
1.	No. of days to panicle initiation	68-75	69.921	10.01
2.	No. of days to 50% flowering	80-97	91.711	18.536
3.	Height of plant at harvest (cm)	91.43 - 145.66	111.675	48.560
4.	Total number of tillers	10.33 - 16.00	13.333	46.153
5.	No. of panicle bearing tillers	5.33 - 11.00	7.553	75.00
6.	Number of panicle/m^2	218.33 - 448	306.053	75.163
7.	Number of spikelets/panicle	39.433 - 117.663	85.876	90.69
8.	Length of panicle (cm)	21.76 - 29.65	25.213	31.29
9.	Thousand grain weight (g)	20.06 - 27.367	23.695	32.03
10.	Kernel length before cooking(mm)	7.04 - 8.90	7.921	23.48
11.	Awnness	0.5 - 9.00	4.518	188.136
12.	Pubescence	2.00 - 4.00	3.553	56.29
13.	pH of raw grain	6.35 - 6.84	6.545	7.48
14.	Number of grains/panicle	30.86 - 76.52	52.721	87.25
15.	Kernel breadth (mm)	1.75 - 2.24	1.967	24.91
16.	L/B ratio	3.55 - 4.76	4.036	29.98

Contd...........

Sl. No.	Characters	R	M	Percentage of magnitudeof the R over M
17.	Number of days to harvest	117.66 - 120	118. 518	1.974
18.	Kernel appearance	4.07 - 4.80	4.460	14.79
19.	Cohesiveness	4.3 - 5.06	4.676	16.25
20.	Tenderness on touching	3.62 - 4.967	4.316	31.41
21.	Tenderness on chewing	3.90 - 5.10	4. 267	28.12
22.	Taste	2.90 - 3.84	3.335	28.18
23.	Aroma	2.93 - 4.33	3.478	40.25
24.	Elongation	2.70 - 4.00	3.252	39. 97
25.	Overall acceptability	1.99 - 3.20	2.672	45.28
26.	Amylose content (%)	12.16 - 19.16	15.104	46.34
27.	Milling percentage (%)	52.53 - 68.75	63.307	25.62
28.	Hulling percentage (%)	71.40 - 79.55	75.364	10.81
29.	Alkali value	4.33 - 6.00	5.719	29.20
30.	Kernel length after cooking (mm)	9.36 - 14.62	12.164	43.24
31.	Elongation ratio	0.246 - 0.911	0.538	120.60
32.	Yield (kg/ha)	1141.53 - 2294.50	1721.601	66.97

Table 4 Phenotypic, genotypic and environmental variances, heritability, genetic advance and genetic gain for different characters

Sl No.	Characters	*PCV(%)	*GCV(%)	*ECV (%)	Heritability (H^2)	Genetic Advance	Genetic Gain (%)
1.	Number of days to panicle initiation	3.49	3.45	0.04	0.980	4.920	7.036
2.	Number of days to 50% flowering	3.72	3.72	0.00	1.000	7.020	7.654
3.	Height of plant at harvest	13.35	12.46	0.89	0.871	26.760	23.962
4.	Number of panicle bearing tillers	23.51	13.37	10.14	0.324	1.180	8.850
5.	Number of panicle/m^2	22.14	17.02	5.12	0.591	82.46	26.943
6.	Length of panicle	7.42	5.91	1.51	0.634	2.44	9.677
7.	Thousand grain weight	10.15	6.93	3.22	0.466	2.310	9.748
8.	Kernel length before cooking	6.02	5.98	0.04	0.989	0.970	12.245
9.	Awnness	81.74	79.51	2.23	0.946	7.200	159.362
10.	pH of raw grain	1.73	1.73	0.00	1.000	0.23	3.514
11.	Kernel breadth	6.66	6.66	0.00	1.000	0.27	13.726
12.	L/B ratio	7.40	7.40	0.00	1.000	0.62	15.361
13.	Kernel appearance	4.46	4.40	0.06	0.974	0.40	8.968
14.	Taste	7.25	7.24	0.01	0.998	0.50	14.992
15.	Aroma	8.68	8.69	0.01	1.000	0.62	17.826
16.	Elongation	13.13	12.87	0.26	0.960	0.84	25.830
17.	Alkali value	12.11	4.37	7.74	0.130	0.19	3.322
18.	Kernel length after cooking	10.73	10.71	0.02	0.996	2.68	22.032
19.	Elongation ratio	30.51	30.31	0.20	0.987	0.33	61.338
20.	Yield	26.01	12.86	13.15	0.245	225.63	13.105

* PCV - Phenotypic coefficient of variation

* GCV - Genotypic coefficient of variation

* ECV - Environmental coefficient of variation

Number of days to 50% flowering :-

The mean number of days to 50% flowering of the genotypes varied from 80 to 97 with a mean of 91.71. This character also showed a comparatively low PCV (3.72) ,GCV (3.72) and lowest possible ECV of 0.00, indicating that there is no environmental effect on this character. The variation is completely due to difference in genotype. The highest possible heritability of 1.00 for this character indicate predominant genotypic influence which is completely heritable. A genetic advance of 7 days is indicated (low genetic gain 7.654) for selection.

Height of plant at harvest :-

The mean height of plant at harvest of the genotypes varied from 91.43 - 145.66 with a mean of 111.67. This character showed PCV of 13.35, GCV 12.46 and a low ECV of 0.89, indicating a low amount of environmental effect on this character. A comparatively high amount of heritability (0.871) also indicated a predominant genotypic influence for this character. A genetic advance of 26cm is indicated (high genetic gain 23.962) for selection.

Number of panicle bearing tillers:-

The mean number of panicle bearing tillers varied from 5 to 11 with a mean of 8 . This character showed a comparatively high PCV (23.5), a medium GCV (13.37) and a comparatively high ECV (10.14) indicating a high amount of environmental effect on this character. A moderate amount of heritability (0.324) indicated a moderate genotypic influence for this character. A genetic advance of 1 panicle bearing tiller is indicated (low genetic gain 8.85%) for selection.

Number of panicles/m^2

The mean number of panicles/m^2 varied from 218 to 448 with a mean of 306. This character showed a comparatively high PCV (22.14), a medium high GCV (17.02) and a medium ECV(5.12) indicating a more or less high amount of environmental effect on this character. A moderately high amount of heritability (0.59) indicated a high genotypic influence for this character. A genetic advance of 82 panicles per square meter is indicated (high genetic gain 26.943%) for selection.

Length of panicle :-

The mean length of panicle varied from 21.76cm to 29.65cm with a mean of 25.21cm. This character showed a comparatively low PCV (7.42), GCV (5.91) and a low ECV(1.51) indicating a low environmental effect on this character. A moderately high amount of heritability (0.634) indicated a high genotypic influence for this character. A genetic advance of 2 cm length of panicle is indicated (low genetic gain 9.677%) for selection.

Thousand grain weight :-

The mean values for thousand grain weight of the genotypes varied from 20.06g to 27.36g with a mean of 23.69g. This character showed a moderate PCV (10.15). GCV (6.93) and a comparatively high (3.22) ECV indicating a high amount of environmental effect on this character. A moderate heritability (0.466) indicator a low genotypic influence for this character. A genetic advance of 2.31gm of grain weight is indicated (low genetic gain 9.748%) for selection.

Kernel length before cooking :-

The mean kernel length before cooking varied from 7.04mm to 8.9mm with a mean of 7.921mm. This character showed a comparatively low PCV (6.02), GCV(5.98) and comparatively very low ECV (0.04), indicating a very low amount of environmental effect on this character. A very high amount of heritability (0.989) indicated a high genotypic influence for this character. A genetic advance of 0.97 mm kernel length is indicated (moderate genetic gain 12.245 %) for selection.

Awnness:-

The awnness of genotypes varied from awnless genotypes to too long and fully awned genotypes, with a mean short and fully awned genotypes. This character showed the highest PCV (81.74), GCV (79.51) and a low ECV (2.23) indicating a low amount of environmental effect on this character. A comparatively high heritability (0.946) indicated a high genotypic influence for this character. A genetic advance of 7 is indicated (high genetic gain 159.362 %) for selection.

pH of raw grain :-

The mean pH of raw grain of the genotypes varied from 6.35 to 6.84 with a mean of 6.54. This character showed the least PCV (1.73) and GCV (1.73) and a nil effect of environment (ECV 0.00) on this character. Heritability of this character is maximum which indicated a very high genotypic influence for this character. A genetic advance of 0.23 pH of raw grain is indicated (low genetic gain 3.514) for selection.

Kernel breadth :-

The mean kernel breadth of genotypes varied from 1.75 mm to 2.24 mm with a mean of 1.967 mm. This character showed a comparatively low PCV (6.66), GCV (6.66) and the environmental effect was nil indicating that there is no effect of environment on the variation of character. Heritability of this character is maximum (1.0) indicating a very high genotypic influence for this character. A genetic advance of 0.27 mm of kernel breadth is indicated for selection (moderate genetic gain 13.726).

L/B ratio :-

The L/B ratio of the genotypes varied from 3.55 to 4.76 with a mean of 4.036. This character showed a comparatively low PCV (7.4), GCV (7.4) and a least ECV (0.00) indicating the nil effect of environment. Heritability for this character is maximum (1.0) indicating a very high genotypic effect for this character. A genetic advance of 0.62 is indicated for selection (moderate genetic gain 15.361 %).

Kernel appearance :-

The kernel appearance ranged from 4.07 to 4.8 with a mean of 4.46. This character showed a comparatively low PCV (4.46), GCV (4.4) and a very low ECV (0.06) indicating a very low environmental effect on the genotype. Heritability for this character is very high (0.974) indicating a very high genotypic influence for this character. A genetic advance of 0.4 is indicated for selection (low genetic gain 8.968 %).

Taste :-

The mean taste ranged from 2.9 to 3.84 with a mean of 3.335. The character showed a comparatively low PCV (7.25), GCV (7.24) and very low ECV (0.01) indicating that the influence of environment on this character is negligible. Heritability for this character is very high (0.998) indicating a very high genotypic influence for this character. A genetic advance of 0.5 is indicated for selection (moderate genetic gain 14.992).

Aroma :-

The mean aroma of genotypes ranged from 2.93 to 4.33 with a mean of 3.478. This character showed comparatively high PCV (8.68), GCV (8.69) and very low ECV (0.01) indicating negligible effect of environment on the aroma of genotypes . Heritability for the character is maximum (1.0) which showing a profound genotypic influence for this character. A genetic advance of 0.62 is indicated for selection (moderate genetic gain 17.826 %).

Elongation :-

The mean elongation of genotypes varied from 2.7 to 4 with a mean of 3.252. This character showed moderate PCV(13.13), GCV(12.87) and ECV (0.26) indicating a comparatively high influence of environment on the elongation of genotypes. Heritability for the character is very high indicating a high genotypic influence for this character. A genetic advance of 0.84 is indicated for selection (high genetic gain 25.83 %).

Alkali Value :-

The mean alkali value of genotypes varied from 4.33 to 6 with a mean of 5.719. This character showed moderate PCV (12.11), low GCV (4.37) and a comparatively very high ECV (7.74) indicating profound environmental influence on this character of genotypes. Heritability for the character is least (0.130) which indicates that this character has least genotypic influence. A genetic advance of 0.19 is indicated for selection (low genetic gain 3.322 %).

Kernel length after cooking :-

The mean of this character ranged from 9.36mm to 14.62mm with a mean of 12.164mm. This character showed moderate PCV (10.73), GCV (10.71) and very low ECV(0.02) indicating a very low environmental effect on the character. Heritability for the character is very high (0.996) indicating a high genotypic influence for this character. A genetic advance of 2.68 mm is indicated for selection (high genetic gain 22.032 %).

Elongation ratio :-

The mean of this character ranged from 0.246 to 0.911 with a mean of 0.538. This character showed the highest PCV (30.51) , GCV (30.31) and a comparatively high ECV(0.2) indicating a moderate environmental effect on the character. Heritability for the character is very high (0.987) indicating a high genotypic influence for this character. A genetic advance of 0.33 is shown for selection (high genetic gain 61.338 %).

Yield :-

The mean yield ranged from 1141.53 kg/ha to 2294.50 kg/ha with mean of 1721.601 kg/ha. This character showed very high PCV (26.01), moderate GCV (12.86) and also highest ECV (13.15) which shows that the environmental effect is very high on yield. Heritability for the character is least 0.245 indicating very low genotypic influence. A genetic advance of 225.63 kg/ha is indicated for selection (moderate genetic gain 13.105 %).

4.2 Genetic divergence among the genotypes

Thirty eight Basmati rice genotypes were found to fall into seven clusters each one having different number of genotypes (Table 5)

The results presented revealed that 12 genotypes constituted cluster I and II each, five genotypes in cluster III three genotypes in cluster IV, and V each, two genotypes in cluster VI and one genotype in cluster VII.

The means of characters for the genotypes belonging to different clusters are presented in Table 6. The minimum mean value of number of days to panicle initiation (68.667 days) was expressed by the variety V_{18} and the maximum of (73.33 days) was expressed by genotypes namely V_{25}, V_{33}, and V_{37}. The minimum mean value of number of days to 50% flowering (87 days) was expressed by the genotypes V_{25}, V_{33}, and V_{37}; and the maximum value (93 days) was expressed by genotypes V_{18}, V_1, V_{10} and V_{16}. The minimum mean height of plant at harvest (93.191cm) was shown by V_{36} and V_{38};and maximum (118.218cm) was expressed by V_{35} ,V_{14}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7 and V_{13}. For the character total number of tillers, the minimum mean value (12.89) was expressed by the genotype V_{30}, V_{15}, V_{21}, V_{22},and V_{26} and the maximum value (15.00) was shown by V_{36} and V_{38}. The minimum mean of number of panicle bearing tillers (6.33) was expressed by V_{25}, V_{33} and V_{37} ; while maximum (9.666) was expressed by V_{36} and V_{38}. The minimum mean of number of panicle/m^2 (266) was expressed by V_{25}, V_{33}, V_{37} and the maximum (383.111) was expressed by V_1, V_{10} and V_{16}. The minimum mean of spikelets/panicle (64.867) was expressed by V_{18} and the maximum mean value of (101.897) was expressed by V_{25}, V_{33}, and V_{37} genotypes.

The minimum mean of length of panicle(23.027 cm) was expressed by V_{36} and V_{38} and the maximum value (25.697 cm) was expressed by V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{26}, V_9, V_7 and V_{13}.

Table 5 Details of Basmati genotypes constituting different clusters.

Clusters	Genotypes	No. of genotypes
Cluster I	Tarori Basmati, HKR 91-408,HKR 91-405, HKR 90-404,NDR 6017,Tarori Basmati,HKR 93-403, RP 3138-78-20-9-2,RP 3121-14-70-2,BK 843-2, HKR 90-413,HKR 91-406	12
Cluster II	HKR 93-402,RP -ST-328,HKR 90-403,HKR 90-414, HKR 92-401,88-H5-2-B-4,RP 3238-33-15-7-1, HKR 90-421,RP 3121-14-10-2,UPR-BS-92-4, RP-3138-60-9 6-6,UPR-BS-92-4	12
Cluster III	HKR 93-401,RP3138-42-11-7-1,RP 3138-56-11-9-3, RP 3138-60-9-6-6,RP-ST-328 composite	5
Cluster IV	UPR 1071-21-1-1,BK 843-7,RP 3138-42-11-7-4	3
Cluster V	Pusa Basmati .1,88-H5-1-1-2,Culture 385	3
Cluster VI	Pusa Basmati,Culture 386	2
Cluster VII	RP 3138-78-25-11-4	1

Table 6 Means of different characters of genotypes constituting different clusters.

Sl No.	Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
1.	No of days to panicle initiation	69.25	69.055	69.40	70.666	73.333	74	68.667
2.	No. of days to 50% flowering	92.33	92.33	91.60	93.0	87.00	89.00	93.00
3.	Height of plant at harvest	118.218	108.099	114.477	113.722	106.611	93.191	101.20
4.	Total no. of tillers	12.99	13.194	12.89	13.667	14.111	15.00	14.33
5.	No. of panicle bearing tillers	7.638	7.222	7.199	8.666	6.333	9.666	8.33
6.	No. of panilce /m^2	311.472	286.722	290.466	383.111	266.00	363.00	326.00
7.	No. of spicklets/panicle	80.682	91.040	91.391	76.593	101.897	72.41	64.867
8.	Length of panicle	25.697	25.200	25.438	24.524	25.342	23.027	23.467
9.	Thousand grain weight	24.057	24.131	23.666	23.689	22.123	21.783	20.067
10.	Kernel length before cooking	8.104	7.750	8.168	8.221	7.279	7.616	8.15
11.	Awnness	5.0	5.708	5.4	1.33	3.5	0.5	9.00
12.	Pubescence	3.5	3.583	3.8	3.0	3.66	3.5	4.00
13.	pH of raw grain	6.528	6.531	6.644	6.494	6.546	6.54	6.58
14.	No. of grains/panicle	49.951	56.748	54.570	44.261	61.486	46.547	39.833
15.	Kernel breadth	2.02	2.037	1.878	1.773	2.016	1.89	1.86
16.	L/B ratio	4.135	3.800	4.343	4.645	3.594	4.018	4.38
17.	No. of days to harvest	118.277	118.666	118.533	118.555	118.889	118.5	118.33
18.	Kernel appearance	4.388	4.544	4.512	4.314	4.463	4.42	4.22

Contd...........

Sl No.	Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
19.	Cohesiveness	4.71	4.635	4.612	4.733	4.76	4.725	4.53
20.	Tenderness on touching	4.572	4.332	4.411	4.31	4.401	4.333	4.40
21.	Tenderness on chewing	4.156	4.304	4.401	4.20	4.366	4.286	4.33
22.	Taste	3.354	3.468	3.239	3.506	2.964	2.95	3.35
23.	Aroma	3.546	3.346	3.348	3.320	3.513	3.915	4.33
24.	Elongation	3.301	3.116	3.18	3.233	3.195	3.898	3.5
25.	Overall acceptability	2.688	2.679	2.5	2.846	2.566	2.85	2.60
26.	Amylose content	15.455	15.509	14.67	14.308	14.56	14.675	13.04
27.	Milling percentage	64.027	64.228	62.808	62.525	59.807	62.143	61.33
28.	Hulling percentage	76.347	75.896	74.103	74.756	73.312	74.246	73.687
29.	Alkali Value	5.861	5.694	5.40	6.0	5.222	5.666	6.00
30.	Kernel length after cooking	12.50	11.401	12.696	12.66	11.428	13.725	12.510
31.	Elongation ratio	0.544	0.474	0.563	0.522	0.572	0.802	0.534
32.	Yield	1666.391	1690.293	1763.72	1743.833	1785.077	2166.916	1399.40

The minimum mean of thousand grain weight (20.067 g) was expressed by V_{18} and the maximum 24.131g was expressed by V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28}, and V_{29}.

The minimum mean of kernel length before cooking (7.279mm) was expressed by V_{25}, V_{33}, and V_{37} and the maximum (8.221mm) by V_1, V_{10} and V_{16}. The minimum mean of awnness (0.5) ie.,no awn was expressed by the varieties V_{36} and V_{38}; and the maximum 9- ie.,long and fully awned character was expressed by the variety V_{18}. The minimum mean value for the character pubescence 3 was expressed by varieties V_1, V_{10} and V_{16} and the maximum value 4 was expressed by the variety V_{18}.

The minimum mean of pH of raw grain (6.494) expressed by the varieties V_1, V_{10} and V_{16} while the maximum (6.644) was expressed by the varieties V_{30}, V_{15}, V_{21}, V_{22} and V_{26}. The minimum mean of number of grains / panicle (39.833) was expressed by V_{18} and the maximum (61.486) by V_{25}, V_{33} and V_{37}.

The minimum kernel breadth (1.773mm) was expressed by the varieties V_1, V_{10} and V_{16} and the maximum (2.037mm) by V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28}, and V_{29}.

The minimum mean L/B ratio (3.594) was expressed by V_{25}, V_{33} and V_{37} and the maximum (4.646) by V_1, V_{10} and V_{16}.

The minimum mean number of days to harvest (118.227 days) was expressed by V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7, V_{13} and the maximum (120 days) was expressed by V_{25}, V_{33} and V_{37}.

The minimum mean kernel appearance (4.22) was expressed by V_{18} and the maximum (4.544) by V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28}, and V_{29}.

The minimum mean cohesiveness (4.53) was expressed by V_{18} and the maximum value (4.76) was expressed by the varieties V_{25}, V_{33} and V_{37}.

The minimum mean of tenderness on touching (4.31) was expressed by the varieties V_1, V_{10} and V_{16} and the maximum (4.572) by the varieties V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7 and V_{13}.

The minimum mean tenderness on chewing (4.156) was expressed by the varieties V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7, V_{13} and the maximum (4.401) by V_{30}, V_{15}, V_{21}, V_{22} and V_{26}.

The minimum mean taste (2.95) was expressed by the varieties V_{36} and V_{38} and the maximum (3.506) by the varieties V_1, V_{10} and V_{16}.

The minimum mean aroma (3.32) was expressed by the varieties V_1, V_{10} and V_{16} and the maximum (4.33) by the variety V_{18}.

The minimum mean elongation (3.116) was expressed by the varieties V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28}, and V_{29} and maximum (3.898) by the varieties V_{36} and V_{38}.

The minimum mean overall acceptability (2.5) was expressed by the variety V_{30}, V_{15}, V_{21}, V_{22} and V_{26} and maximum (2.85) by V_{36} and V_{38}.

The minimum mean amylose content (13.04%) was expressed by the variety V_{18} and maximum (15.455%) by V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7 and V_{13}.

The minimum mean milling percentage (59.807) was expressed by the varieties V_{25}, V_{33} and V_{37} and the maximum (64.228%) by V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28} and V_{29}.

The minimum mean hulling percentage (73.312) was expressed by the varieties V_{25}, V_{33} and V_{37} and the maximum (76.347%)by V_{35}, V_{14}, V_{12}, V_5, V_{11}, V_{24}, V_{32}, V_{17}, V_{20}, V_9, V_7 and V_{13}.

The minimum mean alkali value (5.222) was expressed by the varieties V_{25}, V_{33} and V_{37} and the maximum (6.00) by varities V_{18}, V_1, V_{10} and V_{16}.

The minimum mean kernel length after cooking (11.401mm) was expressed by V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28} and V_{29}.and the maximum (13.725mm) by the variety V_{36} and V_{38}.

The minimum mean elongation ratio (0.474) was expressed by the varieties V_{31}, V_3, V_6, V_8, V_{19}, V_{34}, V_2, V_4, V_{27}, V_{23}, V_{28} and V_{29} and the maximum (0.802) was expressed by V_{36} and V_{38}.

The minimum mean yield (1399.4kg/ ha) was expressed by the variety V_{18} and the maximum (2166.916kg/ ha) by the varieties V_{36} and V_{38}.

The intra and inter cluster D^2 and D values of seven clusters worked out have been presented in Table 7 and Table 8 respectively.

From the result it could be observed that the intra cluster D^2 values were lower than the corresponding inter cluster D^2 values. The average intracluster distances in the seven clusters ranged from 0 (cluster VII) to 103.41 (cluster II), the other clusters possessing the values in between two extremes (Table 8). Cluster V was found to show the maximum average inter cluster distance with anyother cluster and it was found to be the cluster showing maximum distance in all the combinations it could make. It also showed the minimum intracluster distance compared to others other than cluster VII. Cluster I showed the lowest average intercluster distance. The maximum inter cluster distance (323.009) showed between cluster V and cluster VII while the

Table 7 Average intra and inter - cluster genetic distance (D^2 values)

Clusters	I	II	III	IV	V	VI	VII
I	**6473.258**	23343.78	17243.35	63474.19	40217.72	13621.38	24616.58
II		**10694.48**	63415.7	122100.0	15596.83	31338.63	74926.83
III			**4490.4**	18965.13	83041.27	21213.5	12450
IV				**8343.00**	34366	64579.67	22322.33
V.					**1782.16**	36090	104335.0
VI						**5178.00**	24219
VII							**0.00**

Bold figures indicate intra cluster distances.

Table 8 Average intra and inter - cluster genetic distance (D values)

Clusters	I	II	III	IV	V	VI	VII
I	**80.456**	152.786	131.313	251.940	200.543	116.710	156.896
II		**103.41**	251.824	110.499	124.887	170.027	273.727
III			**67.010**	137.713	288.168	145.648	111.579
IV				**91.34**	185.380	254.125	149.406
V					**42.215**	189.973	323.009
VI						**71.958**	155.624
VII							**0.00**

Bold figures indicate intra cluster distances.

minimum (110.499) showed between cluster II and cluster IV. Followed by that of cluster III and cluster VII (111.579); cluster I and cluster VI (116.710); cluster II and V (124.887), cluster I and III (131.313); cluster III and IV (137.713); cluster III and VI (145.648); cluster IV and VII (149.406) cluster I and II (152.786); cluster VI and VII (155.624), cluster I and VII (156.896); cluster II and VI (170.027), cluster IV and V (185.380); cluster V and VI (189.973), cluster I and V (200.543); cluster II and III (251.824) ; cluster I and IV (251.940) ; cluster IV and VI (254.125); cluster II and VII (273.727) and cluster III and V (288.168).

4.3 Correlation between yield and yield components

Considering the relevance of Basmati rice in the analysis of variance, 19 different characters including quantitative and qualitative characters were selected for correlation studies. Genotypic and phenotypic correlations between yield and its selected 19 components and inter correlations among the yield components are furnished in Table 9 and Table 10. For the selected 19 characters the genotypic correlations were higher than the phenotypic correlations.

The yield component characters namely number of days to panicle initiation (0.560), height of plant at harvest (-0.442), number of panicle bearing tillers (-0.329) number of panicles/m^2 (-0.472), thousand grain weight (-0.399), kernel elongation (0.355), alkali value (-0.260) and elongation ratio (0.339), showed significant correlations at 1% level with grain yield (Table 9). Characters such as number of days to 50% flowering (-0.242), awnness(-0.250), aroma (0.231), kernel elongation after cooking (0.222) also showed significant correlation with grain yield but at 5% level. Comparatively low significant correlations were noticed at phenotypic level with yield and its components. Here after correlation denote the genotypic correlation.

Table 9 Genotypic correlation coefficients between yield and yield components in Basmati rice

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
No. of days to panicle initiation (X_1)	1.000	-0.181	-0.425**	0.065	-0.011	-0.399**	-0.359**	-0.517**	-0.003	0.106	-0.326**	-0.122	0.059	-0.269**	0.125	0.251	-0.321**	0.192	0.495**	0.560**
No. of days to 50% flowering (X_2)		1.000	0.043	-0.049	0.112	0.117	0.116	0.135	0.208**	-0.178	-0.031	0.156	-0.146	0.390**	0.043	-0.272**	0.558**	-0.185	-0.253*	-0.242*
Height of plant at harvest (X_3)			1.000	-0.051	0.132	0.403**	0.726**	0.534**	-0.225*	-0.268**	0.328**	0.150	-0.319**	-0.281**	-0.269**	-0.081	0.218*	0.057	-0.231*	-0.442**
No. of panicle bearing tillers (X_4)				1.000	0.961**	-0.918**	0.040**	0.173	-0.025	-0.358**	-0.309**	0.428**	-0.146	0.039	0.141	-0.207*	0.967**	0.095	-0.021	-0.329**
No. of panicles/m^2 (X_5)					1.000	-0.572**	-0.004	0.177	-0.067	-0.347**	-0.328**	0.457**	-0.203*	0.090	0.034	-0.268**	1.000**	0.042	- 0.078	-0.472**
Length of panicle (X_6)						1.000	0.121	0.251*	-0.220*	-0.064**	0.358**	-0.119	-0.068	-0.024	-0.153	0.178	0.401**	0.030	-0.100	0.084
Thousand grain weight (X_7)							1.000	0.384**	-0.331**	-0.354**	0.395**	-0.027	-0.107	-0.159	-0.526**	-0.153	0.452**	-0.018	-0.236*	-0.399**
Kernel length before cooking (X_8)								1.000	0.039	0.025	0.367**	0.499**	-0.428**	-0.026	0.041	0.013	0.369**	0.310**	-0.243	-0.151
Awnness (X_9)									1.000	0.241*	0.119	-0.095	-0.077	0.333**	0.036	-0.252*	0.296**	-0.060	-0.066	-0.250*
pH of raw grain (X_{10})										1.000	-0.214*	0.188	-0.074	-0.093	-0.001	0.278**	-0.923**	0.191	0.166	0.058
Kernel breadth (X_{11})											1.000	-0.622**	-0.038	-0.111	-0.030	-0.118	0.145	-0.058	-0.254**	-0.061
L/B ratio (X_{12})												1.000	-0.326**	0.096	0.054	0.113	0.186	0.297**	0.014	-0.055
Kernel apperance (X_{13})													1.000	0.176	-0.125	-0.206*	-0.035	-0.131	0.097	0.115
Taste (X_{14})														1.000	-0.122	-0.295**	0.564**	-0.182	-0.186	-0.065
Aroma (X_{15})															1.000	0.066	0.098*	0.199*	0.177	0.231*
Elongation (X_{16})																1.000	-0.855**	0.640**	0.645**	0.355**
Alkali Value (X_{17})																	1.000	-0.391**	-0.591**	-0.260**
Kernel elongation after cooking (X_{18})																		1.000	0.844**	0.222*
Elongation ratio (X_{19})																			1.000	0.339**
Yield (X_{20})																				1.000

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

Table 10 Phenotypic correlation coefficients between yield and components in Basmati rice

Sl.No.	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
1.	No. of days to panicle initiation (X_1)	1.000	-0.180	-0.395**	0.039	0.000	-0.309**	-0.230*	-0.511**	-0.005	0.104	-0.323**	-0.121	0.057	-0.266**	0.124	0.245*	-0.121	0.191	0.489**	0.281**
2.	No. of days to 50% flowering (X_2)		1.000	0.040	-0.028	0.086	0.093	0.079	0.134	0.202*	0.178	-0.031	0.156	-0.144	0.389**	0.043	-0.267**	0.201*	-0.185	-0.251*	-0.119
3.	Height of plant at harvest (X_3)			1.000	-0.057	0.072	0.301**	0.470**	0.497**	-0.204*	-0.250*	0.306**	0.140	-0.293**	-0.263**	-0.251*	-0.065	0.092	0.051	-0.215*	-0.088
4.	No. of panicle bearing tillers (X_4)				1.000	0.802**	-0.421**	0.077	0.108	-0.011	-0.200*	-0.176	0.243*	-0.080	0.022	0.080	-0.114	0.271**	0.050	-0.017	0.035
5.	No. of panicles/m^2 (X_5)					1.000	-0.381**	0.096	0.144	-0.054	-0.262**	-0.252*	0.352**	-0.151	0.066	0.026	-0.211*	0.282**	0.032	-0.065	-0.035
6.	Length of panicle (X_6)						1.000	0.152	0.192	-0.180	-0.050	0.285**	-0.095	-0.039	-0.013	-0.122	0.118	-0.003	0.025	-0.070	0.086
7.	Thousand grain weight (X_7)							1.000	0.272**	-0.223*	-0.238*	0.268**	-0.019	-0.068	-0.106	-0.360**	-0.110	0.084	-0.005	-0.153	-0.025
8.	Kernel length before cooking (X_8)								1.000	0.037	0.024	0.365**	0.496**	-0.419**	-0.027	0.041	0.012	0.116	0.308**	-0.247*	-0.062
9.	Awnness (X_9)									1.000	0.234*	0.116	-0.092	-0.076	0.323**	0.035	-0.239*	0.094	-0.055	-0.061	-0.116
10.	pH of raw grain (X_{10})										1.000	-0.214*	0.188	-0.073	-0.093	-0.001	0.272**	-0.335**	0.191	0.165	0.037
11.	Kernel breadth (X_{11})											1.000	-0.622**	-0.037	-0.111	-0.030	-0.116	0.052	-0.058	-0.252*	-0.032
12.	L/B ratio (X_{12})												1.000	-0.322**	0.096	0.054	0.111	0.067	0.297**	0.014	-0.027
13.	Kernel appearance (X_{13})													1.000	0.176	-0.124	-0.199*	0.021	-0.128	0.097	0.041
14.	Taste (X_{14})														1.000	-0.122	-0.289**	0.233*	-0.181	-0.184	-0.038
15.	Aroma (X_{15})															1.000	0.064	0.035	0.199*	0.175	0.114
16.	Elongation (X_{16})																1.000	-0.297**	0.625**	0.627**	0.187
17.	Alkali Value (X_{17})																	1.000	-0.138	-0.193	-0.104
18.	Kernel elongation after cooking (X_{18})																		1.000	0.840**	0.106
19.	Elongation ratio (X_{19})																			1.000	0.154
20.	Yield (X_{20})																				1.000

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

Number of days to panicle initiation showed significant correlations with other yield components such as height of plant at harvest (X_3), length of panicle (X_6), thousand grain weight (X_7), kernel length before cooking (X_8), kernel breadth (X_{11}), taste (X_{14}), alkali value (X_{17}) and elongation ratio (X_{19}).

Number of days to 50% flowering showed significant correlations with other yield components such as taste (X_{14}), elongation (X_{16}) and alkali value (X_{17}).

Height of plant at harvest showed significant correlations with other yield components like number of days to panicle initiation(X_1), length of panicle (X_6), thousand grain weight (X_7), kernel length before cooking (X_8), pH of raw grain (X_{10}), kernel breadth (X_{11}), kernel appearance (X_{13}), taste (X_{14}) and aroma (X_{15}).

Number of panicle bearing tillers showed significant correaltions with yield components like number of panicles/m^2 (X_5), length of panicle (X_6), pH of raw grain (X_{12}), kernel breadth (X_{11}) , L/B ratio (X_{12}) elongation (X_{16}), and alkali value (X_{17}). Number of panicles /m^2 showed significant correlations with other yield components such as number of panicle bearing tillers(X4), length of panicle (X_6), pH of raw grain (X_{10}), kernel breadth (X_{11}), L/B ratio (X_{12}), elongation (X_{16}) and alkali value (X_{17}).

Length of panicle showed significant correlations with other yield components such as number of panicle bearing tillers (X_4), number of panicles /m^2 (X_5), length of panicle (X_6), thousand grain weight (X_7), kernel length before cooking (X_8), awnness (X_9), pH of raw grain (X_{10}), taste (X_{14}), elongation (X_{16}),kernel elongation after cooking (X_{18}) and elongation ratio (X_{19}). Kernel elongation after cooking showed significant correlation with kernel length before cooking (X_8), L/B ratio (X_{12}), elongation (X_{16}), alkali value (X_{17}), elongation ratio(X_{19}) and elongation ratio showed significant correlation with number of days to panicle initiation (X_1), kernel breadth (X_{11}), elongation (X_{16}), alkali value (X_{17}) and kernel elongation after cooking (X_{18}). number of days to panicle initiation (X_1), height of plant at harvest (X_3), number of panicle bearing tillers (X_4), number of panicles / m^2 (X_5), kernel breadth (X_{11}) and alkali value(X_{17}).

Thousand grain weight showed significant correlations with number of days to panicle initiation (X_1), height of plant at harvest (X_3), kernel length before cooking (X_8), awnness(X_9), pH of raw grain (X_{10}), kernel breadth (X_{11}), aroma (X_{15}) and alkali value (X_{17}).

Kernel length before cooking showed significant correlation with number of days to panicle initiation (X_1), height of plant at harvest (X_3), thousand grain weight (X_7), kernel breadth (X_{11}), L/B ratio (X_{12}), kernel appearance (X_{13}), alkali value (X_{17}) and kernel elongation after cooking (X_{18}).

Awness showed significant correlation with thousand grain weight (X_7), taste (X_{14}) and alkali value(X_{17}).

pH of raw grain showed significant correlation with height of plant at harvest (X_3), number of panicle bearing tillers (X_4), number of panicles /m^2 (X_5), thousand grain weight (X_7), elongation (X_{16}) and alkali value(X_{17}).

Kernel breadth showed significant correlation with number of days to panicle initiation (X_1), height of plant at harvest (X_3), number of panicle bearing tillers (X_4), number of panicles /m^2 (X_5), length of panicle (X_6), thousand grain weight (X_7), kernel length before cooking (X_8), L/B ratio (X_{12}) and elongation ratio (X_{19}).

L/B ratio showed significant correlation with other yield components such as number of panicle bearing tillers (X_4), number of panicles /m^2 (X_5), kernel length before cooking (X_8), kernel breadth (X_{11}), kernel appearance (X_{13}) and kernel elongation after cooking (X_{18}).

Kernel appearance showed significant correlation with yield components like height of plant at harvest (X_3), kernel length before cooking (X_8),and L/B ratio (X_{12}).

Taste showed significant correlations with other yield components such as number of days to 50% flowering (X_2), number of days to panicle initiation (X_1), height of plant at harvest (X_3),awnness (X_9),elongation (X_{16}) and alkali value(X_{17}).

Aroma showed significant correlation with height of plant at harvest (X_3) and thousand grain weight (X_7).

Elongation showed significant correlation with yield commponents such as number of days to 50% flowering (X_2), number of panicles /m^2 (X_5), pH of raw grain (X_{10}), taste (X_{14}), alkali value (X_{17}), kernel elongation after cooking (X_{18}) and elongation ratio.Alkali value showed significant correlation with number of days to panicle initiation (X_1), number of days to 50% flowering (X_2),

4.4 Path Coefficient Analysis

In order to show the direct and indirect effect of yield components on yield, path coefficient analysis was done, considering all the characters selected for both the estimation of correlation coefficients. The genotypic correlation of grain yield and its attributes were partitioned into direct and indirect contribution of the components on grain yield. Data presented in Table 11.

The result showed that more than 95% of the variability in grain yield was contributed by the 19 component characters. Residual effect was 0.0452. It is seen from the table that maximum positive direct effect on grain yield was for kernel length before cooking (8.429) followed by kernel elongation ratio (7.282), where as maximum negative direct efect was for kernel elongation after cooking (-7.772) followed

Table 11 Direct and indirect effects of 19 yield characters on grain yield of Basmati rice

Sl.No.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	**0.988**	0.081	0.280	0.000	0.001	-0.194	-0.170	-4.358	0.001	0.006
X_2	-0.179	**0.445**	- 0.028	0.000	-0.012	0.057	0.055	1.140	- 0.100	-0.010
X_3	-0.419	-0.019	**-0.659**	0.000	-0.014	0.196	0.343	4.501	0.108	-0.015
X_4	0.064	0.022	0.034	**-0.001**	-0.102	-0.447	0.019	1.455	0.012	-0.020
X_5	-0.011	-0.050	-0.087	-0.001	**-0.106**	-0.278	-0.002	1.494	0.032	-0.019
X_6	-0.394	-0.052	-0.265	0.001	0.060	**0.487**	0.057	2.113	0.106	-0.004
X_7	-0.355	-0.052	-0.478	0.000	0.000	0.059	**0.472**	3.234	0.159	-0.020
X_8	-0.511	-0.060	-0.352	0.000	-0.019	0.122	0.181	**8.429**	0.019	0.001
X_9	-0.003	-0.093	0.148	0.000	0.007	-0.107	-0.156	0.329	**-0.481**	0.013
X_{10}	0.104	0.079	0.176	0.000	0.037	-0.031	-0.167	0.208	-0.116	**0.056**
X_{11}	-0.322	0.014	-0.216	0.000	0.035	0.174	0.187	3.090	-0.057	-0.012
X_{12}	-0.121	-0.070	-0.099	0.000	-0.048	-0.058	-0.013	4.203	0.045	0.011
X_{13}	0.059	0.065	0.210	0.000	0.021	-0.033	-0.051	-3.606	0.037	-0.004
X_{14}	-0.266	-0.174	0.185	0.000	-0.009	-0.011	-0.075	-0.221	-0.160	-0.005
X_{15}	0.124	-0.019	0.177	0.000	-0.004	-0.075	-0.248	0.345	0.017	0.000
X_{16}	0.248	0.121	0.053	0.000	0.028	+0.087	-0.072	0.109	0.121	0.016
X_{17}	-0.317	-0.249	-0.143	-0.001	-0.106	-0.195	0.213	3.106	-0.142	-0.052
X_{18}	0.190	0.082	-0.038	0.000	-0.004	0.014	-0.009	2.614	0.029	0.011
X_{19}	0.489	0.113	0.152	0.000	0.008	-0.049	-0.111	-2.052	0.032	0.009

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

Sl.No.	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
X_{1}	1.374	0.539	0.004	-0.163	0.048	0.038	-0.024	-1.496
X_{2}	0.130	-0.688	-0.010	0.236	0.017	-0.042	0.041	1.438
X_{3}	-1.381	-0.661	-0.021	-0.170	-0.104	-0.012	0.016	-0.444
X_{4}	1.303	-1.885	-0.010	0.024	0.055	-0.032	0.071	-0.735
X_{5}	1.382	-2.015	-0.013	0.054	0.013	-0.041	0.074	-0.329
X_{6}	-1.506	0.523	-0.005	-0.014	-0.059	0.027	-0.030	-0.231
X_{7}	-1.664	0.117	-0.007	-0.096	-0.204	-0.023	0.033	0.142
X_{8}	-1.544	-2.197	-0.028	-0.016	0.016	0.002	0.027	-2.410
X_{9}	-0.500	0.417	-0.005	0.202	0.014	-0.039	0.022	0.464
X_{10}	0.902	-0.828	-0.005	-0.056	0.000	0.043	-0.068	-1.487
X_{11}	**-4.210**	2.741	-0.003	-0.067	-0.011	-0.018	0.011	0.453
X_{12}	2.619	**-4.406**	-0.022	`0.059	0.021	0.017	0.014	-2.311
X_{13}	0.160	1.437	**-0.066**	0.107	-0.049	-0.032	-0.003	1.020
X_{14}	0.468	-0.425	0.012	**0.607**	-0.047	-0.045	0.042	1.417
X_{15}	0.125	-0.237	-0.008	-0.074	**0.388**	0.010	0.007	-1.547
X_{16}	0.498	-0.500	-0.014	-0.179	0.025	**0.153**	-0.063	-4.971
X_{17}	-0.611	-0.820	-0.002	0.342	0.038	-0.131	**0.074**	3.037
X_{18}	0.245	-1.310	-0.009	-0.111	0.007	0.098	-0.029	**-7.772**
X_{19}	1.069	-0.063	0.006	-0.113	0.068	0.009	-0.044	-6.557

Bold figures represents direct effects. Residual effect = 0.0452.

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

X_{19}	Total correlation with grain yield
3.604	0.560 **
-1.842	-0.242*
-1.685	-0.442**
-0.155	-0.329 **
-0.570	-0.472 **
-0.731	0.084
-1.716	-0.399 **
-1.773	-0.151
-0.483	-0.250 *
1.211	0.058
-1.849	-0.061
0.104	-0.055
0.710	0.115
-1.356	-0.065
1.286	0.231 *
4.694	0.355 **
-4.301	- 0.260 **
6.143	0.222 *
7.282	0.339 **

Where,

X_1. = No. of days to panicle initiation

X_2 = No. of days to 50% flowering

X_3 = Height of plant at harvest

X_4 = No. of panicle bearing tillers

X_5 = No. of panicles/m²

X_6 = Length of panicle

X_7 = Thousand grain weight

X_8 = Kernel length before cooking

X_9 = Awnness

X_{10} = pH of raw grain

X_{11} = Kernel breadth

X_{12} = L/B Ratio

X_{13} = Kernel appearance

X_{14} = Taste

X_{15} = Aroma

X_{16} = Elongation

X_{17} = Alkali value

X_{18} = Kernel elongation after cooking

X_{19} = Elongation ratio.

by L/B ratio (-4.406). The least positive direct effect is shown by pH of raw grain (0.056) followed by kernel appearance (0.066) and its least negative effect is for number of panicle bearing tillers (-0.001) followed by number of panicles/m^2 (-0.106).

Highly significant positive correlation between number of days to panicle initiation and grain yield (0.560) was resulted from high indirect effect of elongation ratio (3.604) and slightly higher direct effect (0.988) as grain yield. The high significant positive genotypic correlation of elongation and yield mainly due to the high indirect effect of elongation ratio (4.694). The high significant positive correlation of elongation ratio (0.339) is due to its direct effect (7.282) of that character.

4.5 SELECTION INDEX.

Selection index through discriminant function analysis was fitted to asertain the extent of contribution of each factor towards grain yield, and also to predict the grain yield based on the phenotypic performance of the selected characters, namely grain yield , number of days to panicle initiation, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, thousand grain weight, elongation, alkali value and elongation ratio.

The characters were selected based on the genotypic correlations, direct and indirect effects on grain yield and requisite Basmati quality parameters. The discriminant functions for the different combinations are presented in Table 12. Table 13 gives the genetic advance through various combinations, its efficiency over direct selection. Maximum efficiency over direct selection was for the selection index constituting nine characters namely yield, number of days to panicle initiation, height of plant at harvest, number of panicles/m^2, number of panicle bearing tillers, thousand grain weight, elongation, alkali value and elongation ratio, and its gain in efficiency was 56.3%. Though the gain in efficiency was slightly lower 51.87%, the selection index constituting the charecters was also promising since it included only five

Table 12 Discriminant function for nine different character combinations

Sl. No.	Combinations	Discriminant function
1.	y, x_1, x_4, x_8	$0.184y + 38.774\ x_1 - 1.131\ x_4 + 65.397\ x_8$
2.	y, x_1, x_2, x_4, x_8	$0.187\ y + 31.399\ x_1 - 3.076\ x_2 - 1.082\ x_4 + 59.485\ x_8$
3.	$y, x_1, x_2, x_4, x_7, x_8$	$0.190\ y + 31.600\ x_1 - 3.126\ x_2 - 1.191\ x_4 + 39.412\ x_7 + 84.686\ x_8$
4.	y, x_1, x_4, x_5, x_8	$0.187\ y + 36.114\ x_1 - 1.090\ x_2 - 12.173\ x_5 + 57.382\ x_8$
5.	y, x_1, x_2, x_8	$0.193\ y + 28.859\ x_1 + 3.495\ x_2 + 92.757\ x_8$
6.	y, x_1, x_8	$0.191\ y + 39.160\ x_1 + 103.352\ x_8$
7.	$y, x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8$	$0.180\ y + 32.880\ x_1 - 2.739\ x_2 + 11.328\ x_3 - 1.342\ x_4 - 5.560\ x_5 + 88.010\ x_6 + 45.824\ x_7 - 65{,}761\ x_8$
	Direct Selection	0.254 (y)

y = yield
x_1 = No. of days to panicle initiation
x_2 = Height of plant at harvest
x_3 = No. of panicle bearing tillers
x_4 = No. of panicles/m^2
x_5 = 1000-grain weight
x_6 = Elongation
x_7 = Alkali value
x_8 = Elongation ratio

Table 13 Genetic advance through selection index, efficiency of selection for different character combinations

Sl. No.	Combinations	Genetic Advance through Selection Index	Efficiency over Direct Selection	Gain in efficiency (%)
1.	y, x_1, x_4, x_8	166.794	1.472	47.28
2.	y, x_1, x_2, x_4, x_8	171.987	1.518	51.87
3.	$y, x_1, x_2, x_4, x_7, x_8$	173.856	1.535	53.52
4.	y, x_1, x_4, x_5, x_8	169.154	1.493	49.36
5.	y, x_1, x_2, x_8	155.916	1.376	37.67
6.	y, x_1, x_8	148.404	1.310	31.04
7.	$y, x_1, x_2, x_4, x_5, x_6, x_7, x_8$	177.011	1.563	56.30
	Genetic Advance through Direct Selection	113.246	1.000	

y = yield
x_1 = No. of days to panicle initiation
x_2 = Height of plant at harvest
x_3 = No. of panicle bearing tillers
x_4 = No. of panicles/m^2
x_5 = 1000-grain weight
x_6 = Elongation
x_7 = Alkali value
x_8 = Elongation ratio

characters namely yield, number days to panicle initiation, height of plant at harvest, number of panicles/m^2 and elongation ratio. The genetic advance of the above two combinations of selection index was 177.01 and 171.987 respectively, where as genetic advance through yield alone was 113.246.

Estimates of selection index using characters namely yield alone, yield and number of days to panicle initiation, number of panicles/m^2, elongation ratio, yield and number of days to panicle initiation, height of plant at harvest, number of panicles/ m^2, elongaton ratio, yield and number of days to panicle initiation, height of plant at harvest, number of panicles/m^2, alkali value, elongation ratio and the ranking given to the genotypes according to these selection index and yield and yield alone are given in Table 14 and 15. Based on the above discriminant functions genotype Basmati culture 385 secured first rank in both selection index and yield.

Genotype UPR-BS-92-4 which got second rank in all the selection indices has got only seventh rank based on direct selection(yield). The variety Pusa Basmati which got second rank based on yield alone got third rank in selection index based on six characters, fourth rank based on four characters and third rank for selection index based on five characters. The genotype IET NO 13551 obtained third rank in the ranking according to yield alone, but it was pushed down to 28th rank in the ranking based on six characters, 27th in rank based on five characters and 14th rank based on four characters. The third rank secured by Pusa Basmati in the ranking according to two indices i.e. based on five and six characters was just pushed down to fourth position in the slection index based on four characters.

Ranks were also given to the genotypes V_1-V_{38} based on the above selection index and yield. The mean values of 32 characters of 38 genotypes of Basmati rice are presented in Appendix **i**. D^2 values considering all the 32 characters simultaneously for 38 genotypes are given in Appendix **ii**.

Table 14

Estimation of selection index using characters grain yield, no.of days to panicle initiation, number of panicles/m² and elongation ratio.				Estimation of selection index using characters grain yield, no.of days to panicle initiation, height of plant at harvest,number of panicles/m² and elongation ratio.			
		Rank According to				Rank According to	
Geno-types	Selection Index	Selection Index	Yield	Geno-types	Selection Index	Selection Index	Yield
37	3083.41	1	1	37	2240.688	1	1
29	3034.894	2	7	29	2181.885	2	7
30	3034.197	3	11	36	2168.589	3	2
36	2985.383	4	2	30	2166.380	4	11
35	2940.938	5	5	35	2062.628	5	5
25	2875.51	6	23	1	2058.228	6	4
1	2873.151	7	4	38	2025.517	7	6
11	2846.449	8	29	11	2006.469	8	29
38	2834.451	9	6	25	1988.627	9	23
21	2802.952	10	8	21	1964.217	10	8
33	2766.406	11	31	23	1937.814	11	9
23	2754.81	12	9	33	1934.728	12	31
28	2726.459	13	12	2	1906.305	13	10
5	2725.293	14	3	19	1897.862	14	14
32	2715.746	15	18	27	1893.090	15	28
24	2703.288	16	13	24	1889.514	16	13
4	2689.784	17	22	22	1867.830	17	19
7	2688.053	18	16	31	1860.481	18	25
34	2679.416	19	37	17	1859.662	19	20
31	2677.372	20	25	28	1854.096	20	12
2	2676.466	21	10	32	1853.597	21	18
22	2674.964	22	19	14	1847.847	22	21
19	2673.096	23	14	4	1847.112	23	22
26	26663.608	24	15	34	1840.482	24	37
27	2662.845	25	28	26	1826.777	25	15
14	2661.324	26	21	3	1809.158	26	17
17	2650.595	27	20	5	1795.274	27	3
20	2648.466	28	24	20	1794.844	28	24
3	2614.207	29	17	18	1785.505	29	33
16	2611.973	30	27	7	1771.579	30	16
6	2603.475	31	30	16	1757.827	31	27
18	2586.200	32	33	8	1721.456	32	34
8	2576.988	33	34	6	1703.492	33	30
9	2525.669	34	35	12	1673.529	34	38
13	2519.813	35	32	9	1666.955	35	35
12	2513.402	36	38	13	1622.003	36	32
10	2500.574	37	26	10	1619.464	37	26
15	2442.989	38	36	15	1539.317	38	36
Efficiency over direct selection = 47.28 %				Efficiency over direct selection = 51.87 %			

Table 15

Estimation of selection index using characters grain yield, no.of days to panicle initiation, height of plant at harvest,number of panicles/m², alkali value and elongation ratio.

		Rank According to	
Genotypes	Selection Index	Selection Index	Yield
37	2457.844	1	1
29	2417.982	2	7
36	2408.587	3	2
30	2373.137	4	11
35	2290.246	5	5
1	2285.13	6	4
11	2235.706	7	29
38	2226.917	8	6
25	2194.501	9	23
23	2150.465	10	9
21	2142.2227	11	8
27	2130.348	12	28
33	2129.683	13	31
19	2124.485	14	14
24	2120.817	15	13
2	2116.637	16	10
17	2089.337	17	20
22	2084.450	18	19
28	2082.974	19	12
4	2080.078	20	22
14	2079.954	21	21
26	2055.184	22	15
31	2051.818	23	25
32	2042.607	24	18
34	2039.624	25	37
3	2034.510	26	17
20	2023.435	27	24
5	2021.036	28	3
18	2012.84	29	33
7	2001.656	30	16
16	1983.326	31	27
6	1929.253	32	30
12	1900.761	33	38
9	1879.365	34	35
13	1844.399	35	32
10	1831.971	36	26
15	1753.521	37	36
8	1747.831	38	34

Efficiency over direct selection = 53.52 %

Ranking based on yield

Genotypes	Yield	Rank
37	2294.500	1
36	2263.500	2
5	2240.533	3
1	2159.000	4
35	2094.133	5
38	2070.333	6
29	2043.333	7
21	2016.833	8
23	2002.333	9
2	2000.933	10
30	1982.800	11
28	1919.000	12
24	1913.333	13
19	1896.133	14
26	1847.000	15
7	1769.233	16
3	1767.833	17
32	1745.500	18
22	1703.533	19
17	1674.400	20
14	1669.500	21
4	1668.833	22
25	1655.433	23
20	1617.767	24
31	1548.833	25
10	1538.400	26
16	1536.100	27
27	1442.333	28
11	1436.833	29
6	1419.333	30
33	1405.300	31
13	1401.900	32
18	1399.400	33
8	1377.033	34
9	1291.533	35
15	1268.467	36
34	1197.600	37
12	1141.533	38

Discussion

5. DISCUSSION

The basic information which a breeder usually requires as a pre-requisite to any breeding programme of a particular crop species is the extent of variability present in the available germplasm. Information on heritability and estimates of that could be obtained in the next cycle of selection are of vital importance to the breeder in deciding the appropriate method of breeding.

The importance of genetic diversity of parents in hybridization programme has been emphasized by many workers. The more diverse the parents within a reasonable range the more would be the chances of improving the characters in question. Mahalanobis D^2 statistic has been found to be a powerful tool in the hands of plant breeder to assess the degree of dissimilarity among the genotypes and to group them based on their phenotypic expression.

A knowledge on the degree of association among the quantitative and qualitative characters would help the breeder to pinpoint a character or character set based on which selection of genotypes would result in an overall progress of the selected genotypes over the base material with respect to the character or characters. The association analysis based on correlation coefficients of components with yield will not give a true picture of the relative merits or demerits of each of the component to final yield, coupled with quality. Hence an assessment of the merit of each character by examining the direct and indirect effects of the same towards final yield coupled with quality is of immence value for the final selection.

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

Even with the introduction of high yielding rice varieties in the rice farming scenario, Kerala farmers are finding it difficult to make rice farming profitable. One of the main problems is the lesser returns from grain yield sold at a relatively low price. But there are other rice types like scented/ Basmati rice which are getting 3-4 times higher unit value than the ordinary rice varieties. These basmati rice varieties also offer a high yield potential. Neverthless, because of the non adaptability of these varieties in Kerala rice farming ecosystem, the cultivation of Basmati rice is not yet popular. With the incorporation of high yielding short duration genetic background to Basmati rice many of the Basmati derived cultivars became adaptable to Kerala rice farming ecosystem. But a scientific and systematic evaluation of these materials is a pre-requisite for selection of suitable ones, if any, to Kerala conditions and to derive the background genetic informations for their further improvement.

Thus the objectives and methodology of the present investigations which basically deal with obtaining the relevant genetic information as a prerequisite for production and quality breeding programme in a number of Basmati rice genotypes are fully justified. The results obtained are discussed in the following pages.

5.1 Variability

The 38 Basmati rice genotypes were significantly different for 28 characters at 1% level out of 32 characters studied namely number of days to panicle initiation, number of days to 50% flowering, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, number of spikelets/panicle, length of panicle, thousand grain weight, kernel length before cooking, awnness, pubescence, pH of raw grain, number of grains/panicle, kernel breadth, L/B ratio, kernel appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation, overall acceptability, amylose content, milling percent, hulling percent, elongation ratio and yield and at 5% level for the remaining four characters viz., total number of tillers, number of days to harvest, alkali value and kernel elongation after cooking.

Of the various estimates of quantitative variability mean, range and coefficient of variation are the basic ones. Success in genetic improvement of a crop would. to a large extent depend upon a wide genetic base resulting in a wider genetic variability. In the present investigation it is seen that the range of variation for the characters is high for 14 characters namely height of plant at harvest (48.56%), total numbers of tillers (46.15%), number of panicle bearing tillers (75%), number of panicles/ m^2(75.16%), number of spikelets/panicle (90.69%), pubescence(56.29%). awnness(188.13%), number of grains/panicle(87.25%), aroma(40.25%), overall acceptability(45.28%), amylose content(46.34%), kernel elongation after cooking(43.24%), elongation ratio(120.60%) and yield (66.97%). This indicated the presence of enough variability in the population under study. Percentage of magnitude of range over mean for significantly correlated characters with yield are shown in Fig. 1 and variation in kernel size is shown in Plate 1. The investigations of De *et al* (1988). Sarangi *et al* (1994) and Patra and Dhua (1996) in scented rice have also shown that a wide range of variation was present for most of the characters considered in Basmati rice crop.

More than the total observed variation, it is the nature of variation which is more important. The total variation can be divided into the heritable and non heritable components. Variance estimates in the present study have indicated the influence of both genetic and environmental factors. High magnitude of PCV and GCV for quantitative characters namely, number of panicle bearing tillers, number of panicle/ m^2, elongation ratio and yield and qualitative character awnness indicates the existence of large variability and scope of genetic improvement of these traits through

X_1	=	No. of days to panicle initiation
X_2	=	No. of days to 50 % flowering
X_3	=	Height of plant at harvest
X_4	=	No. of panicle bearing tillers
X_5	=	No. of panicles /m^2
X_6	=	Thousand grain weight
X_7	=	Awnness
X_8	=	Aroma
X_9	=	Elongation
X_{10}	=	Alkali value
X_{11}	=	Kernel elongation after cooking
X_{12}	=	Elongation ratio
Y	=	Grain yield/ha.

Fig.1. RANGE EXPRESSED AS PERCENTAGE OF MEAN OF 13 CHARACTERS IN BASMATI RICE

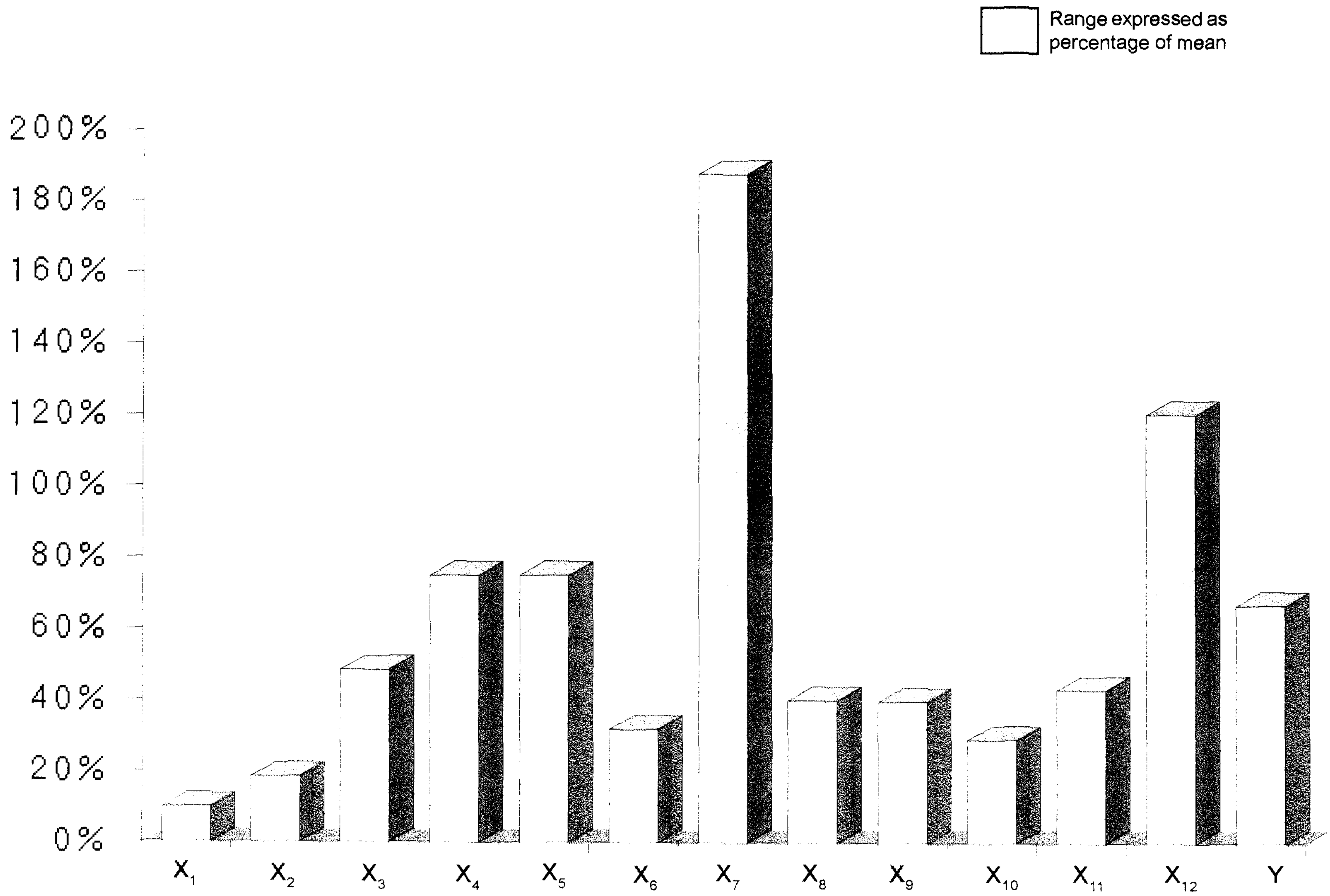
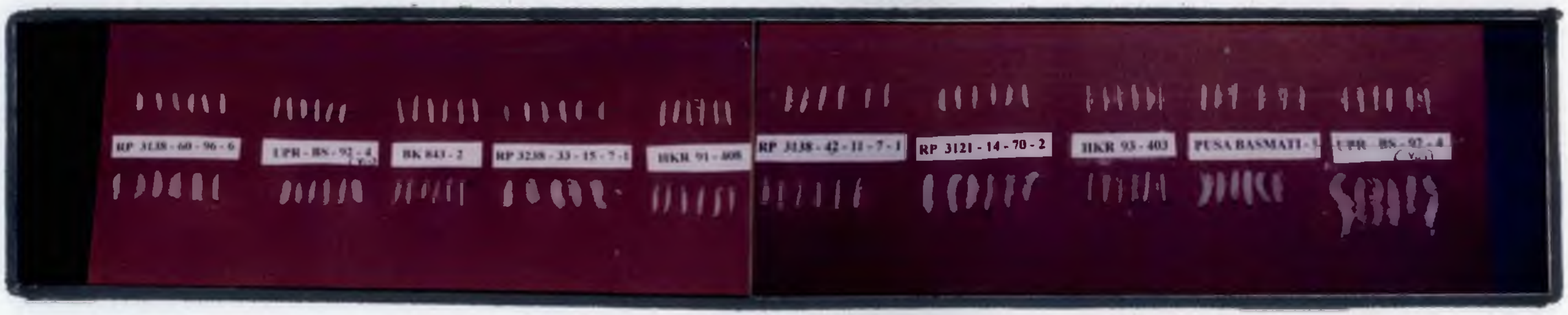


Plate 1 Variation in kernel size of Basmati rice genotypes


RP 3138 - 60 - 96 - 6
UPR - BS - 92 - 4
BK 843 - 2
RP 3238 - 33 - 15 - 7 - 1
HKR 91 - 408
RP 3138 - 42 - 11 - 7 - 1
RP 3121 - 14 - 70 - 2
HKR 93 - 403
PUSA BASMATI - 1
UPR - BS - 92 - 4

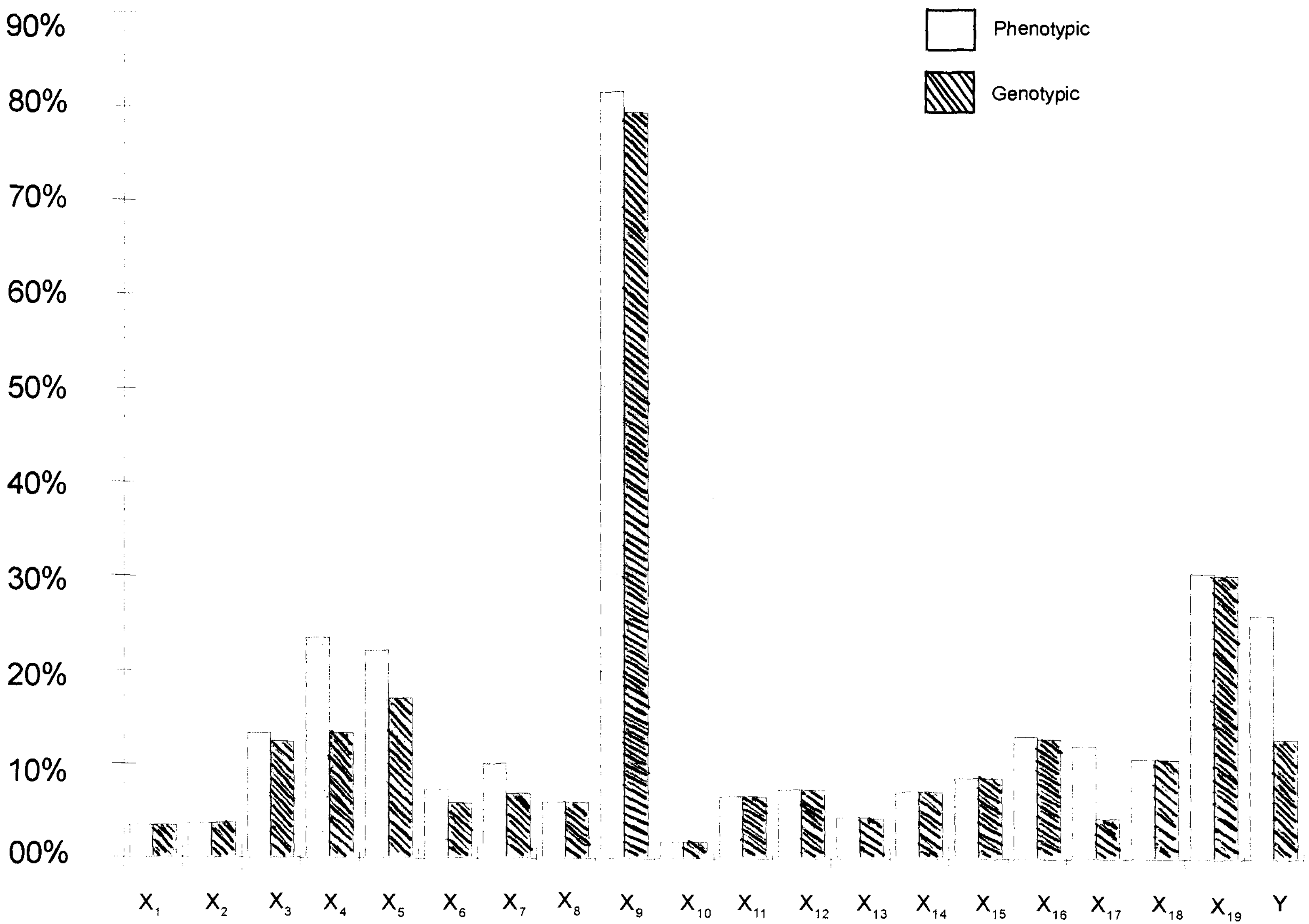
selection(Fig.2). Similar results were also obtained by Shamsuddin (1982), Sarma and Roy (1993) and Sawant and Patil (1995). Moderate level of variability for quantitative characters namely height of plant at harvest and 1000 grain weight and for qualitative traits like elongation and alkali value indicates the usefulness of these characters in rice improvement programme. Slightly deviating from this results, Sarangi *et al.* (1994) reported high variability for quantitative characters namely number of days to panicle initiation, number of days to 50 per cent flowering, length of panicle, L/B ratio and for qualitative characters through selection. Considerable influence of environmental factors were observed in the case of number of panicle bearing tillers, number of panicle/m^2, alkali value and yield/ha, as these characters showed high PCV than GCV. Closeness between PCV and GCV observed in developmental characters like number of days to panicle initiation, number of days to 50 per cent flowering, length of panicles and for all qualitative characters except for alkali spreading value, suggested that these characters might be less influenced by environmental factors reported by Maurya *et al.* (1986).

5.2 Heritability

Twenty characters were selected based on its effect on grain yield and relevance to quality aspects of Basmati rice for further studies. Among the qualitative characters pH of raw grain (1.00), L/B ratio (1.00), kernel breadth (1.00), followed by taste (0.998) showed the maximum heritability that can be obtained for any character indicating lack of influence of environment on them. Heritability of other qualitative characters like kernel length before cooking (0.989), kernel appearance(90.974), elongation (0.960), kernel length after cooking (0.996), elongation ratio (0.987) also showed the same trend. Heritability of quantitative characters viz., number of days to 50% flowering (1.00) and number of days to panicle initiation (0.980) also had little effect of environment in the expression of character. It is also an indicatiion of very few or monogenic effect in its expression. The heritability of other characters like height of plant at harvest (0.871) and length of panicle (0.634) also showed high heritability. The yield which is a complicated character showed very low heritability (0.245) where as another important quality character namely alkali value showed the least heritability (0.130).Kumar *et al.* (1994), Sarawgi and Soni (1994) and Mishra *et al.* (1996) showed similar type of results in their studies.

X_1	=	No. of days to panicle initiation
X_2	=	No. of days to 50 % flowering
X_3	=	Height of plant at harvest
X_4	=	No. of panicle bearing tillers
X_5	=	No. of panicles /m^2
X_6	=	Length of panicle
X_7	=	Thousand grain weight
X_8	=	Kernel length before cooking
X_9	=	Awnness
X_{10}	=	pH of raw grain
X_{11}	=	Kernel breadth
X_{12}	=	L/B ratio
X_{13}	=	Kernel appearance
X_{14}	=	Taste Grain yield/ha.
X_{15}	=	Aroma
X_{16}	=	elongation
X_{17}	=	Alkali value
X_{18}	=	Kernel elongation after cooking
X_{19}	=	Elongation ratio
Y	=	Grain yield/ha

Fig.2 PHENOTYPIC AND GENOTYPIC COEFFICIENT OF VARIATION OF TWENTY CHARACTERS IN BASMATI RICE



5.3 Genetic advance and genetic gain

The heritability indicates only the effectiveness with which selection of genotype can be bared on the phenotypic performance, but fails to show the genetic progress (Johanson *et al.*,1955). High heritability does not, therefore, necessarily mean greatest genetic gain. Genetic advance as the per cent of mean was calculated inorder to ascertain the relative utility of genetic gain. High genetic gain is expected from characters namely, height of plant at harvest, number of panicles/m^2, awnness, kernel length after cooking and elongation ratio. Reddy (1992),Sarma and Roy (1993), Singh *et al.* (1993) and Sawant and Patil (1995) supports the study. The expected genetic gain is moderate in the case of kernel length before cooking, kernel breadth, L/B ratio, taste, aroma and grain yield/ha. This is an agreement with the results of Alfonso *et al.* (1988), Vishwakarma *et al.* (1989) and Kumar *et al.* (1994).

5.4 Genetic divergence among the Basmati rice genotypes.

One of the main objectives of the present investigation is to assess the genetic diversity among the genotypes of Basmati rice and to group them into clusters based on the genetic distance. On the basis of genetic distance computed with reference to twenty economically important characters the 38 genotypes of Basmati rice could be grouped into seven clusters.

The distribution of genotypes into various clusters showed no regularity. Cluster I and II contain twelve genotypes each, while cluster III include five genotypes, cluster IV and V have three genotypes each, cluster VI is with two genotypes and the cluster VII contain only one genotype. Such irregular pattern of distribution has been reported by Buu and Tuan (1989), Sinha *et al.* (1991), Roy and Panwar (1993) and Sarangi *et al* (1994). It is interesting to note that the clustering pattern did not follow the source of parental cross combinations. The segregants of same cross combinations were grouped into different clusters. V_5 and V_6 were evolved from same parental cross combination IET 7313/ HBC 143, but they were grouped into cluster I and II respectively. V_7 and V_8 were evolved from HAUS-298-2/Pusa167 and grouped into cluster I and II respectively. Similarly V_9 and V_{10} both evolved from IET 10364/ Local Basmati were grouped into cluster I and cluster IV respectively. Similarly V_{15}, V_{16}, V_{17}, V_{18}, V_{21}, V_{22}, V_{23}, V_{28} all evolved from the cross combination of Pusa Basmati-1/ Phalguna were grouped into different clusters, V_{15}, V_{21} and V_{22} into cluster III, V_{16} into cluster IV, V_{17} into cluster I, V_{23} and V_{28} into cluster II and V_{18} formed the single membered cluster, cluster VII. V_{30}, V_{31}, V_{32} all were evolved from IR 50/ Tarori Basmati but were grouped into three different clusters namely cluster III, cluster II and cluster I respectively. V_{33} and V34 were evolved from BR 4-10/ PAK Basmati but grouped into clusters V and cluster II respectively. Similarly V_{37} and V_{38} evolved from Punjab Basmati were grouped into cluster V and cluster VI respectively.

The seeds collected from Agricultural Research Station, Mannuthy and that received from Directorate of Rice Research, Hyderabad showed some differences in the case of Pusa Basmati ,V_3 and V_{26}; V_{20} and V_{27} ; V_{22} and V_{28} i.e., they were grouped into adjacent clusters- cluster V and cluster VI; cluster II and III ; cluster I and II ; cluster II and III respectively. This indicated some instability in the expression of characters, when source of origin differed, which may be due to variation in the quality traits. But with respect to Tarori Basmati the source of seed collection has no influence in the clustering pattern and they were grouped in the same cluster (V_{35} and V_{24}) The segregants of different parental combinations are grouped into same cluster. In cluster I all the 12 varieties are of different parental combinations (V_5, V_7, V_{11}, V_{12}, V_{17}, V_{20} and V_{32}) except the two pairs V_{24}, V_{35}, and V_{13} - V_{14} which are Tarori Basmati and HKR 118/Karnal local respectively. Similarly all the varieties of cluster II, IV, V, VI which are the segregants of different parental combinations are grouped under the same cluster.

Among the seven clusters studied cluster VI showed highest mean value for many of the desirable characters like yield, elongation ratio, kernel length after cooking, overall acceptability, elongation, second in aroma, number of panicles/ m^2, number of panicle bearing tillers, shortest in height of plant and highest in the number of days to panicle initiation.

Cluster VII attributed for generally low values for desirable attributes like yield , kernel appearance, amylose content, elongation ratio etc. Rest of the clusters are intermediary in position in many of the characters.

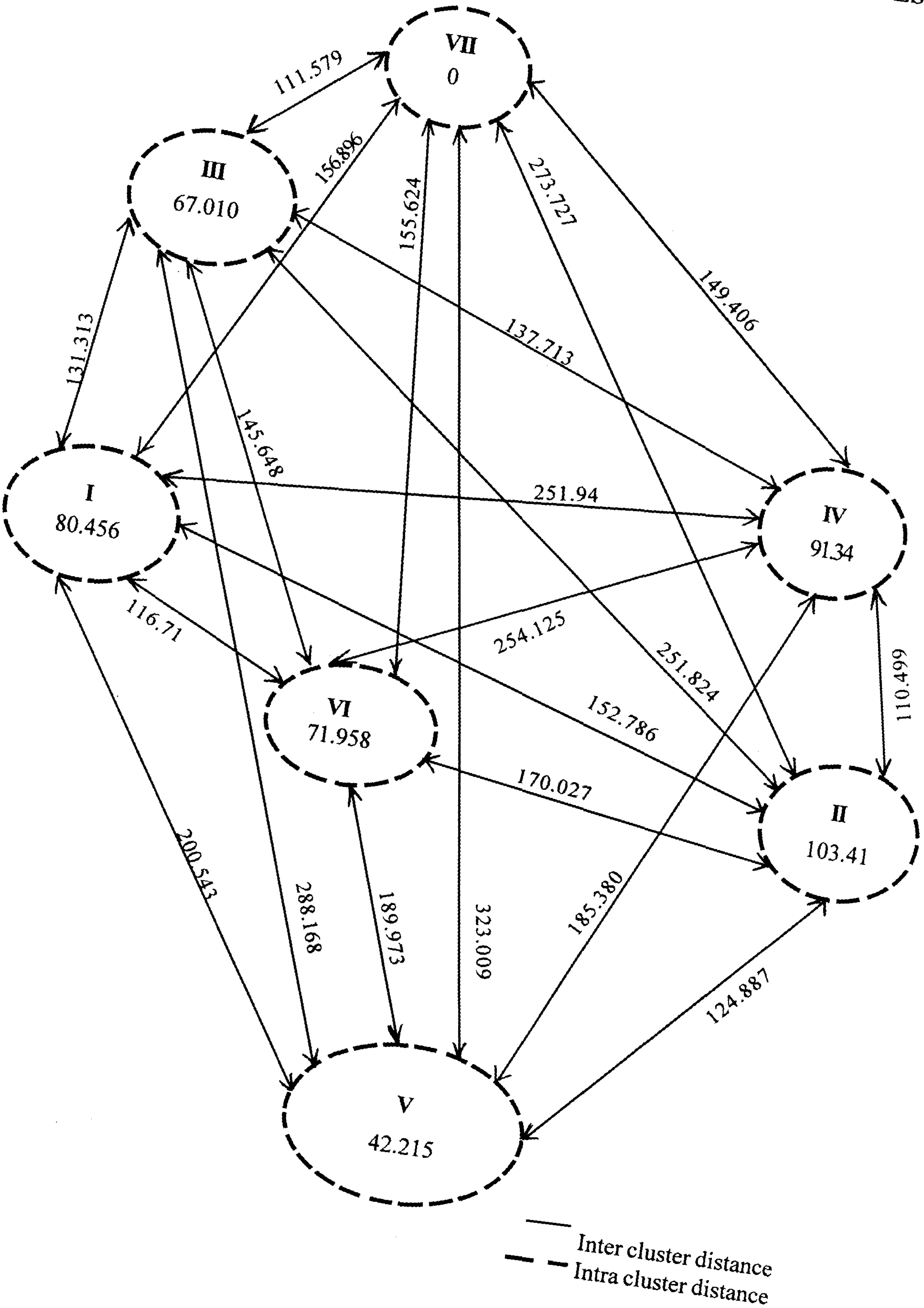
D^2 and D values presented in Table 7 and Table 8 have indicated that minimum distance was between cluster II and IV (110.49) and maximum between cluster V and VII (323.009). The highest intra distance showing in cluster II (103.41) followed by cluster IV (91.34) indicates that variability still exist in those clusters compared to other clusters.

Cluster V comparatively kept the maximum genetic distance from rest of the clusters. A cluster diagram showing all the seven clusters along with their inter cluster distances is furnished in Fig. 3 . This diagram gives an overall picture of the distribution of the seven clusters. It is also seen that cluster I, III, IV are relatively close while cluster II, IV, VII are distant between themselves and also from the rest.

5.5 Correlation Studies

Yield in any crop is a complex character determined by a number of genetic factors and environmental conditions occurring at the various stages of growth of the plant. Investigation on this trait is more complicated while it is linked with qualitative traits. Hence selection for grain yield coupled with indispensable Basmati qualitative traits, merely on the basis of its phenotypic expression is likely to give misleading results. A more rational approach to the improvement of grain yield and quality would therefore need to have some knowledge on the association between different yield components and their relative contributions to the final grain yield and its quality.

Fig.3 CLUSTER DIAGRAM OF 38 BASMATI GENOTYPES



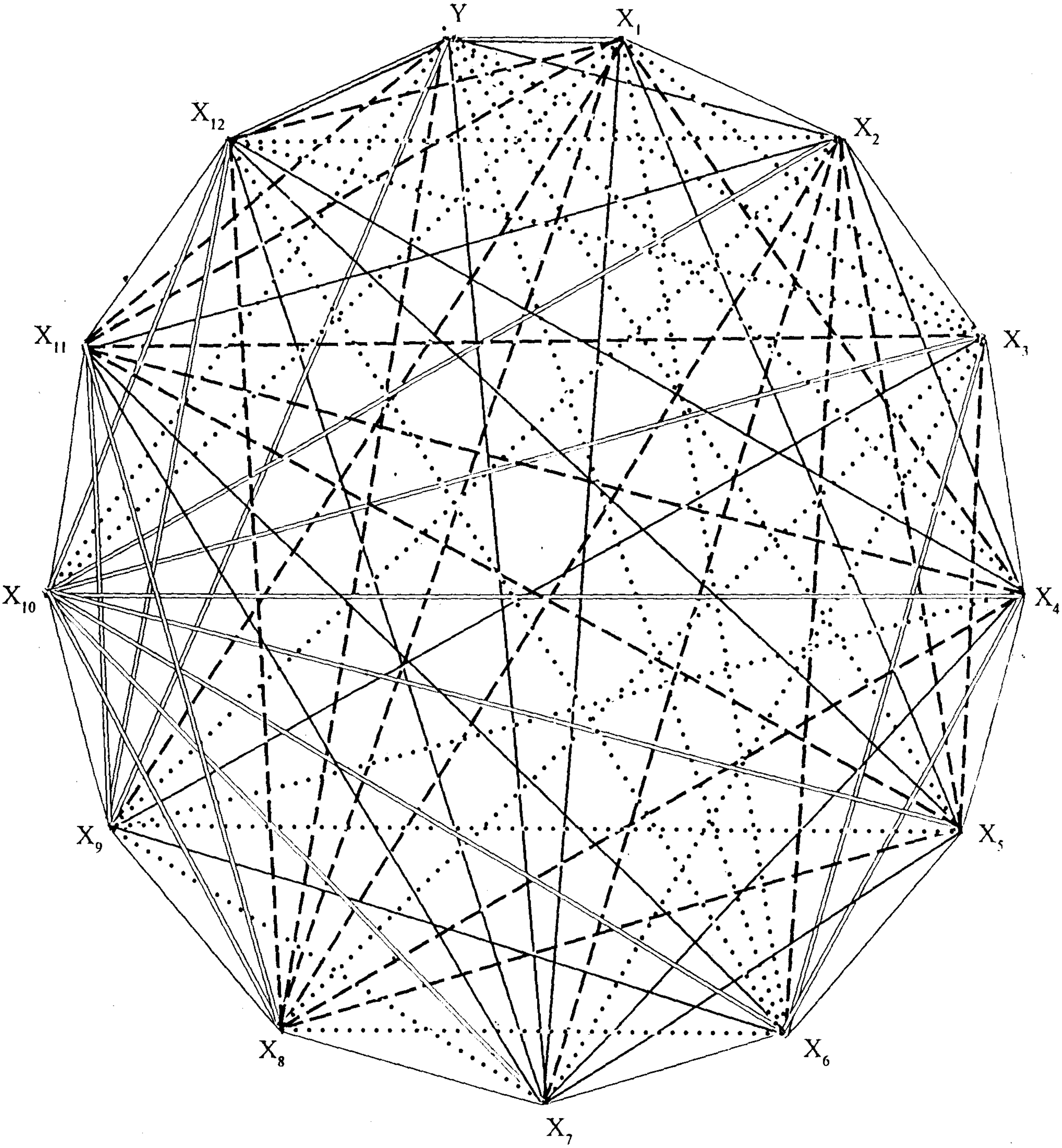
A knowledge of such relationship is essential if selection for the simultaneous improvement of yield components and qualitative traits is to be made effective. For this purpose a simple correlation study seems to be inadequate to measure the association , since different genotypes are susceptible to environments in varying degrees. Robinson *et al.* (1951) have pointed out the usefulness of phenotypic and genotypic correlation in crop improvement programme. Genotypic correlation coefficient provide a measure of the degree of genotypic association between the characters and reveal such of those useful for consideration. With this objective in mind the phenotypic and genotypic correlation coefficient of the yield and 19 of its selected components including quantitative traits and their inter correlations among them were worked out.

The results have shown that twelve out of nineteen traits had significant positive correlation with grain yield at genotypic level and only one at the phenotypic level. Genotypic correlation among different characters are shown in Fig.4. Out of the twelves significant genotypic correlation between the component characters and grain yield half of them are qualitative traits. Among the six quantitative yield attributes the characters except the number of days to panicle initiation (0.560) all others are negatively correlated to grain yield. The yield attributes, number of days to panicle initiation is an indication of vegetative phase, thereby an increase in the duration of vegetative phase will have a corresponding increase in yield. A decrease in the duration of number of days to 50% flowering (-0.242, i.e., short duration) dwarf plant type (-0.442), lesser number of panicle bearing tillers (-0.329), corresponding lesser number of panicles/m^2 (-0.399) and comparatively lesser grain weight (-0.472) will have an effect of increasing grain yield. Amirthadevarathinam,(1983). Gravois and Mc new, (1993) supports the same.

With regards to its qualitative characters an increase in aroma (0.231) with elongated kernel both at pre and post cooking (0.222) has a trend for increasing grain yield. A lesser awnness (-0.250) and alkali value (-0.260) is an indicative of higher grain yield. The results of Malik (1989), is a supporting study.

X_1	=	No. of days to panicle initiation
X_2	=	No. of days to 50 % flowering
X_3	=	Height of plant at harvest
X_4	=	No. of panicle bearing tillers
X_5	=	No. of panicles /m^2
X_6	=	Thousand grain weight
X_7	=	Awnness
X_8	=	Aroma
X_9	=	Elongation
X_{10}	=	Alkali value
X_{11}	=	Kernel elongation after cooking
X_{12}	=	Elongation ratio
Y	=	Grain yield/ha

Fig.4 GENOTYPIC CORRELATIONS AMONG DIFFERENT CHARACTERS IN BASMATI RICE



...... significant negative correlation

—— negative correlation

—— positive correlation

═══ significant positive correlation

The association of yield with its components through simple correlation alone is not adequate for any selection programme. A knowledge about their inter relationship is also needed. Doku (1970) based on his work in cowpea has suggested that intercorrelation among yield components should be estimated since in actual breeding programme rate of improvement in one component might or might not result improvement of other components. The estimates of inter correlations for the yield components in the present study have revealed that out of 190 inter correlations estimated 63 at the phenotypic level and 89 at the genotypic level were significant.

The highest significant positive genotypic correlation of yield was with number of days to panicle initiation. This was followed by elongation and elongation ratio. Significant negative correlations were expressed by number of days to 50 per cent flowering, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, thousand grain weight and alkali values. This reveals that improvement in grain yield per hectare could be achieved by exercising selection simultaneously for prolonged number of days to panicle initiation, increased kernel elongation increased elongation ratio and reduced height of plant (dwarf plant type), panicle bearing tillers, number of panicles/m^2, thousand grain weight and alkali spreading value. Lu *et al.* (1988), Panwar *et al.* (1989) Paramasivan and Rangasamy (1988) and Dhanraj *et al.* (1987) give supportive results.

The high degree of significant positive association both at phenotypic and genotypic levels between number of days to panicle initiation and grain yield suggest that number of days to panicle initiation is a highly reliable component of yield. Zheng and Wang (1988) supports the study. The negative influence of days to 50 per cent flowering and positive influence of days to panicle initiation reveal the negative influence of days from panicle initiation to 50 per cent flowering. This also suggests that while making selections for yield one must go for varieties which have less time span between panicle initiation and 50 per cent flowering.

There is significant positive correlation between elongation ratio and kernel elongation after cooking and strong negative correlation between elongation ratio and kernel breadth. So during selection we must go for higher elongation ratio with reduced kernel breadth. The strong negative correlation of height of plant at harvest with grain yield, suggest the possibility of developing high yielding genotypes coupled with dwarf plant type. The strong negative correlations of number of panicle bearing tillers and number of panicles/m^2 with grain yield suggest the possibility of developing high yielding genotypes with lesser number of panicle bearing tillers and reduced number of panicles/ m^2, but with optimum grain weight. The strong negative correlation between alkali value with grain yield suggests that while selection varieties with lesser alkali value should be selected. The correlation of 1000 grain weight to panicles/m^2 and final yield was negative, while the correlation between panicles/m^2 and yield was also negative. This points to the fact that while selecting for yield we should go for an optimum level of grain weight.

Inter correlations among yield components revealed that heavy selection pressure on number of days to panicle initiation would bring forth correlated response for desirable characters such as short stature of plant, short panicle, optimum grain weight, reduced kernel length and breadth before cooking, a little reduction in taste, low alkali value and high kernel elongation ratio. The positive significant correlations between kernel elongation ratio and kernel elongation after cooking and number of days to panicle initiation indicate that for genotypes with long vegetative phase will have more kernel elongation on cooking and hence high elongation ratio. Elongation ratio has no association with L/B ratio. Malik (1989) supports the study. The significant negative correlations of yield reducing characters alkali value and kernel breadth with kernel elongation ratio indicate that for high yielding genotypes with high kernel elongation ratio, alkali value and kernel breadth will be low. The negative trend of height at harvest with yield and its positive association with yield reducing character 1000 grain weight along with negative association with yield attributes, number of days to panicle initiation indicate that while selecting for higher yield one must go for semidwarf plant type. The positive significant correlation between number of panicles/ m^2 and number of panicle bearing tillers, L/B ratio of grain and alkali value indicate that for slender grained genotypes there will be more number of panicles/m^2, more numbering of panicle bearing tillers and high alkali value. Since alkali value is a yield reducing characters, it should be made optimum during selection. Intercorrelations of panicle length with others yield components reveal that when panicle length with others yield components reveal that when panicle length increases vegetative phase of the plant decreases which has significant positive correlation with yield height of the plant and alkali value are increased which have negative significant correlation with yield. Significant yield reducing attributes like number of panicle bearing tillers and panicles/m^2 are reduced by increasing panicle length. Hence, eventhough panicle length had no direct significant correlation with yield it has significant indirect influence on yield.

From the intercorrelation studies of aroma with other yield component it is very clear that short statured varieties have strong aroma with lesser thousand grain weight. With respect to awnness, fully awned varieties will have lesser 1000 grain weight, good taste, high alkali spreading value and will take more days for 50 per cent flowering. Similarly from the intercorrelations of pH of raw grain with other yield components, we can see that there is significant indirect effect on yield by reducing traits like height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, thousand grain weight and alkali spreading value. Good, tastier varieties will take short duration for panicle initiation and long time for completion of 50 per cent flowering, they will be short statured, awned and will have high alkali spreading value.

In breeding programmes to improve a number of traits simultaneously, a significant correlation of the traits with yield would be considered desirable. The present study, the strong positive correlation of number of days to panicle initiation and elongation ratio and strong negative correlation of height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, thousand grain weight and alkali spreading value with grain yield suggest that these are the principal yield determining attributes.

A comparison of the magnitude of phenotypic and genotypic correlation coefficiants in the present investigation has shown that within the limits of acceptable error genotypic correlation coefficients are seen to be more that the corresponding phenotypic correlation coefficients. This indicates the inherent genetic correlation of the component characters with yield. Chaubey and Singh (1994) supports the same with his work.

5.6 Path analysis

The association analysis through correlaion studies alone will not provide a true picture of the relative merits or demerits of each of the components to final yield, since an individual component may either have a direct influence in the improvement of yield or indirect role thorugh other components in the improvement of yield or both. Path coefficient analysis was developed by Wright (1923) and applied for first time in plant. Dewey and Lu (1959) furnished a means for finding out the direct and indirect effects of individual components to final yield.

In the present study the path coefficient analysis was performed taking all the yield components used for correlation studies. The cause and effect relationship between yield and its 19 components is discussed.

Results of path coeeficient analysis in the present study have revealed kernel length before cooking has the maximum direct effect (8.429) towards grain yield followed by kernel elongation ratio (7.282). Both of these are qualitative in nature. The elongation ratio has also significant direct effect with yield (0.339). Followed by elongation ratio, number of days to panicle initiation (0.988), taste (0.607), length of panicle (0.487), thousand grain wieght (0. 472), aroma (0.388), elongation (0.153) alkali value (0.074), kernel appearance (0.066) and pH of raw grain (0.056) showed positive direct effect on yield. The direct effects of the other characters namely number of days to 50 per cent flowering, height of plant at harvest, number of panicles m^{-2}, awnness, kernel breadth, L/B ratio, kernel elongation after cooking are seen to be negative. Many of these characters also registerd significant negative correlations. Singh and Banerjee (1987) , Reuben and Katuli (1989) , Sardana *et al.* (1989), Ibrahim *et.al.* (1990). Sarma and Roy (1993), Marwat *et al.* (1994) supports the same observations.

Eventhough maximum direct effect was shown by kernel length before cooking, it has shown a negative nonsignificant relationship (-0.151) with yield in its genotypic correlations. This may be due to the strong negative indirect effect of component characters like kernel breadth,kernel elongation after cooking and L/B ratio. Kernel elongation ratio has the second largest positive direct effect on yield and it has significant positive correlation also with yield. But there is very strong negative indirect effect through kernel length before cooking towards yield. This is balanced by the positive indirect effect of kernel breadth on elongation ratio and the high indirect effect of elongation ratio on yield via, number of days to ,panicle initiation and kernel elongation after cooking. These findings shows that the kernel elongation ratio can change with the average length and breadth kernel of the selected bare materials and the ultimate grain yield. High positive direct-effect excerted by thousand grain weight on yield and at the same time its negative significant correlation with yield indicate that there should be an optimum grain weight for maximising yield. The negative indirect effects of kernel breadth and kernel elongation after cooking resulted in reduced correlation of aroma with grain yield compared to its high direct effect. The strong positive indirect effect of kernel is reduced by the negative indirect effects of days to panicle initiation, height at harvest,kernel breadth, kernel elongation after cooking and elongation ratio thereby reducing its positive correlation with yield. Eventhough not very high the positive direct effect exerted by alkali value oon yield and at the same time its strong negative significnt correlation with yield indicate that there should be some compromise between alkali value and grain yield.

The character kernel elongation after cooking which shows highest negative direct effect (-7.772) has a significant positive genotypic correlation with yield. This is explainabale because these components might influence yield by their indirect effects through other components. Thus for example, kernel elongation after cooking has very high indirect effect through elongation ratio (6.143) and kernel length before cooking (2.614) towards grain yield thereby making the correlation with yield positive. Height of plant at harvest has very high indirect effect through kernel length before cooking (4.501); thereby reducing its negative correlation with yield kernel breadth has very high indirect effect through kernel length before cooking (3.090) and L/B ratio(2.741); L/B ratio has very high indirect effect through kernel length before cooking (4.203) and kernel breadth (2.619); number of panicles/m^2 has indirect effect through kernel length before cooking (1.494) and kernel breadth (1.382); number of panicle bearing tillers has indirect effect through kernel length before cooking (1.455) and kernel breadth (1.303) towards grain yield. So the strong negative correlation of both number of panicles/m^2 and panicle bearing tillers is reduced by kernel length before cooking and kernel breadth. From the above descriptions it is clear that kernel length before cooking is the character which is affecting most of other characters indirectly. De *et al.* (1994), gives supportive results in his study.

Coming to the reverse trend, number of panicle bearing tillers has nominal or nil indirect effect on all other characters. No. of days to panicle initiation is negligibly affected by kernel length before cooking. Kernel length before cooking, L/B ratio and elongation ratio are indirectly affected with lowest values by kernel elongation after cooking; L/B ratio has very low indirect effect on kernel length after cooking.Elongation ratio has nominal effect on kernel breadth and kernel breadth has very low effect on length of panicle. Thousand grain weight is negligibly affected by elongation ratio, followed by kernel breadth.

Hence for improving grain yield coupled with Basmati quality traits much emphasis has to be given in quantitative characters such as longer days to panicle initiation, shorter days to flowering, semi dwarf plant type, lower number of panicle bearing tillers, optimum number of panicles/m^2 with medium long panicles medium kernel length before cooking and higher kernel elongation ratio. In case of qualitative characters higher aroma and absence of awns are preferred.

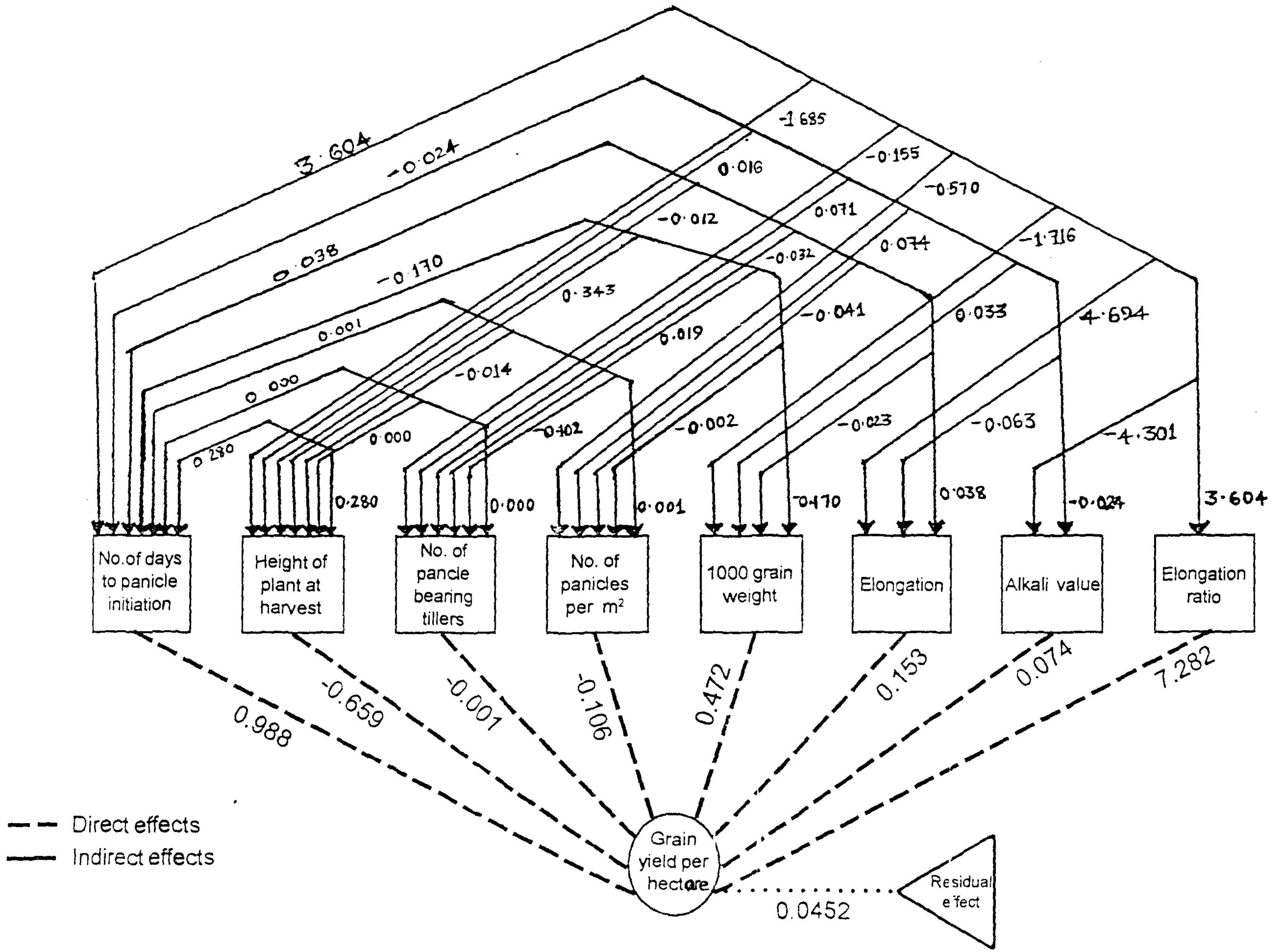
The residual effect calculated in the path coefficient analysis amounts only 0.0452. This indicate that about 95% of the variation in grain yield in Basmati rice is contributed by twenty component traits considered for path analysis. This comparatively low value obtained in the present case fully supports the right choice of the components in Basmati rice for path coefficient analysis. As such from the results of present study it can be concluded that greater emphasis has to be laid for improving yield, elongation ratio, number of days to panicle initiation, optimum grain weight with respect to quantity traits and also improving kernel length before cooking, taste etc.with respect to qualitative traits. With respect to other quantitative characters like number of days to 50% flowering, height of plant at harvest and qualitative characters like awnness, kernel breadth, L/B ratio, kernel elongation after cooking etc. show negative direct effect. So with respect to quantitative characters shorter duration and reduction in plant height (semi dwarf type) is perferred and in qualitative characters all characters have strong indirect effects so with the improvement of other characters they will be automatically corrected. Path diagram indicating direct and indirect effects of eight main characters on yield are presented in Fig. 5.

5.7 DISCRIMINANT FUNCTION ANALYSIS

Hazel (1943) suggested that selection based on a suitable index was highly efficient. Goulden (1959) believed that the discriminant function would ensure the maximum concentration of the desired genes in the plants or in the lines selected. Hence the discriminant function analysis Fisher (1936) and Smith (1936) was carried out with a view to evolve a selection index for isolating superior genotypes. Seven models using various character combination of yield and its componets were tried. The traits were selected based on their direct effect and genetypic correlation with yield.

Maximum efficiency of selection index over direct selection (56.30%) was observed when all the nine characters namely grain yield, number of days to panicle initiation, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, thousand grain weight elongation, alkali value and elongation ratio were included. But for the ease of selection the selection index should be formulated with minimum number of easily measurable and requisite Basmati qualitative characters. Here the selection index formulated by using grain yield, number of days to panicle initiation, height of plant at harvest, number of panicle/m^2, alkali value and elongation ratio which has an efficiency of 53.52% is more useful. If alkali value is not

Fig. 5 PATH DIAGRAM INDICATING DIRECT AND INDIRECT EFFECTS OF THE COMPONENT CHARACTERS ON YIELD.



taken into account the selection index using grain yield number of days to panicle initiation, height of plant at harvest, number of panicle/m^2 and elongation ratio which has an efficiency of 51.87% can be used. Bao(1989); Reddy (1992) Paramasivan and Rangasamy (1988) supports the similar type of selection index. Hence from the results of discriminant function analysis carried out in the present study it can be concluded that greater emphasis has to be laid for increasing number of days to panicle initiation, alkali value and elongation ratio and a reduction in height of plant at harvest and number of panicles/m^2. The selection index formulated by using grain yield, number of days to panicle initiation, height of plant at harvest, number of panicles/m^2, alkali value and elongation ratio; and another using grain yield, number of days to panicle initiation, height of plant at harvest, number of panicles/m^2 and elongation ratio are suggested for selecting superior genotypes. By using the above selection index V_{37} followed by V_{29} is suggested for selection in for increasing grain yield with requisite qualities in Basmati rice. Field view and representative samples of some top ranking genotypes are shown in Plate 2 (A, B, C) and Plate 3 (A,B) respectively.

Plate 2 Field view of Basmati rice genotypes

2A Basmati culture 385

2B Basmati culture 386

2A

2B

2C Tarori Basmati

2D Pusa Basmati

2C

2D

2E UPR-BS-92-4

2F HKR-93-401

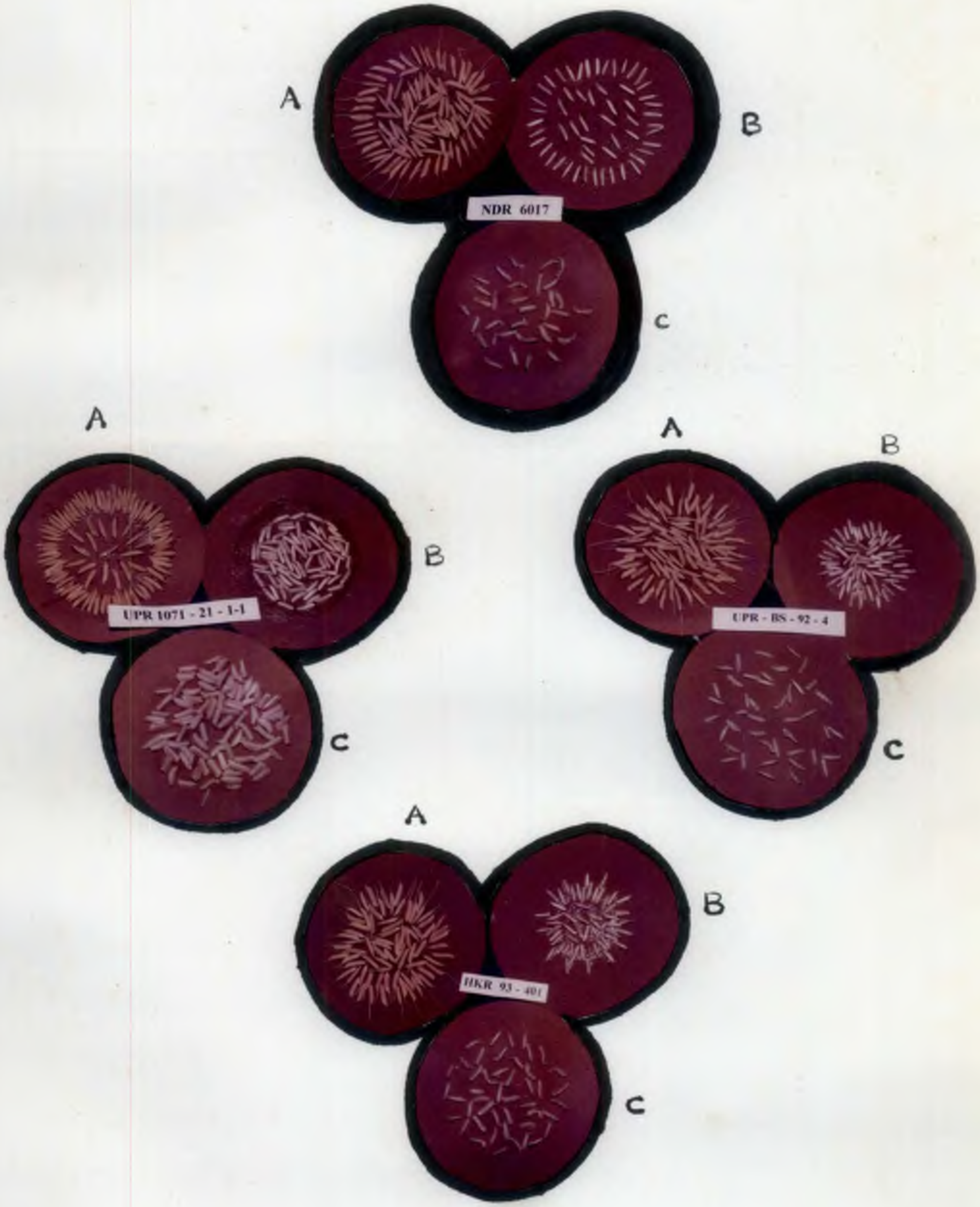
2E

2F

Plate 3 Representative samples of some top ranking Basmati rice genotypes

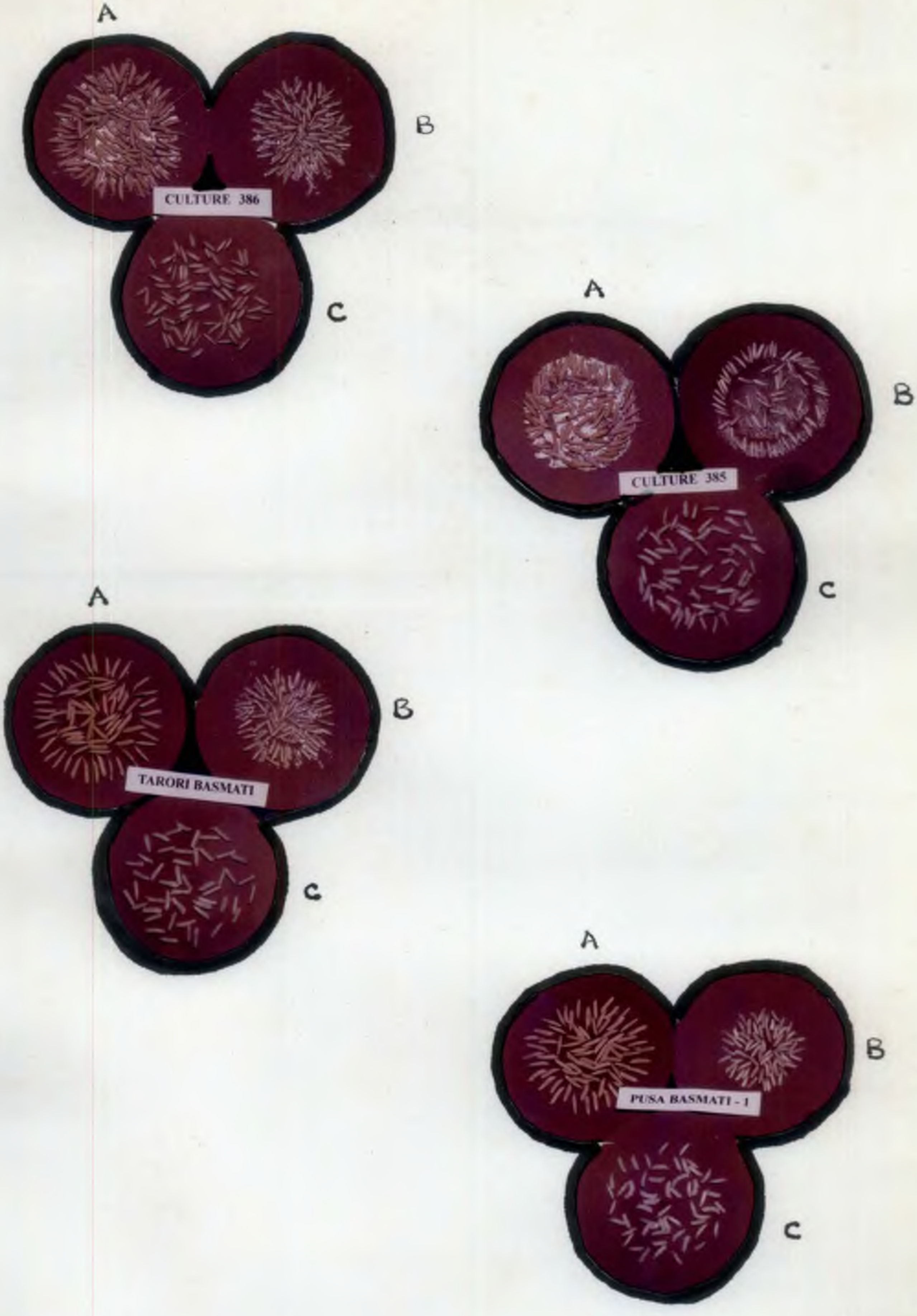
3.1

A. Grain B. Kernel C. Cooked kernel


A
B
NDR 6017
C
A
B
UPR 1071 - 21 - 1-1
C
A
B
UPR - BS - 92 - 4
C
A
B
HKR 93 - 401
C

3.2

A. Grain B. Kernel C. Cooked kernel


A
B
C
CULTURE 386
A
B
C
CULTURE 385
A
B
C
TARORI BASMATI
A
B
C
PUSA BASMATI - 1

Summary

SUMMARY

The present investigation of 'Genetic Divergence and Selection Parameters in Basmati Rice' was conducted in the Department of Plant Breeding and Genetics. College of Horticulture, Kerala Agricultural University during 1995-1997. Field trial was laid out at the Agricultural Research Station, Mannuthy of the Kerala Agricultural University.

The investigation was carried out with a view to study the genetic divergence among advanced breeding lines of Basmati Rice and also, to formulate selection parameters for further genetic improvement. The experiment was also aimed at selection of high yielding quality Basmati rice genotype suited to Kerala ecosystem.

The materials consisted of 38 advanced breeding lines of Basmati rice evolved at various rice research centre in India namely, IARI, New Delhi, DRR, Hyderabad and ARS, Mannuthy, Kerala.

Field experiment was laid out in randomised block design with three replications. The spacing was 20 cm X 15 cm with a plot size constituting 8 rows of 36 hills. Observations on 32 different quantitative and qualitative characters were recorded for 10 randomly selected tagged plants from each plot after leaving the border rows. The data were subjected to statistical analysis.

The salient findings of the study are:

1. The 38 genotypes studied showed significant difference at 1% level for 28 out of 32 characters namely, number of days to panicle initiation, number of days to 50 per cent flowering, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, number of spikelets/ panicle, length of panicle , thousand grain weight, kernel length before cooking, awnness, pubescence, pH of raw grain, number of grains/ panicle, kernel breadth, L/B ratio. kernel appearance, cohesiveness, tenderness on touching and chewing, taste, aroma, elongation, overall acceptability, amylose content, milling percent. hulling per cent, elongation ratio and grain yield/ha. The rest four characters differed at 5% level.

2. Heritability in the broad sense was high for number of days to panicle initiation, number of days to 50 per cent flowering, length of panicle, pH of raw grain, kernel appearance coupled with low expected genetic gain (EGG) and low genotypic coefficient of variation (GCV). The characters namely height of plant at harvest, elongation/ kernel length after cooking were found to have high broad sense heritability and high EGG coupled with moderate GCV. The awnness and elongation ratio have high GCV, heritability and EGG. The characters kernel length before cooking, kernel breadth, L/B ratio, taste and aroma, were found to have high heritability coupled with moderate EGG and low GCV.

3. The principal yield determining components identified are number of days to panicle initiation, number of days to 50 per cent flowering, height of plant at harvest, number of panicle bearing tillers, number of panicles/m^2, 1000 grain weight, aroma, kernel length before and after cooking, alkali value and awnness.

4. While selecting genotypes for higher yield potential, emphasis should be given for moderate vegetative period, short period from panicle initiation to 50 per cent flowering and semi dwarf plant type.

5. Results of path coefficient analysis brought out that the characters kernel length before cooking , elongation ratio, number of days to panicle initiation,taste, panicle length, thousand grain weight, number of days to 50 per cent flowering, aroma, elongation, alkali value, kernel appearance and pH of raw grain have positive direct effect on yield in that order. The characters kernel elongation after cooking, L/B ratio, kernel breadth, height at harvest, awnness, number of panicle/m^2 and number of panicle bearing tillers have negative direct effect on yield.

6. A selection model was formulated consisting of the characters namely, yield/ ha, number of days to panicle initiation, height of plant at harvest, number of panicle/m^2, alkali value and elongation ratio with 53.52% efficiency.

7. A comparison of different genotypes based on the index value has revealed the superiority of the genotypes, culture 385 and UPR-BS-92-4 over others.

8. The 38 genotypes were grouped into seven clusters based on genetic distance. There was no parallelism between geographical distribution and genetic diversity.

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* Originals not seen.

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Appendices

Appendix i Mean performance of 38 Basmati rice varieties for different quantitative and qualitative characters

	Characters						
Entry no	No.of days to panicle initiation	No. of days to 50% flowering	Height of plant at the time of harvest	Total No. of Tillers	No.of panicle bearing tillers	No.of panicle per m^2	No.of spikelets per panicle
V_1	74.000	93.000	94.533	14.667	8.667	383.667	93.147
V_2	68.667	94.000	92.367	13.000	8.333	331.333	74.800
V_3	68.000	97.000	104.833	14.000	7.333	334.667	84.833
V_4	69.000	95.000	113.657	12.333	6.000	294.000	98.400
V_5	68.000	93.000	145.663	12.333	7.333	308.667	73.970
V_6	68.000	94.000	134.733	11.667	6.333	280.000	91.347
V_7	68.000	92.000	140.067	12.000	6.667	267.000	77.200
V_8	69.000	93.000	118.500	15.000	8.667	339.667	43.800
V_9	70.000	92.000	118.333	15.000	9.333	392.000	49.800
V_{10}	69.000	92.000	128.533	12.000	9.333	429.667	39.433
V11	75.000	97.000	98.733	13.000	7.667	318.000	88.467
V_{12}	68.000	89.000	115.200	11.667	7.333	330.000	66.623
V_{13}	68.333	91.000	134.230	11.000	9.667	379.667	64.800
V_{14}	69.000	93.000	104.493	12.334	7.000	323.667	110.633
V_{15}	69.000	92.000	135.520	14.667	10.000	448.000	67.133
V_{16}	69.000	94.000	118.100	14.334	8.000	336.000	97.200
V_{17}	68.667	94.000	98.100	12.667	9.000	314.000	87.533
V_{18}	68.667	93.000	101.200	14.333	8.333	326.000	64.867
V_{19}	69.000	93.000	92.907	14.667	9.000	338.333	89.900
V_{20}	69.000	93.000	117.667	15.667	8.000	319.333	80.467
V_{21}	68.000	91.000	113.800	10.667	5.333	220.667	99.110
V_{22}	68.000	95.000	104.567	16.000	7.000	262.333	85.733
V_{23}	69.667	93.000	104.700	15.333	7.000	293.333	82.523
V_{24}	68.000	94.000	106.967	14.333	6.667	277.667	97.733
V_{25}	74.000	91.000	116.167	15.667	7.000	295.667	107.993
V_{26}	68.000	87.000	114.767	13.000	7.333	303.000	115.433
V_{27}	68.000	87.000	91.433	13.333	7.667	243.333	117.663
V_{28}	68.000	87.000	125.900	11.000	6.667	247.000	94.333
V_{29}	74.000	92.000	103.933	11.333	6.667	238.667	116.740
V_{30}	74.000	93.000	108.733	10.333	6.333	218.333	89.550
V_{31}	69.000	92.000	105.167	13.000	7.333	275.333	91.347
V_{32}	68.000	89.000	121.533	13.000	6.667	261.667	85.300
V_{33}	71.000	90.000	104.533	15.667	5.333	242.000	108.433
V_{34}	69.000	91.000	110.933	13.667	5.667	225.000	107.300
V_{35}	72.000	91.000	117.633	13.000	6.333	246.000	85.667
V_{36}	74.000	95.000	93.733	15.333	8.333	313.000	72.040
V_{37}	75.000	80.000	99.133	11.000	6.667	260.333	89.267
V_{38}	74.000	83.000	92.650	14.667	11.000	413.000	72.780
Grand Mean	69.921	91.711	111.675	13.333	7.553	306.053	85.876

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

Appendix i (Contd................)

Entry no.	Length of Panicle	Thousand Grain Wt.	Kernel Lgth. before cooking	Awnness	Pubescence	pH of raw grain	No. of Grains/ Panicle	Kernel Breadth	L/B Ratio	No. of Days to harvest	Kernel Appearance
V_{1}	24.883	23.567	8.217	0.500	3.000	6.453	53.917	1.760	4.690	119.000	4.323
V_{2}	23.887	24.133	7.123	1.000	3.000	6.523	49.700	1.800	3.960	119.000	4.680
V_{3}	25.020	22.833	7.900	9.000	3.000	6.610	58.167	2.080	3.790	119.667	4.430
V_{4}	27.720	22.833	7.797	5.000	3.000	6.350	64.100	2.080	3.750	119.667	4.680
V_{5}	26.977	26.267	8.907	1.000	2.000	6.350	48.813	2.240	3.980	117.667	4.143
V_{6}	26.053	27.369	8.523	1.000	4.000	6.560	64.907	2.220	3.840	117.667	4.217
V_{7}	29.657	27.233	8.553	5.000	3.000	6.390	48.687	2.160	3.960	117.667	4.327
V_{8}	22. 657	26.133	8.277	9.000	4.000	6.450	30.867	2.200	3.740	117.667	4.580
V_{9}	21.767	26.833	7.610	5.000	4.000	6.440	34.733	1.860	4.100	117.667	4.420
V_{10}	22.710	24.100	8.383	3.000	3.000	6.580	25.167	1.750	4.767	118.000	4.280
V_{11}	24.293	22.500	7.350	9.000	3.000	6.620	46.037	1.800	4.080	119.333	4.670
V_{12}	25.093	21.890	8.140	5.000	4.000	6.640	33.540	1.970	4.120	118.000	4.700
V_{13}	24.567	25.967	8.443	1.000	4.000	6.420	42.533	2.010	4.187	118.000	4.480
V_{14}	27.093	23.567	8.000	7.000	4.000	6.550	65.270	1.960	4.080	118.667	4.590
V_{15}	24.600	25.933	7.887	7.000	4.000	6.470	42.667	1.810	4.340	118.000	4.240
V_{16}	25.980	23.400	8.067	0.500	3.000	6.450	53.700	1.810	4.480	118.667	4.340
V_{17}	24.810	24.267	8.350	9.000	4.000	6.480	56.567	2.120	3.940	118.667	4.320
V_{18}	23.467	20.067	8.150	9.000	4.000	6.580	39.833	1.860	4.380	118.333	4.220
V_{19}	25.200	23.767	7.643	0.500	4.000	6.510	50.767	1.970	3.870	117.667	4.580
V_{20}	25.743	22.100	7.757	7.000	4.000	6.630	47.233	1.970	3.940	118.333	4.421
V_{21}	26.677	23.967	8.150	1.000	4.000	6.750	64.710	1.920	4.240	118.667	4.800
V_{22}	25.597	20.800	8.503	9.000	4.000	6.590	46.900	1.910	4.460	118.667	4.517
V_{23}	25.367	20.467	7.500	9.000	4.000	6.580	43.630	2.000	3.750	119.333	4.550
V_{24}	26.130	23.533	8.633	9.000	4.000	6.740	52.700	2.040	4.220	119.333	4.070
V_{25}	25.200	21.467	7.283	0.500	4.000	6.430	65.893	2.040	3.550	118.667	4.520
V_{26}	27.180	23.400	8.030	1.000	4.000	6.570	56.467	1.870	4.290	118.667	4.730
V_{27}	23.513	24.200	7.567	7.000	4.000	6.430	54.190	2.040	3.700	118.667	4.770
V_{28}	25.957	26.467	8.133	1.000	4.000	6.560	63.000	2.100	3.880	118.667	4.760
V_{29}	24.427	25.267	7.180	7.000	3.000	6.560	76.520	2.007	3.570	119.333	4.800
V_{30}	24.137	24.233	8.273	9.000	3.000	6.840	62.107	1.880	4.387	118.667	4.277
V_{31}	25.723	21.667	7.900	9.000	4.000	6.530	63.430	2.060	3.830	118.667	4.303
V_{32}	26.270	23.667	7.937	1.000	3.000	6.610	59.600	1.880	4.210	118.000	4.367
V_{33}	26.627	24.033	7.473	1.000	4.000	6.570	62.133	2.080	3.587	118.000	4.470
V_{34}	27.083	24.433	7.467	1.000	3.000	6.710	61.700	1.900	3.920	118.000	4.180
V_{35}	25.970	23.900	7.577	1.000	3.000	6.470	63.700	1.890	4.087	118.000	4.370
V_{36}	23.667	22.033	7.043	0.500	4.000	6.410	47.547	1.780	3.950	119.333	4.550
V_{37}	24.200	20.600	7.083	9.000	3.000	6.640	56.433	1.930	3.647	120.000	4.400
V_{38}	22.387	21.533	8.190	0.500	3.000	6.670	45.547	2.000	4.087	117.667	4.420
Grand Mean	25.213	23.695	7.921	4.518	3.553	6.545	52.721	1.967	4.036	118.518	4.460

Entry no	Cohesieveness	Tenderness on touching	Tenderness on chewing	Taste	Aroma	Elongation	Overall Acceptability	Amylose content	Milling Per cent	Hulling Per cent	Alkali value	Kernal length after cooking	Elongation Ratio	Yield
V_1	4.500	4.250	4.200	3.520	3.400	3.500	2.830	14.633	62.850	75.600	6.000	13.320	0.620	2159.000
V_2	4.500	4.400	4.000	3.840	3.100	2.700	2.930	17.910	62.103	74.813	5.667	9.3630	0.314	2000.933
V_3	4.300	4.180	4.080	3.500	2.930	3.300	2.620	14.470	62.920	74.003	6.000	11.613	0.471	1767.833
V_4	4.800	4.500	4.250	3.580	3.780	2.700	2.650	16.407	64.767	78.023	6.000	12.527	0.609	1668.833
V_5	4.500	4.220	4.380	3.200	3.400	3.300	2.240	19.060	65.483	77.407	6.000	12.377	0.390	2240.533
V_6	5.000	3.620	3.960	3.250	3.520	2.802	2.460	16.080	67.150	78.573	6.000	11.427	0.342	1419.333
V_7	4.600	4.230	4.380	3.240	3.070	3.500	3.030	15.520	63.903	76.000	6.000	12.167	0.426	1769.233
V_8	4.500	4.090	4.000	3.320	3.480	2.900	2.900	13.553	65.613	77.400	6.000	12.377	0.495	1377.033
V_9	4.500	4.000	3.770	3.180	3.380	2.500	2.300	13.520	62.957	76.157	6.000	9.6170	0.263	1291.533
V_{10}	5.050	4.130	3.900	3.420	3.320	3.100	2.900	15.040	62.847	74.977	6.000	11.983	0.429	1538.400
V_{11}	4.500	4.037	3.930	3.480	3.400	2.900	2.500	15.320	64.327	78.927	6.000	11.137	0.515	1436.833
V_{12}	4.900	4.760	4.850	3.566	3.480	3.500	2.900	12.560	67.870	79.550	6.000	13.223	0.611	1141.533
V_{13}	5.000	4.040	4.100	3.100	3.440	3.600	3.000	18.600	64.483	76.777	6.000	13.837	0.638	1401.900
V_{14}	4.670	4.407	4.140	3.440	3.680	3.300	2.500	13.560	65.567	77.087	6.000	13.480	0.685	1669.500
V_{15}	4.670	4.200	4.140	3.230	3.100	2.800	2.200	13.960	62.680	74.464	6.000	12.677	0.625	1268.467
V_{16}	4.650	4.550	4.500	3.580	3.240	3.100	2.900	13.253	61.880	73.693	6.000	12.257	0.519	1536.100
V_{17}	4.600	4.020	4.000	3.480	3.950	3.003	2.700	16.880	60.897	72.643	6.000	12.833	0.536	1674.900
V_{18}	4.500	4.400	4.330	3.350	4.330	3.500	2.600	13.040	61.333	73.687	6.000	12.510	0.534	1399.400
V_{19}	4.800	4.070	4.070	3.530	3.750	3.000	2.300	15.840	63.993	75.750	6.000	11.327	0.481	1896.133
V_{20}	4.750	4.270	3.930	3.270	3.620	3.900	2.400	14.080	63.680	75.950	6.000	12.100	0.559	1617.767
V_{21}	4.740	4.967	4.967	3.067	4.540	3.500	2.500	15.080	62.883	75.207	4.333	13.733	0.685	2016.833
V_{22}	4.450	4.960	4.500	3.400	3.500	2.900	2.000	13.960	62.197	73.847	5.667	11.027	0.330	1703.533
V_{23}	4.950	4.500	4.497	3.800	3.750	2.800	3.000	12.160	62.737	74.433	5.667	9.433	0.258	2002.333
V_{24}	4.930	4.300	3.997	3.500	3.770	3.200	2.800	16.480	62.087	74.293	6.000	12.417	0.438	1913.333
V_{25}	4.450	4.500	3.997	2.997	3.660	2.800	2.900	14.767	62.200	74.200	5.333	11.303	0.551	1655.433
V_{26}	4.500	4.030	3.900	3.300	3.200	3.200	2.900	16.400	60.167	73.000	6.000	11.833	0.456	1847000
V_{27}	4.600	4.967	4.997	3.700	3.220	2.800	2.900	13.960	64.347	75.950	6.000	11.400	0.551	1442.333
V_{28}	4.580	4.300	4.200	2.997	3.330	2.900	1.997	16.730	62.883	75.207	6.000	10.133	0.246	1919.000
V_{29}	4.600	4.600	4.300	3.600	2.997	3.800	3.200	14.400	62.197	76.847	5.667	13.727	0.911	2043.333
V_{30}	4.700	3.901	4.500	3.200	3.400	3.500	2.900	13.950	66.113	74.000	5.000	14.226	0.719	1982.800
V_{31}	4.400	4.800	4.997	3.400	3.200	3.700	2.997	16.440	68.753	78.577	5.000	11.333	0.434	1548.833
V_{32}	4.900	4.500	4.400	3.400	3.630	4.000	2.993	14.760	64.267	76.953	4.667	14.480	0.824	1745.500
V_{33}	5.060	4.700	5.100	2.900	3.360	3.467	2.800	14.010	64.690	74.337	5.000	10.740	0.437	1405.300
V_{34}	4.600	3.963	4.300	3.100	3.140	3.997	2.200	19.160	63.277	74.180	5.000	11.823	0.583	1197.600
V_{35}	4.670	3.967	3.997	3.400	3.740	4.000	2.900	15.120	62.737	74.433	5.667	12.450	0.644	2094.166
V_{36}	4.900	4.467	4.600	2.900	4.080	3.800	2.800	14.270	62.087	74.293	6.000	12.823	0.820	2263.500
V_{37}	4.780	4.003	4.003	2.997	3.520	3.320	2.600	14.920	52.533	71.400	5.333	12.243	0.728	2294.500
V_{38}	4.550	4.200	3.973	3.000	3.750	3.997	2.900	15.080	62.200	74.200	5.333	14.627	0.785	2070.333
GM	4.676	4.316	4.267	3.335	3.478	3.252	2.672	15.104	63.307	75.304	5.719	12.164	0.538	1721.601

Appendix ii D^2 analysis of 38 Basmati rice genotypes for different characters

* Entry no	V_{1}	V_{2}	V_{3}	V_{4}	V_{5}	V_{6}	V_{7}	V_{8}	V_{9}	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}
V_{1}	0.00	109035.87	135943.47	140731.24	68567.23	108179.74	76747.37	135748.79	56173.45	1959.19	67263.80	54207.74	33774.07	57462.78	18950.45	8293.01	87851.55	22083.04	110654.72
V_{2}		0.00	6003.39	11324.62	16730.30	10890.26	12795.99	12050.00	20389.51	129253.69	9509.50	14292.25	4669.63	17364.06	48433.73	58024.77	13657.72	66226.51	7493.08
V_{3}			0.00	8732.96	16993.43	6700.40	11231.58	4561.09	25003.41	157846.58	14567.75	21386.78	45652.79	22747.63	59376.63	78701.39	16588.60	84080.54	8337.07
V_{4}				0.00	18194.99	6092.91	18271.53	2831.82	28598.42	166130.26	17004.47	22034.25	47828.50	19557.04	68585.13	84948.65	7505.09	72563.83	2412.99
V_{5}					0.00	5487.68	1452.10	12766.51	3111.26	84601.28	3725.69	4566.88	8382.34	3095.46	18658.42	32699.65	6188.81	30685.06	9579.04
V_{6}						0.00	5359.54	2218.11	11390.92	127845.07	6824.17	11577.12	25850.66	9535.05	41960.99	60373.71	4730.01	52657.35	2506.85
V_{7}							0.00	1165.55	4650.26	92896.17	4002.90	6333.14	12572.95	6305.10	21446.33	37175.89	9783.44	41794.88	10415.39
V_{8}								0.00	21684.96	188752.13	13758.70	22092.62	4008.78	17869.95	59757.27	80923.29	8851.15	72310.94	3511.46
V_{9}									0.00	68630.68	3796.80	6308.12	6664.05	5350.18	12524.18	24930.83	11862.34	24820.34	15882.45
V_{10}										0.00	83396.83	69696.65	44519.00	73632.08	26032.27	14677.76	107936.23	30942.81	132402.78
V_{11}											0.00	2397.52	13129.74	2768.25	20324.52	30741.28	2849.16	30978.39	7467.67
V_{12}												0.00	9196.82	943.07	15398.09	22154.18	6466.83	22591.29	11342.73
V_{13}													0.00	7919.09	4348.27	13869.22	21067.66	13681.97	31849.15
V_{14}														0.00	16976.00	25629.27	3965.44	20180.60	9640.64
V_{15}															0.00	4706.49	36141.23	15867.26	48249.23
V_{16}																0.00	47194.30	13942.15	62014.89
V_{17}																	0.00	33883.42	2548.49
V_{18}																		0.00	51925.27
V_{19}																			0.00
V_{20}																			
V_{21}																			
V_{22}																			
V_{23}																			
V_{24}																			
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V_{33}																			
V_{34}																			
V_{35}																			
V_{36}																			
V_{37}																			
V_{38}																			

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

* similar to that in Table1

Appendix ii (Contd................)

V_{20}	V_{21}	V_{22}	V_{23}	V_{24}	V_{25}	V_{26}	V_{27}	V_{28}	V_{29}	V_{30}	V_{31}	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}
87114.83	32726.49	10377.09	165877.30	38079.22	195129.50	26099.31	166218.86	101333.06	211250.51	17212.96	117108.65	34448.06	182859.23	91411.11	56102.34	83347.08	167395.84	39779.73
12776.04	46278.22	59289.98	10764.06	27060.54	33944.90	36844.65	9009.56	19179.75	23936.89	58692.09	5690.88	31533.74	31309.62	14923.37	18321.44	37876.72	27211.96	37961.14
11586.26	51431.44	77912.87	11075.42	38432.17	17323.22	46887.52	3864.19	12912.33	10138.17	68984.52	1616.76	40483.66	13557.43	9345.00	24709.17	34767.12	11714.01	37481.49
10005.83	54091.76	81529.49	4325.47	35992.24	12334.76	54478.72	4865.27	17149.84	14644.94	75107.49	5983.83	39186.79	15677.08	17359.73	20460.55	225104.43	10973.28	35110.79
2840.69	12768.32	29439.11	32421.19	9755.71	34099.41	12441.19	28340.31	5817.25	46794.61	23952.76	9218.11	8918.47	29274.39	4158.39	3126.52	8870.76	24073.81	6739.44
1602.85	29956.59	55204.92	14252.61	21495.31	14451.32	31105.41	12036.18	3784.87	24207.08	47269.39	2160.00	23369.25	12202.88	3742.55	10106.25	12511.39	8607.30	16899.33
4105.10	17358.09	35220.41	30561.92	14697.66	32098.38	14750.25	23325.86	4919.55	38924.51	28821.78	6111.86	13552.11	25564.26	2213.48	6921.72	14710.67	21778.93	11640.72
6340.05	45507.84	76138.39	9394.56	34754.25	7674.29	46802.59	5692.20	8067.09	13318.85	66534.86	2296.62	36472.13	7350.80	8767.42	19034.32	19778.47	4530.16	27948.17
6568.49	9216.15	19841.92	41582.73	8506.58	45384.28	7132.81	39423.64	7566.64	62283.44	17967.74	15835.87	9163.85	38647.03	7532.63	4666.50	11047.46	33522.82	7834.42
105027.36	42032.18	15728.77	192000.83	50707.30	221618.12	34759.62	192447.41	117610.18	240954.19	24235.90	137923.33	47386.42	206501.53	107892.94	72274.72	100377.87	191419.27	68804.93
3135.25	15473.02	27813.77	25576.35	7678.71	37523.01	12630.24	24633.35	8667.71	43663.69	24258.31	8194.76	9522.61	33111.53	5847.85	3031.19	14275.48	26296.38	10867.73
5893.32	11250.75	21026.01	33428.25	3294.76	49869.61	9109.47	32459.59	15223.11	54035.28	17774.87	13905.58	3668.35	45353.82	9963.76	1867.36	16592.23	36797.71	9170.43
16578.20	1560.65	10353.65	69450.66	7399.34	70981.68	2825.81	64895.98	20810.65	90542.53	5865.68	33275.39	3591.70	62908.36	17711.57	7757.25	14452.94	54714.44	4277.37
3110.02	10086.51	22620.26	32800.09	3528.05	44040.81	10525.89	32755.22	12672.79	54100.64	18563.99	138811.61	3647.30	40826.92	9293.69	494.53	10209.86	32198.83	5822.71
30265.45	5617.87	4022.48	58941.87	11127.40	99751.92	1446.54	53423.16	35365.99	113739.87	3261.69	47345.50	7884.81	88460.98	29326.28	16853.24	32435.71	79473.33	15519.31
45848.94	14994.55	2282.28	103470.01	14213.06	130599.96	7145.07	102198.13	57354.66	139086.00	7200.06	62264.06	12433.99	120311.10	48736.43	25115.76	50714.01	108502.80	29447.68
2674.50	24697.12	42791.83	17018.32	11709.26	27762.70	26434.72	19941.05	12229.41	38011.21	38381.01	8790.94	14228.17	28461.15	11039.36	4265.55	10717.21	20717.57	13425.67
37461.37	12217.92	8044.18	92924.17	10036.65	111747.64	15181.92	101409.84	51968.21	138837.45	10940.85	65217.07	10647.88	107633.52	49006.15	19643.96	29847.66	93625.97	18591.57
3577.93	36141.70	58000.92	7749.04	21243.55	17768.67	35973.34	9226.17	10387.44	23226.28	53225.77	3710.37	24544.26	18665.74	9865.77	10052.20	19617.85	13085.41	22318.81
0.00	19080.18	40416.01	20287.16	12635.91	22877.55	20996.53	19195.91	4167.77	34591.10	33300.63	5069.40	13886.48	20054.62	3288.80	4478.33	7941.05	14371.57	9359.71
	0.00	9501.14	75329.57	7864.32	76732.98	3450.75	72258.63	3482.67	98202.93	3782.54	38549.69	4547.05	67697.54	20303.78	10362.88	15900.40	58644.91	4249.15
		0.00	100206.37	11398.82	121205.47	5234.19	101517.48	49594.02	138661.65	4275.08	62798.07	10905.88	111105.20	44358.20	21848.82	40656.30	99807.30	22721.97
			0.00	48870.69	18263.28	71999.75	4277.50	28479.20	13439.59	96572.44	10978.38	56503.45	22143.70	28225.92	33620.51	43807.97	15235.49	55300.57
				0.00	68659.93	6921.84	52317.13	24483.69	79876.00	10451.80	27232.92	1821.37	63862.61	19193.46	3635.36	18869.23	53247.04	9064.20
					0.00	83115.01	14291.81	18842.84	14302.25	106645.39	15902.56	70507.75	1902.43	24372.06	44459.60	31878.43	2066.11	50183.04
						0.00	67960.97	25521.22	96220.20	4316.71	35944.43	4852.22	72950.94	20879.21	10545.94	24727.86	64864.32	10858.47
							0.00	23247.13	4744.42	94050.22	6342.20	55836.43	15282.14	21483.37	34649.00	44074.19	13190.51	52974.09
								0.00	36137.12	41187.89	7237.20	24642.20	13098.36	2576.80	12891.98	9933.39	11376.72	13792.18
									0.00	123934.10	16115.61	81686.33	15248.76	33292.30	56818.60	61909.19	14531.72	72950.57
										0.00	55192.89	7510.86	95836.02	34232.36	18730.00	31971.17	84287.12	13099.13
											0.00	29170.71	12769.18	4959.41	14835.38	22327.92	9844.73	9844.73
												0.00	64883.09	18478.07	3952.37	17238.70	54294.12	6182.79
													0.00	17403.64	42543.03	30148.40	1380.99	44710.17
														0.00	10039.21	13248.95	14121.11	11999.12
															0.00	9036.96	33087.76	5792.56
																0.00	23476.71	5178.41
																	0.00	36145.16
																		0.00

GENETIC DIVERGENCE AND SELECTION PARAMETERS IN BASMATI RICE

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Agriculture

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ABSTRACT

The research project 'Genetic divergence and selection parameters in Basmati rice was carried out in the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period 1995-'97. The major objectives of the study were to study the genetic divergence among advanced breeding lines of Basmati rice evolved at various rice research centres in India and to select high yielding quality Basmati rice genotypes adopted to Kerala ecosystem.

The study, about components of heritable variation revealed that the range of variation is high for height of plant at harvest, total number of tillers, numbers of panicle bearing tillers, number of panicles/m^2, number of spikelets/panicle, pubescence, awnness, number of grains/panicle, aroma, overall acceptability, amylose content, kernel elongation after cooking, elongation ratio and yield.

Heritability studies revealed that pH of raw grain, L/B ratio, kernel breadth and taste showed the maximum broad sense heritability among the qualitative characters; number of days to panicle initiation also had high heritability among the quantitative characters.

Cluster analysis revealed that there was no parallelism between geographical distribution and genetic diversity. The 38 genotypes were grouped into seven clusters.

Correlation studies revealed that the principal yield determining components in Basmati rice are number of days to panicle initiation, number of days to 50% flowering, height of plant at harvest, number of panicle bearing tillers, number of panicles/ m^2 ,1000 grain weight , aroma, kernel length before and after cooking, alkali value and awnness. While selecting genotypes for higher yield potential, emphasis should be given for comparatively long vegetative period, short period from panicle initiation to 50 percent flowering and dwarf plant type.

A selection model was formulated consisting of the characters namely, yield/ha, number of days to panicle initiation, height of plant at harvest, number of panicles/m^2, alkali value and elongation ratio.

Basmati culture 385 and UPR-BS-92-4 are identified as superior genotypes among the entries studied.