

**STUDY OF GENE ACTION FOR QUALITY AND YIELD COMPONENTS
IN RICE (Oryza sativa L.)**

BY

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M.Sc. (Ag.)

**THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
In The Faculty of Agriculture**

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**DEPARTMENT OF GENETICS AND PLANT BREEDING
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1994

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Sri P.S.N. Murthy has satisfactorily prosecuted the course of research and that the thesis entitled **STUDY OF GENE ACTION FOR QUALITY AND YIELD COMPONENTS IN RICE (Oryza sativa L.)** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination and the work was done under my supervision and guidance. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

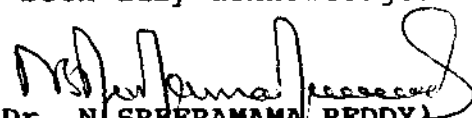
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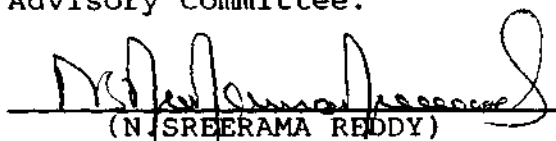
No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.


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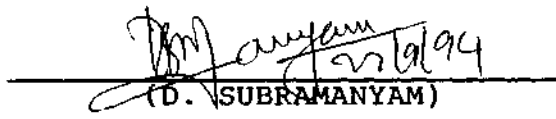
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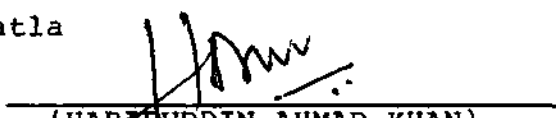
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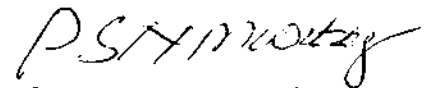
There are many other who have in various ways helped me and I sincerely thank all of them and request their forgiveness for not mentioning them name by name.

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DECLARATION

I, P.S.N. Murthy hereby declare that the thesis entitled STUDY OF GENE ACTION FOR QUALITY AND YIELD COMPONENTS IN RICE (Oryza sativa L.) submitted to the Andhra Pradesh Agricultural University for the degree of Doctor of Philosophy in Agriculture in the major field of Genetics and Plant Breeding is the result of original research work done by me. It is further declared that the thesis or any part thereof has not published earlier in any manner.

Date: 27-9-94


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ABSTRACT

From the genetic divergence study of 79 genotypes of rice, eleven clusters were formed. Seven parents viz., (BASMATI-370, DW 8, IET-1444, Tellahamsa, PRABHAT, Taichung Native-1 and BPT-1235 were selected, keeping in view of the breeding objective from different clusters. The seven parents were crossed in 7 x 7 diallel excluding reciprocals and resulted in 21 F₁ and 21 F₂ progenies. The above material was studied from kharif, 1987 to kharif 1990 at Rice Research Unit, Agricultural College Farm, Bapatla.

The data collected on sixteen characters viz., eight on yield and yield components, three grain quality

characters, one hulling character, three cooking quality characters and one nutritional character (protein content of brown rice (%)) from material of 7 x 7 diallel and their 21 F_1 and F_2 progenies was computed for analysis of variance, combining ability, heterotic effects, variability, heritability, genetic advance and genetic advance over percent mean, character associations and path analysis to find out the nature of gene action for yield, yield components and the quality characters.

The analysis of variance indicated that treatmental differences were highly significant for most of the characters indicating the existence of high genetic variability in the material for the characters under study.

When both F_1 and F_2 results of the combining ability analysis were taken into consideration, the common characters which showed highly significant mean squares due to GCA and SCA with relatively high SCA variance over GCA in magnitude both in F_1 and F_2 were effective tillers per plant, panicle length, number of grains per panicle, spikelet sterility, 100 grain weight, grain yield per plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice indicating that the above characters are controlled by

additive and non-additive gene effects with predominance of non-additive gene action. The results suggest that improvement of these characters is possible only through recurrent selection but not by simple selection through pedigree method.

The remaining characters i.e., days to 50 per cent flowering, plant height, breadth of grain and kernal elongation which showed highly significant mean squares both in F_1 and F_2 for both GCA and SCA or GCA alone with relatively high GCA variance in magnitude over SCA indicates control of additive and non-additive gene effects or only additive effects with predominance of additive gene action. The results suggest that improvement of these characters is possible by simple selection in F_2 of rice crop and use of pedigree method is desirable.

From the data on GCA and SCA effects, it is observed that the parent, DW 8 showed significant GCA effects for maximum number of eight characters with higher per se performance both in F_1 and F_2 followed by Basmati-370, Prabhat and T.N. 1 indicating that they are good combiners and DW 8 is considered as the best among all parents. It is further observed that parents with significant positive GCA effect for a particular character may not possess high

per se performance for that particular trait and vice versa. Parents possessing high GCA need not result in high SCA effect. Significant positive SCA effects may not be associated with high per se performance and vice versa. Therefore, selection of parents based on genetic divergence studies alone is not adequate but requires confirmation by actual crossing in a diallel manner.

The heterotic studies revealed that in general relationship existed between SCA effects and heterotic effects. Based on heterotic effects, nine out of 21 crosses viz., C₄ (Basmati-370/Prabhat), C₇ (DW 8/IET 1444), C₈ (DW 8/Tellahamsa), C₉ (DW 8/Prabhat), C₁₀ (DW 8/T.N 1), C₁₁ (DW 8/BPT 1235), C₁₂ (IET 1444/Tellahamsa), C₁₅ (IET 1444/BPT 1235) and C₁₆ (Tellahamsa/Prabhat) were found superior in present study combining yield, yield components and quality characters in a desirable direction, crosses derived from parents viz., DW 8, IET 1444, Tellahamsa and Basmati-370 showed good heterotic effects. Though some parents viz., IET 1444 and Basmati-370 possessed poor GCA for some traits showed high heterotic effects to those traits. Therefore, the choice of parents should be based on four factors i.e., per se performance, GCA, SCA effects and finally the heterotic effects.

From the variability, heritability and genetic advance studies, it is observed that for most of the characters higher PCV estimates were seen over GCV both in F_1 and F_2 indicating higher degree of interaction of genotypes exists with environment. The heritability per cent, genetic advance per cent and genetic advance over mean per cent were found to be in a decreasing trend from F_1 to F_2 for most of the characters and may be attributed due to segregation and more of environmental influence in F_2 . The improvement of the characters viz., plant height, grains per panicle, 100 grain weight, grain yield per plant, length of grain, breadth of grain, L/B ratio, volume expansion, water uptake and protein content of brown rice per cent is possible by selection since high to moderate heritability accompanied by high to moderate genetic advance was recorded both in F_1 and F_2 .

Thus it is possible to combine yield, yield components and quality characters in a desirable direction by adopting suitable breeding methodologies such as recurrent selection, pedigree method of breeding and backcross method of breeding.

Correlation studies revealed that grain yield per plant exhibited significant positive association with yield

components and with grain quality traits both in F_1 and F_2 . Similarly quality characters showed positive association among themselves i.e., hulling recovery, volume expansion, water uptake, kernal elongation and protein content and with grain quality characters. Thus, it is evident that grain quality characters attained a special status and are playing critical role as buffer in deciding grain yield and quality characters. Hence selection of plant type possessing high yield and quality characters can be achieved through compromised selection of grain quality characters acceptable for consumer and trader for improvement of rice crop in a desirable direction. /

The path analysis indicates that high path coefficients coupled with positive association for the traits viz., plant height, effective tillers per plant and number of grains per panicle in F_1 whereas in F_2 for the traits viz., 100 grain weight, plant height, effective tillers per plant and number of grains per panicle existed suggesting that selection for these characters would be more effective to bring simultaneous improvement of yield components and yield in rice. /



INTRODUCTION

INTRODUCTION

Rice is an important staple food crop for more than half the population in the world. Though, India ranks first in area (41.0 million ha) under rice, the productivity is very low (2,487 kg/ha) compared to world average (3,320 kg/ha). With the all round advancement in science, especially human nutrition in the recent years, the quality consciousness, viz., hulling recovery, cooking quality and protein content of rice grain, is growing among the consumers. Scientists have, therefore, realised the importance of incorporation of both yield and quality characters in rice for consumers acceptance.

Rice offers a great wealth of material for genetical studies because of its wide ecological distribution and enormous variation for various morphological and physiological characters. Thus, rice breeding in India has made great strides in the last two decades. Now, the emphasis is diversified on Rice varietal front to improve the grain quality besides productivity all over the world. Therefore, there is every need to strengthen the research programme, aimed at not only stepping up the yield but also improving quality of rice.

Yield is a complex character governed by large number of genes, which are especially important in plant breeding. Application of biometrical procedures in plant breeding in recent years, led to a greater understanding of genetics of quantitative characters and proved to be extremely useful to the plant breeder for systematic genetic analysis and planning for sound breeding programme. Rice breeders have utilized the genetic potential of rice crop and achieved higher rice yields through plant type concept. Though, the breeders achieved a remarkable yield level, quality improvement remained unsolved posing a problem to combine yield and quality in rice crop.

From the consumers point of view, quality means not only the grain size and shape but also the cooking quality. From millers view, quality means hulling and milling out-turn and from scientists interpretation, the nutritional value especially the protein content being an important constituent of human dietary requirement.

In India grading is popularised and the commercial value of rice grain depends on Length/Breadth (L/B) ratio besides hulling recovery (%), cooking quality and nutritional quality (protein) of rice. Hence in order to find out the genetics of traits contributing to yield and

quality, the present investigation was undertaken with the following objectives.

1. To study the genetic diversity among the genotypes and to select parents possessing genetic diversity with breeding objective for diallel crossing.
2. To study the combining ability for yield and quality components in F_1 and F_2 generations.
3. To study the heterotic effects of different crosses in F_1 generation.
4. To study the heritability and genetic advance of yield, its components and quality characters in F_1 and F_2 generations.
5. To study the association of quantitative characters with yield and quality through correlation study in F_1 and F_2 generations.
6. To assess the magnitude of direct and indirect effects of the quantitative characters for yield by path coefficient analysis in F_1 and F_2 generations.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The scientific information on rice generated over the years is quite exhaustive and is beyond comprehensive. Hence, the more relevant and recent literature on rice crop, pertaining to the present study is reviewed and presented hereunder under the following heads.

1. Genetic diversity.
2. Analysis of variance.
3. Combining ability analysis.
4. Heterosis.
5. Variability, heritability and genetic advance.
6. Correlation estimates, and
7. Path analysis.

1. GENETIC DIVERSITY:

Mahalanobis's D^2 analysis has been useful in quantifying genetic divergence in rice. The same has been put to use by Das and Borthakur (1973), Ratho (1984) and Nanda and Singh (1988).

Environmental variations may also be responsible for this diversity in rice. This was confirmed by many of the workers (Singh et al. (1979), Singh (1983) and Ratho, (1984).

A knowledge about the nature and magnitude of genetic variability present in plant material plays a vital role in formulating successful breeding programme. It is an established fact that diverse parents are likely to result in desirable gene recombinations and produce promising genotypes. For the first time Nair and Mukherjee (1960) used D^2 statistic as a measure of genetic divergence in case of plantation Teak for classification. Thus, the basic importance of genetic divergence in plant breeding for higher yield has long been recognised and is evident from the results revealed by several workers.

Murty and Arunachalam (1966) reported that the greatest contributing traits to genetic diversity in grain crops were flowering time, plant height and tiller number per plant. Successful hybridization and selection depends primarily on selection of parents having high genetic diversity for different characters (Bhatt, 1970).

Flowering time, 1000 grain weight and plant height (Das and Borthakur, 1973) were found to be important contributing factors to genetic divergence. Panicle weight, days to maturity, plant height and grain size (^{Kamwal}~~Karnal~~ et al. 1983) have contributed maximum to genetic divergence in rice.

Ratho (1984) while studying on quality characters of scented rice varieties reported that Kernel length followed by volume expansion, kernel breadth and protein content contributed to genetic divergence in the descending order. Raut et al. (1985) reported that change in environment alters clustering pattern due to genotype - environmental interactions.

According to Nanda and Singh (1986) effective tillers per plant and grain weight contributed maximum to genetic divergence. Singh et al. (1986) reported that grains per panicle and days to 50% flowering are contributing much to genetic divergence followed by test weight and panicle length.

De and Surya Rao (1987) reported sterility percentage, EBT/hill, yield/m² and grain length are the major contributing characters to the genetic divergence.

Singh et al. (1988) reported plant height, grain length, breadth, test weight, panicle length and spikelet number were mainly responsible for the divergence in low land rice cultivars. Kwo and Hong (1988) opined that selecting parents from different clusters would be useful when the aim is to breed for high quality.

Hong et al. (1989) reported that growing area was one of the most important factors affecting rice quality, its effect differed between genotypes.

2. ANALYSIS OF VARIANCE:

Ghosh et al. (1981), Kotaiah (1983) and Gopinath et al. (1984) reported that the analysis of variance estimates for most of the characters in rice were found to be significant.

De and Surya Rao (1988) reported significant differences among 30 strains of rice with a wide range of variation for almost all the characters excepting 1000 grain weight and grain breadth.

Deosarkar et al. (1989a and b) noticed significant differences in respect of characters viz., plant height, 1000 grain weight, number of grains per panicle and effective tillers per plant.

Chauhan et al. (1990) observed substantial variability among F_2 populations for plant height, tillers and panicles per plant.

Gomathinayagam et al. (1990) reported significant differences among the 40 rice strains studied for different characters.

3. COMBINING ABILITY ANALYSIS:

Ghosh, Mitra and Sampath (1976) reported genetic improvement of protein content in rice by using 23 rice varieties with protein content varying from 10-14% as donors. Low protein exhibited partial dominance over high protein, and the inheritance of protein content was controlled by a few major genes besides minor genes showing maternal influence in F_1 , whereas in F_2 mean values were more or less similar and suggested that selection for protein content should be done in advanced generations and also indicated possibility to evolve high yielding varieties with increased protein content.

Singh and Richharia (1977) while studying combining ability for grain dimension and shape in unhulled rice of 6 x 6 diallel reported that for all traits the GCA and SCA variances are highly significant. Performance of parents per se was an indication of their GCA effects. Crosses showing high SCA effects for grain size were also significant for long grain and low grain breadth.

Singh and Singh (1982) while studying nature of gene action for quality components in rice in 8 x 8 diallel cross reported that both additive and non-additive components of genetic variation were equally important with complete predominance of non-additive gene action for protein content. The improvement of protein value could be rapidly achieved by kinds of selection which involve certain degree of intercrossing.

Good, Siddique and Zaman (1983) from a study on genetic analysis of kernel elongation in rice of 5 x 5 diallel cross, excluding reciprocals and involving varieties differing in degree of grain elongation on cooking, indicated that both additive and non-additive types of gene action influence grain elongation, with latter predominating. Parents with different GCA values of high x low and high x medium kernel elongation types exhibited significant and positive SCA effects.

RuiC and Zhao (1983) while studying genetic analysis of grain weight and shape in a diallel cross of 6 x 6 of Indian rice cultivars reported that additive effects were important for grain length and width. While additive dominance effects and epistasis were important for grain

thickness, Additive effects, partial dominance and epistasis contributed to grain weight.

According to Puri and Siddique (1983) GCA effects were greater than SCA effects although the latter was appreciable in F_3 .

The data on 1000-grain weight, grain length, width and shape (length and width ratio) from a diallel cross of 10×10 , without reciprocals, indicated that both additive and non-additive gene effects were significant with additive effects predominating (Panwar ^{and} Paroda, 1983). Good GCA and SCA cross combinations were identified for all four characters.

Sukanya Subramanian and Rathinam (1984) reported that most of the desirable grain yield attributes are controlled by both additive and non-additive gene actions as indicated by significant GCA and SCA mean square values. Plant height, panicle length, grain number and 100 grain weight are predominantly governed by additive factors while tiller number and grain yield influenced by non-additive factors. The grain quality characters viz., length, width, length-width ratio of grain are predominantly controlled by additive gene action. In a situation, where predominance of

non-additive components or influence of both additive and non-additive components are there simple pedigree selection method may not be adequate since it will not yield a desirable level of improvement and probably this may be the reason for slow progress in combining high yield and fine grain quality of grains. So the suggestion was that quality improvement can be achieved either by moderate back crossing method or recurrent selection instead of normal selection procedures.

Studies on combining ability for grain weight and its components in a 6 x 6 diallel without reciprocals on five grain characters in parents and F_1 by Singh (1984) suggested that both additive and non-additive gene effects were important for all the characters. Data on combining ability effects revealed high GCA for grain length, L/B ratio and grain weight and four hybrids showed high SCA.

Sonrexa (1984) reported parents with high GCA values for grain size, volume weight, hulling percent and ~~found~~ several crosses of such parents were found to have superior SCA effects.

Khan and Ali (1985) observed highest volume expansion, water absorption and kernel elongation during cooking in Basmati-370.

Singh and Singh (1985) while studying heterosis and combining ability for kernel size in rice of 8 x 8 diallel reported good SCA values for grain length, breadth and L/B ratio and a close association of per se performance and GCA effects of parents.

Mahapatra and Mohanty (1985) studied the inheritance of some quantitative characters in deciding heterosis in rice by combining ability analysis in a 12 x 12 diallel without reciprocals and scored for 30 characters. They found out GCA and SCA effects were highly significant for almost all the characters. Additive effects appeared to predominate for 21 traits including days to 50% flowering and grains per panicle. Spikelet sterility showed predominating SCA effects. Crosses involving parents with high and low GCA effects exhibited a greater SCA effects than the high x high or low x low crosses indicating the importance of interaction effects for most of the characters.

Clement and Poisson (1985) studied diallel analysis of three quality characters in five crosses and reported that for grain length both GCA and SCA variances were highly significant.

Diallel analysis with 8 varieties of rice by Singh and Singh (1985) indicated that the gene action appeared to be additive for kernel length whereas both additive and non-additive gene actions were found for kernel breadth and length-breadth ratio.

Sarath², Singh and Perraju (1986) opined that both additive and non-additive effects were important in the expression of water uptake, kernel elongation and yield per plant. Basmati-370 was the best parent having highly significant GCA effects for all quality characters including yield. Double crossing and 3-way crossing utilising Basmati-370 are suggested for improvement of rice.

Ghosh and Hossain (1986) from a study on combining ability of indigenous exotic crosses of rice of 5 x 5 half diallel cross involving three Indian and two foreign varieties in respect of grain yield per plant and 5 related traits revealed that foreign varieties (Deo-Geo-Woo-gen (D) and IR8) had higher GCA effects than Indian varieties (B.V-1, Sativa and B.J-1). F_1 hybrids from crosses between the foreign and Indian varieties had higher positive SCA effects. Crosses between foreign and Indian varieties viz., D x B.V-1 and D x Sativa were found to be the best for most yield components.

Kumar and Sreerangaswamy (1986) from a study on 6 x 6 diallel analysis for plant height in rice opined that height was governed predominantly by additive gene effects with some dominance gene action.

From a diallel cross of 5 x 5 Good and Siddique (1986) reported that crude protein content was found to range from 7.85 to 12.77 per cent. For this trait both additive and non-additive effects were involved with predominance of the former. Varieties with high protein content generally showed high positive general combining ability effects.

Sardana and Borthakur (1987) from a study on the combining ability for yield in rice of 5 x 5 diallel reported that GCA and SCA were significant for grain yield per plant, days to 50% flowering, plant height, effective tillers per plant, panicle length, number of grains per panicle and 100-grain weight indicating that parents with high GCA for yield gave best cross combinations than low x high and moderate x moderate.

Kuo and Liu (1987) from a study on inheritance of physical properties of cooked rice in a 6 x 6 diallel cross reported significant differences among the parents for 5

characters of cooked rice. Additive and dominance effects were significant for all characters with the former predominating.

Kim (1987) from a study of diallel cross analysis for six panicle characters in rice reported that all panicle traits had the presence of non-allelic gene interactions and were more influenced by dominance than by additive gene actions. Some characters were controlled by partial dominance and mean squares for GCA and SCA for all the characters, (except SCA for the number of grains) were highly significant. Effects of GCA were larger than SCA effects for all the characters.

Tomar (1987) stressed the importance of grain quality as a breeding objective after grain yield. The quality characters viz., cooking quality, grain size and shape, hulling recovery etc. are of particular interest, since major proportion of world's rice is consumed as cooked rice. The cooking quality of rice is mainly indexed by high water uptake, volume expansion and kernel elongation and at present varieties with high hulling, volume expansion, water uptake, linear kernel elongation and protein content are mostly preferred. However very little is understood on the genetics of these quality traits requiring attention on the

study of the important genetic parameters for these quality traits. The improvement for these quality traits can also be made through diallel selective mating system (Jensen, 1970, Hoff, 1972, Singh and Ikehashi (1981) proposed composite crosses involving genetic male sterility for rice crop improvement.

^{Kw}~~Kw~~ and Liw (1987) while studying on genetic studies on large grains and inheritance of grain yield from a 9 x 9 diallel analysis including reciprocals reported that both additive and dominance gene effects were important with predominance of dominance effects being more important for grain yield. General and specific combining ability effects were significant for grain yield with the former being more important and maternal effects also detected for grain yield.

Kalaimani and Sundaram (1988) from a study on combining ability in rice of 7 x 7 diallel cross indicated that GCA variance was greater than SCA for yield and yield components.

Agarwal and Sharma (1988) from studies of combining ^{ability} analysis of duration in rice of 7 x 7 diallel, parents, F_1 and F_2 indicated partial dominance for flowering and

importance of additive and dominance effects in inheritance of other traits.

Kaushik and Sharma (1988) observed predominance of additive gene action for plant height, panicle length and grains per panicle in 7 x 7 diallel and predominance of non-additive gene actions for 100 grain weight, sterility %, yield per plant, days to 50% flowering and number of tillers per plant. GCA parents of High x Moderate and Moderate x High gave best crosses with high SCA for yield.

Zaman, Siddique and Prasad (1989) while studying genetic analysis of water absorption and volume expansion in rice of 6 x 6 diallel of parents, F_1 and F_2 s have reported significant GCA and SCA effects for water absorption and volume expansion during cooking.

Studies of Dhaliwal and Sharma (1990) on combining ability as per Griffing (1956) on maternal effects for agronomic traits and grain characters in rice revealed that yield and quality of rice varieties can be improved if genetic information on agronomic and grain characters is available. And they reported that for grain characters viz., L/B Ratio, grain density, 100 grain weight and grain

yield per plant were when seven diverse rice varieties were crossed among them in all possible combinations to estimate GCA and SCA effects. It is observed that mean squares due to GCA and SCA were found to be significant for flowering, grain length and breadth, plant height, tillers per plant, panicle length, grains per panicle, 100 grain weight and grain yield indicating non-additive gene action and suggested improvement of these characters through hybridization.

Genetic studies more particularly for grain characters viz., grain length, breadth and L/B Ratio are important for improving yield and quality of rice and their information would be useful for formulating an effective breeding strategy in rice improvement programmes (Cicereo and Osri, 1977).

4. HETEROSIS:

For kernel length and L/B ratio, Paramasivan (1979) observed heterosis over mean of parents.

Significant heterosis for grain yield per plant was observed in seven crosses by Srivastava and Seshu (1982).

Mahapatra^a and Mohanty (1985) reported heterosis over mid-parental value for grain yield varied widely. The parents with high GCA also showed high variability in heterosis. SCA was significant in some heterotic hybrids. Heterotic hybrids appeared more frequently in crosses between high and low GCA parents than in high x high or low x low crosses indicating importance of interaction effects in producing heterosis.

Singh and Singh (1985) while studying heterosis and combining ability for kernel size in rice in 8 x 8 diallel noticed very poor manifestation of heterosis for kernel length, breadth and L/B ratio.

Positive heterosis recorded for kernel length and breadth of rice hybrids (Sahai et al (1986).

Sarathe, Singh and Perraju (1986) while studying heterosis and combining ability for quality characters in rice of 8 x 8 diallel reported significant positive heterosis over better parents for water uptake and kernel elongation, whereas yield per plant manifested positive heterosis.

Paramasivan (1986) while estimating heterosis in rice hybrids for quantitative characters viz., plant height, effective tillers per plant, number of grains per panicle, 100-grain weight and grain yield per plant, reported significant positive heterosis for 100-seed weight.

Kalaimani and Sundaram (1987) from a study on heterosis in rice for 7 x 7 diallel cross reported high mean values for all combinations and significant heterosis for yield but none excelled, IR 8 and similar observations for yield components indicated a lack of exploitable heterosis.

Tomar (1987) reported that in hulling recovery, mid-parental value was significant and heterosis showed a significant positive direction and in some cases negative direction for kernel elongation, Water uptake, volume expansion and protein content.

Sasmal (1988) reported hybrid vigour for yield and 4 of its components viz., grain length, grain breadth, panicle length and rachilla~~s~~ per panicle. Heterosis for grain yield was associated with heterosis for grain length, breadth, panicle length. In F_2 there was reduction in heterosis for grain length and breadth whereas heterosis was noticed for yield.

Kalaimani and Kadambavanasundaram (1988) reported that heterosis for yield was not affected by heterosis difference for its component characters viz., tillers per plant, grains per panicle and 100-grain weight except days to 50% flowering where heterosis for lateness positively affected yield.

Mandal and Sunil Saron (1989) while studying hybrid rice breeding for grain characters reported that hybrids involving a CMS line used as common female parent and four rice varieties as males were screened for nine quality characters in respect of heterobeltiosis and standard heterosis and indicated that one cross showed varying magnitudes of heterobeltiosis/standard heterosis for six characters viz., hulling recovery, kernel length, L/B ratio, kernel elongation, volume expansion and water uptake.

^u
Mandal and Palaniswamy (1989) while studying heterosis and correlation in rice on nine yield components in six cultivars and their F_1 hybrids, correlated grain yield significantly and positively with days to 50% flowering, plant height, panicles per plant, panicle length and grains per panicle.

Rao and Sang (1989) reported that heterosis for grain characters viz., length, width, thickness and weight in two crosses were around mid-parental value in F_1 whereas in F_2 grain width, thickness and weight were above mid-parental value.

5. VARIABILITY, HERITABILITY AND GENETIC ADVANCE:

Heritability of a character is a parameter of a particular significance to the plant breeder as it measures degree of resemblance between parents and offspring and its magnitude indicates the heritability with which a genotype can be identified by its phenotypic expression. Heritability primarily is a method of quantifying the concept i.e., whether progress of selection for a plant character is relatively easy or difficult in breeding programme. Heritability in broad sense refers to genetic variation in the population in relation to the total observed variation. Genetic advance refers to the improvement of the mean genotypic value of the selected families over the base population. It is possible to predict the genetic gain with the knowledge of heritability for any quantitative trait in segregating generations and aids in exercising selection pressure.

High genetic gain along with high heritability indicate that improvement could be made for such of those characters by simple selection on phenotypic appearance. The broad sense of heritability and genetic advance estimates for different characters by the different workers are reviewed below.

1. Days to 50% flowering:

Mahapatra and Mohanty (1985) reported that additive effects appeared to predominate for this trait.

Kalaimani and Sundaram (1987) reported that both additive and non-additive components with predominance of non-additive component control for days to 50% flowering and also observed overdominance for this trait.

Kaushik and Sharma (1988) reported epistatic interactions and complimentary interaction operate in expression for this trait.

Agarwal and Sharma (1988) while studying diallel analysis of 7 x 7 parents, F_1 and F_2 involving diverse genotypes of rice reported partial dominance for days to 50% flowering and the importance of additive and dominance

effects in inheritance with high narrow sense of heritability for this character.

2. Plant height:

High heritability coupled with high genetic advance for this trait was observed in rice by Maurya et al (1986).

Singh et al (1986) in upland rice cultivars and Shailaja Hittalmani et al., (1991) in elite rice cultures reported high heritabilities for this trait.

Reddy et al (1988), Pathak and Patel (1989) observed high heritability coupled with high genetic advance for this trait.

In rice, high heritability coupled with moderate to low genetic advance was reported for this trait (Ramesh Kumar, 1989) and Chauhan et al, 1990).

Deosarkar et al., (1989a) recorded high values of heritability coupled with high genetic advance for this trait in F_5 and F_6 breeding lines of upland rice.

Phenotypic and genotypic variability was found to be moderate for plant height in rice in F_2 (Ganesan and Subramanian, 1990).

3. Effective tillers per plant:

In a study on aromatic rice varieites Reddy and Reddy (1986) observed both high heritability and high genetic advance for this trait.

De and Surya Rao (1988) reported high heritability and high genetic advance over per cent mean for this trait in hill rices.

High heritability with high genetic advance as well as low heritability with low genetic advance was observed for this trait in F_2 generation of different rice crosses by Paramasivan and Sreerangaswamy (1988b).

Rama Rao (1990) and Srinivasa Rao (1989) observed high heritability with low genetic advance for this trait in F_2 generation of rice crosses.

Shailaja Hitalmani et al., (1991) observed moderate heritability for this trait in rice.

4. Panicle length:

High heritability coupled with high genetic advance was observed in rice by Maurya et al., (1986).

Paramasivan (1986), Sardana et al., (1989a) in tall x dwarf indica rice crosses and in rice cultures respectively recorded high to moderate estimates of heritability with low genetic advance for this trait.

Low genotypic coefficients of variation, moderate to low heritability and low genetic advance for this trait was observed by Deosarkar et al (1989a) in F_5 and F_6 breeding lines of upland rice.

High heritability with high genetic advance, low heritability and low genetic advance was recorded in different crosses of F_2 generation of rice by Paramasivan and Sreerangaswamy (1988b).

5. Number of grains per panicle:

Maurya et al., (1986), Paramasivan (1988), Reddy and Reddy (1986) and Pathak and Pat~~e~~l (1989) observed high heritability coupled with high genetic advance for this trait.

High to low heritability coupled with high to low genetic advance in F_2 generation of different rice crosses was recorded by Paramasivan and Sree Rangasamy (1988b).

The estimates of heritability and genetic advance were moderate for this trait as reported by (Deosarkar et al., 1989a).

High heritability with moderate genetic advance of this trait in drought tolerant genotypes of rice was reported by Gomathinayagam et al., (1990).

6. Spikelet sterility (%):

De and Surya Rao (1988) reported high heritability with high to moderate genetic advance over per cent of mean for this trait.

Ramesh Kumar (1989) observed moderate heritability with very low expected genetic gain and low expected genetic gain over per cent mean for this trait.

7. 100-grain weight:

High heritability with very low genetic advance was observed for this trait in F_2 and F_3 generations by Ghosh and Bh^{aw}mik (1985).

Paramasivan (1986) reported high heritability and low genetic advance for this trait in F_2 of a rice cross.

Rao and Jagadish (1986) reported that heritability tended to decrease from F_3 to F_4 of five different crosses of rice studied.

Reddy and Reddy (1986) and Pathak and Patel (1989) reported high heritability with high genetic advance for this trait.

Progressive increase of heritability was observed by Subramanyam et al., (1986) from F_2 to F_5 generations of three rice crosses for this trait.

Dhanraj et al., (1987a) reported heritability of 81.9% with a genetic advance of 43.9% in F_2 of selected rice crosses for this trait.

Deosarkar et al., (1989a) recorded high to moderate values of heritability with moderate genetic advance for this trait in F_5 and F_6 breeding lines of upland rice.

8. Grain yield per plant:

Heritability (Broad sense) of 78.01% with 7.02% expected genetic gain for this trait was reported by Paramasivan (1986) in F_2 of rice cross.

Yoshikawa (1988) reported that it would be possible to select for high yields and high quality.

Genetic variability studies in 18 early diverse genotypes of upland rice showed higher genotypic and phenotypic coefficient of variability for grain yield (Pathak and Patél, 1989).

A low heritability accompanied by low genetic advance was recorded for grain yield per plant by Deosarkar et al., (1989a)

In F_2 of four rice crosses, high heritability coupled with high to moderate genetic advance was recorded for this trait by Paramasivan and Sreerangaswamy (1989b).

Gomathinayagam et al., (1990) reported high heritability with high genetic advance for this trait in drought tolerant genotypes of rice.

Phenotypic and genotypic variability was high for grain yield per plant in F_2 (Ganesan and Subramanian, 1990).

9. Length of grain:
10. Breadth of the grain:
11. L/B Ratio:

From the pattern of inheritance on grain quality characters of crosses involving 6 varieties from tall and dwarf rices, Sukanya Subramanian and Madhava Menon (1973) indicated that all traits showed partial dominance. The grain length found to be governed by one major gene pair with incomplete dominance and was influenced by modifiers with enhancing effect to a higher degree. The breadth of grain was controlled by a polygenic system of simple nature consisting of fewer genes with more or less of same effect. The inheritance of shape of grain indicated by the index L/B followed the Pattern of length of grain.

Jennings et al., (1979) reported that studies on grain quality as expressed by length and shape of grain are independently inherited and can be combined as desired. There are no barriers to recombination of grain length and shape with other quality traits such as endosperm appearance, plant type, dormancy or maturity period. Grain length and shape are quantitatively inherited, F_1 is typically intermediate and transgressive segregation for grain length is common in F_2 and highly heritable in most environments. Grain length and shape appear to be fixed

early in segregating generations. If the desired expression is not found in F_2 the chance of finding better types in F_3 is obscure. This indicates extreme importance of putting strong selection pressure on F_2 generation of crosses.

Das ~~et al~~ ~~Ahmed and Borthakur~~ (1980) indicated that inclusion of either breadth or thickness, such that length and any one of the other two variables preferably breadth could jointly determine width and shape with only a small loss in efficiency.

Mc Kenzie (1981) reported that grain length and width appeared to be governed by quantitative genes in all six rice crosses effected, which also showed high heritability values indicating selection for both would be effective.

According to Singh (1982) both additive and non-additive gene effects were important for all grain characters in parents and F_1 of 6 x 6 diallel without reciprocals.

Qi et al

Qi, ~~Li~~ ~~Bj~~ ~~Yang~~ and ~~Wu~~ (1983) reported average heritability in narrow sense to be 61.73% for grain length and width.

Ruiz and Zhao (1983) stressed the importance of additive effects for grain length and width.

Panwar and Paroda (1983) indicated that both additive and non additive effects were significant with the former predominating for grain length, width and L/B ratio of 10 x 10 diallel without reciprocals.

Sukanya Subramanian and Rathinam (1984) reported that the grain quality factors viz., length, width, L/B ratio are controlled predominantly by additive gene action.

Paramasivan (1984) reported that L/B ratio of grain in hybrids expressed intermediate values with transgressive segregation and polygenic control.

Clement and Poisson (1984) obtained high heritability estimates (90%) and no overall dominance for grain length and predominance of additive effects.

Sonrexa (1984) noticed additive gene effects, partial dominance, high heritability and high genetic advance for grain size in Line x Tester analysis using 16 lines and 3 testers suggesting simple breeding procedures for improvement of this trait.

Singh and Singh (1985) reported that gene actions appeared to be additive for grain length and laid emphasis on both additive and non-additive gene actions for grain breadth and L/B ratio in a diallel of 8 x 8 varieties of rice.

Maurya et al., (1986) reported high heritability coupled with high genetic advance for L/B ratio in 48 low land rice varieties.

Narasamma (1987) reported high heritability (85%) for L/B ratio, which suggested additive type of gene action.

Hsieh and Wang (1988) reported that grain length is under polygenic control or under control of 3 alleles with slender grain dominating over bold grain.

Moderate heritability with low genetic advance was observed for L/B ratio in F_2 and F_3 generations (Ramesh Kumar, 1989 and Rama Rao, 1990).

Deosarkar et al., (1989b) observed high heritability with low genetic advance for L/B ratio in a study on breeding lines of rice.

Dhaliwal and Sharma (1990) indicated that yield and quality of present rice varieties can be improved provided genetic information on agronomic and grain characters are available and reported non-additive gene action was predominant for all grain quality characters. The study would be useful for formulating an effective breeding strategy in rice improvement programmes.

Quality characters:

Tomar (1987) stated the grain quality is only next in importance to yield as a breeding objective. Among quality characters, cooking quality besides grain size and shape, hulling recovery etc., are of particular interest, since a very large proportion of world's rice is consumed as cooked rice. Rice varieties with high hulling, volume expansion, water uptake, linear kernel elongation and protein content are mostly preferred.

12. Hulling recovery:

Gardon (1952) reported that hulling per cent is related to size and shape and hardness of varieties.

Adair (1955) noted differences in hulling quality of varieties with the same rice grain type.

Jodon (1955) from the available information expressed that it is possible to obtain varieties with high hulling per cent by breeding.

Ghosh et al., (1956) developed a quick hulling test for rice varieties which consists of rubbing a few grains of paddy between the palms of hands to remove husk.

and Hallick

Beachell/~~et al.~~, (1957) opined that the differences among varieties for hulling recovery were largely hereditary.

From studies on the variability of genetic stock of rice for hulling percentage ^hRichharia and Seetharaman (1959-60) found highest recovery (80.36%) in a variety, Changsen, from Manipur which was a glabrous type and concluded that this trait is hereditary in nature.

Richharia and Govindaswami (1962) concluded that hulling per centage is a varietal character and controlled by genes and showing association with size and shape of grain.

and Menon

Sivasubramanian ~~et al.~~, (1973) concluded that hulling percentage was independent of grain size and shape.

Gopalakrishna, ^{et al}~~Agarwal and Mani~~ (1982) noticed high hulling recovery in slender grained types.

Sonrexa (1984) reported that for hulling percentage non-additive gene effects, high to low heritability percentage, moderate to low heritability and moderate to low genetic advance are observed.

Tomar and Nanda (1985) reported that fine rices had low hulling recovery.

Tomar (1987) from a study on genetic analysis of generation means for some quality characters in rice, indicated that hulling character exhibited significant additive effect and improvement of hulling could be achieved through conventional breeding method. Diallel selective mating system proposed by Jensen, (1970). Hoff (1972), Singh and Ikehashi (1981) with composite crosses involving genetic male sterility for improvement of this trait in rice crop.

13.	Volume expansion:	All three characters are combined since meagre literature is available on the subject.
14.	Water uptake:	
15.	Kernel elongation:	

Vergheese (1950) described the method of estimating volume expansion of rice after cooking for determining cooking quality for experimental purposes.

Sanjeevi Rao et al., (1952) reported that swelling number (volume expansion) is a measure of cooking quality.

Batcher et al., (1956) reported that differences due to variety existed for cooking quality traits viz., grain type, water absorption and volume expansion.

Beachell ^{and Hallick} ~~et al.~~, (1957) determined that differences in cooking quality were largely hereditary.

Deskachari and Subramanyam (1959) reported that increase in length and breadth of rice on cooking was a measure of their swelling capacity and observed that old rice increased more in length over new rice.

Crane (1959) observed increase in water intake of brown rice ripend under cooler temperature.

Prema and Menon (1969) reported that increase in volume on cooking was highest in TN 1 and water uptake maximum in IR-8.

Tomar and Nanda (1982) while studying inheritance of cooking quality components of rice in parents, F_1 , F_2 , B.C 1 and B.C 2 generations of the crosses found that genetic components of variance for water uptake, volume expansion and grain elongation indicated that all characters showed transgressive segregation (polygenic) with additive gene effects and high heritability.

Good, ^{et al} ~~Siddique and Zaman~~ (1983) in a study of genetic analysis of kernel elongation in rice of 5 x 5 diallel without reciprocals indicated that both additive and non-additive types of gene actions influence grain elongation with the former and later predominating in different crosses.

Thagumanovin and Sadasivan (1984) indicated existence of varietal differences for cooking quality characters viz., volume expansion, water uptake and kernel elongation etc.

Sonrexa (1984) reported that for volume expansion non-additive gene effects, low heritability and low genetic advance occurred in a line x tester analysis using 16 lines and 3 testers and suggested biparental mating and recurrent selection for the improvement of this trait.

Cooking quality of rice as influenced by source and level of "N" fertilisation indicated that source viz., A/S, urea, CAN or DAP and level of "N" application affects cooking quality (Jayakumar and Kanda Swamy (1985).

Khan and Ali (1985) reported that volume expansion, water uptake and grain elongation after cooking was highest in Basmati-370 compared to rice varieties viz., Jhona 349 and Palaman 246.

Tomar and Nanda (1985) indicated that kernel shape was independent of kernel elongation during cooking.

Sarathe, ^{et al} ~~Singh and Perreju~~ (1986) reported that both additive and non-additive gene effects were important in the expression of water uptake and kernel elongation of 8 x 8 diallel of rice and suggested double crossing and 3 way crossing using Basmati-370, Madhuri and Laloo 14 varieties for the improvement of rice.

Kwo and Liw (1987) while studying inheritance of physical properties of cooked rice in 6 x 6 diallel noticed significant additive and dominant effects for all cooking quality characters, with the former predominating. Maternal

effects were also noted with partial dominance for all characters.

Tomar (1987) noticed significant and positive additive effects for volume expansion, water uptake and kernel elongation in some crosses. Dominant effect was significant for kernel elongation in some cases. The effect was usually dominant for volume expansion and water uptake. For the improvement of kernel elongation, conventional breeding method may be effective whereas the results of volume expansion and water uptake revealed that improvement of these characters may be possible by recurrent selection using suitable male sterility system.

16. Protein content of brown rice:

Baptiste (1950) and Hoover ~~et al.~~ ^{and Jaya Sanyal}, (1951) noticed wide variations in the protein content within rice varieties.

In Maize hybrids genetic factors determined protein content (Hunt et al., 1952).

Norden et al., (1952) found differences in protein content in Maize hybrids due to genetic factors and environment played little role.

Hofmon and Hohenburger (1952) concluded that heavy manuring with nitrogen increased protein content in Barley.

^{and Rao}
Ramaiah (1952) opined that quality of rice can be improved by increasing protein.

Baba (1954) pointed out that INDICA varieties contain low nitrogen percentage than JAPANICA varieties and it is possible to transfer higher protein of later to former by hybridization.

Sturgis et al., (1952) concluded that varietal inheritance mostly determines protein content than do soil conditions or fertiliser treatments.

Butkevic (1954) reported that protein content of wheat varieties altered with environment, and each variety displayed a different response to a given environment.

Rennie (1956) observed that protein content in wheat varied with soil and climatic conditions rather than NPK fertilization.

According to Sampath and Seshu (1957) long-glumes in paddy are associated with higher protein than short glumes.

Tetraploids in rice had the average protein content of 11.7% and wild rices average 8 to 9 per cent.

Kido ^{and Yamaguchi} ~~et al~~, (1968) reported that heavy "N" fertilization in rice resulted in small kernels with high protein and early varieties formed kernels with high protein than late varieties.

Ghosh, ^{et al} ~~Mitra and Sampath~~ (1976) used 23 rice varieties with 10-14 per cent protein as donors and found out low protein showing partial dominance over high protein and its inheritance was controlled by a few major genes besides minor genes though maternal influence was noted in F_1 seeds, the F_2 mean values were nearly similar suggesting that selection for protein should be carried out in advanced generation for evolving high yielding varieties with increased protein content.

Jennings et al., (1979^o) during a preliminary study on protein content of 7,419 samples reported that 101 samples including several glutinous varieties, contained more than 13.5 per cent and a few exceeded 15 per cent and these high values exemplified one of the problems of protein evaluation and about 25-50 per cent of protein variability was estimated to be genetically controlled. Samples of high

protein are resistant to abrasive milling, yield less bran and on polish gives increased head rice yields and are darker in appearance than lower protein samples requiring more water and longer cooking time and having same eating quality as normal rice.

Kaul (1981) reported additive gene action and partial dominance of genes controlling protein content in a study of diallel analysis and further stated that more recessive than dominant alleles appeared to control protein content.

Singh and Singh (1982) reported that both additive and dominance components of genetic variances were equally important for protein content with complete dominance and high heritability in a study of graphic analysis of a 8 x 8 diallel cross of rice.

et al
Kambayashi ~~and Sasabara~~ (1984) reported that protein content was controlled by 6-7 genes in F_2 .

Heda and Reddy (1984) from the data on parents, F_1 , F_2 and F_3 of six crosses each involving one parent with high and one with low protein content indicated the dominance of low over high content. Frequency of desirable segregates

combining high yield and high protein content increased from F_2 to F_3 in all crosses.

Petibskaya (1984) reported medium heritability estimate (52%) for protein content.

Mosina (1985) reported additive, dominance and epistatic effects in the genetic control of protein content of rice in a diallel set of 7 x 7 with reciprocals of F_1 and F_2 hybrids. Dominance and over dominance of high protein content was observed in the inheritance of this trait.

Good and Siddique (1986) reported that both additive and non-additive effects were involved with former predominating for protein content in a diallel cross of 5 x 5 and crude protein content ranged from 7.85 to 12.77 per cent.

Narasamma (1987) reported additive type of gene action with medium heritability for protein content indicating response to selection may be anticipated in improving this character.

Tsu^uyaki, Murakami and Shi^uda (1989) from the studies on the F_2 - F_5 generation of cross of high protein, scented

Nepalese variety Brimful (12.76% protein) and Japonica variety Koshihikari (9.54% protein) suggested that high protein character was controlled by multiple genes or polygenes. Heritability (narrow-sense) value was 0.589 and was not correlated with major yield components nor with grain flavour.

6. CORRELATION ESTIMATES:

Correlation coefficients indicate the magnitude of association between pairs of characters and form the basis of selection thereby aiding the plant breeder in developing superior progenies. The literature on association of yield components and quality characters is reviewed hereunder.

1. Days to 50% flowering:

In rice, plant height showed positive correlation with heading date (Kanwal and Sahu (1969).

Das and Borthakur (1973) and Sindhu⁸⁰ (1973) reported negative association of days to 50% flowering with grain yield.

High positive correlation of days to 50% flowering with yield was reported by Reddy and Reddy (1981).

2. **Plant height:**

Chauhan et al (1986), Hedge (1987), Pathak and Patel (1989), Majumdar et al, (1990) and Sharma and Reddy (1991) in rice varieties, Paramasivan (1988, 1989) in rice accessions and Wilfred Manuel and Palaniswamy (1989) in rice hybrids reported positive association of this trait with grain yield. However, Kalaimani and Kadambavanasundaram (1988) and Tahir et al., (1988) in rice varieties, Reuben and Katuli (1989) in upland rice breeding lines recorded negative association between this trait and grain yield.

3. **Effective tillers per plant:**

A positive and significant relationship between grain yield and effective tillers per plant was observed by Chauhan et al. (1986), Hedge (1987), Wu et al. (1987), Rahangdale and Keorgade (1988) and Majumder et al. (1990) in rice varieties. Similar findings were also reported by Paramasivan and Sreerangaswamy (1988a) in rice crosses and by Ganesan (1987) in F_2 generation of the crosses. Whereas positive but non-significant association was observed in F_3 generation by Rama Rao (1990) for this trait.

4. **Panicle length:**

The relationship between panicle length and grain yield was found to be positively significant in rice

varieties (Chauhan et al., 1986, Reddy and Reddy, 1986, Pathak and Patel, 1989 and Majumder et al. 1990), in rice accessions (Paramasivan, 1987, 1988 and 1989), in rice hybrids and varieties (Wilfred Manuel and Palanisamy, 1989) and in F_2 generation of rice crosses (Dhanaraj et al. 1987b).

5. Number of grains per panicle:

The association of grain yield with number of grains per panicle was found to be positively significant in rice varieties (Reddy and Reddy, 1986, Sampath et al. 1989, Swaraj et al. 1989 and Majumder et al. 1990); in elite rice cultures (Anita Saha and Das Gupta, 1990); in hybrids and varieties (Wilfred Manuel and Palaniswamy, 1989); and in F_2 generation (Dhanraj et al. 1987b; Paramasivan and Sree Rangasamy. 1988a), whereas Zhong et al., (1987) reported negative correlation between floret number and grain yield per plant.

6. Spikelet sterility:

Prasad et al. (1988) in rice varieties, Ramesh Kumar (1989) in F_2 generation recorded negative relationship between grain yield and spikelet sterility, while

Paramasivan (1989) observed negative association with number of chaff grains per panicle.

7. 100-grain weight:

The observations by Chauhan et al., (1986), Kalaimani and Kadambavanasundaram (1988), Prasad et al., (1988) and Sampath et al., (1989) in rice varieties, Anitha Saha and Das Gupta (1990) in elite cultures of rice; Paramasivan and Sree Rangaswamy (1988a) in rice crosses; Dhanraj et al., (1987b) in F_2 generation of rice crosses indicated positive and significant association of this trait with grain yield per plant. Ganesan (1987) reported a positive, but non-significant association between grain yield and test weight in F_2 and F_3 generations while Zhong et al., (1987) reported negative correlation of grain yield with grain test weight. Malano (1968) reported negative correlation between kernel weight and protein per cent in sorghum and positive correlation between seed density and protein per cent in sorghum. Smith and Weber (1968) reported that high seed density was associated with high protein in soyabean.

8. Grain yield per plant:

Rahangdale and Khorgade (1988), Dhanraj et al., (1987b), Kalaimani and Kadambavanasundaram (1988), Paramasivan (1988), Prasad et al. (1988), Deosarkar et al.,

(1989a), Wilfred Manuel and Palanisamy (1989), Pathak and Patel (1989), Sampath et al., (1989), Majumder et al., (1990) and Sharma and Reddy (1991) reported that selection for more plant height, number of effective tillers per plant, number of grains per panicle would be highly effective in improving this character.

Grain quality characters:

9. Length of grain:
10. Breadth of grain:
11. L/B ratio:

Voluminous studies have been made in relating yield with its components, but this aspect in respect of quality characters has been neglected in many crops (Tripathi, Gupta and House (1971)).

Soomrith et al., (1979) reported negative correlation of L/B ratio with grain yield.

Kaul (1983) reported that protein content was negatively correlated with grain weight and grain yield in rice.

Paramasivan (1984) reported in F_2 generation that size of grain and L/B ratio showed significant positive correlation with yield in rice.

Sasmal (1988) reported that grain yield was associated with grain length, breadth, panicle length and rachillates per panicle.

Tsujuki et al., (1989) reported that protein content was not correlated with major yield components.

and Yamalore
Kido ~~et al.~~, (1968) reported that heavy N fertilization, dense planting, injury to root and leaf blade and lodging induces small kernels which are usually rich in protein.

and Memon
Siva Subramanian ~~et al.~~, (1973) concluded that hulling percentage was independent of grain shape and size and L/B ratio is positively associated with amylose content which in turn is positively associated with cooking quality.

Mallick et al., (1978) reported that grain yield was negatively associated with plant height and L/B ratio of grain in rice.

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Jennings et al., (1979) reported that cooking quality (gel temperature) has no relation with grain traits and so a wide range of desirable traits viz., grain length, shape and cooking qualities can be recombined eventhough grain characters are independently inherited.

Soomrith et al., (1979) observed negative relationship of L/B ratio with grain yield.

Vidal (1980) reported that short grained varieties (less L/B ratio) gave highest hulling recovery.

Paramasivan (1980) reported positive correlation between grain length and breadth and also with grain yield.

Das et al., (1980) noticed a close relationship between grain weight and grain dimensions (L, B and T) and proposed specifications for slender (> 3.6), quasi-slender (2.8 to 3.6) bold (2.4 to 2.79) and round (< 2.4) and proposed L/B ratio classification considered as tenable.

Chauhan and Nanda (1982) reported that kernel shape (L/B ratio) and kernel size i.e., grain length had no relationship with hulling percentage whereas physico-chemical properties of kernels lacked appreciable magnitude

of association with hulling percentage. Hence hulling percentage appears to be independent of kernel size, shape and kernel length and L/B ratio which are positively associated with each other and the results further indicate that compromise has to be made between kernel length and L/B ratio and hulling recovery because of negative correlations with hulling recovery.

Hsieh and Kwo (1982) reported that amylose content (cooking quality) was negatively correlated with protein percentage and plant height was positively correlated with 1000-grain weight.

Gopalakrishna et al., (1982) obtained highest hulling out turn from slender-grain (L/B ratio fine) varieties.

Mc Kenzie and Rutger (1983) reported negative correlation of grain length and width with amylose content in all crosses which in turn is associated with good cooking quality.

Neel~~an~~^{ant}back (1984) reported that kernel length also showed positive correlation with yield.

Sukanya Subramanian and Rathinam (1984) reported that L/B ratio was negatively associated with grain yield and 100 grain weight while positive correlation existed between the later two traits and may be the reason for the rare combination and slow progress of fine grain quality (high L/B ratio) combined with yield. This association can be dissociated with recombinations possessing high yield and fine grain quality can be secured either by modified back crossing method or recurrent selection.

Kambayashi et al., (1984) observed positive correlations between 1000 grain weight and protein in F_2 generation of pooled data but not in individual crosses.

Tomar and Nanda (1985) studied genetics of kernel shape in segregating generations of six crosses of rice and its association with size, hulling recovery, water uptake and kernel elongation during cooking. The six crosses were classified into three groups as per kernel shape of parental varieties i.e., slender x bold, slender x medium and medium x bold. Slender was dominant over medium and bold and medium kernel was dominant over bold. No association was seen between kernel size and shape. The slender kernel rices had low hulling but had high water uptake when

compared to bold kernel rice. The kernel shape was independent of kernel elongation during cooking.

Panduranga Rao et al., (1986) reported negative correlation between grain breadth and yield.

Good and Siddique (1986) reported that grain length and L/B ratio was significantly and positively correlated with water uptake.

Kwo (1986) from a study of 10 grain quality characters in Japonica and Indica varieties reported that mean grain length and L/B ratio were superior in the later while the remaining characters tended to be superior in the former.

Sinha and Banerjee (1987) noticed a positive correlation between L/B ratio and yield.

Sasmal (1988) reported that heterosis for grain yield was associated with heterosis of grain length, breadth both in F_1 and F_2 .

Yadav and Singh (1989) suggested that hulling character is independent of grain shape.

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Rao and Song (1989) reported that the grain length and width were inherited independently and governed by different sets of genes.

The association between L/B ratio and grain yield was found to be positive in upland rice breeding lines (Deosarkar et al., 1989b); in F_2 generation (Ramesh Kumar, 1989). However, negative relationship was recorded by Srinivasa Rao (1989) and Sarial and Uma Ahuja (1991) in rice varieties.

Juliano (1990) reviewed various factors influencing grain quality components notably varietal and environmental in relation to consumer demand and international trade and indicated that grain components and constituents are considered in breeding work to improve various quality characters viz., cooking quality, nutritional value and protein content.

12. Hulling percentage:

Gordon (1952) reported that hulling percentage is variable with size, shape and hardness of varieites.

Panda (1962) reported that glabrousness in lemma-palea is associated with high hulling out turn.

Siva Subramanian et al., (1973) and Yadav and Singh (1989) also concluded that hulling percentage was independent of grain shape and size.

Jennings et al., (1979) recorded that high hulling types had more protein content, required more water and longer cooking time.

Gopalakrishna et al., (1982) reported that hulling recovery was high in varieties with slender grains.

Hartley et al., (1983) reported that hulling out turn was positively correlated with protein content.

Tomar and Nanda (1985) reported that slender kernel rices had low hulling recovery.

Cooking quality characters:

13.	Volume expansion	Since meagre literature is available, all the three characters are reviewed combinedly.
14.	Water uptake	
15.	Kernel elongation	

Of late, cooking quality is gaining increasing importance. The released varieties satisfied farmers in yield capacity, but, still need acceptance by trade and

consumer. It is therefore essential that quality tests need to be carried out side by side, for the purpose of breeding suitable strains.

Jones (1938) advocated the use of alkali test, for it was an indication of cooking quality and found that milled grains which disintegrate into clear masses are of better cooking quality than those which break down in opaque mass in 2.38% KOH solution and also reported that long grains have desirable cooking quality.

Vergheese (1950) described the method of cooking rice for experimental purpose, for determining the trait of volume expansion after cooking.

Varieties having good cooking quality showed highest amylose (Rao et al., 1962).

and Gad

Pan ~~et al.~~, (1954) observed significant differences between durations and between varieties with regard to cooking quality. But the correlation of volume expansion and length of grain with cooking quality were found to be negative but non-significant.

Batcher et al., (1956) concluded that grain type was the chief factor influencing water absorption and volume.

Primo et al., (1962) demonstrated that the protein content of the outer layer of cooked polished rice grains differed among varieties and had a highly significant negative correlation with cooking quality score whereas positive correlation existed between protein of raw rice and cooking quality preference.

Jennings et al., (1979) reported that gel temperature is negatively associated with cooking quality (high gel temperature and low amylose). Among milled rices treated with 1.07% KOH solution for 23 hours at 30°C, the grains with low gel dissolve completely and rices with high gel temperature are unaffected by alkali. Rices of high gel require more water and time to cook and are classified as poor quality rices. Low gel temperature grains (good quality) are prone to damage by insects and fungus than high gel types.

Good, Siddique and Zaman (1979) revealed that water uptake was the only character that showed positive and significant influence on kernel elongation.

Hsieh and Kwo (1982) reported that amylose content (good cooking) was negatively correlated with protein content and plant height but positively correlated with 100 grain weight.

Tomar and Nanda (1982) observed positive correlation between water uptake and all other characters as that of volume expansion and grain elongation.

Singh and Singh (1982) reported that amylose content and protein content closely followed each other in heritability indicating that higher protein and good cooking quality could be rapidly achieved by selection involving intercrossing and shifting of genes towards desirable direction was possible.

Chauhan and Nanda (1982) reported that kernel length and L/B ratio were positively and significantly related with high amylose content and similar findings were reported earlier by Webb (1968) ~~IRRI, Philippines (1974)~~, Julliano et al., (1964) and Dwivedi (1977).

According to Chauhan and Nanda (1983) grain yield per plant had no relation with cooking quality.

Chang et al., (1984) reported that Indica varieties, TN1 and Tainan 15 had highest values of protein and also had high amylose contents (good cooking quality).

Singh and Singh (1985) reported ~~was~~ close association of per se performances of parents for kernel length, breadth and L/B ratio with their GCA effects.

Tomar and Nanda (1985) reported that slender kernel rices had high water uptake as compared to bold kernel rices and kernel shape (L/B ratio) was independent of kernel elonga-tion during cooking.

Jaya Kumar and Kandaswamy (1985) reported that cooking quality in rice differs with varieties and fertilization, but much work has not been done on this aspect. Amylose increase in grain increases quality of cooked rice and application of A/S and urea increases amylose content. Lowest swelling number is desirable. Increase in water uptake is not desirable.

Good and Siddique (1986_a) reported that grain elonga-tion on cooking depended on water uptake significantly. Although the traits volume expansion, length and L/B ratio of uncooked grains did not influence grain elongation, they

were significantly and positively correlated with water uptake, thereby showing the independently inherited nature of these traits.

Sarath et al., (1986) reported significant positive relation between water uptake and kernel elongation whereas yield per plant was positively correlated with amylose content of kernel (good cooking).

Sadananda, et al ~~Zaman and Siddique~~ (1989) reported that most varieties with high volume expansion also showed high water absorption on cooking. High density i.e., number of grains per panicle appeared to be associated with high volume expansion and water absorption whereas in varieties, Karnal Local and Basmati 370, the trait, high density was associated with volume expansion only.

et al
Zaman (1989) reported that moderate water absorption ✓ and high volume expansion are desirable for consumer acceptability.

Nutritional quality:

16. Protein content of brown rice:

Work on genetical analysis of protein content of rice in respect of correlation studies is meagre and the available literature is reviewed.

Hunt et al., (1952) recorded that protein content in maize hybrids decreased with advancing maturity.

^{and Rao}
Ramaiah (1953) opined that quality of rice can be improved by increasing the protein content and through application of N fertilizers.

Losza (1953) reported that protein content was highest in rice grown in alkali soils and lowest in clay soils. No variation was observed in rice samples in different years in respect of protein content.

Sampath and Seshu (1957) reported that rice tetraploids with higher protein content of 11.7% gave poor yields.

^{Yamlore}
^{and} Kido ~~et al.~~, (1968) reported that heavy 'N' application and dense planting results in root injury, lodging and small grains rich in protein. Early varieties formed kernels rich in protein.

Malano (1968) worked out negative correlation between kernel weight and protein percentage in sorghum..

Jaros et al., (1969) and Sunanda and Bose (1970) reported that protein content in rice was not correlated with 100 grain weight.

Hillerislammers et al., (1973) stated that high protein content in rice was negatively correlated with test weight. A strong and negative correlation between grain yield and grain protein content was also seen in the above studies.

Jennings et al., (1979) observed that high protein rice types require more water and longer cooking time.

Kaul (1981) obtained ^αnegative correlation between protein content and grain weight and yield and recommended selection for high protein and yield rather than protein content alone in rice.

Singh and Singh (1982) reported that inheritance^α of protein content closely followed that of amylose content and suggested that improvement of high protein and desired combination of amylose (good cooking index) could be rapidly achieved by kinds of selection in rice involving certain

degree of intercrossing. TN 1 parent appeared best for protein content.

Hsieh and Kwo (1982) noticed negative relationship between amylose percentage and protein percentage and plant height and positive correlation of amylose content with 1000-grain weight in rice.

Hartley ~~and~~ ^{et al} ~~Leclerc~~ (1983) noticed positive correlation between protein content in rice and hulling and milling out turn.

Tomar and Nanda (1984) reported that gel temperature was negatively correlated with protein content in F_2 rice crosses i.e., good cooking was positively correlated with protein content.

Heda and Reddy (1984) concluded that hybridization followed by selection in rice may help in developing varieties with high protein content and superior yield potential.

et al
Kambayashi, ~~Tsuchi~~ and Sasahara (1984) reported that
in F₂ 1000 grain weight was positively correlated with

protein content in the pooled data but not in individual crosses of rice.

Madar and Bhat (1984) reported that cooking quality was directly related to amylose content in rice.

Jaya Kumar and Kandaswamy (1985) reported increased amylose content (cooking quality index) and protein with increased application of A/S and Urea. So increase in protein content is associated with cooking quality in rice.

Good and Siddique (1986) reported that crude protein content in rice ranged from 7.85 to 12.77% and varieties of high protein had high and positive general combining ability effects.

Tsujuki and Kurida (1989) reported success in achieving higher grain protein yield but grain yield was lower in comparison to protein content in rice.

Tsujuki ^{and Shada} ~~et al.~~, (1989) selected 15 promising lines with high protein contents (11.5 to 14%) and suitable agronomic characteristics in F_5 .

7. PATH COEFFICIENT ANALYSIS

Yield being a quantitative character and polygenically inherited, direct selection may not be a reliable approach on account of its being highly influenced by environmental factors. Therefore, it becomes essential to identify component characters, related to yield for its improvement. Though correlations give information about the components of a quantitative character like yield, they could not provide correct picture of relative importance of direct and indirect contributions of the component characters. Path coefficient analysis is a vital test for partitioning the correlation coefficients into direct and indirect effects of an independent variable on dependent variables. Thus, correlation in combination with path analysis would give a better insight into the cause and effect relationship between different pairs of characters. Thus, literature pertaining to path analysis for yield and yield components is reviewed hereunder.

1. Days to 50% flowering:

Path analysis in rice crop revealed that days to 50% flowering had a high direct effect on grain yield followed by negative indirect effects through spikelet number per panicle and tiller number per hill (Sastry et al., 1967; Wang, 1967 and Ish Kumar and Saini, 1973), while Das and

Borthakur (1973) reported that days to 50% flowering had a negative direct effect on yield coupled with negative increased effects through plant height, tillers per hill and positive indirect effect viz spikelets per panicle. This trait had a negative correlation with yield.

Siva Subramanian and Madhav Menon (1973) indicated that flowering duration had direct positive effect on yield coupled with negative indirect effects through plant height and positive indirect effects through grains per panicle.

Amrithadevarathinam (1983) reported that total number of effective tillers per hill and days to 50% flowering had positive and direct contributions to plant height and grain yield in upland rice.

2. Plant height:

In rice, Panduranga Rao et al., (1986) and Rama Rao (1990) reported high negative direct effect of plant height on grain yield.

Positive direct effect of plant height on grain yield in rice was reported by Bui Chi Bui^w and Do ~~Xuan~~^{Xuan} Trung^o (1988).

Gomathinayagam et al., (1988) observed direct contribution of plant height to yield and indirectly via all other characters except 1000 grain weight in upland rice varieties. Plant height and number of filled grains had high positive direct effect on grain yield in rice (Reuben and Katuli, 1989).

In F_2 generation of rice crosses, Srinivasa Rao (1989) observed plant height to have a positive direct effect on grain yield. Ibrahim et al., (1990) reported that the effect of plant height was slightly negative.

3. Effective tillers per plant:

Reddy and Reddy (1986) and Sardana et al., (1989) in their study observed low direct effect of number of panicles per plant on yield.

The productive tiller number and grain number per panicle showed highest direct effects on grain yield in rice under poor and optimum fertilizer conditions as reported by Hegde (1987).

Gomathinayagam et al., (1988) reported that productive tillers affected the grain yield directly as well as indirectly in upland varieties of rice.

Number of productive tillers per plant had the greatest direct effects on grain yield as reported by Panduranga Rao et al., (1986) and Tahir et al., (1988).

Reubin and Katuli (1989) reported that tiller number had moderate positive effect on grain yield.

Ibrahim et al., (1990) observed that the direct effect of this trait had a highly positive contribution to grain yield in F_2 .

4. Panicle Length:

In aromatic varieties of rice, Reddy and Reddy (1986) observed large positive direct effect of panicle length on seed yield.

Sukanya Subramanian and Rathinam (1988) reported positive indirect effect of panicle length on grain yield through 100 grain weight.

Negative direct effect of panicle length on grain yield was observed by Bui Chi Buu and Do Xwon Truong (1985) in rice.

Gomathinayagam et al., (1988) observed a direct effect of panicle length on the grain yield as well as indirect effects through other characters in upland rice varieties, while Sardana et al., (1989) observed negligible direct effect of panicle length on grain yield.

The independent effect of panicle length on yield was strong and negative as reported by Reuben and Katuli (1989).

Reuben and Kisanga (1989) reported moderately positive and significant correlation of this trait with grain yield. The positive direct effect was relatively high.

5. Number of grains per panicle:

Reddy and Reddy (1986) observed large positive direct effect of number of grains per panicle on grain yield in their study on aromatic varieties of rice.

High positive direct effect of number of grains per panicle on grain yield was observed by Panduranga Rao et al., (1986) and Hegde (1987).

Bui Chi Buu and Do Xuan Trunong (1988) reported that filled grains per panicle had the largest direct effect on

grain yield. However, its effect through sterility percentage was negative, even though the total correlation with yield was significant.

Filled grains per panicle had the high positive direct effect on grain yield as reported by Gomathinayagam et al., (1988) and Reuben and Katuli (1989).

6. Spikelet sterility:

Sterility percentage showed a high direct effect on grain yield as reported by Bui chi Buu and Do Xuan Truong (1988), while Paramasivan and Sreerangaswamy (1988a) observed negative direct effect for chaffy grains per panicle.

7. 100 grain weight:

Reddy and Reddy (1986) and Rama Rao (1990) observed low direct effect of 100 seed weight on yield.

Bui Chi Buu and Do Xaon Truong (1988) reported the negative direct effects of 100-grain weight and panicle length on grain yield.

Srinivasa Rao (1989) observed that this trait exerted a positive direct effect on grain yield in F_2 generation of a rice cross.

8. **L/B ratio:**

Srinivasa Rao (1989) observed that this trait showed a negative direct effect and negative indirect effect on grain yield through plant height, effective tillers per plant and 100 grain weight, while Rama Rao (1990) observed a negligible positive direct effect on grain yield in F_3 generation.

MATERIALS AND METHODS

MATERIALS AND METHODS

The material for the present investigation comprises of 79 genotypes of traditional tall and dwarf rice varieties. The details depicting the source and origin with specific characters of these genotypes are furnished in Table 1. Genetic variability of paddy and rice samples of germplasm are presented in Fig. 1A. Out of these 79 genotypes, seven genotypes viz., Basmati-370, DW 8, IET 1444 (Rasi), Tellahamsa, Prabhat, Taichung Native-1 and BPT 1235 showing wider genetic diversity for various characters were selected as parents and a diallel (7x7) crossing programme (excluding reciprocals) was effected during kharif 1988. A total of 21 crosses were made and the F_1 and F_2 's were raised during kharif 1989 and 1990.

METHODS

a) Study on genetic diversity among genotypes to select parents

The field experiment was conducted at the facilities of Rice Research Unit, Agricultural College Farm, Bapatla. The 79 genotypes were grown in a complete randomised block design with three replications during kharif 1987. Each genotype was grown in three rows of 3 meters length with a

Table 1: Details regarding source and origin with specific characters of 79 genotypes used for genetic divergence study

Sl. No.	Name of the genotype	Source or origin	Specific characters
1	2	3	4
1.	FRG 11	CRRI	Tall type, long duration, coarse grain, pigmented rice.
2.	DW 8	CRRI	Tall type, long duration, coarse grain, white rice.
3.	Eswarakorra	Warangal	Tall type, long duration, short bold grain, pigmented rice.
4.	DW 17	CRRI	Tall type, long duration, medium slender grain, white rice.
5.	MTU 17	Maruteru	Tall type, short duration, coarse grain, pigmented rice.
6.	PLA 2	Pulla	Tall type, long duration, medium slender, white rice grain.
7.	Vellathilcheera	Pattambi	Tall type, long duration, medium bold grain, pigmented rice.
8.	PLA 4	Pulla	Tall type, long duration, medium slender grain, excellent white rice.
9.	Vellathacheera	Pattambi	Tall type, long duration, short bold grain, white rice.
10.	Vellalakalyan	Pattambi	Tall type, long duration, short bold grain, pigmented rice.

contd...

1	2	3	4
11.	TKM 3	CRRI	Tall type, short duration, short bold grain, pigmented rice.
12.	Teetep	CRRI	Tall type, medium duration, medium slender grain, excellent white rice.
13.	Sinnasivappu	CRRI	Tall type, long bold grain, long duration, white rice.
14.	Welhendria	CRRI	Tall type, short bold grain, long duration, pigmented rice.
15.	Leaung-152	CRRI	Tall type, medium duration, excellent medium slender, white rice,
16.	Lebmuenhang (LMN)	CRRI	Tall type, long duration, medium slender, white rice.
17.	PTB 33	Pattambi	Tall type, long duration, medium slender, pigmented rice.
18.	PTB 12	Pattambi	-do-
19.	Kottamalli	CRRI	Tall type, long duration, short bold, pigmented rice.
20.	Choorapundy	CRRI	Tall type, long duration, short bold, pigmented rice.
21.	Chemban	CRRI	Tall type, medium duration, short bold, pigmented rice.
22.	Kokowabao	CRRI	Tall type, medium duration, excellent medium slender, white rice.
23.	Chempan	CRRI	Tall type, long duration, short bold, pigmented rice.
24.	Rathuheenati	CRRI	Tall type, long duration, short bold, pigmented rice.

contd....

1	2	3	4
25.	Singora	CRRRI	Tall type, long duration, excellent medium slender white rice.
26.	Gorsa	CRRRI	Tall type, long duration, short bold, white rice.
27.	PLA 3	Pulla	Tall type, long duration, excellent medium slender, white rice.
28.	ARC 10550	CRRRI	Tall type, long duration, coarse white rice.
29.	Milfer	CRRRI	Tall type, medium duration, medium slender, white rice.
30.	Mettasannalu	CRRRI	Tall type, short duration, coarse pigmented rice.
31.	Mecantigo	CRRRI	Tall type, medium duration, medium slender, white rice.
32.	Mecambino	CRRRI	Tall type, long duration, pigmented coarse rice.
33.	Manoharsali	CRRRI	Tall type, long duration, coarse white rice.
34.	Bhanslot	CRRRI	Tall type, medium duration, pigmented coarse rice.
35.	Bengawon	CRRRI	Tall type, long duration, long bold, white rice.
36.	Banglei	CRRRI	Tall type, long duration, short bold, white rice.
37.	Balam	CRRRI	Tall type, long duration, medium slender, white rice.
38.	Solak	CRRRI	Tall type, medium duration, excellent medium slender, white rice.

contd...

1	2	3	4
39.	PTB 10	Pattambi	Tall type, long duration, short bold, pigmented rice.
40.	PTB 8	Pattambi	Tall type, medium duration, short bold, pigmented rice.
41.	TKM 8	CRRI	Tall type, medium duration, medium slender, white rice.
42.	Basmati-370	CRRI	Tall type, long duration, scented superfine, white grain.
43.	Tokasannalu	CRRI	Tall type, long duration, long bold, white rice.
44.	TKM 9	CRRI	Tall type, medium duration, short bold, pigmented rice.
45.	TKM 7	CRRI	Tall type, medium duration, medium bold, pigmented rice.
46.	TKM 6	CRRI	Tall type, medium duration, medium slender, white rice.
47.	TKM 5	CRRI	Tall type, medium duration, medium slender, white rice.
48.	TKM 8	CRRI	Tall type, medium duration, short bold, white rice.
49.	ARC 13788	CRRI	Tall type, long duration, short bold, white rice.
50.	ARC 11281	CRRI	Tall type, long duration, long slender, pigmented rice.
51.	ARC 7255	CRRI	Tall type, long duration, long slender, white rice.
52.	ARC 6619	CRRI	Tall type, long duration, medium slender, white rice.

contd...

1	2	3	4
53.	ARC 11704	CRRI	Tall type, long duration, short bold, white rice.
54.	ARC 11128	CRRI	Tall type, long duration, short bold, white rice.
55.	ARC 10660	CRRI	Tall type, long duration, short bold, white rice.
56.	ARC 7080	CRRI	Tall type, long duration, medium bold, white rice.
57.	ARC 6159	CRRI	Tall type, long duration, medium bold, white rice.
58.	ARC 6650	CRRI	Tall type, long duration, medium bold, white rice.
59.	ARC 6248	CRRI	Tall type, long duration, medium bold, white rice.
60.	Annaikompon	CRRI	Tall type, long duration, short bold, white rice.
61.	ARC 5778	CRRI	Tall type, long duration, long slender, white rice.
62.	ARC 6605	CRRI	Tall type, long duration, medium slender, pigmented rice.
63.	ARC 6632	CRRI	Tall type, long duration, medium bold, white rice.
64.	ARC 5752	CRRI	Tall type, long duration, long slender, white rice.
65.	Aganni	CRRI	Tall type, long duration, short bold, pigmented rice.
66.	ARC 5764	CRRI	Tall type, long duration, medium bold, white rice.

contd...

1	2	3	4
67.	ARC 16372	CRRRI	Tall type, long duration, medium slender, light pigmented rice.
68.	BPT 1235	RRU,Bapatla	High yielding, semidwarf, short duration, rabi popular variety in K.G. zone, long slender, white rice.
69.	IET 1444	DRR, Hyd.	High yielding, semidwarf, short duration, rabi variety in K.G.zone, medium slender, white rice.
70.	Prabhat	ARS, Maruteru	High yielding, semidwarf, medium duration, rabi and kharif popular variety in K.G. zone, coarse white rice.
71.	MTU 4870	ARS, Maruteru	High yielding, semi tall, long duration, medium slender, white rice.
72.	Tellahamsa	ARI, R'nagar	High yielding, semidwarf, rabi popular variety in Telangana region, long slender, white rice.
73.	IR 62	IRRI, Manila	High yielding, semidwarf, short duration, medium slender, white rice.
74.	MTU 5293	ARS, Maruteru	High yielding, semitall, long duration, long slender, white rice.
75.	BPT 856	RRU, Bapatla	High yielding, semitall, long duration, medium slender, white rice.
76.	Taichung native-1	CRRRI	High yielding dwarf, short duration, medium bold, white rice.

contd...

1	2	3	4
77.	MTU 5249	ARS, Maruteru	High yielding, semitall, long duration, medium slender, white rice.
78.	MTU 2067	ARS, Maruteru	High yielding, semitall, long duration, medium slender, white rice, local kharif popular variety in K.G. zone.
79.	Mahsuri	RRU, Bapatla	High yielding tall, long duration, medium slender, white rice.

1. CRRI - Central Rice Research Institute, Cuttack, Orissa.
2. DRR - Directorate of Rice Research, Hyderabad.
3. IRRI - International Rice Research Institute, Manila.
4. RRU - Rice Research Unit, Bapatla.
5. ARS - Agricultural Research Station, Maruteru.
6. ARI - Agricultural Research Institute, Rajendranagar, Hyd.



Fig. PADDY AND RICE SAMPLES OF SEVEN PARENTS AND THEIR
21 F_1 s OF 7 x 7 DIALLEL.

spacing of 20 cm between and 15 cm within the rows. Standard agronomic practices including application of fertilizers and plant protection methods were taken up as per schedule. From the Central row, 5 plants were selected at random and data on seven quality characters along with one yield component viz., Length of rice kernel (mm), Breadth of rice kernel (mm), L/B Ratio, Hulling recovery (%), Alkali spreading score (No.), Protein content of brown rice (%) along with 1000-grain weight (g) and grain yield/plant (g) which were considered as components of fitness were collected to study the genetic diversity among the genotypes.

Based on genetic divergence study on 79 genotypes, seven parents viz., Basmati-370, DW 8, IET.1444, Tellahamsa, Prabhat, T.N 1 and BPT 1235, each selected from seven different clusters. The seven selected parents were crossed during kharif 1988 in 7 x 7 diallel system of mating without reciprocals resulting in 21 crosses and the F_1 seeds from each cross were collected, dried and utilised for sowing during kharif 1989.

Seven parents alongwith 21 F_1 crosses were planted during kharif 1989 in a randomised block design with three replications and the progeny advanced to F_2 . F_1 and F_2

populations of 21 crosses with the seven parents were planted during kharif 1990 in a randomized block design adopting a spacing of 20 cm between rows and 15 cm within rows. Standard agronomic practices and plant protection measures were taken up as per schedule.

COLLECTION OF DATA

Observations were made during kharif 1989 and kharif 1990 and the data were recorded on sixteen traits (eight yield and yield components): Days to 50 per cent flowering, Plant height (cm), Number of productive tillers per plant, Panicle length (cm), Number of grains per panicle, Spikelet sterility (%), 100-grain weight (g) and Grain yield per plant (g). Three grain quality characters: Length of grain (mm), Breadth of grain (mm) and L/B Ratio. One milling quality character: Hulling recovery (%). Three cooking quality characters: Volume expansion, Water uptake (ml), Kernel elongation. One nutritional quality character: Protein content of brown rice (%) of seven parents, F_1 and F_2 populations of 21 crosses.

In each replication, five parent plants from each variety and 15 F_1 plants and 250 F_2 plants from each cross were selected for recording data on the traits above

mentioned. The mean values were considered for statistical analyses.

YIELD AND YIELD COMPONENTS

1. Days to 50 per cent flowering

The number of days taken for 50 per cent tillers of each plant to flower from the date of sowing were recorded.

2. Plant height

Plant height (in centimeters) was measured from the ground level to the tip of the panicle at the time of harvest.

3. Number of productive tillers per plant

The number of productive panicle bearing tillers in each plant were counted at the time of harvest.

4. Panicle length

Length of 3 panicles from each plant was measured (in centimeters) from neck to the tip of panicle and the mean taken for analysis.

5. **Number of grains per panicle**

In each plant filled grains were counted in 3 panicles and the mean values considered as the number of grains per panicle.

6. **Spikelet sterility**

The per cent sterile spikelets were worked out based on the number of unfilled grains to the total number of filled grains in 3 panicles of each plant and the mean value taken for analysis.

7. **100-grain weight**

This was obtained by weighing 100 well filled grains at 12 per cent moisture level from each plant.

8. **Grain yield per plant**

The grains harvested from each plant were weighed at 12 per cent moisture level after thorough cleaning.

GRAIN QUALITY TRAITS

9. **Length of grain**

Five grains from each panicle were dehusked by hand and the length (in millimeters) was recorded by using Dial-micrometer.

10. Breadth of the grain

Five grain from each panicle were dehusked by hand and the breadth (in millimeters) was recorded by using Dial-micrometer.

11. Length/Breadth (L/B) ratio

The L/B Ratio was calculated by using the formula

$$\text{L/B Ratio} = \frac{\text{Mean length of grain in millimeters}}{\text{Mean breadth of grain in millimeters}}$$

MILLING QUALITY TRAIT

12. Hulling recovery

The character was determined after dehulling the paddy sampe of 10 gms from each plant by using the following formula.

$$\text{Hulling recovery (\%)} = \frac{\text{Weight of dehusked grain or brown rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

COOKING QUALITY TRAITS

The cooking of grains was done by the following methods.

(a) Chemical method:

Used for Germplasm types for genetic divergence study. Starch disintegration by potassium hydroxide (Little et al., 1960) was followed.

(b) Physical method:

Imbibition method (By actual cooking test) of Verghese (1950) was made use of in estimation of cooking quality (Volume Expansion).

13. Volume Expansion

Volume expansion ratio was determined by actual cooking test as suggested by Verghese (1950). The volume expansion ratio (V_2/V_1) was worked out by measuring the initial volume of uncooked rice (V_1) and final volume of cooked rice (V_2) by water displacement method by using representative rice sample of 2 grams from each plant.

14. Water uptake

The tubes with 2 gm. rice sample having 10 ml distilled water were put in a water bath at 77°C for 30 minutes. After 30 minutes, the tubes were taken out and put in running cold water in a tray to stop the cooking process immediately. The volume of remaining water (V_1) after cooking was measured by a graduated tube and the water

uptake (ml) calculated duly following the method suggested by Hallick and Kelley (1959).

$$\text{Water uptake (ml)} = \frac{10 - V_1}{2} \times 100$$

15. Kernel elongation

The length of raw rice grains of each sample was measured before and after cooking directly on a scale and kernel elongation ratio worked out as follows.

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

NUTRITIONAL QUALITY CHARACTER

16. Protein content of brown rice

The protein content (%) of the hulled grain was determined by micro-kjeldhal method ($N \times 5.95$).

STATISTICAL ANALYSES

The data recorded on the above characters were subjected to the following statistical analyses.

- a) Genetic divergence study among genotypes by using D^2 analysis of Mahalanobis statistic.
- b) Analysis of variance.
- c) Combining ability analysis.

- d) Heterosis.
- e) Genotypic and Phenotypic coefficient of variation.
- f) Heritability and genetic advance.
- g) Character associations.
- h) Direct and indirect effects of characters using path coefficient analysis.

a) **Genetic divergence using D^2 analysis**

A measure for group distance based on multiple characters was given by Mahalanobis (1936) using D^2 technique. With the help of this, genetic divergence between genotypes was estimated.

D^2 value between i^{th} and j^{th} genotypes for 'p' characters was calculated as:

$$D^2_{ij} = \sum_{t=1}^P (\bar{Y}_{it} - \bar{Y}_{jt})^2$$

where,

$\bar{Y}_{it}$ = is uncorrelated mean value of i^{th} genotype for 't' character

$\bar{Y}_{jt}$ = is uncorrelated mean value of j^{th} genotype for 't' character

D^2_{ij} = is D^2 between i^{th} and j^{th} genotype.

The various steps involved in estimation of D^2 values are given below:

Test of significance

After testing the differences between genotypes for each of the characters, a simultaneous test of significance for differences in the mean values of a number of correlated variables with regard to the pooled effect of characters was carried out by using 'v' statistic which in turn utilises wilk's ' Λ ' criterion. The sum of squares and sum of products of error + genotype were used for this purpose. The estimation of ' Λ ' (Wilk's criterion) was done using the following relationship:

$$'\Lambda' = \frac{W}{S}$$

where,

' Λ ' = wilk's criterion

W = Determinant of error matrix

S = Determinant of error variety matrix

$$V(\text{Stat}) = -m \log_e '\Lambda' = -\left(n - \frac{P+Q+1}{2}\right) \log_e '\Lambda'$$

where,

m = $n - (P + Q + 1)/2$

P = Number of variables or characters

Q = Number of variables - 1 (or d.f. for population)

n = degrees of freedom for error t varieties

$$\log_e '\Lambda' = 2.3026 \log_{10} '\Lambda'$$

V (Stat) is distributed as χ^2 with PQ ($8 \times 30 = 240$) degrees of freedom.

Transformation of correlated variables

In the present model, computation of D^2 values were reduced to simple summation of the differences in mean values of various characters of the two genotypes i.e., d_i^2 . Therefore, transformation of correlated variables to uncorrelated one was done before working out the D^2 values. Transformation was done by using pivotal condensation method.

Computation of D^2 values

For a given combination of i and j genotype the mean deviation i.e., $Y_{it} - Y_{jt}$ for $t=1, 2, \dots, P$ variables were computed and D^2 values were calculated as sum of squares of the deviations.

$$= \sum_{t=1}^P (\bar{Y}_{it} - \bar{Y}_{jt})^2$$

Testing of significance of D^2 values

The D^2 value obtained for a pair of populations is taken as the calculated value of χ^2 and is tested against the tabulated value of χ^2 for P degrees of freedom, where P is the number of characters considered.

Grouping of genotypes into various clusters

Grouping of populations into different clusters was done using Tocher's method as described by Rao (1952). The criterion used in clustering by this method is that any two varieties belonging to the same cluster should at least on an average show a smaller D^2 value than those belonging to different clusters. For this purpose D^2 values of all combinations of each genotype were arranged in increasing order of magnitude in a tabular form as described by Singh and Chowdhury (1979). To start with two populations having the smallest distance from each other were considered to which a third population having the smallest D^2 value from the first two populations was added. Similarly next, the nearest fourth population was considered and this procedure was continued. At certain stage where it was felt that after adding a particular population there was abrupt increase in the average D^2 value, that population was not considered for including in that cluster. The group of the first cluster was then omitted, and the rest was treated in a similar way. This process was continued till the genotypes were included into one or the other clusters.

Average intra-cluster distance

For the measurement of intra-cluster distance, the formula used was $\sum D_i^2/n$.

where,

D_i^2 = Sum of distance between all possible combinations
(n) of the populations included in a cluster.

n = Number of clusters

Average inter-cluster distance

Clusters were taken one by one and their distance from other clusters were calculated. The distance between two clusters was the sum of the D^2 values between the numbers of one cluster to each of the members of the other cluster divided by the product of number of genotypes in both the clusters under consideration.

b) Analysis of variance:

The data for different characters were statistically analysed on the basis of model described by Panse and Sukhatme (1978).

c) Combining ability analysis:

Estimation of combining ability variance and effects from diallel crosses were calculated following method 2, Model I of Griffing (1956). This method was considered more appropriate since, the study was restricted to the parents and single set of crosses. Model I assumes that variety and block effects are constant but environmental effect is

variable and the experimental material is the population about which inferences are to be made. The method helps to compare combining ability of parents when parents themselves are used as testers. Error is independently distributed with mean zero and variance as σ^2_e .

The mathematical model for the combining ability in Model I is assumed to be

$$X_{ij} = \mu + g_i + g_j + S_{ij} + 1/bc + \sum_k \sum_l e_{ijkl}$$

$$i, j = 1, \dots, P$$

$$K = 1, \dots, b$$

$$l = 1, \dots, c$$

where,

P = number of variances

b = number of blocks

c = number of observations for each of the plots

~~μ = population mean~~

g_i = general combining ability of the i^{th} parent

μ = Population mean

g_i = general combining ability of the i^{th} parent
 g_j = general combining ability of the j^{th} parent
 S_{ij} = Specific combining ability effect such that
 $S_{ij} = S_{ji}$
 and e_{ijkl} = environmental effect pertaining to the
 $ijkl^{\text{th}}$ observation.

The restrictions imposed on this model are:

$$\sum_{gi} = 0 \quad \text{and} \quad S_{ij} + S_{ii} = 0 \quad (\text{for each } i).$$

Estimation of combining ability variances

The general and specific combining ability variances were estimated by the following formulae:

$$Sg = \frac{1}{(P+2)} \left[\sum (x_i + x_{ii})^2 - \frac{4}{P} x \dots x^2 \right]$$

$$Ss = \left[\sum x_{ij}^2 - \frac{1}{P+2} (x_i + x_{ii})^2 + \frac{2}{(P+1)(P+2)} x^2 \dots \right]$$

where,

Sg = Sum of squares due to GCA

Ss = Sum of squares due to SCA

P = Number of parents

x_i = Total array of i^{th} parent

x_{ii} = mean value of i^{th} parent

$x \dots$ = grand total of $1/2 P(P-1)$ progenies and P parental values

x_{ij} = mean value in the diallel table

Analysis of variance table for combining ability was further partitioned into GCA and SCA as furnished below.

Source	d.f.	M.S.	Expectation of mean sum of squares
GCA	p-1	Mg	$\sigma_e^2 + \frac{P+2}{P-1} \sum g_i^2$
SCA ability	$\frac{P(P-1)}{2}$	Ms	$\sigma_e^2 + \frac{2}{P(P-1)} \sum_{i \leq j} \sigma_{ij}^2$
Error	Me		σ_e^2

The mean sum of squares for general and specific combining ability were obtained by dividing their sum of squares by respective degrees of freedom. The error mean square (M'e) for combining ability analysis was obtained by dividing error mean square obtained from simple RBD analysis of variance for the experiment by number of replications. For 'F' test each mean square was tested against M'e.

Estimation of GCA and SCA effects

The GCA and SCA effects were obtained as follows:

General combining ability (GCA) effects of i^{th} parent:

$$\Lambda_{gi} = \frac{1}{P+2} \left(X_i + X_{ii} - \frac{2}{P} \times \dots \right)$$

Specific combining ability (SCA) effects of j^{th} cross:

$$\hat{S}_{ij} = [X_{ij} - \frac{1}{P+2} (X_i + X_{ii} + X_j + X_{jj}) + \frac{2}{(P+1)(P+2)} X_{..}]$$

Standard error of an estimate was calculated as the square root of the variance of the estimate. The variances of various estimates were calculated as follows:

$$\text{Variance } \hat{g}_i = \frac{P-1}{P(P+2)} e^2$$

$$\text{Variance } \hat{S}_{ij} = \frac{P^2 + P + 2}{(P+1)(P+2)} e^2 \quad (i = j)$$

Test of significance of GCA and SCA effects

Each GCA and SCA value was tested for its significance by 't' test.

$$t = \frac{\hat{g}_i}{SE(\hat{g}_i)} \text{ and } t = \frac{\hat{S}_{ij}}{SE(\hat{S}_{ij})} \text{ respectively}$$

The 't' values thus obtained were compared at error degrees of freedom. The significance of differences between two estimates was tested by comparing them with critical difference (CD).

$$CD = \text{SE of difference between two estimates} \times t \text{ at } 0.05 \text{ at error degrees of freedom}$$

Thus, SE of difference of two estimates was taken as the square root of the variance of the difference of two estimates. The variance of the differences of the two estimates was calculated as follows:

$$\text{Var } (\hat{g}_i - \hat{g}_j) = \frac{2}{P+2} e^2 \quad i \neq j$$

$$\text{Var } (\hat{S}_{ij} - \hat{S}_{ik}) = \frac{2(P+1)}{P+2} e^2 \quad (i \neq j, k, J \neq K) \text{ for SCA estimates in one array}$$

$$\text{Var } (\hat{S}_{ij} - \hat{S}_{kl}) = \frac{2P}{P+2} e^2 \quad (i \neq j, k, l; j \neq K, l; K \neq l)$$

for any two specific combining ability estimates

where,

P = Number of parents.

e^2 = Error mean square.

d) Heterosis:

The magnitude of hybrid vigour expressed by each cross was calculated over the mean of parents (relative heterosis), over better parent (Heterobeltiosis) and over standard variety, Prabhat (Standard Heterosis).

In the present study, the estimates of heterosis over mid, better and standard parent in different cross

combinations were computed in percentage using the following formula.

$$\text{Relative Heterosis} = \frac{\text{Mean of } F_1 - \overline{\text{Mid parental value}}}{\overline{\text{Mid parental value}}} \times 100$$

$$\text{Heterobeltiosis} = \frac{\text{Mean of } F_1 - \text{Mean of better parent}}{\text{Mean of better parent}} \times 100$$

$$\text{Standard variety} = \frac{\text{Mean of } F_1 - \text{Mean of standard variety}}{\text{Mean of standard variety}} \times 100$$

e) **Coefficients of variation:**

The genotypic and phenotypic coefficients of variabilities were calculated according to the formulae given by Falconer (1981).

Genotypic coefficient of variation (GCV)

$$= \frac{\text{Genotypic Standard deviation}}{\text{Mean}} \times 100$$

2) Phenotypic coefficient of variation (PCV)

$$= \frac{\text{Phenotypic Standard deviation}}{\text{Mean}} \times 100$$

f) **Heritability and genetic advance:**

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability (h^2) in the broad sense was calculated according to the formula given by Burton (1952).

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

where,

$$\begin{aligned} \sigma_g^2 &= \text{genotypic variance} \\ \sigma_p^2 &= \text{phenotypic variance} \end{aligned}$$

Genetic advance refers to the expected gain or improvement in the next generation by selecting the superior individuals under certain amount of selection pressure. From the heritability estimates the genetic advance was estimated by the following formula given by Burton (1952).

$$GA = K \cdot h^2 \cdot \sigma_P$$

where,

$$\begin{aligned} GA &= \text{Expected genetic advance} \\ K &= 2.06 \text{ at 5 per cent selection intensity} \\ \sigma_P &= \text{Phenotypic standard deviation} \\ h^2 &= \text{Heritability in broad sense} \end{aligned}$$

In order to visualize the relative utility of genetic advance among the characters, genetic advance as per cent of mean was computed.

$$\text{Genetic advance as per cent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

g) **Character associations:**

The correlation coefficients were calculated by using the following formula:

$$r_{XY} = \frac{\text{Cov. (X,Y)}}{\sqrt{V(X) \cdot V(Y)}}$$

where,

r_{XY} = Correlation coefficient between X and Y

Cov. (X,Y) = Covariance between X and Y

$v(X)$ = Variance of X

$V(Y)$ = Variance of Y

X and Y = Two related variables

Similarly

$$\text{Phenotypic } r(P) = \frac{\text{Covariance of XY (Phenotypical)}}{\sqrt{\text{Variance of } V_x \cdot V_y (\text{Phenotypical})}}$$

$$\text{Genotypic } r(G) = \frac{\text{Covariance of XY (Genotypical)}}{\sqrt{\text{Variance of } V_x \cdot V_y (\text{Genotypical})}}$$

The significance of r was tested by 't' test at $(n-2)$ degrees of freedom from the t table of Fisher and Yates (1963) at $P = 0.05$ and $P = 0.01$ where n is the number of genotypes tested.

h) Path coefficient analysis:

Path co-efficient analysis was carried out by using the phenotypic and genotypic correlation coefficients, to know the direct and indirect effects of the yield components as suggested by Wright (1921) and as illustrated by Dewey and Lu (1959). The path coefficients were obtained by solving the 'P' normal equation following the matrix method.

Correlations among all the variables were utilized to set up the simultaneous equations.

$$r_{1Y} = P_{1Y} + r_{12} P_{2Y} + r_{13} P_{3Y} + \dots + P_{1I} P_{IY}$$

$$r_{2Y} = r_{21} P_{1Y} + P_{2Y} + r_{23} P_{3Y} + \dots + r_{2I} P_{IY}$$

:

$$r_{IY} = r_{I1} P_{1Y} + r_{I2} P_{2Y} + r_{I3} P_{3Y} + \dots + P_{II}$$

where,

$r_{1Y}, r_{2Y} \dots r_{IY}$ are the correlation coefficients of independent variables $X_1, X_2 \dots X_I$ with the dependent variable Y

$r_{12}, r_{13} \dots r_{I-1}, I$ are the coefficients of correlation between the independent variables

$P_{1Y}, P_{2Y} \dots P_{IY}$ are the direct effects of variables $X_1, X_2 \dots X_I$ on Y .

The above equations were written in matrix form as under.

$$\begin{array}{ccc}
 \text{A} & \text{C} & \text{B} \\
 \left[\begin{array}{c} r_{1Y} \\ r_{2Y} \\ r_{3Y} \\ \dots \\ r_{IY} \end{array} \right] & = & \left[\begin{array}{ccccc} 1 & r_{12} & r_{13} & \dots & r_{1I} \\ r_{21} & 1 & r_{23} & \dots & r_{2I} \\ r_{31} & r_{32} & 1 & \dots & r_{3I} \\ \dots & & & & \\ r_{I1} & r_{I2} & r_{I3} & \dots & 1 \end{array} \right] \left[\begin{array}{c} P_{1Y} \\ P_{2Y} \\ P_{3Y} \\ \dots \\ P_{IY} \end{array} \right]
 \end{array}$$

Then $B = C^{-1} \cdot A$

$$\text{Where } C^{-1} = \left[\begin{array}{ccccc} c_{11} & c_{12} & c_{13} & \dots & c_{1I} \\ c_{21} & c_{22} & c_{23} & \dots & c_{2I} \\ .. & .. & .. & & .. \\ c_{I1} & c_{I2} & c_{I3} & \dots & c_{II} \end{array} \right]$$

The direct effects were calculated as follows:

$$P_{1Y} = \sum_{i=1}^I c_{1i} r_{iY}$$

$$P2Y = \sum_{i=1}^I C2i \, riY$$

$$PIY = \sum_{i=1}^I CIi \, riY$$

The residual effect (PRY) was calculated by using the formula.

$$\text{Residual effect} = \sqrt{1 - (P1y \, r1y + P2y \, r2y \dots PIy \, rIy)}$$

RESULTS

RESULTS

The results obtained from the investigation are presented under the following heads:

- a) Genetic divergence.
- b) Analysis of variance.
- c) Combining ability analysis.
- d) Heterosis
- e) Variability, heritability and genetic advance.
- f) Correlation estimates, and
- g) Path coefficient analysis.

a) Genetic divergence

The data collected on eight characters viz., 1000-grain weight (g), length of grain (mm), breadth of grain (mm), L/B ratio (No.), hulling recovery (%), alkali spreading score (No.), protein content of brown rice (%) and grain yield per plant (g) from 79 genotypes were used for estimating genetic divergence. The results are presented hereunder characterwise.

Means:

The mean data of eight characters of 79 genotypes are presented in Table 2.

Table 2: Mean values of eight characters of 79 genotypes used for genetic divergence study

Sl. No.	Name of the genotype	1000 grain weight (g)	Length of grain (mm)	Breadth of grain (mm)	L/B ratio (No.)	Hulling recovery (%)	Alkali spreading score (No.)	Protein content of brown rice (%)	Grain yield/plant (g)
1	2	3	4	5	6	7	8	9	10
1.	FRG 11	30.1	6.7	2.7	2.4	74.7	5	9.1	24.6
2.	DW 8	35.1	6.9	2.2	3.1	74.5	5	10.9	33.9
3.	Eswarakorra	30.0	5.8	2.7	2.1	73.0	2	9.3	24.0
4.	DW 17	24.2	6.3	2.4	2.6	75.8	2	9.2	25.0
5.	MTU 17	29.4	6.5	2.6	2.5	76.0	2	11.3	25.6
6.	PLA 2	24.0	6.6	2.3	2.8	75.5	3	6.5	24.2
7.	Vellathilcheera	24.2	5.8	2.9	2.4	74.7	2	8.3	25.0
8.	PLA 4	23.9	7.1	2.2	3.1	67.1	4	9.6	29.4
9.	Vellathacheera	25.0	5.4	2.6	2.1	74.7	3	10.5	22.0
10.	Vellalakalyan	31.2	6.1	2.8	2.2	70.8	3	7.0	25.9
11.	TKM 3	21.8	5.7	2.5	2.2	71.0	5	9.3	23.7
12.	Teetep	20.5	6.5	2.2	2.3	80.1	2	9.4	24.0
13.	Sinnasivappu	25.0	6.5	2.3	2.8	77.5	3	8.0	25.2

contd....

1	2	3	4	5	6	7	8	9	10
14.	Welhendria	26.5	5.5	2.6	2.1	76.7	5	7.6	23.3
15.	Leaung-152	23.9	6.7	2.3	2.9	74.0	5	11.9	25.7
16.	Lebmuenhang (LMN)	28.1	7.1	2.4	3.0	75.1	4	8.2	28.9
17.	PTB 33	28.3	5.3	2.7	2.0	76.0	4	8.5	32.0
18.	PTB 12	28.4	5.4	2.8	1.9	77.0	4	8.2	31.2
19.	Kottamalli	26.4	4.4	2.6	1.7	77.0	4	9.3	31.0
20.	Choorapundy	26.1	5.9	2.6	2.3	75.9	3	9.3	24.7
21.	Chemban	26.8	5.9	2.8	2.1	77.2	3	9.3	25.3
22.	Kokowabao	20.5	6.1	2.2	2.7	78.0	5	6.8	22.8
23.	Chempan	26.5	5.8	2.8	2.1	79.5	5	8.9	25.6
24.	Rathuheenati	24.3	5.9	2.7	2.2	73.5	5	7.9	24.2
25.	Singora	29.4	7.1	2.4	3.0	78.2	4	9.6	30.0
26.	Gorsa	26.9	5.4	2.8	1.9	64.9	5	10.3	25.9
27.	PLA 3	24.2	6.4	2.3	2.7	79.2	4	7.9	23.1
28.	ARC 10550	32.5	6.7	2.8	2.4	74.3	5	10.6	23.8
29.	Milfer	27.3	7.0	2.2	3.2	73.5	4	8.5	32.0

1	2	3	4	5	6	7	8	9	10
30.	Mettasannalu	24.2	6.1	2.6	2.3	73.5	3	9.5	26.1
31.	Mecantigo	20.4	5.9	2.3	2.9	75.6	2	9.1	24.7
32.	Mecambino	27.9	6.0	2.7	2.3	76.8	2	9.8	24.4
33.	Manoharsali	27.3	6.4	2.5	2.4	75.4	4	9.0	25.0
34.	Bhanslot	29.7	6.6	2.6	2.6	76.4	3	11.6	26.3
35.	Bengawon	26.3	7.1	2.6	2.7	74.1	3	11.5	31.0
36.	Banglei	26.8	5.6	2.6	2.1	76.6	2	8.0	23.2
37.	Balam	26.3	6.9	2.2	3.1	76.0	3	11.9	30.5
38.	Solak	15.9	5.5	1.9	2.8	76.3	3	11.9	23.0
39.	PTB 10	22.2	5.7	2.5	2.3	73.7	3	11.5	24.0
40.	PTB 8	20.4	5.2	2.2	2.4	74.7	3	12.2	25.2
41.	TKM 8	20.0	5.8	2.1	2.7	76.7	2	8.3	22.6
42.	Basmati-370	20.2	7.2	1.8	3.9	69.3	3	10.0	9.9
43.	Tokasannalu	20.0	5.6	2.2	2.6	76.5	3	8.3	24.2
44.	TKM 9	21.5	5.6	2.5	2.2	75.7	7	11.3	24.0
45.	TKM 7	22.8	5.9	2.6	2.3	70.1	2	9.9	23.3

1	2	3	4	5	6	7	8	9	10
46.	TKM 6	17.0	5.8	2.2	2.7	74.6	2	11.2	25.0
47.	TKM 5	17.0	5.7	1.9	2.9	76.5	2	10.5	25.6
48.	TKM 8	17.5	5.3	2.3	2.3	76.3	3	11.7	23.3
49.	ARC 13788	21.7	5.9	2.4	2.4	70.8	3	8.4	25.1
50.	ARC 11281	20.0	6.3	2.0	3.2	74.9	4	10.3	25.2
51.	ARC 7255	24.9	7.1	2.3	3.2	73.2	3	10.4	28.5
52.	ARC 6619	22.4	6.5	2.3	2.8	74.8	6	9.5	23.6
53.	ARC 11704	17.9	4.7	2.5	1.9	73.7	6	11.8	25.9
54.	ARC 11128	22.5	5.3	2.5	2.1	74.2	3	10.2	24.7
55.	ARC 10660	19.2	5.7	2.3	2.5	74.7	3	10.3	23.1
56.	ARC 7080	25.6	6.5	2.3	2.7	75.0	3	11.0	16.2
57.	ARC 6159	23.6	6.3	2.5	2.6	75.3	4	7.4	25.4
58.	ARC 6650	25.0	5.8	2.8	2.1	76.2	3	10.4	24.8
59.	ARC 6248	29.1	5.5	2.8	1.9	78.7	2	10.7	32.0
60.	Annaikompon	19.6	4.9	2.6	1.9	77.1	2	10.9	31.8
61.	ARC 5778	22.0	6.7	2.1	3.1	74.2	2	11.3	24.3

contd....

1	2	3	4	5	6	7	8	9	10
62.	ARC 6605	22.3	6.0	2.3	2.6	66.9	2	7.8	28.4
63.	ARC 6632	23.9	6.2	2.5	2.5	74.4	3	8.8	23.2
64.	ARC 5752	20.0	6.4	2.9	3.3	77.3	2	9.3	31.6
65.	Aganni	22.7	5.8	2.5	2.3	77.2	2	12.4	23.2
66.	ARC 5764	24.1	6.3	2.4	2.7	74.3	3	10.8	23.0
67.	ARC 10372	22.0	6.0	2.2	2.8	77.4	2	7.7	24.4
68.	BPT 1235	23.4	6.8	2.3	3.3	69.5	2	11.2	20.9
69.	IET 1444	19.7	5.3	2.1	2.5	81.8	5	12.9	19.1
70.	Prabhat	24.7	6.2	2.5	2.5	75.0	6	10.7	23.6
71.	MTU 4870	22.9	5.9	2.3	2.7	73.1	4	11.1	24.0
72.	Tellahamsa	20.2	6.2	1.9	3.4	71.0	2	10.0	17.2
73.	IR 62	21.6	6.1	2.2	2.8	71.4	4	8.8	22.0
74.	MTU 5293	20.2	6.3	2.1	3.0	71.3	4	12.5	27.0
75.	BPT 856	19.0	5.2	2.3	2.6	77.3	2	10.6	24.3
76.	Taichung native-1	20.0	5.1	2.4	2.2	78.0	7	14.4	20.7
77.	MTU 5249	19.0	5.9	2.3	2.5	78.0	3	9.8	22.2

contd...

1	2	3	4	5	6	7	8	9	10
78.	MTU 2067	21.0	5.9	2.3	2.5	76.7	4	11.7	23.3
79.	Mahsuri	15.4	5.3	2.1	2.6	76.6	2	11.6	19.3
	General Mean	23.6	6.0	2.4	2.5	74.9	3.4	9.9	24.85
	C.D.	0.31	0.06	0.03	0.02	0.30	0.82	0.53	0.58
	C.V. %	1.6	1.2	1.5	1.3	0.50	19.1	6.5	3.6

Analysis of Variance:

Analysis of variance was carried out for all the eight characters and the differences were found to be highly significant for all the characters excepting breadth of grain. The results of analysis of variance are presented in Table 3.

1000 Grain Weight:

The 1000 grain weight among the genotypes ranged from 15.4 to 35.1 (g) indicating high variability for the character. Mahsuri was the lowest of all genotypes while DW 8 was the highest. Thirty four genotypes exceeded genral mean of 1000 grain weight.

Length of Grain:

The trait data among the genotypes varied from 4.4 to 7.2 (mm) indicating high variability for the character. The genotype, Kottamalli was the lowest of all genotypes whereas Basmati-370 was the highest. Thirty six genotypes exceeded general mean of length of grain.

Breadth of Grain:

The character values among the genotypes ranged from 1.8 to 2.9 (mm) indicating variability. Basmati-370 was the lowest of all genotypes while ARC 5752 and Vellathil Cheera

Table 3: Analysis of variance results of eight characters of 79 genotypes

Source of variation	D.F.	1000 grain weight (g)	Length of grain (mm)	Breadth of grain (mm)	L/B ratio (No.)	Hulling recovery (%)	Alkali spreading score (No.)	Protein content of brown rice (%)	Grain yield/plant (g)
Replications	2	0.17	0.092	0.002	0.025	0.309	0.114	0.169	0.173
Treatments	78	47.562**	1.148**	0.199	0.529**	28.060**	5.061**	7.475**	45.158**
Error	156	0.149	0.005	0.001	0.001	0.143	1.011	0.425	5.059
General Mean		23.681	6.069	2.426	2.562	74.998	3.456	9.919	24.856
SEm		0.316	0.060	0.031	0.029	0.309	0.821	0.532	1.836
C.V. (%)		1.632	1.201	1.556	1.362	0.504	19.102	6.574	0.589

** Significant at 1% level

were the highest. Thirty five genotypes exceeded genral mean of the trait.

Length/Breadth (L/B) ratio:

The L/B ratio among the genotypes varied from 1.7 to 3.9 indicating high variability for the trait. Kottamalli was the lowest of all genotypes whereas Basmati-370 was the highest. Thirty eight genotypes exceeded general mean of the character.

Hulling recovery:

The trait data among the genotypes ranged from 64.9 to 81.8 per cent indicating high variability for the character. The genotype, Gorsa was the lowest of all genotypes while IET 1444 was the highest. Fourty three genotypes exceeded general mean of hulling recovery.

Alkali Spreading Score:

The trait values among the genotypes varied from two to seven indicating the existance of wide variability for the character. Both Tellahamsa and BPT 1235 recorded the lowest of all genotypes indicating good cooking quality whereas Taichung Native-1 was the highest. Fourty seven genotypes were below the general mean of the trait indicating good cooking quality representation of the trait.

Protein Content of Brown Rice:

The character values among genotypes ranged from 6.5 to 14.4 per cent indicating high variability for the character. PLA 2 was the lowest of all genotypes while T.N 1 was the highest. Forty genotypes exceeded the general mean of the trait.

Grain Yield per Plant:

The grain yield values among genotypes varied from 9.9 to 33.9 (g) indicating wide variability of the trait. Basmati-370 was the lowest of all genotypes whereas DW 8 recorded the highest. Thirty five genotypes exceeded the general mean of the character.

D² analysis:

The quantitative assessment of genetic divergence has been taken up by utilising Mahalanobis's D² static^{dis} and based upon that eight characters were studied.

Grouping of Genotypes into Various Clusters:

The 79 genotypes were grouped into 11 clusters using the Tocher's procedure. The distribution of genotypes into various clusters are presented in Table 4.

Table 4: Composition of D² clusters of 79 genotypes

Cluster Number	Genotypes included	No. of genotypes
I	1,3,4,5,6,7,9,11,12,13,14,20,21,22,23,24,27,28,30,32,33,34,36,39,40,41,43,44,45,48,49,52,54,55,56,57,58,63,65,66,67,70,71,73,75,77,78 (Prabhat)	47
II	17,18,19,59,60	5
III	15,31,38,46,47,50,61,72,74,79 (Tellaamsa)	10
IV	8,16,25,29,35,37,51,68 (BPT 1235)	8
V	53,76 (TN 1)	2
VI	10,26	2
VII	2 (DW 8)	1
VIII	42 (Basmati-370)	1
IX	62	1
X	64	1
XI	69(IET 1444)	1

NB:- The serial number given in Table 1 indicates the name of the genotype included in the cluster

Inter and Intra Cluster D^2 Values:

The inter and intra cluster D^2 values were calculated as per procedure given by Singh and Choudary (1977) and are presented in Table 5.

Intra cluster average D^2 values ranged from zero to 595.74 and cluster VI had the maximum intra cluster distance. The average inter cluster D^2 values between II and VIII was maximum (7717.65) while minimum divergence was found between clusters IV and VII (740.23). Clusters separated by the largest statistical distances (D^2) or square root of D^2 values show the maximum divergence. In general, clusters VIII and XI, were most divergent to other clusters. Cluster I is having maximum divergence with VIII (61.94) followed by VII (40.95); cluster II is having maximum divergence with VIII (87.85) followed by IV (58.19); cluster III is having maximum divergence with VI (53.49) followed by VII (44.87); cluster IV showed maximum divergence with V (55.70); cluster V is showing maximum divergence with VIII (78.39) followed by VII (62.24); cluster VI is showing maximum divergence with VIII (79.30) followed by XI (59.99); cluster VII is showing maximum divergence with XI (55.94) and cluster VIII is showing maximum divergence with XI (71.04).

Table 5: Inter and Intra (diagonal) cluster average D^2 values of 79 genotypes

Cluster Group	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	473.25 (21.75)	1131.73 (33.64)	1012.58 (31.82)	1269.34 (35.63)	985.51 (31.39)	1306.13 (36.14)	1676.93 (40.95)	3836.69 (61.94)	825.80 (28.74)	1341.96 (36.64)	1240.72 (35.22)
II		368.74 (19.20)	2838.69 (53.28)	3386.00 (58.19)	816.76 (28.61)	1097.76 (33.13)	3233.39 (56.86)	7717.65 (87.85)	2458.90 (49.59)	3351.07 (57.89)	1783.84 (42.24)
III			397.50 (19.94)	945.15 (30.74)	1725.52 (41.54)	2861.03 (53.40)	2013.40 (44.87)	1612.41 (40.15)	862.75 (29.37)	914.31 (30.24)	1369.97 (37.01)
IV				336.06 (18.35)	3102.27 (55.70)	2626.30 (51.25)	740.23 (27.21)	1432.55 (37.85)	1112.25 (33.35)	852.23 (29.19)	2561.44 (50.61)
V					326.42 (18.07)	1731.16 (41.61)	3874.50 (62.24)	6144.54 (78.39)	1496.30 (38.68)	2690.99 (51.87)	1067.66 (32.68)
VI						595.74 (24.41)	2509.38 (50.09)	6289.01 (79.30)	1096.06 (33.11)	3281.01 (57.28)	3598.62 (59.99)
VII							0.00	2837.60 (53.27)	1928.99 (43.91)	1096.36 (33.16)	3129.48 (55.94)
VIII								0.00	2665.55 (51.63)	1907.33 (43.67)	5046.77 (71.04)
IX									0.00	1595.13 (39.94)	2620.20 (51.19)
X										0.00	1949.84 (44.16)
XI											0.00

Figures in parenthesis are "D" values (Square root of D^2)

Cluster	I	consisted of 47 genotypes.
Cluster	II	consisted of 5 genotypes.
Cluster	III	consisted of 10 genotypes.
Cluster	IV	consisted of 8 genotypes.
Cluster	V	consisted of 2 genotypes.
Cluster	VI	consisted of 2 genotypes.
Cluster	VII	consisted of 1 genotype\$.
Cluster	VIII	consisted of 1 genotype\$.
Cluster	IX	consisted of 1 genotype\$.
Cluster	X	consisted of 1 genotype\$.
Cluster	XI	consisted of 1 genotype\$.
Total	----- 11 -----	----- 79 -----

The mutual relationship between clusters was diagrametically represented in Fig. 1 by taking square root of average inter and intra cluster D^2 values i.e., D values to denote distances in cluster diagram.

Cluster Mean Values:

The cluster mean values for eight characters are presented in Table 6.

Mean Values of Selected Parents:

The mean values of eight characters of selected seven parents viz., Basmati-370, DW 8, IET 1444, Tellahamsa,

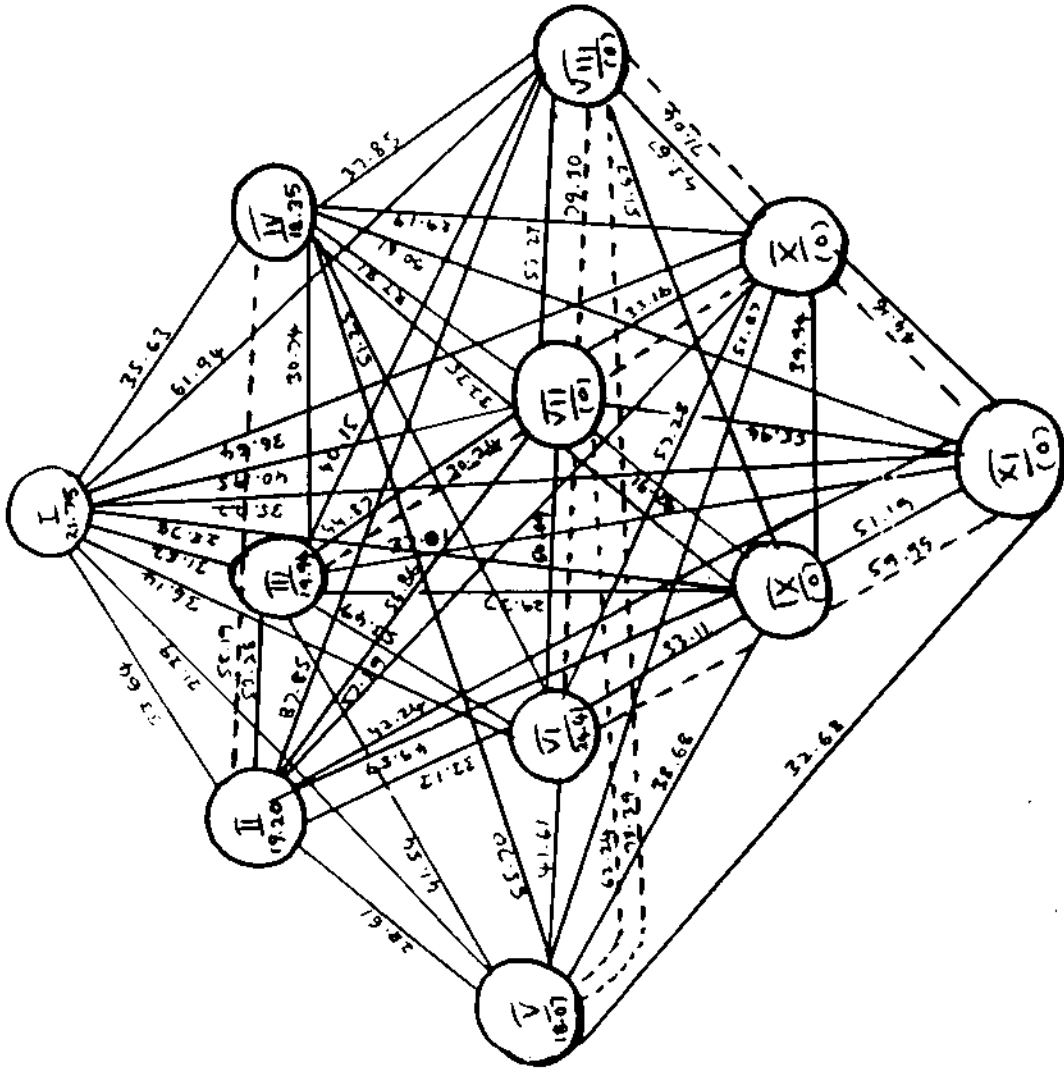


Fig.1: CONFIGURATION OF CLUSTERS AND THEIR MUTUAL RELATIONSHIP.

Table 6: Cluster means for eight characters of 79 genotypes

Cluster Group	1000-grain weight (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling recovery (%)	Alkali Spreading score (No.)	Protein content (%)	Grain yield/plant (g)
I	23.90	6.01	2.49	2.45	75.46	3.38	9.58	24.2
II	26.38	5.16	2.72	1.88	77.17	5.20	9.53	31.6
III	19.22	6.08	2.06	2.95	74.52	3.20	11.03	23.7
IV	26.21	7.13	2.33	3.09	73.35	3.50	10.12	28.9
V	18.95	4.91	2.45	2.05	75.86	6.50	13.10	23.3
VI	29.08	5.80	2.84	2.05	67.88	4.00	8.67	25.9
VII	35.10	6.97	2.20	3.10	74.53	5.00	10.90	33.9
VIII	20.23	7.23	1.83	3.90	69.30	3.00	10.00	9.9
IX	22.33	6.00	2.30	2.60	66.93	2.00	7.80	28.4
X	20.00	6.40	2.90	3.30	77.30	2.00	9.30	31.6
XI	19.73	5.37	2.13	2.53	81.80	5.00	12.90	20.74
Range	18.95 to 35.10	4.91 to 7.23	1.83 to 2.90	1.88 to 3.90	66.93 to 81.80	2.00 to 6.50	7.80 to 13.10	9.9 to 33.90

Prabhat, Taichang Native 1, and BPT 1235 are furnished in Table 7.

The above seven parents were selected each from seven different clusters viz., VIII, VII, XI, III, I, V and IV respectively from out of total 11 clusters formed for utilization in the 7 x 7 diallel crossing programme.

The parents were selected as per the breeding objectives and also on the basis of their superiority for the characters noted against them as detailed below depending on their per se performance and also the cluster performance.

S. No.	Name of the variety	Specific character for which selected
1.	Basmati-370	Highest length of grain and L/B ratio. Scented variety.
2.	DW 8	Highest test weight and grain yield per plant.
3.	IET 1444	Highest hulling recovery and popular rabi variety with blast tolerance.
4.	Tellahamsa	Good cooking quality as shown by lowest Alkali spreading score.
5.	Prabhat (Standard Variety in heterotic study)	Highyielder. Popularly grown in kharif and rabi seasons in Krishna-Godavari zone.
6.	Taichung Native 1	Highest protein content of brown rice %

Table 7: Mean values of 8 characters of seven selected parents

S.No.	Name of Variety	1000-grain weight (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling recovery (%)	Alkali Spreading Score (No.)	Protein content (%)	Grain yield/plant (g)
1.	Basmati-370	2.1	7.4	1.9	3.9	76.2	3	10.0	9.9
2.	D.W. 8	3.4	7.1	2.6	2.8	76.9	5	10.9	33.9
3.	IET 1444	2.0	5.5	2.3	2.5	81.8	5	12.9	19.1
4.	Tellahamsa	2.1	6.6	1.9	3.4	75.9	2	10.0	17.2
5.	Prabhat	2.7	6.1	2.5	2.4	77.3	6	10.7	23.6
6.	T.N.1	2.1	5.4	2.5	2.1	79.4	7	14.4	20.7
7.	BPT 1235	2.5	7.2	2.2	3.3	76.0	2	11.2	20.9

7. BPT 1235 Lowest alkali spreading score representing good cooking quality. Popularly grown rabi variety in Krishna-Godavari zone with Gallmidge pest tolerance.

The above parents were crossed in 7 x 7 diallel crossing programme excluding reciprocals and the details of cross combinations with coding given to each cross are furnished below for easy reference in the text.

S.No.	Name of cross combination	Code No. of cross
1	2	3
1.	Basmati/DW 8	C ₁
2.	Basmati/IET 1444	C ₂
3.	Basmati/Tellahamsa	C ₃
4.	Basmati/Prabhat	C ₄
5.	Basmati/Taichung Native-1	C ₅
6.	Basmati/BPT 1235	C ₆
7.	DW 8/IET 1444	C ₇
8.	DW 8/Tellahamsa	C ₈
9.	DW 8/Prabhat	C ₉
10.	DW 8/Taichung Native-1	C ₁₀
11.	DW 8/BPT 1235	C ₁₁
12.	IET 1444/Tellahamsa	C ₁₂

1	2	3
13.	IET 1444/Prabhat	C ₁₃
14.	IET 1444/Taichung Native-1	C ₁₄
15.	IET 1444/BPT 1235	C ₁₅
16.	Tellahamsa/Prabhat	C ₁₆
17.	Tellahamsa/Taichung Native-1	C ₁₇
18.	Tellahamsa/BPT 1235	C ₁₈
19.	Prabhat/Taichung Native-1	C ₁₉
20.	Prabhat/BPT 1235	C ₂₀
21.	Taichung Native-1/BPT 1235	C ₂₁

b) **Analysis of variance, range and means:**

The analysis of variance for 16 different characters viz., Days to 50% flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant, length and breadth of grain, L/B ratio, hulling recovery, volume expansion, water uptake, kernel elongation and protein content of brown rice are presented in Table 8 & 9 respectively for 7 parents and their F_1 and F_2 of 21 rice crosses. The analysis of variance showed significant differences between the

Table 8: General ANOVA for 16 characters of 7 parents and their 21 F₁S (7x7 diallel) (Mean sum of squares)

Source of variation	D.F.	Days to 50% FLD (No.)	Plant height (cm)	EST/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100- grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling very (%)	Volume expansion (%)	Water uptake (ml)	Kernel weight (No.)	Protein content of brown rice (%)
Replications	2	182.5938	130.5625	10.2002	5.8516	4763.5938	23.4063	0.0853	161.0430	0.0287	0.0011	9.7719	13.9375	0.0514	1546.5000	0.0030	0.5674
Treatments	27	447.3333	2798.5510	155.2722	17.1956	2321.8311	137.5525	0.3887	1626.0067	1.0391	0.1808	11.1289	18.1771	1.1904	12150.9258	0.0681	7.1472
Error	54	3.2130	12.6852	5.4974	2.3457	100.3785	2.7336	0.0304	2.7927	0.0238	0.0177	10.1236	0.4803	0.1231	3527.4075	0.0048	0.0679
G. Mean	-	99.6637	107.2250	19.3464	22.8821	79.9512	19.8250	2.6280	35.4429	6.3750	2.4214	3.9000	71.8774	3.0429	339.5167	1.4929	12.1214
SED	-	1.4635	2.9081	1.9144	1.2505	8.1804	1.3500	0.1423	1.3645	0.1258	0.1088	2.5979	0.5659	0.2865	48.4932	0.0567	0.2127
C.D	-	2.8700	5.7060	3.7500	2.4500	16.0300	2.6500	0.2800	2.6700	0.2500	0.2100	--	1.1100	0.5600	95.0500	0.1100	0.4200
C.V.%	-	1.7985	3.3219	12.1192	6.6933	12.5313	8.3396	6.6339	4.7151	2.4169	5.5006	106.0589	0.8910	11.5304	17.4931	4.6540	2.1498

** Significant at 1% level

* Significant at 5% level

Table 9: General ANOVA for 16 characters of 7 parents and their 21 F₂S (7x7 diallel) (Mean sum of squares)

Source of variation	D.F.	Days to 50% FLD (No.)	Plant height (cm)	Ear/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100- grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling reco- very (%)	Volume expan- sion (No.)	Water up- take (ml)	Kernel elon- gation (No.)	Protein content of brown rice (%)
Replications	1	360.0625	120.3750	5.2842	15.1250	535.6250	13.7090	0.0255	21.9531	0.0090	0.0216	0.0787	1.3125	0.1027	3.5000	0.0007	1.1143
Treatments	27	1458.7384	1501.0463	52.7620	8.9004	970.0220	16.8061	0.1570	719.2652	0.5086	0.0939	0.3298	9.3206	0.6696	3742.8889	0.0375	4.3379
Error	27	1167.9236	57.1366	4.6992	3.2146	127.5000	4.0272	0.0352	6.6869	0.0713	0.0327	0.0288	3.9144	0.1444	361.2963	0.0248	0.5615
G. Mean	--	108.9643	104.9232	16.6193	21.8946	79.3286	20.6089	2.5500	31.0268	6.3196	2.3518	2.5446	76.0322	2.8464	320.1964	1.4179	9.4768
SED	--	34.1749	7.5589	2.1678	1.7929	11.2916	2.0068	0.1880	2.5859	0.2671	0.1809	0.1696	1.9785	0.3760	19.0083	0.1574	0.7493
C.D.	--	-	15.5200	4.4500	3.6800	23.1700	4.1200	0.3900	17.1000	0.5500	0.3700	0.3500	4.0600	0.7700	39.0000	-	1.5400
C.V.%	--	31.3634	7.2042	13.0280	8.1889	14.2340	9.7375	7.3731	8.3344	4.2260	7.6913	6.6637	2.6022	13.2098	5.9364	11.1040	7.9071

** Significant at 1% level

* Significant at 5% level

treatments for all the sixteen characters with an exception of L/B ratio in F_1 , kernel elongation and days to 50% flowering in F_2 . The mean performance of sixteen characters recorded for parents, their F_1 and F_2 generations of 21 rice crosses are presented in Table 10 & 11.

1. Days to 50% flowering (No):

The analysis of variance for this character was significant only in F_1 but not in F_2 generation. In parents it ranged from 83 to 131 days with a mean of 100 days whereas a range of 85 to 115 days with a mean of 99.5 days was observed in F_1 generation and a range of 97.5 to 135 days with a mean of 109 days in F_2 generation was observed. The cross (Basmati/DW 8) showed highest number of days of 125 and 135 in F_1 and F_2 generation crosses respectively. Individual crosses in F_2 generation showed transgressive segregation as seen from the range of variation.

2. Plant height:

The analysis of variance for this character exhibited significant differences in F_1 and F_2 generations. In parents it varied from 72.3 to 160.6 cm with a mean of 102.2 cm while in F_1 and F_2 generations a mean plant height of 107 cm and 105 cm with a range of 72.2 to 144.4 cm and 77.5 to 137.5 cm respectively was observed. The cross (Basmati/

Table 10: Mean values of 16 characters of 7 parents and their 21 F₁S

Sl. No.	Variety	Days to 50% FLE (No.)	Plant height (cm)	FT/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100-grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling reco-very (%)	Volume exten-sion (No.)	Water take (ml)	Kernel elong-ation (No.)	Protein content of brown rice (%)
1.	Basmati-370	131	160.6	9.8	23.0	36.6	26.5	2.43	9.9	7.4	1.9	3.9	76.1	3.0	355	1.7	10.0
2.	D.W. 8	112	157.0	14.0	27.1	109.6	20.8	3.10	33.9	6.8	2.8	2.4	77.4	3.3	330	1.3	10.9
3.	1ET 1444 (Rasi)	87	72.3	18.0	15.1	42.0	18.4	1.90	20.7	5.3	2.2	2.4	77.2	3.5	375	1.8	12.9
4.	Tellahansa	83	91.3	22.3	21.3	52.50	16.7	2.10	21.3	6.7	2.0	3.4	79.5	3.7	400	1.4	11.1
5.	Prabhat	100	79.0	18.7	21.2	66.60	14.8	2.70	28.2	5.6	2.5	2.2	77.7	2.8	288	1.7	10.7
6.	T.N. 1	90	73.30	26.0	20.8	51.2	15.1	2.20	24.3	5.5	2.6	2.1	81.8	3.0	335	1.5	14.4
7.	BPT 1235	97	82.0	17.3	22.9	65.0	19.7	2.30	20.3	7.3	2.2	3.5	80.8	4.0	350	1.3	11.2
Parent Mean		100	102.2	18.0	21.6	60.5	20.6	2.38	22.5	6.37	2.3	2.8	76.64	3.3	347.5	1.5	11.7
C ₁		125	125.5	10.0	24.2	121.40	24.1	2.30	18.8	5.5	2.4	2.3	74.6	2.5	340	1.5	11.0
C ₂		108	141.6	9.0	24.5	123.10	15.8	2.65	28.0	6.27	2.6	2.4	80.4	2.5	335	1.4	11.5
C ₃		106	136.8	12.4	25.3	124.50	24.9	2.70	37.2	5.9	2.4	2.5	75.2	3.3	315	1.4	11.0
C ₄		115	136.7	11.7	24.1	136.30	35.9	2.50	38.3	6.2	2.5	2.5	80.0	2.0	265	1.5	11.0
C ₅		115	106.0	12.3	21.1	69.50	31.6	2.80	14.0	6.2	2.6	2.4	78.6	3.0	270	1.6	13.7
C ₆		109	144.4	20.6	23.8	98.70	28.9	2.20	22.0	6.6	2.1	3.1	72.7	2.5	365	1.4	11.3
C ₇		101	134.6	32.0	23.8	95.60	17.6	2.90	78.0	6.5	2.5	2.6	79.3	4.0	380	1.4	11.2
C ₈		100	139.8	31.2	24.0	98.60	16.2	3.00	75.2	6.9	2.3	3.0	76.8	2.0	285	1.4	11.0
C ₉		104	133.3	28.8	26.4	115.70	17.4	3.30	96.6	7.3	2.8	2.6	78.7	3.0	350	1.5	11.2
C ₁₀		98	137.3	33.7	26.5	83.20	23.0	3.20	86.6	6.3	2.2	2.2	78.1	3.0	285	1.4	14.5
C ₁₁		103	134.0	28.8	24.7	104.00	17.9	3.20	71.6	7.5	2.5	3.0	78.1	2.6	285	1.4	12.1
C ₁₂		85	90.2	20.3	23.8	82.50	10.0	2.20	37.2	6.0	2.0	3.0	74.0	2.5	270	1.3	12.3
C ₁₃		94	75.6	18.3	22.1	60.00	16.2	2.80	22.6	6.4	2.5	2.5	78.5	3.3	380	1.5	11.7
C ₁₄		86	74.0	22.5	22.0	62.20	15.3	2.50	25.0	6.4	2.5	2.5	80.2	3.3	280	1.5	15.2
C ₁₅		92	88.5	17.5	24.5	84.50	11.5	2.30	32.6	6.1	2.2	2.2	73.9	2.5	270	1.3	12.2
C ₁₆		86	94.2	22.1	22.3	63.20	13.9	2.80	32.0	6.1	2.4	2.4	75.5	4.0	460	1.6	11.2
C ₁₇		86	80.5	23.0	21.3	49.00	14.5	2.50	28.4	6.1	2.4	2.4	80.0	2.8	390	1.8	13.5
C ₁₈		90	84.5	12.6	21.5	68.60	13.7	2.70	16.9	6.9	2.3	2.3	77.7	4.0	395	1.3	11.2
C ₁₉		95	72.2	23.3	21.4	45.10	37.2	2.70	25.5	5.8	2.6	2.6	80.7	2.5	375	1.7	15.2
C ₂₀		96	82.6	19.0	21.8	66.00	17.1	2.90	27.0	6.6	2.6	2.5	75.6	3.6	335	1.6	11.1
C ₂₁		93	74.5	16.5	20.2	63.40	14.4	2.70	21.1	6.5	2.5	2.6	81.5	3.3	425	1.5	15.1
F ₁ Mean		99.5	108.9	19.8	23.3	84.5	19.4	2.7	39.74	6.385	2.45	2.55	77.6	2.9	352.1	1.47	12.3
G Mean		99.67	107.23	19.35	22.88	79.95	19.83	2.63	35.44	6.372	2.4214	2.60	77.86	3.04	349.52	1.49	12.12
C.D.		3.66	7.47	4.92	3.21	19.80	3.47	0.37	3.51	0.35	0.28	0.38	1.48	87.88	147.86	0.15	0.55
C.V.%		1.80	3.32	12.12	6.69	12.53	8.34	6.63	4.71	2.40	5.50	106.06	90.89	11.53	17.49	4.65	2.15

C₁ = Basmati-370/DW 8
 C₂ = " / 1ET 1444
 C₃ = " / Tellahansa
 C₄ = " / Prabhat
 C₅ = " / TN 1
 C₆ = " / BPT 1235
 C₇ = DW 8/1ET 1444
 C₈ = " / Tellahansa
 C₉ = " / Prabhat
 C₁₀ = " / TN 1
 C₁₁ = " / BPT 1235
 C₁₂ = " / 1ET 1444/Tellahansa
 C₁₃ = 1ET 1444/Prabhat
 C₁₄ = " / TN 1
 C₁₅ = " / BPT 1235
 C₁₆ = Tellahansa/Prabhat
 C₁₇ = " / TN 1
 C₁₈ = " / BPT 1235
 C₁₉ = Prabhat/TN 1
 C₂₀ = " / BPT 1235
 C₂₁ = TN 1/BPT 1235

Table 11: Mean values of 16 characters and their range for 21 F₂ crosses

S. Entry No.	Days to 50% FTD (No.)		Plant height (cms)		E/T/Plant (No.)		Panicle length (cms)		No. of grains/panicle (No.)		Spillet Sterility (%)		100 grain wt. (g)		Yield/Plant (g)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
	1	2	3	4	5	6	7	8								
1. C ₁	135.0	105-150	117.5	70-170	9.5	8-15	22.0	16-28	117.5	65-125	22.00	15.0-35.0	2.30	1.9-2.8	17.00	10.5-25.5
2. C ₂	117.5	85-140	127.5	70-165	8.0	7-14	22.5	18-25	107.5	65-120	17.85	14.5-28.5	2.55	2.0-2.8	22.25	10.0-30.0
3. C ₃	125.0	90-145	130.0	85-165	12.0	9-23	23.0	17-26	107.5	50-130	18.90	15.0-29.7	2.65	2.0-3.0	27.15	8.5-33.0
4. C ₄	127.5	90-150	130.0	75-165	11.0	9-20	22.0	18-25	115.0	70-140	21.85	12.5-38.3	2.55	2.1-2.9	30.90	9.5-36.0
5. C ₅	127.5	95-150	102.5	75-130	12.0	8-24	21.0	17-26	82.5	55-100	22.45	12.0-35.5	2.70	1.8-2.9	16.25	9.8-25.0
6. C ₆	127.5	90-150	137.5	80-165	10.5	9-20	22.0	18-27	90.0	50-110	22.35	15.5-32.3	2.25	1.7-2.6	20.65	10.5-23.0
7. C ₇	107.5	85-130	127.5	70-160	24.0	18-30	22.0	16-25	92.5	60-115	19.15	16.5-25.5	2.70	1.7-3.0	64.15	38.5-85.5
8. C ₈	107.5	85-140	130.0	75-160	24.5	19-30	22.0	18-27	92.5	65-120	22.15	14.5-24.5	2.90	2.1-3.2	64.75	37.8-86.0
9. C ₉	122.5	100-140	125.0	80-160	22.0	16-28	25.5	18-28	105.0	70-120	20.90	14.0-27.8	3.00	2.0-3.4	84.00	39.5-98.0
10. C ₁₀	107.5	95-145	132.5	75-160	26.0	18-33	26.0	19-29	90.0	50-105	20.70	14.5-28.5	2.80	1.9-3.2	68.65	38.2-90.5
11. C ₁₁	112.5	95-140	132.5	80-150	21.0	19-27	22.0	18-25	97.5	60-105	19.40	15.5-25.8	2.75	1.8-3.2	63.15	37.5-88.5
12. C ₁₂	97.5	80-120	87.5	75-105	17.5	12-24	20.0	15-24	77.5	60-100	19.25	16.0-21.5	2.20	1.9-2.5	27.65	16.5-45.5
13. C ₁₃	120.0	90-140	77.5	70-100	14.5	11-22	21.0	15-25	65.0	40-105	21.74	14.0-25.0	2.70	2.0-3.0	19.65	17.5-30.8
14. C ₁₄	115.0	90-140	77.5	70-110	19.0	11-28	21.0	16-26	67.5	55-110	19.00	13.5-24.5	2.50	1.7-2.9	21.40	16.5-28.5
15. C ₁₅	120.0	95-145	87.5	75-110	15.0	8-20	21.0	15.5-24	82.5	50-105	21.75	15.5-24.5	2.25	1.9-2.5	27.30	16.0-45.0
16. C ₁₆	120.0	90-135	82.5	75-110	17.0	13-25	20.5	18-25	70.0	50-110	19.15	15.0-22.5	2.70	2.0-3.0	27.65	18.5-48.0
17. C ₁₇	120.0	95-140	77.5	75-105	15.0	12-28	21.0	19-26	62.5	50-105	19.75	14.5-23.0	2.50	1.9-2.8	25.25	17.5-45.0
18. C ₁₈	122.5	90-135	85.0	70-110	12.0	8-20	22.0	18-25	72.5	40-110	20.50	15.5-33.5	2.70	2.0-3.0	16.15	11.5-27.0
19. C ₁₉	122.5	90-140	85.0	70-105	18.0	14-28	22.0	17-24	65.0	45-95	20.50	13.5-34.5	2.65	2.0-3.1	23.50	19.0-31.0
20. C ₂₀	120.0	90-135	87.5	75-110	17.0	8-21	21.0	16-26	67.5	40-100	21.75	13.0-30.5	2.70	2.1-3.1	21.85	17.5-32.5
21. C ₂₁	115.0	90-140	82.5	70-105	14.0	10-24	21.0	18-25	70.0	45-105	21.75	14.5-32.5	2.65	2.0-3.0	21.75	18.5-28.5
Mean	108.9643		104.9232		16.6393		21.8946		79.3286		20.6089		2.5500		31.0268	
C.D.	34.1749		7.5589		2.1678		1.7929		11.2916		2.0068		0.1880		2.5859	
C.V. %	31.3634		7.2042		13.0280		8.1889		14.2340		9.7375		7.3731		8.3344	

Note: C₁ to C₂₁ same as in Table 10

Contd.....

S. Entry No.	Length of grain (mm)		Breadth of grain (mm)		L/B Ratio (No.)		Hulling Recovery (%)		Volume expansion (No.)		Water uptake (ml)		Kernel elongation (No.)		Protein content of brown rice %	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. C ₁	5.70	5.4-6.9	2.35	1.8-2.9	2.25	2.1-3.0	73.0	70.3-78.0	2.40	2.2-3.2	300	270-360	1.40	1.2-1.8	8.50	7.5-11.0
2. C ₂	6.50	5.3-7.5	2.50	1.9-2.7	2.30	2.1-3.5	75.75	72.0-81.5	2.45	2.3-3.1	300	260-365	1.30	1.1-1.9	8.75	7.5-13.0
3. C ₃	6.20	5.4-7.5	2.30	1.9-2.8	2.40	2.2-3.2	74.25	72.0-80.0	3.00	2.3-3.5	295	270-350	1.30	1.1-1.8	8.50	7.0-11.0
4. C ₄	6.30	5.3-7.5	2.40	1.8-2.7	2.35	2.2-3.3	76.25	74.0-80.5	1.75	1.4-2.9	255	240-310	1.45	1.2-1.8	8.50	7.5-11.0
5. C ₅	6.40	5.4-7.5	2.50	1.8-2.8	2.40	2.1-3.4	75.25	73.5-80.0	2.90	2.1-3.2	257.5	240-310	1.50	1.3-1.8	9.50	8.5-14.0
6. C ₆	6.70	6.1-7.7	2.05	1.8-2.6	2.90	2.3-3.6	72.4	71.5-77.0	2.40	2.2-3.0	350	300-370	1.35	1.2-1.6	8.50	7.5-11.0
7. C ₇	6.55	5.1-7.6	2.40	2.1-2.9	2.40	2.2-2.8	75.25	72.0-79.0	3.50	3.0-3.8	320	290-360	1.35	1.1-1.7	8.75	7.5-11.5
8. C ₈	6.70	6.0-6.9	2.25	2.0-3.0	2.70	2.3-3.4	74.75	72.0-78.0	1.90	1.7-2.8	270	250-300	1.30	1.1-1.8	8.40	7.5-11.0
9. C ₉	6.75	5.5-7.1	2.60	2.2-3.0	2.45	2.1-2.8	75.0	73.0-78.0	2.80	2.4-3.4	325	290-360	1.30	1.1-1.7	8.50	7.5-13.0
10. C ₁₀	6.60	5.4-7.0	2.60	2.1-2.9	2.10	1.8-2.8	75.75	72.5-80.5	2.70	2.2-3.4	280	250-320	1.30	1.1-1.6	8.75	7.5-11.5
11. C ₁₁	6.70	6.1-7.5	2.50	2.1-3.0	2.70	2.3-2.4	76.25	74.0-81.0	1.95	1.8-2.6	275	260-340	1.35	1.1-1.6	8.55	8.0-11.5
12. C ₁₂	5.90	5.2-6.9	1.90	1.7-2.5	2.60	2.2-3.5	73.5	71.0-80.0	2.40	2.2-3.2	265	250-320	1.30	1.1-1.7	9.75	8.0-11.5
13. C ₁₃	6.20	5.2-6.6	2.40	2.0-2.8	2.45	2.1-2.8	76.5	74.0-79.0	2.50	2.4-3.5	360	300-380	1.45	1.2-1.7	8.75	8.0-13.5
14. C ₁₄	6.10	5.2-6.8	2.40	2.1-2.7	2.40	2.0-2.8	76.25	73.0-82.0	3.00	2.3-3.6	275	260-320	1.45	1.3-1.7	9.00	7.5-13.0
15. C ₁₅	6.05	5.3-7.4	2.15	2.0-2.8	2.65	2.3-3.5	72.75	70.5-77.0	2.45	2.1-3.1	265	250-310	1.30	1.1-1.8	8.75	7.5-11.5
16. C ₁₆	6.00	5.4-6.9	2.30	1.9-2.8	2.40	2.1-3.5	75.0	73.0-79.0	3.70	3.0-4.0	390	310-420	1.45	1.3-1.7	8.50	8.0-13.5
17. C ₁₇	5.90	5.4-6.9	2.30	1.9-2.9	2.30	2.0-3.6	76.50	74.0-82.0	2.60	2.3-3.1	360	300-385	1.50	1.3-1.7	9.00	7.5-11.5
18. C ₁₈	6.60	6.1-7.4	2.30	2.0-2.8	2.70	2.5-3.5	76.75	74.0-81.0	3.50	3.1-4.0	350	310-370	1.25	1.1-1.5	9.65	8.0-13.0
19. C ₁₉	5.80	5.4-6.8	2.50	2.2-2.9	2.15	1.8-3.8	76.25	74.0-82.0	2.40	2.1-3.0	350	300-370	1.50	1.3-1.8	9.00	8.0-13.0
20. C ₂₀	6.30	5.5-7.2	2.50	2.1-2.8	2.40	2.1-3.4	74.5	73.0-80.5	3.40	3.0-4.0	315	280-360	1.45	1.3-1.7	8.50	7.5-11.5
21. C ₂₁	6.40	5.4-7.3	2.45	2.0-2.8	2.55	2.0-3.5	77.5	75.0-82.0	3.00	2.3-3.4	375	300-400	1.45	1.2-1.7	9.50	8.5-14.8
Mean	6.3196		2.3518		2.5446		76.0322		2.8464		320.1964		1.4179		9.4768	
C.D.	0.2671		0.1809		0.1696		1.9785		0.3760		19.0083		0.1574		0.7493	
C.V. %	4.2260		7.6913		6.6637		2.6022		13.2098		5.9364		11.1064		7.9071	

BPT 1235) recorded highest plant height of 144.4 and 137.5 cm in F_1 and F_2 generations, respectively. Transgressive segregation was seen in individual crosses of F_2 generation as observed from the range of variation.

3. Effective tillers per plant:

The analysis of variance showed significant differences both in F_1 and F_2 generations for this character. In parents a range of 9.8 to 26.0 with a mean of 18.0 was shown where as it showed a range of 9.0 to 33.7 with a mean of 19.4 in F_1 generation and a range of 8.0 to 26.0 with a mean of 16.6 in F_2 generation, The cross (DW 8/ T.N 1) recorded the highest value of 33.7 in F_1 generation and 26 in F_2 generation. A transgressive trend of segregation was seen in individual crosses of F_2 generation for this trait.

4. Panicle length:

This trait showed significant differences both in F_1 and F_2 generations. In parents the trait values ranged from 15.1 to 27.1 cms with a mean of 21.6 cms whereas a range of 20.2 to 26.5 cms with a mean of 22.9 cms in F_1 generation and a range of 20.5 to 26.0 cms with a mean of 21.9 cms in F_2 generation was recorded for this character. The cross (DW 8/T.N 1) showed maximum panicle length of 26.5 in F_1 and

26.0 cms in F_2 generation. Individual crosses in F_2 showed transgressive trend of variation.

5. **Number of grains per panicle:**

This character showed highly significant differences in F_1 and F_2 generations. In parents it varied from 36.6 to 109.6 with a mean of 60.5 whereas it ranged from 45.1 to 136.3 with a mean value of 79.9 in F_1 and 62.5 to 117.5 with a mean of 79.3 in F_2 generation. The cross Basmati/Prabhat) recorded highest number of grains per panicle (136.3) in F_1 while it was 117.5 with the cross Basmati/DW 8 in F_2 generation. Individual crosses exhibited transgressive trend of variation in F_2 generation.

6. **Spikelet sterility:**

The analysis of variance for this character was found to be highly significant in F_1 and F_2 generations. The parents showed a range of 14.8 to 29.7% with a mean of 20.6% while this trait showed a range of 10.0 to 37.2% with a mean of 19.8% in F_1 and a range of 17.85 to 22.45% with a mean of 20.6% in F_2 generation. In F_1 generation, the cross, IET 1444/Tellahamsa recorded low spikelet sterility (%) of 10 per cent compared to the cross (Prabhat/TN 1) where it went upto 37.2% in F_2 , lowest spikelet sterility of 17.9%

was recorded by the cross (Basmati/IET 1444) as against 22.5% with cross (Basmati/Prabhat).

7. 100-grain weight:

The analysis of variance for this trait was significant both in F_1 and F_2 generations. In parents it ranged from 1.9 to 3.1 (g) with a mean of 2.38 (g). The 100-grain weight ranged from 2.2 to 3.3 (g) with a mean of 2.6 (g) in F_1 and in F_2 it varied from 2.2 to 3.0 (g) with a mean of 2.55 (g). The cross DW 8/Prabhat recorded highest grain weight of 3.3 (g) and 3.0 (g) in both F_1 and F_2 generations, respectively. Individual crosses in F_2 generation showed transgressive segregation.

8. Grain yield per plant:

Highly significant differences for grain yield per plant were observed in F_1 and F_2 generations. In parents the trait ranged from 9.9 g to 33.9 g with a mean of 22.5g whereas it recorded a mean yield of 35.4 g with a range of 14.0 g to 96.6 g in F_1 generation and a mean of 31.0 g with a range of 16.15 g to 84.0 g in F_2 . The cross DW 8/Prabhat recorded highest grain yield of 96.6g and 84.0 g per plant in F_1 and F_2 generations, respectively. A transgressive trend of segregation was observed in individual crosses of F_2 for this trait.

9. Length of grain:

The analysis of variance for this character was significant in F_1 and F_2 generations. In parents it ranged from 5.3 to 7.4 with a mean of 6.37 mm whereas the length of the grain in F_1 generation was in the range of 5.5 to 7.5 mm with a mean of 6.37 mm and in F_2 it varied from 5.7 mm to 6.7 mm with a mean of 6.32 mm. The cross DW 8/BPT 1235 recorded highest grain length (7.5 mm) in F_1 generation whereas in F_2 , the cross D.W.8/PRABHAT recorded the maximum of 6.75 mm. Individual crosses in F_2 showed transgressive type of segregation.

10. Breadth of grain:

The analysis of variance for this character was significant in F_1 and F_2 generations. The parents varied from 1.9 to 2.8 mm with a mean of 2.3 mm for this trait. This trait showed a mean of 2.42 mm and 2.35 mm with a range of 2.0 to 2.9 mm and 1.9 to 2.6 mm in F_1 and F_2 generations, respectively. The cross DW 8/TN 1 recorded highest breadth of grain (2.6 mm) in F_1 while in F_2 crosses (DW 8/TN 1 & D.W.8/BPT 1235) the maximum breadth of grain was 2.6 mm. Transgressive segregation was observed in individual crosses of F_2 generation.

11. L/B Ratio:

Analysis of variance for this trait was non-significant in F_1 and significant in F_2 generation. The L/B ratio of parents ranged from 2.1 to 3.9 with a mean of 2.8. This trait showed a range of 2.2 to 3.1 with a mean of 2.6 in F_1 and a range of 2.1 to 2.9 with a mean of 2.54 in F_2 generation. The cross Basmati/BPT 1235 showed highest L/B ratio of 3.1 and 2.9 in F_1 and F_2 generations, respectively.

12. Hulling recovery:

Analysis of variance for this character showed significant differences in F_1 and F_2 generations. In parents it ranged from 76.1 to 81.8 per cent with a mean of 78.64 per cent. The mean value for this trait is 77.88 with a range of 72.7 to 81.5 per cent in F_1 and in F_2 a mean value of 76.8 per cent with a range from 72.4 to 77.5 per cent was recorded. The cross T.N₁/BPT 1235 recorded highest hulling recovery (81.5 and 77.5%) in F_1 and F_2 generations, respectively. Individual crosses in F_2 showed transgressive trend in segregation.

13. Volume Expansion:

The analysis of variance for this trait was significant in both F_1 and F_2 generations. In parents, it varied from 2.8 to 4.0 with a mean of 3.3. The volume

expansion in F_1 and F_2 generations ranged from 2.0 to 4.0 and 1.75 to 3.70 with a mean of 3.04 and 2.85, respectively. The crosses DW 8/IET 1444 and Tellahamsa/Prabhat recorded highest volume expansion value of 4.0 in F_1 and 3.7 in F_2 generation of the cross (Tellahamsa/Prabhat).

14. Water uptake:

The analysis of variance for this trait exhibited significant differences in F_1 and F_2 generation. In parents it ranged from 288 to 400 ml with a mean of 347.5 ml. The water uptake was in the range of 265 to 460 ml with a mean of 349.5 ml in F_1 and 255 to 390 ml with a mean of 320.2 ml in F_2 generation. The cross Tellahamsa/Prabhat recorded highest value of 460 ml and 390 ml in F_1 and F_2 generations, respectively.

15. Kernel elongation:

The analysis of variance for this character was observed to be significant in F_1 and non-significant in F_2 . The parents recorded kernel elongation in the range of 1.3 to 1.8 with a mean of 1.5. The mean performance of this trait in F_1 and F_2 generations ranged from 1.3 to 1.8 and 1.25 to 1.5 with a mean of 1.49 and 1.42, respectively. The cross Tellahamsa/TN 1 recorded highest value of 1.8 in F_1 .

The cross (Basmati/TN 1) recorded highest value of 1.5 in F_2 generation.

16. **Protein content of Brown rice:**

The analysis of variance for this trait exhibited significant differences in F_1 and F_2 generation. In parents it ranged from 10.0 to 14.4% with a mean of 11.6%. This trait showed a range of 11.0 to 15.2% with a mean of 12.12% in F_1 and a range of 8.4 to 9.5% with a mean of 9.48% in F_2 generation. The crosses (IET 1444/BPT 1235) and (Prabhat/TN 1) recorded highest protein content of 15.2% in F_1 generation whereas in F_2 crosses (Basmati/TN 1) and (TN 1/BPT 1235) recorded low value of 9.5 per cent. Individual crosses in F_2 generation showed transgressive trend of variation.

ANALYSIS OF VARIANCE FOR COMBINING ABILITY

Analysis of variance for combining ability for 16 characters were presented in Tables 12 & 13.

The results of combining ability analysis revealed that in F_1 , the mean squares due to GCA and SCA were highly significant for the traits days to 50 per cent flowering, plant height, E/T/plant, panicle length, number of grains per panicle, spikelet sterility, 100-grain weight, grain

Table 12: Results of combining ability analysis for 16 characters in respect of 7 parents and their 21 F₁s (7 x 7 diallel) (Mean sum of squares)

Source	D.F.	Days to 50% FLO.	Plant height (cm)	E/T/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100 grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Mulling very (s)	Volume expansion (No.)	Water uptake (ml)	Kernel elongation (No.)	Protein content of brown rice (%)
GCA	6	654.3426	3575.0276	137.3602	13.0694	1418.8379	95.5096	0.3142	1124.4179	0.7230	0.1840	3.3581	9.5324	0.2797	7195.9258	0.0463	8.9751
SCA	21	4.7582	177.9390	27.2994	3.6353	589.6957	31.6627	0.0768	375.5979	0.2388	0.0249	3.8101	5.0670	0.4303	3151.5952	0.0160	0.4989
Error	54	1.0710	4.2284	1.8325	0.7819	33.4595	0.9112	0.0101	0.9309	0.0079	0.0059	3.3745	0.1601	0.0410	1175.7963	0.0146	0.0226
Estimated GCA variance		72.59	396.76	15.06	1.37	153.93	10.51	0.03	124.83	0.08	0.20	0.0018	1.04	0.027	668.9	0.0035	0.99
Estimated SCA variance		3.69	123.1	25.46	2.85	556.24	30.75	0.07	374.65	0.23	0.19	0.44	4.91	0.389	1957.8	0.0014	0.48

** Significant at 1% level

Table 13: Results of combining ability analysis for 16 characters in respect of 7 parents and their 21 F₂s (7 x 7 diallel) (Mean sum of squares)

Source	D.F.	Days to 50% FLG (No.)	Plant height (cm)	E/T/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100 weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Mulling reco- very (%)	Volume expan- sion (No.)	Water up- take (ml)	Kernel elon- gation (No.)	Protein content of brown rice (%)
GCA	6	1058.5634	2888.5186	68.1578	12.3322	946.2546	18.6458	0.1962	835.8021	0.6077	0.1466	0.3855	5.6991	0.2381	1111.7777	0.0361	1.8396
SCA	21	635.3095	139.6682	14.4447	2.1979	353.2277	5.4765	0.0449	223.5851	0.1534	0.0185	0.1018	4.3638	0.3624	2088.4880	0.0138	2.2631
Error	27	583.9618	28.5964	2.3496	1.6073	63.7494	2.0136	0.0177	3.3434	0.0357	0.0164	0.0144	1.9572	0.0707	180.6481	0.0124	0.2808
Estimated GCA variance		52.74	317.77	7.31	1.19	98.06	1.89	0.02	92.5	0.06	0.014	0.04	0.42	0.019	103.46	0.0026	0.1732
Estimated SCA variance		51.35	111.10	12.09	0.60	289.48	3.46	0.03	220.2	0.12	0.002	0.09	2.41	0.291	1907.84	0.0014	1.982

** Significant at 1% level

yield/plant, length of grain, breadth of grain, hulling recovery, volume expansion, water uptake and protein content of brown rice. The mean squares due to GCA only was significant for kernel elongation character whereas mean squares of both GCA and SCA were found to be non significant for L/B ratio. The SCA variance was found greater than GCA variance in magnitude for the characters E/T/plant, panicle length, grains/panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, L/B ratio, hulling recovery, volume expansion and water uptake whereas GCA variance was found greater than SCA variance in magnitude for the characters days to 50 per cent flowering, plant height, breadth of grain, kernel elongation and protein content of brown rice.

In F_2 generation, the mean squares due to both GCA and SCA were found to be highly significant for the traits plant height, E/T/plant, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice. The mean squares due to GCA was found significant for the traits panicle length, breadth of grain and kernel elongation, whereas both GCA and SCA variances were found to be non-significant for days to 50 per cent flowering only. The

SCA variance was found to be greater than GCA variance in magnitude for the characters E/T/plant, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice whereas GCA variance was found greater than SCA variance in magnitude for the characters days to 50 per cent flowering, plant height, panicle length, breadth of grain and kernel elongation.

The common characters which showed significant mean squares due to GCA and SCA both in F_1 and F_2 were found to be plant height, E/T/plant, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, hulling recovery, volume expansion, water uptake and protein content of brown rice. The mean squares due to GCA was significant for kernel elongation both in F_1 and F_2 . The remaining characters days to 50 per cent flowering, panicle length, L/B ratio and breadth of grain behaved in a different manner. The characters with SCA variance greater than GCA variance in magnitude were E/T/plant, grains/panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, L/B ratio, hulling recovery, volume expansion and water uptake whereas the characters with GCA variance greater than SCA variance

in magnitude were days to 50 per cent flowering, plant height and breadth of grain. The remaining characters panicle length, kernel elongation and protein content of brown rice behaved in a different manner i.e., panicle length (high magnitude of SCA variance in F_1 and high magnitude of GCA in F_2), kernel elongation (high magnitude of GCA variance both in F_1 and F_2) and protein content of brown rice (high magnitude of GCA variance in F_1 and high magnitude of SCA variance in F_2).

General combining ability (GCA) effects:

The GCA effects of the parents in F_1 and F_2 generations in respect of sixteen characters are presented in Tables 14 and 15 respectively. The GCA effects are the numerical values assigned to parents according to their average performance in hybrid combinations.

1. Days to 50% flowering:

The GCA effects ranged from -8.704 (Tella-hamsa) to 15.852 (Basmati) in F_1 whereas it varied from -16.690 (IET 1444) to 16.143 (Basmati) in F_2 . The two parents viz., Basmati (15.852) and DW 8 (6.630) showed significant positive GCA effects in F_1 whereas Basmati (16.143) only showed significant positive GCA effect in F_2 indicating that Basmati is a very good combiner followed by DW 8 for days

Table 14: Estimates of GCA effects of 16 characters in F_1 generation of 7 x 7 diallel

Entry	Days to 50% FLO.	Plant height (cm)	EST/ plant height (No.)	Panicle length (cm)	Panicle sterility (%)	100 grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Milling recovery (%)	Volume expansion (No.)	Water uptake (ml)	Kernel elongation of brown rice (%)
Basmati-370	15.652	28.267	-7.686	0.660	11.906	-0.112	-11.934	-0.033	-0.108	-0.111	-1.035	-0.283	-10.681	0.035
OW B	6.630	28.967	4.192	2.305	20.899	0.342	23.455	0.289	0.181	0.678	-0.291	-0.138	-30.348	-0.091
IET 1444	-6.148	-12.078	-0.092	-1.350	-6.412	-0.208	-2.075	-0.322	-0.075	-0.378	-0.265	0.841	-21.459	0.006
Teilahamsa	-8.704	-5.467	1.270	-0.251	-4.245	-0.103	-1.560	-0.033	-0.174	0.989	-1.535	0.179	22.837	-0.027
Prabhut	-0.741	-11.689	0.648	-0.284	-2.234	0.153	1.673	-0.156	0.114	-0.533	0.153	0.006	47.874	0.102
TW 1	-4.703	-16.522	3.170	-0.995	-17.201	-0.025	-3.816	-0.300	0.148	-0.600	2.187	-0.060	-19.185	0.057
BPT 1235	-2.185	-9.478	-1.686	-0.084	-2.712	-0.047	-5.742	0.422	-0.086	-0.044	-0.213	0.212	10.962	-0.083

** Significant at 1% level

Table 15: Estimates of GCA effects of 16 characters in F_2 generation of 7 x 7 diallel

Entry	Days to 50% Flo.	Plant height (cm)	EBT/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100- grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling reco- very (%)	Volume expan- sion (No.)	Water up- take (ml)	Kernel elon- gation (No.)	Protein content of brown rice (%)
Basmati-370	16.143 ^{**}	25.167 ^{**}	-5.546 ^{**}	0.371	6.582 ^{**}	1.503	-0.067	-10.690	-0.227	-0.102	0.227 ^{**}	-1.017	-0.208	-10.452	0.396 ^{**}	-0.396
DM 8	4.976	26.624	2.431 ^{**}	2.060 ^{**}	19.982 ^{**}	0.114	0.250 ^{**}	20.142 ^{**}	0.227 ^{**}	0.165 ^{**}	-0.106	-0.606	-0.102	-14.619	-0.083	-0.290
1ET 1444	-16.690	-12.198	0.098	-1.940	-6.459	-1.013 ^{**}	-0.189	-2.713	-0.295	-0.074	-0.084	-0.429	0.059	-2.952	-0.045	0.360 ^{**}
Tellahansa	-1.468	-7.143	1.054 ^{**}	-0.195	-5.237	-0.863 ^{**}	-0.061	-1.890	0.016	-0.163	-0.171	0.166	0.192	18.714	-0.049	-0.146
Prabhat	6.196	-10.432	0.421	-0.084	-1.548	-1.080 ^{**}	0.144 ^{**}	1.771 ^{**}	-0.223	0.098 ^{**}	-0.195	0.071	-0.136	1.048	0.073 ^{**}	-0.296
TN 1	0.865	-15.032	2.543 ^{**}	-0.173	-10.525	-1.106 ^{**}	-0.022	-2.535	-0.262	0.126 ^{**}	-0.251	1.427 ^{**}	-0.019	0.659	0.400	0.860 ^{**}
BPT 1236	-10.023	-6.987	-1.002	-0.040	-2.737	2.446	-0.056	-4.085	0.310	-0.052	0.238 ^{**}	0.388	0.214	7.603	-0.066	-0.090

** Significant at 1% level

to 50% flowering. The remaining parents viz., IET 1444, Tellahamsa, Prabhat, TN 1 and BPT 1235 are poor combiners since they exhibited non-significant GCA effects both in F_1 and F_2 progenies.

2. Plant height:

In F_1 the GCA effects varied from -18.522 (T N 1) to 28.967 (DW 8) whereas in F_2 it ranged from -15.032 (TN 1) to 26.624 (DW 8). The two parents viz., DW 8 (28.967 in F_1 and 26.624 in F_2) and Basmati (28.267 in F_1 and 25.167 in F_2) exhibited significant positive GCA effects both in F_1 and F_2 material indicating that Basmati and DW 8 are very good combiners for plant height. The remaining parents are poor combiners with negative GCA effects both in F_1 and F_2 study.

3. Effective tillers/plant:

The GCA effects ranged from -7.686 (Basmati) to 4.192 (DW 8) in F_1 whereas in F_2 it varied from -5.546 (Basmati) to 2.543 (TN 1). The three parents viz., DW 8 (4.192) in F_1 and 2.432 in F_2 , Tellahamsa (1.269) in F_1 and 1.054 in F_2 , and T.N₁ (3.169) in F_1 and 2.543 in F_2 showed significant positive GCA effect in the study indicating that DW 8, T.N₁ and T.Hamsa are very good combiners for the trait. The remaining parents are proved to be poor combiners with non-significant GCA effects both in F_1 and F_2 study.

4. Panicle length:

In F_1 the GCA effects varied from -1.350 (IET 1444) to 2.305 (DW 8) while in F_2 it ranged from -1.940 (IET 1444) to 2.060 (DW 8). The two parents viz., Basmati (0.660) and DW 8 (2.305) exhibited significant positive GCA effect in F_1 study whereas only DW 8 (2.060) showed significant positive GCA effect in F_2 study indicating that DW 8 is a very good combiner for the trait followed by Basmati. The remaining parents are poor combiners having shown negative GCA effects in F_1 and F_2 .

5. Grains per panicle:

The GCA effects varied from -17.201 (TN 1) to 20.899 (DW 8) in F_1 whereas in F_2 it ranged from -10.525 (TN 1) to 19.952 (DW 8). The two parents viz., Basmati (11.906) in F_1 & 6.55 in F_2 and DW 8 (20.899 in F_1 and 19.952 in F_2) showed significant positive GCA effects both in F_1 and F_2 study indicating that the two parents are very good combiners for grains per panicle. The remaining parents are poor combiners with negative GCA values both in F_1 and F_2 .

6. Spikelet sterility:

In F_1 the GCA effects ranged from -3.933 (IET 1444) to 6.178 (Basmati) whereas in F_2 it varied from -1.108 (TN 1) to 2.448 (BPT 1235). The parents viz., IET 1444 (-3.93

in F_1 and -1.013 in F_2), T. Hamsa (-3.11 in F_1 and -0.863 in F_2), Prabhat (-1.080 in F_2) and TN 1 (-1.108 in F_2) showed significant negative GCA effects indicating their poor combining ability which is desirable for the trait. The remaining parents are not desirable since they are good combiners for this trait.

7. **100-grain weight:**

The GCA effects varied from -0.208 (IET 1444) to 0.342 (DW 8) in F_1 whereas in F_2 it ranged from -0.189 (IET 1444) to 0.250 (DW 8). The two parents viz., DW 8 (0.342 in F_1 and 0.259 in F_2) and Prabhat (0.152 in F_1 and 0.144 in F_2) exhibited significant positive GCA effects indicating that these two parents are good combiners for this trait. The remaining parents are poor combiners as they exhibited non-significant negative GCA effects in F_1 and F_2 generations.

8. **Grain yield per plant:**

The GCA effects varied from -11.934 (Basmati) to 23.455 (DW 8) in F_1 while in F_2 it ranged from -10.690 (Basmati) to 20.142 (DW 8). The two parents viz., DW 8 (23.455 in F_1 and 20.143 in F_2) and Prabhat (1.673 in F_1 and 1.771 in F_2) showed positive significant GCA effects indicating that they are very good combiners for this trait.

The other parents are poor combiners showing significant negative GCA values both in F_1 and F_2 for this character.

9. **Length of grain:**

In F_1 the GCA effects ranged from -0.322 (IET 1444) to 0.422 (BPT 1235) whereas in F_2 it varied from 0.295 (IET 1444) to 0.310 (TN 1). The parents viz., DW 8 (0.289 in F_1 and 0.227 in F_2), BPT 1235 (0.422 in F_1 and TN 1 0.310 in F_2) and Tellahamsa (0.016) in F_2 exhibited positive significant GCA effects indicating that these parents are very good combiners for this trait. Others are poor combiners with negative GCA effects.

10. **Breadth of grain:**

The GCA effects varied from -0.174 (Tellahamsa) to 0.181 (DW 8) in F_1 while in F_2 it ranged from -0.163 (Tellahamsa) to 0.165 (DW 8). The parents viz., DW 8, TN 1, and Prabhat (0.181, 0.148 and 0.114) in F_1 and (0.165, 0.126 and 0.098) in F_2 study ^{respectively} showed significant positive GCA effects, indicating that the three parents are good combiners for this trait. The remaining parents recorded negative GCA effects pronouncing poor combining ability for breadth of grain.

11. L/B Ratio:

The GCA effects ranged from 0.600 (TN 1) to 0.989 (Tellaahamsa) in F_1 whereas in F_2 it varied from -0.251 (TN 1) to 0.238 (BPT 1235). The GCA effects for this trait were negative for all the parents in F_1 , the exception being DW 8 (0.677) and Tellaahamsa (0.988) with positive GCA effects. In F_2 study Basmati (0.227) and BPT 1235 (0.238) showed significant positive GCA effects indicating that these two parents are good combiners for L/B ratio. The remaining parents with negative GCA effects are poor combiners.

12. ^UHalling recovery:

In F_1 the GCA effects varied from -1.535 (Tellaahamsa) to 2.187 (TN 1) whereas in F_2 it ranged from -1.017 (Basmati) to 1.427 (TN 1). The parents viz., TN 1, (2.187 in F_1 and 1.427 in F_2) only showed significant positive GCA effects both in F_1 and F_2 study whereas Prabhat showed only significant positive GCA effects (0.153) in F_1 indicating that the parents TN 1 followed by Prabhat are very good combiners for this trait. The remaining parents with negative GCA values in F_1 and non-significant GCA values in F_2 are considered as poor combiners for this trait.

13. Volume expansaion:

The GCA effects ranged from -0.283 (Basmati) to 0.841 (IET 1444) in F_1 while in F_2 it ^{var}ried from -0.208 (Basmati) to 0.214 (BPT 1235). The parents viz., T. Hamsa (0.178 in F_1 and 0.192 in F_2) and BPT 1235 (0.212 in F_1 and 0.214 in F_2) showed significant positive GCA effects indicating that these two parents are good combiners for this trait whereas the remaining parents with negative ~~and indecisive~~ GCA effects both in F_1 and F_2 are considered as poor combiners for this character.

14. Water uptake:

In F_1 the GCA effects varied from -30.348 (DW 8) to 47.874 (Prabhat) while in F_2 it ranged from -14.619 (DW 8) to 18.714 (Tellahamsa). The two parents viz., Tellahamsa (22.837 in F_1 and 18.714 in F_2), BPT 1235 (10.963 in F_1 and 7.603 in F_2) and one parent, Prabhat with 47.874 in F_1 only showed highly significant GCA effects indicating that the two former parents as good combiners followed by Prabhat for water uptake. It is interesting to note that Prabhat which showed highly significant GCA effects in F_1 has shown low GCA effects value of 1.048 in F_2 generation. This may be due to complementary gene action. The remaining parents are poor combiners with negative GCA values in F_1 and F_2 generations.

15. **Kernel elongation:**

The GCA effects ranged from -0.091 (DW 8) to 0.102 (Prabhat) in F_1 whereas in F_2 it varied from -0.083 (DW 8) to 0.396 (Basmati). The parent, Prabhat, showed significant positive GCA values of 0.102 in F_1 and 0.073 in F_2 whereas the parents, Basmati (0.035 in F_1 and 0.396 in F_2) and TN 1 (0.057 in F_1) showed significant values indicating that Prabhat is a very good combiner followed by Basmati and TN 1. The remaining parents are poor combiners with non-significant GCA values in F_1 and F_2 generations.

16. **Protein content of brown rice:**

In F_1 the GCA effects varied from -0.830 (DW 8) to 2.114 (TN 1) in F_1 whereas in F_2 it ranged from -0.396 (Basmati) to 0.860 (TN 1). The two parents viz., IET 1444 (0.325) in F_1 and 0.360 in (F_2) and TN 1 (2.114) in F_1 and 0.860 in (F_2) exhibited significant positive GCA effects both in F_1 and F_2 generations indicating that the two parents are good combiners for this trait. The remaining parents are poor combiners with negative GCA values both in F_1 and F_2 generations.

Specific combining ability (SCA) effects:

The estimates of SCA effects for 21 crosses in respect of sixteen characters both in F_1 and F_2 study are presented in Tables 16 and 17.

1. Days to 50% flowering:

In F_1 study, the SCA effects varied from -4.33 in cross (Basmati/BPT 1235) to 4.186 in cross 5 (Basmati/TN 1) whereas in F_2 study, it ranged from -92.25 in cross 15 (IET 1444/BPT 1235) to 25.028 in cross 18 (Tellahamsa/BPT 1235). In F_1 generation, three cross combinations viz., (Basmati/D.W8), (Basmati/TN 1) and (DW 8/T.H.) showed highly significant positive SCA effects with highest value of 4.196 in cross 5 (Basmati/TN 1) whereas none of the cross combinations were good in F_2 . The results indicate that parents, Basmati and DW 8 have given good cross combinations.

2. Plant height:

The SCA effects varied from -38.959 (Basmati/DW 8) to 19.630 (DW 8/TN 1) in F_1 study whereas in F_2 it ranged from -39.215 (Basmati/DW 8) to 15.985 (DW 8/TN 1). In F_1 study ten cross combinations viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} and C_{16} showed highly significant positive SCA effects with highest value of 19.630 in cross 10 (DW 8/TN 1)

Table 16: Estimates of SCA effects for 16 characters in respect of 21 F_1 crosses of 7 x 7 diallel

Cross	Days to 50% Flo. (No.)	Plant height (cm)	EST/Plant (No.)	Panicle length (cm)	Grains/panicle (No.)	Spikelet sterility (%)	100 grain weight (g)	Grain yield/plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling reco-very (%)	Volume expansion (No.)	Water uptake (ml)	Kernel elongation (No.)	Protein content of brown rice (%)
C ₁	2.852	-38.958	-5.853	-1.647	8.644	-1.814	-0.558	-28.130	-1.120	-0.094	-1.267	-1.951	-0.122	41.513	0.063	0.172
C ₂	-1.370	18.186	-2.753	2.308	37.655	-6.269	0.342	6.567	0.014	0.361	-0.111	3.823	-0.344	27.624	-0.134	-0.117
C ₃	-0.815	6.775	-0.531	2.008	36.888	2.008	0.287	15.252	-0.542	0.261	-1.378	-1.106	0.361	-36.672	-0.071	0.217
C ₄	0.222	12.897	-0.608	0.842	46.677	9.597	-0.169	13.119	-0.053	0.072	0.144	3.005	-0.767	-111.709	-0.130	0.172
C ₅	4.185	-10.970	-2.531	-1.448	-5.156	5.419	0.309	-5.693	0.092	0.139	0.111	-0.429	0.300	-39.650	1.444	0.294
C ₆	-4.333	18.387	0.625	0.347	9.555	2.420	-0.269	4.233	-0.231	-0.128	0.256	-3.929	-0.472	45.202	-1.556	0.183
C ₇	0.852	10.486	8.369	-0.037	-8.838	1.797	0.138	21.178	0.158	-0.028	-0.700	1.979	1.011	-49.709	-0.008	-0.783
C ₈	2.407	9.075	6.392	-0.936	1.995	-0.425	0.133	17.862	0.203	-0.128	7.933	-0.251	-1.083	-47.006	-0.004	-0.150
C ₉	-1.556	8.797	4.614	1.497	17.084	-2.636	0.178	36.030	0.792	0.083	-0.544	0.960	0.089	-7.043	-0.003	0.006
C ₁₀	-3.593	19.631	6.992	2.308	-0.499	3.086	0.255	31.519	-0.064	0.149	-0.878	-1.673	0.156	-4.983	-0.059	0.728
C ₁₁	-1.111	7.286	6.947	-0.403	5.862	-2.314	0.277	18.444	0.414	-0.017	-0.633	0.727	-1.117	-35.131	0.051	0.617
C ₁₂	0.185	0.519	-0.408	2.519	13.205	-2.781	-0.117	5.393	-0.086	-0.172	-0.611	-3.077	-0.806	-70.894	-0.172	0.361
C ₁₃	1.222	-7.858	-1.786	0.853	-11.305	-0.008	0.227	-12.441	0.503	0.039	0.411	0.734	0.167	14.069	-0.101	-0.283
C ₁₄	-0.815	-2.625	-0.108	1.464	5.862	-0.749	0.105	-4.552	0.647	0.005	0.478	0.401	0.233	-18.872	-0.057	0.640
C ₁₅	0.667	2.831	-0.254	3.053	13.673	-4.869	-0.073	5.041	-0.375	-0.061	0.222	-3.500	-0.839	-59.020	-0.117	-0.072
C ₁₆	-4.222	4.131	0.836	-0.047	-10.271	-3.114	0.122	-3.556	-0.153	-0.039	-0.956	-1.995	0.772	56.439	0.032	0.050
C ₁₇	-0.259	-2.736	-0.786	-0.336	0.495	-2.391	-0.004	-1.667	-0.005	0.006	-0.889	0.471	-0.411	46.831	0.278	-0.228
C ₁₈	1.222	-7.781	-6.330	-1.047	-4.393	-3.492	0.222	-11.241	-0.069	0.139	-0.944	0.571	0.567	21.683	-0.043	-0.239
C ₁₉	0.778	-4.813	0.136	-0.203	-15.416	10.897	-0.056	-7.710	-0.119	-0.083	0.333	0.482	-0.489	7.128	0.048	1.428
C ₂₀	-0.074	-3.458	0.692	-0.714	-9.005	-3.503	0.166	-4.374	-0.042	0.149	0.078	-2.218	0.739	101.646	0.148	-0.383
C ₂₁	0.222	-4.725	-4.331	-1.603	3.362	-6.080	0.144	-4.785	0.003	0.017	0.244	1.649	0.056	-51.494	0.032	1.039

** Significant at 1% level

Table 17: Estimates of SCA effects for 16 characters in respect of 21 F₂ crosses of 7 x 7 diallel

Cross	Days to 50% Flo.	Plant height (cm)	ESP/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100-grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling reo-very (%)	Volume expan-sion (No.)	Water up-take (ml)	Kernel elong-ation (No.)	Protein content of brown rice (%)
C ₁	4.917	-39.215	-4.025	-2.326	11.667	-0.226	-4.333	-23.479	-1.074	-0.065	-0.415	-1.408	-0.136	4.875	0.025	-0.290
C ₂	9.083	9.607	-3.192	2.174	28.078	-3.249	0.256	4.627	0.249	0.324	-0.387	1.164	-0.247	-6.792	-0.203	-0.690
C ₃	1.361	7.051	-0.147	0.929	26.856	-2.349	0.228	8.704	-0.363	0.213	-0.543	-0.931	0.169	-33.458	-0.108	-0.435
C ₄	-8.806	10.340	-0.514	-0.182	30.667	0.818	-0.078	8.793	0.024	0.051	-0.226	1.164	-0.753	-55.792	-0.081	-0.285
C ₅	1.528	-12.560	-1.636	-1.093	7.144	1.446	0.239	-1.561	-0.115	0.124	-0.121	-1.192	0.281	-52.903	0.002	-0.440
C ₆	12.417	14.396	0.408	-0.226	6.856	-2.299	-0.178	4.398	-0.157	-0.049	-0.102	-3.003	-0.453	32.653	-0.042	-0.496
C ₇	10.250	8.151	4.831	-0.015	-0.322	-0.560	0.089	15.693	0.299	-0.043	0.046	0.253	0.697	17.374	-0.031	-0.796
C ₈	-4.972	5.596	4.375	-1.760	-1.544	2.290	0.161	15.471	0.137	-0.105	0.090	-0.843	-1.036	-54.292	0.014	-0.640
C ₉	2.361	3.885	2.508	1.629	7.267	1.257	0.056	31.060	0.426	-0.015	0.207	-0.497	0.192	18.375	-0.108	-0.390
C ₁₀	-7.306	15.984	4.386	2.218	1.244	1.085	0.022	20.015	0.315	-0.043	-0.087	-1.103	-0.025	-26.236	-0.075	-1.296
C ₁₁	8.583	7.940	2.931	-1.915	0.956	-3.771	0.006	16.066	-0.157	0.035	0.024	0.436	-1.008	-38.181	0.081	-0.596
C ₁₂	6.694	1.918	-0.292	0.240	9.867	0.518	-0.100	1.236	-0.140	-0.215	-0.032	-2.269	-0.697	-70.958	-0.114	-0.440
C ₁₃	21.528	-4.793	-2.658	1.129	-6.322	2.884	0.194	-10.435	0.399	0.024	0.185	0.825	-0.269	41.708	-0.086	-0.760
C ₁₄	21.861	-0.193	-0.281	1.218	5.155	1.063	0.161	-4.379	0.337	-0.004	0.190	-0.781	0.114	-42.903	-0.053	-1.696
C ₁₅	-92.250	1.763	-0.736	1.085	12.367	-0.293	-0.056	3.071	-0.285	-0.076	-0.049	-3.242	-0.669	-59.847	-0.097	-0.997
C ₁₆	6.306	-4.849	-1.114	-1.115	-2.544	0.485	0.067	-3.257	-0.113	0.013	-0.121	-1.269	0.757	50.042	0.008	-0.535
C ₁₇	11.639	-5.249	-5.236	-0.526	-1.067	1.112	0.033	-1.351	-0.174	0.015	-0.165	-1.125	-0.419	20.431	0.092	-1.190
C ₁₈	25.028	-5.793	-4.692	0.340	1.144	-1.693	0.267	-8.901	-0.046	0.162	-0.254	0.164	0.247	3.486	-0.054	-0.590
C ₁₉	6.472	5.540	-1.603	0.362	-2.256	2.079	-0.022	-6.762	-0.035	-0.076	0.051	-1.281	-0.292	28.097	-0.031	-1.040
C ₂₀	14.861	-0.004	0.942	-0.771	-7.544	-0.226	0.061	-6.862	-0.107	0.101	-0.187	-1.992	0.475	-13.847	0.025	-0.590
C ₂₁	15.194	-0.404	-4.181	-0.682	3.933	-0.199	0.178	-2.657	0.032	0.024	0.018	-0.347	-0.042	46.542	0.058	-0.746

** Significant at 1% level

D 4549 155
4 295

whereas in F_2 study, four cross combinations viz., C_2 , C_4 , C_6 and C_{10} showed positive significant SCA effects with highest value of 15.985 in cross 10 (DW 8/TN 1). The results indicate that parent, DW 8 has given good cross combination. It is observed that the number of superior cross combinations decreased from F_1 to F_2 generation.

3. Effective tillers per plant:

In F_1 study, the SCA effects varied from -6.330 (Tellahamsa/BPT 1235) to 8.370 (DW 8/IET.1444) whereas in F_2 study the effects ranged from -5.236 (Tellahamsa/TN 1) to 4.830 (DW 8/IET 1444). In F_1 study, five cross combinations viz., C_7 , C_8 , C_9 , C_{10} and C_{11} exhibited significant positive SCA effects with maximum value of 8.370 (DW 8/IET 1444) whereas in F_2 study, four cross combinations viz., C_7 , C_8 , C_{10} and C_{11} showed positive significant SCA effects with highest value of 4.830 (DW 8/IET 1444). The results indicate that parent, DW 8 has given good cross combinations which decreased from F_1 to F_2 .

4. Panicle length:

The SCA effects varied from -1.647 (Basmati/DW 8) to 3.052 (IET 1444/BPT 1235) in F_1 study whereas it ranged from -2.326 (Basmati/DW 8) to 2.218 (DW 8/TN 1) in F_2 study. In F_1 study, five cross combinations viz., C_2 , C_3 , C_{10} , C_{12} and

C_{15} showed significant positive SCA effects with highest value of 3.052 (IET 1444/BPT 1235) while in F_2 study, all cross combinations showed non-significant positive and negative SCA effects. The results indicated that the parents Basmati, DW 8 and IET 1444 have given good cross combinations in F_1 and none in F_2 .

5. Grains per panicle:

In F_1 study the SCA effects varied from -15.415 (Prabhat/TN 1) to 46.677 (Basmati/Prabhat) whereas in F_2 study, it ranged from -7.544 (Prabhat/BPT 1235) to 30.667 (Basmati/Prabhat). In F_1 study, seven cross combinations viz., C_1 , C_2 , C_3 , C_4 , C_9 , C_{12} , and C_{15} showed highly significant positive SCA effects with highest value of 46.677 (Basmati/Prabhat) whereas in F_2 study, three cross combinations viz., C_2 , C_3 and C_4 showed significant positive SCA effects with highest value of 30.667 (Basmati/Prabhat). The results indicate that parents Basmati followed by DW 8 and IET 1444 in F_1 and only Basmati in F_2 has given good cross combinations and number of superior crosses decreased from F_1 to F_2 .

6. Spikelet sterility:

The SCA effects varied from -6.269 (Basmati/IET 1444) to 10.897 (Prabhat/TN 1) in F_1 generation while in

F_2 , it ranged from -3.771 (DW 8/BPT 1235) to 2.885 (IET 1444/Prabhat). In F_1 study eleven crosses viz. C_1 , C_2 , C_9 , C_{11} , C_{12} , C_{15} , C_{16} , C_{17} , C_{18} , C_{19} and C_{21} showed highly significant negative SCA effects with maximum negative SCA values of -6.269 (Basmati/IET 1444) whereas in F_2 study, two crosses viz., C_2 and C_{11} showed significant negative SCA values with highest negative SCA value of -3.771 (DW 8/BPT 1235). The results indicate that the number of superior crosses decreased from F_1 to F_2 and parents Basmati, DW 8, IET 1444, Tellahamsa, Prabhat and TN 1 are good in F_1 whereas Basmati and DW 8 are found to be good when both F_1 and F_2 are considered in giving superior crosses.

7. 100-grain weight:

The SCA effects varied from -0.558 (Basmati/DW 8) to 0.342 (Basmati/IET 1444) in F_1 and -0.433 (Basmati/DW 8) to 0.267 (T. HAMSA/BPT 1235) in F_2 . Seven crosses viz., C_2 , C_3 , C_5 , C_9 , C_{11} , C_{13} and C_{18} in F_1 and three crosses viz., C_2 , C_5 and C_{18} in F_2 showed highly significant positive SCA effects, indicating that Basmati, DW 8, IET 1444 and Tellahamsa parents in F_1 and Basmati and Tellahamsa parents in F_2 have given good crosses. The number of superior crosses decreased from F_1 and F_2 .

8. Grain yield per plant:

In F_1 study, the SCA effects varied from -28.130 (Basmati/DW 8) to 36.030 (DW 8/Prabhat) whereas in F_2 study it ranged from -23.479 (Basmati/DW 8) to 31.060 (DW 8/Prabhat). Eleven crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} , C_{12} and C_{15} in F_1 and nine crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} and C_{11} in F_2 showed highly significant positive SCA effects indicating that the parents Basmati and DW 8 have given superior cross combinations both in F_1 and F_2 study. There was slight reduction in number of superior crosses from F_1 and F_2 .

9. Length of grain:

The SCA effects varied from -1.197 (Basmati/DW 8) to 0.792 (DW 8/Prabhat) in F_1 whereas in F_2 , it varied from -1.074 (Basmati/DW 8) to 0.426 (DW 8/Prabhat). In F_1 , six crosses viz., C_7 , C_8 , C_9 , C_{11} , C_{13} and C_{14} and in F_2 three crosses viz., C_9 , C_{13} and C_{14} showed highly significant positive SCA effects indicating that the parents DW 8 and IET 1444 have given good crosses both in F_1 and F_2 with decreasing number of superior crosses from F_1 to F_2 .

10. Breadth of grain:

In F_1 study, the SCA effects varied from -0.172 (IET 1444/Tellahamsa) to 0.361 (Basmati/IET 1444) while in

F_2 , it ranged from -0.215 (IET 1444/Tellahamsa) to 0.324 (Basmati/IET 1444) while in F_1 , it ranged from -0.215 (IET 1444/Tellahamsa) to 0.324 (Basmati/IET 1444). Six crosses viz., C_2 , C_3 , C_5 , C_{10} , C_{18} and C_{20} in F_2 and only one cross viz., C_2 in F_1 were good with significant positive SCA effects indicating parents Basmati, DW 8 and Tellahamsa in F_2 and only Basmati in F_1 have given good crosses with the number of superior crosses decreased from F_1 to F_2 .

11. L/B Ratio

In F_1 study, the SCA effects varied from -1.378 (Basmati/Tellahamsa) to 7.933 (DW 8/Tellahamsa) Whereas in F_2 , it ranged from -0.543 (Basmati/Tellahamsa) to 0.207 (DW 8/Prabhat). In F_1 , only one cross (DW 8/Tellahamsa) showed significant positive SCA effect whereas in F_2 none of the crosses showed SCA effect indicating that DW 8 has given good cross combinations.

12. HULLING RECOVERY :

The SCA effects varied from -3.929 (Basmati/BPT 1235) to 3.823 (Basmati/IET 1444) in F_1 and -3.204 (IET 1444/BPT 1235) to 1.164 (Basmati/IET 1444) in F_2 . In F_2 seven crosses viz., C_2 , C_4 , C_7 , C_9 , C_{11} , C_{13} and C_{21} showed significant positive SCA values while it was nil in F_1 . The

parents Basmati, DW 8, IET 1444 and TN 1 have given good crosses in F_1 .

13. Volume expansion:

In F_1 , the SCA effects ranged from -1.116 (DW 8/BPT1235) to 1.011 (DW 8/IET 1444) whereas in F_2 , it varied from -1.036 (DW 8/Tellahamsa) to 0.797 (Tellahamsa/Prabhat). In F_1 six crosses viz., C_3 , C_7 , C_{10} , C_{11} , C_{18} and C_{20} and in F_2 three crosses viz., C_7 , C_{16} and C_{20} showed highly significant positive SCA effects indicating that parents DW 8, Tellahamsa and Prabhat have given good crosses both in F_1 and F_2 whereas parent, Basmati gave good cross in F_1 study.

14. Water uptake:

The SCA effects varied from -111.709 (Basmati/Prabhat) to 101.645 (Prabhat/BPT 1235) in F_1 whereas in F_2 it ranged from -70.958 (IET 1444/Tellahamsa) to 50.417 (Tellahamsa/Prabhat). Only one cross viz., C_{20} in F_1 and five crosses viz., C_6 , C_{13} , C_{16} , C_{19} , and C_{21} in F_2 showed highly significant positive SCA effects. The results indicate that parent, Prabhat in F_1 and F_2 study and parents, Basmati, IET 1444, Tellahamsa and TN 1 in F_2 only have given good crosses showing increase in number of superior crosses from F_1 to F_2 generation.

15. Kernel elongation:

In F_1 study, the SCA effects varied from -1.556 (Basmati/BPT 1235) to 1.444 (Basmati/TN 1) whereas in F_2 study, it ranged from -0.203 (Basmati/IET 1444) to 0.092 (Tellaahamsa/TN 1). In F_1 three crosses viz., C_5 , C_{17} and C_{20} showed significant positive SCA effects whereas in F_2 none of the crosses showed positive significant SCA effects indicating that the prents, Basmati, Tellaahamsa and Prabhat gave good cross combinations.

16. Protein content of brown rice:

The SCA effects varied from -0.783 (DW 8/IET 1444) to 1.428 (Prabhat/TN 1) in F_1 study whereas it ranged from -0.285 (Basmati/Prabhat) to - 1.696 (IET 1444/TN 1) in F_2 study. In F_1 study, eight crosses viz., C_3 , C_5 , C_{10} , C_{11} , C_{12} , C_{14} , C_{19} and C_{21} exhibited significant positive SCA effects whereas none of F_2 s showed significant positive SCA effects indicating that the parents, Basmati, DW 8 IET 1444, Prabhat and TN 1. have given good crosses. The number of superior crosses from eight in F_1 decreased to nil in F_2 .

D) HETEROSIS:

The magnitude of hybrid vigour (Relative Heterosis, Heterobeltiosis and Standard heterosis) exhibited by the 21 F_1 s in respect of 16 characters studied were presented in

Table 18. Prabhat was used as standard variety for calculating standard heterosis.

1. **Days to 50% flowering:**

a) **Relative Heterosis:**

Out of 21 crosses five viz., C_1 , C_5 , C_7 , C_8 and C_{13} with positive, four with nil and twelve crosses with negative heterotic effects were observed. The heterotic effects ranged from -6.011% (Tellahamsa/Prabhat) to 4.072% (Basmati/TN 1). The results indicate that the parents viz., Basmati, DW 8, and IET 1444 have given heterotic crosses.

b) **Heterobeltiosis:**

All crosses showed negative heterotic effects ranging from -19.084% (Basmati/Tellahamsa) to -2.0% (IET 1444/TN 1).

c) **Standard heterosis:**

Out of 21 crosses, nine crosses viz. C_1 , C_2 , C_3 , C_4 , C_5 , C_6 , C_7 , C_9 and C_{11} with positive, one with nil and eleven with negative heterotic effects were observed. The heterotic effects ranged from -15% (IET 1444/Tellahamsa) to 25% (Basmati/DW 8) indicating that parents viz., Basmati and DW 8 have given heterotic crosses.

Table 18: Heterosis percent over Mid Parent (d1), over the better parent (Heterobeltiosis) (d11) and over standard variety (d111) for 16 characters in respect of 21 F₁s of 7 x 7 diallel

F ₁	Days to 50% Flo. (No.)			Plant height (cm)			Effective tillers/ plant (No.)			Panicle length (cm)		
	d1	d11	d111	d1	d11	d111	d1	d11	d111	d1	d11	d111
Hybrid	1			2			3			4		
C ₁	2.881	- 4.580	25.0	-20.967	21.855	58.861	-15.966	-28.571	-46.524	- 3.200	-10.701	14.150
C ₂	-0.917	-17.557	8.0	21.597	-11.831	79.241	-35.252	-50.000	-51.872	28.941	6.522	15.566
C ₃	-0.935	-19.084	6.0	8.615	-14.819	73.165	-22.741	-44.395	-33.689	14.221	10.000	19.340
C ₄	-0.433	-12.214	15.0	14.107	-14.882	73.038	-33.143	-37.433	-37.433	9.050	4.783	13.680
C ₅	4.072	-12.214	15.0	- 9.363	-33.998	34.177	-29.714	-52.692	-34.225	- 3.653	- 8.261	- 0.472
C ₆	-4.386	-16.793	9.0	-19.044	-10.087	82.785	-21.771	-38.728	-43.316	3.704	3.478	12.264
C ₇	1.506	- 9.821	1.0	-17.400	-14.268	70.380	100.000	77.778	-71.123	12.796	-12.177	12.264
C ₈	2.564	-10.714	0.0	12.606	-10.955	76.962	71.901	39.910	66.845	- 0.826	-11.439	13.208
C ₉	-1.886	- 7.143	4.0	12.966	-15.095	68.734	76.147	54.011	54.011	9.317	- 2.583	24.528
C ₁₀	-2.970	-12.500	-2.0	18.874	-12.548	73.737	68.500	29.615	80.214	10.879	- 2.214	25.050
C ₁₁	-1.435	- 8.036	3.0	12.134	-14.649	69.620	84.026	66.474	54.011	- 1.200	- 8.856	16.509
C ₁₂	0.000	- 2.299	-15.0	10.269	- 1.205	14.177	0.744	- 8.969	8.856	30.769	11.737	12.264
C ₁₃	0.535	- 6.000	-6.0	- 0.066	- 4.304	- 4.304	- 0.272	- 2.139	- 2.139	21.763	4.245	4.245
C ₁₄	-0.565	- 2.000	-12.0	2.351	0.955	- 6.329	2.270	-13.462	20.321	22.563	5.769	3.775
C ₁₅	0.000	- 5.155	-8.0	14.712	7.927	12.025	- 0.850	- 2.778	- 6.417	28.947	- 6.987	15.566
C ₁₆	-6.011	-14.000	-14.0	10.628	3.176	19.241	- 0.850	- 0.897	18.180	4.941	4.695	5.189
C ₁₇	-0.578	- 4.444	-14.0	- 2.188	-11.829	1.899	- 4.762	-11.538	22.995	1.188	0.000	0.472
C ₁₈	0.000	- 7.216	-10.0	- 2.481	- 7.448	6.962	-36.360	-43.498	-32.620	- 2.273	- 6.114	1.415
C ₁₉	0.000	- 5.000	-5.0	- 5.187	- 8.608	- 8.608	4.251	-10.385	24.599	1.905	- 6.556	0.943
C ₂₀	-2.538	- 4.000	-4.0	2.609	- 0.732	4.651	5.550	1.604	1.604	- 0.229	- 4.803	2.831
C ₂₁	-0.535	- 4.124	-7.0	- 4.057	- 9.146	- 5.696	-23.791	-36.538	-11.765	- 7.551	-11.790	- 4.717

F_1	Grains/Panicle (No.)			Spikelet Sterility (%)			100-grain weight (g)			Grain Yield/Plant (g)		
Hybrid	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
	5			6			7			8		
C_1	66.074	10.766	82.282	1.900	15.865	62.83	-16.36	-25.81	-14.814	-12.150	-44.543	-33.330
C_2	213.232	193.095	84.834	-29.620	-14.130	67.56	-23.26	9.05	-1.851	53.005	35.266	-0.709
C_3	179.461	137.143	86.936	10.170	33.155	68.24	20.00	11.11	0.000	146.357	74.646	31.915
C_4	164.147	104.655	104.154	73.849	142.567	142.56	-1.96	-7.40	-7.407	105.914	35.816	35.815
C_5	58.314	35.742	4.354	51.920	109.270	113.51	21.74	15.23	3.704	-15.662	-42.387	-50.355
C_6	94.391	51.846	48.198	2.846	9.056	95.27	-6.38	-9.46	-18.518	50.685	8.374	-21.986
C_7	12.929	21.898	28.528	-10.200	-4.347	18.91	16.00	-6.45	7.407	185.714	130.088	176.596
C_8	21.653	-10.036	48.048	-17.974	-13.368	9.45	15.38	-3.23	11.111	172.464	121.829	166.660
C_9	31.380	5.566	73.723	-2.247	17.567	17.56	13.79	6.45	22.222	210.610	184.950	242.550
C_{10}	3.483	-24.087	24.924	28.133	-52.317	55.40	20.75	3.23	18.518	197.595	155.457	207.092
C_{11}	19.129	-5.109	56.156	-29.108	-13.942	20.94	18.52	3.23	18.518	174.330	111.869	153.900
C_{12}	74.603	57.143	23.873	-46.090	-45.652	-32.43	10.00	4.76	3.704	77.143	74.648	31.950
C_{13}	10.497	-9.909	-9.909	-2.409	9.459	9.45	21.74	3.70	3.704	-7.755	-19.858	-19.858
C_{14}	33.476	21.484	-6.606	-8.656	1.324	3.37	21.95	13.64	-7.407	11.120	2.880	-11.348
C_{15}	57.944	30.000	26.876	-52.182	-37.500	-22.29	9.52	0.00	-14.814	59.024	57.488	15.603
C_{16}	6.129	-5.105	-5.105	-17.014	-6.080	-6.08	-40.00	3.70	3.700	29.032	13.475	13.475
C_{17}	-5.497	-6.667	-26.426	-14.201	-3.970	-2.02	16.28	13.64	-7.407	24.561	16.872	0.709
C_{18}	16.766	5.538	3.003	-43.388	-26.730	-7.43	22.73	17.39	0.000	-18.750	-20.651	-40.070
C_{19}	-23.429	-32.282	-32.282	108.695	110.810	110.81	10.20	0.00	0.000	-3.042	-9.557	-9.574
C_{20}	0.304	-0.901	-0.901	-20.898	15.540	15.54	16.00	7.41	7.407	11.110	-4.255	-4.255
C_{21}	8.935	-2.462	-4.800	-35.714	-4.630	-2.70	20.00	17.39	0.000	-5.380	-13.168	-25.177

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Hybrid	Length of grain (mm)			Breadth of grain (mm)			L/B Ratio (No.)			Hulling Recovery (%)		
	d1	d11	d111	d1	d11	d111	d1	d11	d111	d1	d11	d111
	9			10			11			12		
C ₁	-22.53	-25.676	- 1.785	2.128	-14.286	- 4.0	-26.984	-41.023	- 4.545	- 2.801	- 3.618	- 3.990
C ₂	- 0.78	-15.270	11.964	26.829	18.182	4.0	-23.809	-38.402	9.090	4.892	4.145	3.475
C ₃	-16.31	-20.270	5.357	23.077	20.000	- 4.0	-31.507	-35.897	13.630	- 3.342	- 5.409	- 3.218
C ₄	- 4.62	-16.216	10.714	27.273	0.000	0.0	-18.033	-35.897	13.630	4.031	2.960	2.960
C ₅	- 3.87	-16.216	10.714	15.556	0.000	4.0	-20.000	-38.462	9.090	- 0.443	- 3.912	1.158
C ₆	-10.20	-10.811	17.857	2.449	- 4.545	-16.0	-13.889	-20.513	40.900	- 7.329	-10.028	- 6.435
C ₇	7.44	- 7.794	16.071	0.000	-10.714	0.0	8.333	8.333	4.000	2.587	2.455	2.059
C ₈	2.22	1.471	23.214	- 4.167	-17.857	- 8.0	3.448	-11.765	36.360	- 2.103	- 3.396	- 1.158
C ₉	17.74	7.353	30.357	5.660	0.000	0.0	13.043	8.333	4.000	1.483	1.287	1.287
C ₁₀	2.44	- 7.353	12.500	7.407	3.571	16.0	- 2.220	- 8.333	0.000	- 1.884	- 4.523	0.515
C ₁₁	6.38	2.739	33.926	0.000	-10.714	0.0	5.263	- 9.091	36.360	- 1.264	- 3.342	0.515
C ₁₂	0.00	-10.448	7.143	- 2.439	- 9.091	-20.0	3.448	-11.765	36.360	- 5.552	- 6.918	- 4.762
C ₁₃	17.43	14.286	14.286	6.383	0.000	0.0	8.697	4.167	13.630	1.356	1.029	1.096
C ₁₄	4.07	16.364	14.286	4.167	- 3.846	0.0	11.110	4.167	13.630	0.881	- 1.956	3.218
C ₁₅	-13.48	-16.438	8.929	0.000	13.636	-12.0	19.149	-15.152	27.270	- 6.456	- 8.539	- 4.891
C ₁₆	1.66	- 8.955	8.929	6.666	- 4.000	- 4.0	-10.714	-26.471	13.630	- 3.941	- 5.031	- 2.831
C ₁₇	12.96	- 8.955	8.929	4.348	- 7.692	- 4.0	- 9.091	-26.471	13.630	- 0.806	- 2.200	2.960
C ₁₈	9.52	- 5.479	23.214	9.524	4.546	- 8.0	-10.448	-11.765	36.360	- 3.057	- 3.887	0.000
C ₁₉	4.50	3.571	3.571	1.961	0.000	4.0	2.326	0.000	0.000	1.191	- 1.345	3.861
C ₂₀	2.33	- 9.589	17.857	10.638	4.000	4.0	- 9.091	-24.242	13.630	- 4.606	- 6.436	- 2.702
C ₂₁	1.56	-10.959	16.071	4.167	- 3.846	0.00	- 3.704	-21.212	4.000	0.246	- 0.367	- 4.891

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F ₁	Volume expansion (No.)			Water uptake (ml)			Kernal elongation (No.)			Protein content of brown rice		
Hybrid	d1	d11	d111	d1	d11	d111	d1	d11	d111	d1	d11	d111
	13			14			15			16		
C ₁	-20.639	-24.240	-10.714	- 0.730	- 4.225	18.055	0.000	-11.764	-11.765	5.263	0.917	2.804
C ₂	-23.076	-28.571	-10.714	- 8.219	-10.660	16.319	-20.000	-22.220	-17.647	0.437	-10.883	7.477
C ₃	-14.285	-10.810	-17.857	-16.556	-21.250	9.375	- 9.677	-17.647	-17.647	4.265	- 0.900	2.804
C ₄	-31.034	-33.330	-28.571	-17.573	-25.352	- 7.986	-11.765	-11.764	-11.765	5.280	2.804	2.804
C ₅	0.000	0.000	7.143	-21.739	-23.944	- 6.250	0.000	- 5.882	- 5.882	-12.295	-4.861	-28.037
C ₆	-28.571	-37.500	-10.714	9.220	8.451	33.681	- 6.667	-17.647	-17.647	6.604	0.893	5.607
C ₇	17.647	14.286	42.857	- 3.546	- 9.333	18.055	- 9.677	-22.220	-17.647	- 2.609	-13.178	4.673
C ₈	-42.859	-45.946	-28.571	-21.918	-28.750	- 1.042	- 3.704	0.000	-17.647	0.000	- 0.900	2.804
C ₉	- 1.639	- 9.090	7.143	13.269	6.060	21.528	0.000	-11.764	-11.765	3.704	0.917	4.673
C ₁₀	- 4.761	- 9.090	7.143	-16.788	-14.925	- 1.042	0.000	- 6.660	-17.647	14.625	0.690	35.510
C ₁₁	-45.205	-50.000	-28.857	-16.176	-18.571	- 1.045	7.692	7.692	-17.647	-10.000	8.036	13.084
C ₁₂	-30.550	-32.432	-10.714	-30.323	-32.500	- 6.250	-18.750	-27.770	-23.529	2.500	- 4.651	14.953
C ₁₃	4.761	- 5.714	17.857	14.286	1.330	31.944	-14.286	-16.660	-11.765	- 0.847	- 9.362	9.346
C ₁₄	1.538	- 5.714	17.857	-21.127	-25.330	- 2.777	- 9.090	-16.660	-11.767	-11.355	5.550	42.056
C ₁₅	-33.330	-37.500	-10.714	-25.517	-28.000	- 6.250	-16.129	-27.770	-23.529	1.245	- 4.651	-14.019
C ₁₆	23.076	8.108	42.857	26.890	15.000	69.722	39.226	- 5.882	- 5.882	2.489	0.900	4.673
C ₁₇	-17.910	-25.675	- 6.250	3.401	- 5.000	31.944	21.138	20.000	5.882	5.882	- 6.250	26.168
C ₁₈	3.898	0.000	42.857	5.330	- 1.250	37.153	- 3.704	- 7.143	-23.529	0.448	0.000	4.673
C ₁₉	13.793	-16.660	-10.714	20.385	17.940	30.208	6.250	0.000	0.000	21.116	5.550	42.056
C ₂₀	5.882	-10.000	28.571	6.688	- 4.286	-16.319	6.660	- 5.882	- 5.882	- 3.057	- 0.892	3.738
C ₂₁	- 7.142	-18.750	16.071	24.078	21.429	47.569	7.143	0.000	0.000	17.969	4.861	41.121

d) **Over all performances:**

None of the crosses showed heterotic effects in all three classes but three crosses viz., C_1 , C_5 and C_7 only showed positive heterotic effects both in relative heterosis (di) and standard heterosis indicating that the parents Basmati and DW 8 are good in showing heterotic effects only in relative and standard heterosis.

2. **Plant height:**

a) **Relative heterosis:**

Out of 21 crosses, 14 crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} , C_{12} , C_{14} , C_{15} , C_{16} and C_{20} showed positive heterosis, whereas seven crosses exhibited negative heterosis. The heterotic effects ranged from -20.967% (Basmati/DW 8) to 21.597% (Basmati/IET 1444) indicating that parents, Basmati, DW 8 and IET 1444 have given heterotic crosses.

b) **Heterobeltiosis:**

Out of 21 crosses 5 crosses viz. C_1 , C_{14} , C_{15} , C_{16} and C_{20} expressed positive values whereas 16 crosses exhibited negative heterosis. The heterotic effects ranged from -33.998% (Basmati/TN 1) to 21.855% (Basmati/DW 8) indicating that parents, Basmati, IET 1444, Tellahamsa and Prabhat gave good crosses.

c) Standard heterosis:

Out of 21, seventeen crosses viz., C_1 to C_{12} , C_{15} to 18 and C_{20} showed positive values whereas four crosses expressed negative heterosis. The heterotic effects ranged from -8.608% (Prabhat/TN 1) to 82.785% (Basmati/BPT 1235) indicating that parents viz., Basmati, DW 8, IET 1444, Tellahamsa and Prabhat gave good crosses.

d) General performance:

Out of 21, three crosses viz., C_{15} , C_{16} and C_{20} showed positive heterotic values in all three crosses indicating that parents IET 1444, Tellahamsa and Prabhat have given each one good cross combination.

3. Effective tillers per plant:

a) Relative Heterosis:

Out of 21 crosses, nine crosses, viz., C_7 to C_{12} , C_{14} , C_{19} and C_{20} expressed positive heterotic values. The heterotic effects ranged from -36.360 (Tellahamsa/BPT 1235) to 100% (DW 8/IET 1444). The results indicate that parents DW 8, IET 1444 and Prabhat gave heterotic combinations.

b) Heterobeltiosis:

Out of 21 crosses, six crosses viz., C_7 to C_{11} and C_{20} exhibited positive heterotic values. The heterotic

effects ranged from -52.692 (Basmati/TN 1) to 77.778 (DW 8/ IET 1444) indicating that parents viz., DW 8 and Prabhat gave five and one crosses respectively with positive values.

c) Standard heterosis:

Out of 21 crosses, eleven crosses viz., C_7 to C_{12} , C_{14} , C_{16} , C_{17} , C_{19} and C_{20} showed positive heterotic values. The heterotic effects varied from -51.872% (Basmati/ IET 1444) to 80.214% (DW 8/ TN 1). The results indicate that parents viz., DW 8, IET 1444, Tellahamsa and Prabhat gave good crosses.

d) General performance:

Six crosses viz., C_7 to C_{11} and C_{20} out of 21 exhibited positive heterotic values in all three classes indicating that parents viz., DW 8 and Prabhat resulted in good crosses.

4. Panicle length:

a) Relative heterosis:

Out of 21 crosses, 14 crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_9 , C_{10} , C_{12} to C_{17} and C_{19} showed positive values. The heterotic effects ranged from -7.551% (TN 1/BPT 1235) to 30.769% (IET 1444/Tellahamsa) indicating that parents viz.,

Basmati, DW 8, IET 1444, Tellahamsa and Prabhat gave good crosses.

b) Heterobeltiosis:

Out of 21 crosses, 9 crosses viz., C_2 , C_3 , C_4 , C_6 , C_{12} to C_{16} expressed positive values. The heterotic effects ranged from -12.177% (DW 8/IET 1444) to 11.737% (IET 1444/Tellahamsa) indicating that parents, Basmati, IET 1444 and Tellahamsa gave heterotic combinations.

c) Standard heterosis:

Nineteen crosses viz., C_1 to C_4 , C_6 to C_{20} out of 21 exhibited positive values. The heterotic effects varied from -4.717% (TN 1/BPT 1235) to 25.050% (DW 8/TN 1) indicating that all parents gave good crosses.

d) General performance:

Nine crosses viz., C_2 , C_3 , C_4 , C_6 , C_{12} to C_{16} , out of 21 expressed positive heterotic values in all three classes indicating that parents, Basmati and IET 1444 gave good crosses.

5. Grains per panicle:

a) Relative heterosis:

Out of 21 crosses, 19 crosses excepting C_{17} and C_{19} showed positive values. The heterotic effects ranged from

-23.429% (Prabhat/TN 1) to 213.232% (Basmati/IET 1444) indicating that all parents gave good crosses.

b) **Heterobeltiosis:**

Out of 21 crosses, 12 crosses viz., C_1 to C_7 , C_9 , C_{12} , C_{14} , C_{15} and C_{18} showed positive values. The heterotic effects varied from -32.282% (Prabhat/TN 1) to 193.095% (Basmati/IET 1444) indicating that the parents, Basmati, DW 8 and IET 1444 gave good cross combinations.

c) **Standard heterosis:**

Fourteen, out of 21 crosses, viz., C_1 to C_{12} , C_{15} , C_{18} exhibited positive values. The heterotic effects ranged from -32.282% (Prabhat/ TN 1) to 104.105% (Basmati/Prabhat) indicating that parents Basmati, DW 8 and IET 1444 gave good crosses.

d) **General performance:**

Eleven crosses viz., C_1 to C_7 , C_9 , C_{12} , C_{15} and C_{18} out of 21 expressed positive heterotic values in all three classes indicating that parents Basmati, DW 8 and IET 1444 gave good crosses.

6. **Spikelet sterility:**

Negative values to be preferred for this trait.

a) Relative heterosis:

Out of 21 crosses 14 crosses viz., C_2 , C_7 to C_{21} excepting C_{10} and C_{19} showed negative values. The heterotic effects varied from 108.695% (Prabhat/TN 1) to -52.182% (IET 1444/BPT 1235) indicating that all parents ~~all~~ excepting Basmati are good for this trait.

b) Heterobeltiosis:

Ten out of 21 crosses viz., C_2 , C_7 , C_8 , C_{11} , C_{12} , C_{15} to C_{18} and C_{21} expressed negative values. The heterotic effects ranged from 142.567% (Basmati/Prabhat) to -45.652% (IET 1444/Tellahamsa) indicating parents DW 8, IET 1444, Tellahamsa and TN 1 gave good crosses.

c) Standard heterosis:

Six crosses viz., C_{12} , C_{15} to C_{18} and C_{21} out of 21 exhibited negative values. The heterotic effects varied from 142.56% (Basmati/Prabhat) to -32.43% (IET 1444/Tellahamsa) indicating that parents viz., IET 1444, Tellahamsa and TN 1 gave good crosses.

d) General performances:

Six crosses viz., C_{12} , C_{15} to C_{18} and C_{21} out of 21 showed negative heterotic values in all three classes

indicating that IET 1444, Tellahamsa and TN 1 are good parents.

7. 100-grain weight:

a) Relative heterosis:

Out of 21 crosses, 18 crosses excepting C_1 , C_4 and C_6 exhibited positive values. The heterotic effects ranged from -16.36% (Basmati/ DW 8) to 40.0% (Tellahamsa/Prabhat) indicating that all parents gave good cross combinations.

b) Heterobeltiosis:

Sixteen crosses excepting C_1 , C_4 , C_6 , C_7 and C_8 out of 21 crosses showed positive values. The heterotic effects ranged from -25.81% (Basmati/DW 8) to 17.39% (TN 1/BPT 1235) indicating that all parents gave good crosses.

c) Standard heterosis:

Out of 21 crosses, 14 crosses excepting C_1 , C_2 , C_4 , C_6 , C_{14} , C_{15} and C_{17} expressed positive values. The heterotic effects ranged from -18.518% (Basmati/BPT 1235) to 22.222% (DW 8/Prabhat) indicating that all parents have given good crosses.

d) General performance:

Eight crosses viz., C_5 , C_9 , C_{10} , C_{11} , C_{12} , C_{13} , C_{16} , and C_{20} out of 21 showed positive heterotic values in all the three classes indicating Basmati, DW 8, IET 1444, Tellahamsa and Prabhat gave 1, 3, 2, 1 and 1 number of good crosses respectively.

8. Grain yield per plant:

a) Relative Heterosis:

Out of 21 crosses, 15 crosses excepting C_1 , C_5 , C_{13} , C_{18} , C_{19} and C_{21} expressed positive values. The heterotic effects varied from -18.75% (Tellahamsa/BPT 1235) to 210.610% (DW 8/Prabhat) indicating that all parents gave good crosses.

b) Heterobeltiosis:

14 crosses excepting C_1 , C_5 , C_{13} , C_{18} to C_{21} , exhibited positive values. The heterotic effects ranged from -44.543% (Basmati/ DW 8) to 184.95% (DW 8/Prabhat) indicating that parents Basmati, DW 8, IET 1444 and, Tellahamsa, gave good crosses.

c) Standard Heterosis:

Eleven crosses excepting C_1 , C_2 , C_5 , C_6 , C_{13} , C_{14} and C_{18} to C_{21} showed positive values. The heterotic effects

varied from -50.355% (Basmati/TN 1) to 242.55% (DW 8/Prabhat) indicating that Basmati, DW 8, IET 1444 Tellahamsa are good parents.

d) General performance:

Ten crosses viz., C_3 , C_4 , C_7 to C_{12} , C_{15} , C_{16} and C_{17} out of 21 showed positive heterotic values in all three classes indicating Basmati, DW 8, IET 1444 and Tellahamsa have given good crosses. DW 8/Prabhat is the best combination in all the three classes.

9. Length of the grain:

a) Relative Heterosis:

14 crosses excepting C_1 to C_6 , and C_{15} out of 21 expressed positive values. The heterotic effects ranged from -22.53% (Basmati/DW 8) to 17.74% (DW 8/Prabhat) indicating that parents DW 8, IET 1444, Tellahamsa, Prabhat and TN 1 gave good crosses.

b) Heterobeltiosis:

Six crosses viz., C_8 , C_9 , C_{11} , C_{13} , C_{14} and C_{19} out of 21 exhibited positive values. The heterotic effects varied from -25.676% (Basmati/DW 8) to 16.364% (IET 1444/TN 1) indicating that parents viz., DW 8, IET 1444 and Prabhat gave good crosses.

c) Standard Heterosis:

Twenty crosses excepting C_{21} showed positive values. The heterotic effects ranged from -1.785% (Basmati/DW 8) to 33.926% (DW 8/BPT 1235) indicating that all parents excepting TN 1 gave good crosses.

d) General performance:

Six crosses viz., C_8 , C_9 , C_{11} , C_{13} , C_{14} and C_{19} out of 21 crosses recorded positive heterotic values in all the three classes indicating that parents DW 8, IET 1444 and Prabhat gave good crosses.

10. Breadth of grain:

a) Relative Heterosis:

Nineteen crosses excepting C_8 and C_{12} out of 21 exhibited positive values. The heterotic effects ranged from -4.167% (DW 8/Tellahamsa) to 27.273% (Basmati/Prabhat) indicating that all parents gave good crosses.

b) Heterobeltiosis:

Seven crosses viz., C_1 , C_2 , C_3 , C_{10} , C_{15} , C_{18} and C_{20} out of 21 showed positive values. The heterotic effects varied from -17.857% (DW 8/Tellahamsa) to 20% (Basmati/Tellahamsa) indicating that Basmati, DW 8, IET 1444,

Tellahamsa and Prabhat gave 3, 1, 1, 1 and 1 good crosses, respectively.

c) Standard Heterosis:

Five crosses viz., C_2 , C_5 , C_{10} , C_{19} and C_{20} out of 21 expressed positive values. The heterotic effects ranged from -20% (IET 1444/Tellahamsa) to 16% (DW 8/TN 1) indicating that Basmati, DW 8 and Prabhat gave good crosses.

d) General performance:

Three crosses viz., C_2 , C_{10} and C_{20} but of 21 recorded positive heterotic values in all three classes indicating Basmati, DW 8 and Prabhat gave each one good cross.

11. L/B Ratio:

a) Relative Heterosis:

Nine crosses viz., C_7 , C_8 , C_9 , C_{11} to C_{15} and C_{19} out of 21 expressed positive values. The heterotic effects ranged from -31.507% (Basmati/Tellahamsa) to 19.149% (IET 1444/BPT 1235) indicating that parents DW 8, IET 1444 and Prabhat gave good crosses.

b) Heterobeltiosis:

Four crosses viz., C_7 , C_9 , C_{13} and C_{14} out of 21 exhibited positive values. The heterotic effects varied from -41.023% (Basmati/DW 8) to 8.333% (DW 8/IET 1444 and DW 8/Prabhat) indicating that DW 8 and IET 1444 gave good crosses.

c) Standard heterosis:

All 21 crosses showed positive values recording highest value of 40.9% (Basmati/BPT 1235) indicating that all parents have given good crosses.

d) General performance:

Four crosses viz., C_7 , C_9 , C_{13} and C_{14} out of 21 showed positive heterotic values in all three classes indicating DW 8 and IET 1444 gave good crosses.

12. Hulling Recovery:

a) Relative heterosis:

Eight crosses viz., C_2 , C_4 , C_7 , C_9 , C_{13} , C_{14} , C_{19} and C_{21} out of 21 expressed positive values. The heterotic effects ranged from -4.606% (Prabhat/BPT 1235) to 4.892% (Basmati/IET 1444) indicating that parents Basmati, DW 8, IET 1444 and TN 1 gave 2, 2, 2, and 1 good crosses respectively.

b) Heterobeltiosis:

Five crosses viz., C_2 , C_4 , C_7 , C_9 and C_{13} out of 21 exhibited positive values. The heterotic effects varied from -10.028% (Basmati/BPT 1235) to 4.145% (Basmati/IET 1444) indicating Basmati, DW 8 and IET 1444 gave good crosses.

c) Standard heterosis:

Twelve crosses viz., C_2 , C_4 , C_5 , C_7 , C_9 , C_{10} , C_{11} , C_{13} , C_{14} , C_{17} , C_{19} and C_{21} out of 21 recorded positive values. The heterotic effects ranged from -6.435% (Basmati/BPT 1235) to 4.891% (TN 1/BPT 1235) indicating Basmati, DW 8, IET 1444, Tellahamsa, Prabhat and TN 1 gave good crosses.

d) General performance:

Five crosses viz., C_2 , C_4 , C_7 , C_9 and C_{13} out of 21 showed positive heterotic values in all three crosses indicating that parents Basmati, DW 8 and IET 1444 gave good crosses.

13. Volume Expansion:

a) Relative heterosis:

Five crosses viz., C_7 , C_{13} , C_{14} , C_{16} and C_{18} out of 21 expressed positive values. The heterotic effects ranged

from -45.205% (DW 8/BPT 1235) to 17.647% (DW 8/IET 1444) indicating that parents Basmati, IET 1444 and Tellahamsa gave good crosses.

b) Heterobeltiosis:

Two crosses viz., C_7 and C_{16} recorded positive values. The heterotic effects varied from -45.946% (DW 8/Tellahamsa) to 14.286% (DW 8/IET 1444) indicating parents DW 8 and Tellahamsa gave each one good cross.

c) Standard heterosis:

Ten crosses viz., C_5 , C_7 , C_9 , C_{10} , C_{13} , C_{14} , C_{16} , C_{18} , C_{20} and C_{21} out of 21 exhibited positive values. The heterotic effects ranged from -28.57% (Basmati/Prabhat) to 42.857% (DW 8/IET 1444) indicating that all parents gave good crosses.

d) General performance:

Two crosses viz., C_7 and C_{16} out of 21 showed positive heterotic values in all three classes indicating that parents, DW 8 and Tellahamsa gave each one good cross combination.

14. Water uptake:

a) Relative heterosis:

Nine crosses viz., C_6 , C_9 , C_{13} , C_{16} to C_{21} expressed positive values. The heterotic effects ranged from -30.323% (IET 1444/Tellahamsa) to 26.890% (Tellahamsa/Prabhat) indicating that all parents gave good crosses.

b) Heterobeltiosis:

Six crosses viz., C_6 , C_9 , C_{13} , C_{16} , C_{19} and C_{21} exhibited positive values. The heterotic effects ranged from -32.5% (IET 1444/Tellahamsa) to 21.429% (TN 1/BPT 1235) indicating that all parents gave each one good cross combination.

c) Standard heterosis:

Thirteen crosses viz., C_1 , C_2 , C_3 , C_6 , C_7 , C_9 , C_{13} , C_{16} to C_{21} out of 21 recorded positive values. The heterotic effects varied from -7.986% (Basmati/Prabhat) to 59.722% (Tellahamsa/Prabhat) indicating that all parents gave good crosses.

d) General performance:

Six crosses viz., C_6 , C_9 , C_{10} , C_{16} , C_{19} and C_{21} out of 21 showed positive heterotic values in all the crosses

indicating that all parents excepting IET 1444 gave each one good cross combination.

15. Kernel elongation:

a) Relative heterosis:

Seven crosses viz., C_8 , C_{10} , C_{16} , C_{17} , C_{19} , C_{20} and C_{21} out of 21 exhibited positive values. The heterotic effects ranged from -18.75% (IET 1444/Tellahamsa) to 24.138% (Tellahamsa/TN 1) indicating that DW 8, Tellahamsa, Prabhat and TN 1 gave good crosses.

b) Heterobeltiosis:

Two crosses viz., C_{11} and C_{17} out of 21 expressed positive values. The heterotic effects varied from -22.22% (Basmati/IET 1444) to 20% (Tellahamsa/TN 1) indicating that DW 8 and Tellahamsa gave each one good cross combination.

c) Standard heterosis:

Only one cross (Tellahamsa/TN 1) showed positive value. The heterotic effects ranged from -23.529% (IET 1444/Tellahamsa) to 5.882% (Tellahamsa/TN 1) indicating Tellahamsa gave one good cross combination.

d) General performance:

Only one cross viz., (Tellahamsa/TN 1) showed positive heterotic value in all three classes indicating Tellahamsa has given one good cross combination.

16. Protein content of brown rice:

a) Relative heterosis:

All the 21 crosses with the exception of C_7 , C_{13} and C_{20} exhibited positive values. The heterotic effects ranged from -3.057% (Prabhat/BPT 1235) to 21.116% (Prabhat/TN 1) indicating that all parents gave good crosses.

b) Heterobeltiosis:

Ten out of 21 crosses viz., C_1 , C_4 , C_6 , C_9 , C_{10} , C_{11} , C_{14} , C_{16} , C_{19} and C_{21} expressed positive values. The heterotic effects varied from -13.178% (DW 8/IET 1444) to 8.036% (DW 8/BPT 1235) indicating that all parents gave good crosses.

c) Standard heterosis:

All 21 crosses showed positive values. The heterotic effects varied from 2.804% (Basmati/DW 8) to 42.056% (IET 1444/ TN 1).

d) General performance:

Ten crosses viz., C_1 , C_4 , C_6 , C_9 , C_{10} , C_{11} , C_{14} , C_{16} , C_{19} , and C_{21} out of 21 crosses recorded positive heterotic values in all three classes indicating that all parents gave good crosses.

E) VARIABILITY, HERITABILITY AND GENETIC ADVANCE:

Data on Genotypic and Phenotypic coefficient of variation, heritability, genetic advance and genetic gain over per cent mean for all the sixteen characters both in F_1 and F_2 generations are presented in Table 19.

General:

The overall performance of the material on sixteen characters both in F_1 and F_2 in respect of variability, heritability, genetic advance and genetic advance over per cent of mean revealed that PCV % (phenotypic coefficient of variation) were higher than GCV % (Genotypic coefficient of variation) both in F_1 and F_2 generations. The GCV % ranged from 3.1% to 65.6% in F_1 and 2.2% to 60.8%, in F_2 , whereas PCV % varied from 3.2% to 65.8% in F_1 and 3.4 to 61.4% in F_2 indicating that all the characters are subject to environmental effect in expression. In general, heritability values were higher in F_1 over F_2 and varied from 3.2 to 99.5% in F_1 and 18.7 to 98.2% in F_2 indicating

Table 19: Coefficients of genotypic and phenotypic variance, heritability, genetic advance and genetic advance over mean in F_1 and F_2 generations of 21 crosses of 7 x 7 diallel for 16 characters

Character	GCV %		PCV %		Heritability %		Genetic Advance %		Genetic Advance over mean %	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Days to 50% FLD(No.)	12.2	11.1	12.3	25.6	97.9	18.7	25.1	24.8	25.2	22.8
Plant height (cm)	28.4	25.6	28.6	34.6	98.7	55.0	62.8	55.3	58.6	52.8
E/T/Plant (No.)	36.5	29.4	38.5	32.2	90.1	83.6	14.6	10.1	75.2	60.7
Panicle length (cm)	9.7	7.7	11.8	11.2	67.9	47.0	4.6	3.5	20.0	15.9
Grains per panicle (No.)	34.4	25.9	36.8	29.5	88.1	76.8	56.1	42.3	70.1	53.3
Sterility (%)	33.8	12.3	34.8	14.3	94.3	61.3	13.8	5.2	69.7	25.3
100-grain weight (g)	13.2	9.7	14.7	12.2	79.7	63.2	71.2	50.8	27.1	19.9
Yield per Plant (g)	65.6	60.8	65.9	61.4	99.5	98.2	47.9	38.9	135.2	125.3
Length of grain (mm)	9.1	7.4	9.4	8.5	93.5	75.4	119.9	96.3	18.8	15.2
Breadth of grain(mm)	9.6	7.4	11.1	10.7	75.5	48.3	48.1	36.0	19.8	15.3
L/B Ratio (No.)	19.3	15.3	10.8	16.6	3.2	84.0	119.7	79.9	39.9	31.4
Hulling Recovery(%)	3.1	2.2	3.2	3.4	92.5	41.0	50.0	3.4	6.4	4.5
Volume Expansion (No.)	19.6	18.1	22.7	22.4	74.3	65.1	122.9	105.9	40.4	37.2
Water uptake (ml)	15.8	12.8	23.6	14.2	44.9	82.4	110.5	84.7	32.5	26.5
Kernel elongation (No.)	9.7	5.6	10.8	12.4	81.5	20.4	29.9	16.4	20.0	11.5
Protein content of brown rice (%)	12.7	14.5	12.9	16.5	97.2	77.1	31.2	28.3	26.1	29.9

that the characters are heritable in different intensities and desirable improvement can be achieved by selection. Genetic advance and genetic advance over mean values also showed higher values in F_1 and F_2 and ranged from 4.6% to 119.9% in F_1 and 3.4% to 105.9% in F_2 in respect of genetic advance. The genetic advance over per cent mean ranged from 6.4% to 135.2% in F_1 and 4.5 to 125.3% in F_2 indicating possibility for selection in the desirable direction of improvement by adopting proper breeding methodologies.

1. Days to 50% flowering:

In general, PCV values were higher than GCV both in F_1 and F_2 recording 12.3% and 25.6% for PCV and 12.2% and 11.1% in F_2 for GCV respectively. High heritability values 97.9%, low genetic advance 25.1% and genetic advance over mean 25.2% in F_1 , whereas low heritability of 18.7%, genetic advance per cent (24.8%) and genetic advance over mean 22.8% in F_2 were obtained.

2. Plant Height:

In general, PCV values were higher than GCV for this trait. The GCV for this character was 28.4% (F_1) and 25.6% (F_2) whereas PCV was 28.6% (F_1) and 34.6% (F_2). High heritability of 98.7% (F_1) with moderate value of 55% in F_2 generation was recorded. High genetic advance of 62.8% (F_1)

and 55.3% (F_2) coupled with high genetic advance over mean 58.6% (F_1) and 52.8% (F_2) was recorded for this trait.

3. Effective tillers per plant:

PCV estimates were higher than GCV estimates for this trait. The GCV values for this character were 36.5% in F_1 and 29.4% in F_2 whereas PCV values were 38.5% in F_1 and 32.2% in F_2 . High heritability values of 90.1% in F_1 and 83.6% in F_2 were observed for this trait. Low genetic advance of 14.6% and 10.1% along with high genetic gain over mean (75.2% and 60.7%) were recorded for this trait both in F_1 and F_2 generations respectively.

4. Panicle length:

PCV values were more than GCV for this character. The GCV for this trait was 9.7% (F_1) and 7.7% (F_2) whereas PCV was 11.8% (F_1) and 11.2% (F_2). Moderate heritability of 67.9% and 47.0% both in F_1 and F_2 , respectively was observed for this trait. Low genetic advance of 4.6% (F_1) and 3.5% (F_2) along with low genetic gain over per cent mean of 20.0% (F_1) and 15.9% (F_2) was recorded for this trait.

5. Grains per panicle:

The GCV was 34.4% in F_1 and 25.9% in F_2 whereas PCV was 36.3% in F_1 and 29.5% in F_2 for this trait. High

heritability values of 88.1% (F_1) and 76.8% (F_2) were observed for this character. A moderate genetic advance of 56.1% in F_1 and 42.3% F_2 coupled with moderate genetic gain over per cent mean of 70.1% in F_1 and 53.3% in F_2 was recorded for this trait.

6. Spikelet sterility:

The GCV for this character was 33.8% (F_1) and 12.3% (F_2) whereas PCV was 34.8% (F_1) and 14.3% (F_2). High heritability values of 94.3% and 61.3% in F_1 and F_2 , respectively were obtained for this trait with low genetic advance of 13.8% (F_1) and 5.2% (F_2) along with high genetic advance over mean of 69.7% (F_1) and low value of 25.2% (F_2) was observed for this trait.

7. 100-grain weight:

The GCV for this trait was 13.2% and 9.7% in F_1 and F_2 generations, respectively, whereas PCV for this trait was 14.7% and 12.2% in F_1 and F_2 generations, respectively. High heritability values of 79.7% (F_1) and 63.2% (F_2) were observed for this trait. A high genetic advance of 71.2% and 50.8% coupled with low genetic gain over per cent mean of 27.1% and 19.9% was recorded both in F_1 and F_2 generations, respectively.

8. Grain yield per plant:

The PCV estimates were higher than GCV estimates for this trait. The GCV was 65.6% (F_1) and 60.8% (F_2) whereas PCV was 65.8% (F_1) and 61.4% (F_2) for this character. High heritability values of 99.5% in F_1 and 98.2% in F_2 were observed for this trait. Moderate genetic advance of 47.9% in F_1 and 38.9% in F_2 coupled with very high genetic gain over per cent mean of 135.2% and 125.3% was recorded both in F_1 and F_2 generations, respectively for this trait.

9. Length of grain:

The GCV for this trait was 9.1% (F_1) and 7.4% (F_2) whereas PCV was 9.4% (F_1) and 8.5% (F_2). High heritability values of 93.5% in F_1 and in F_2 75.4% along with high genetic advance of 119.9% in F_1 and 96.3% in F_2 was obtained. Low genetic gain over per cent mean of 18.8% and 15.2% was recorded in F_1 and F_2 generations respectively.

10. Breadth of grain:

PCV estimates were higher than GCV for this trait. The GCV of 9.6% (F_1) and 7.4% (F_2) and PCV of 11.1% (F_1) and 10.7% (F_2) was obtained. High heritability values of 75.5% in F_1 and moderate heritability of 48.3% in F_2 along with moderate genetic advance of 48.1% in F_1 and 36.0% in F_2 were recorded for this trait. A low genetic gain over per cent

mean of 19.8% and 15.3% was recorded in F_1 and F_2 generations respectively.

11. **L/B Ratio:**

The GCV value was higher than PCV values. The GCV for this trait was 19.3% (F_1) and 15.3% (F_2) whereas PCV was 10.8% (F_1) and 16.6% (F_2). Low heritability of 3.2% in F_1 and high heritability of 84.0% in F_2 accompanied by very high genetic advance of 119.7% in F_1 and high genetic advance of 79.9% in F_2 were recorded for this trait. Moderate genetic gain over per cent mean of 39.9% and 31.4% were observed both in F_1 and F_2 generations, respectively.

12. **Hulling recovery:**

The PCV estimate was higher than GCV. The GCV for this character was 3.1% (F_1) and 2.2% (F_2) whereas PCV was 3.2% (F_1) and 3.4% (F_2). High heritability of 92.5% in F_1 and moderate heritability of 41.0% in F_2 along with high genetic advance of 50.0% (F_1) and very low genetic advance of 3.4% in F_2 was recorded for this trait. Low genetic gain over per cent mean of 6.4% and 4.5% was recorded in F_1 and F_2 generations, respectively for this trait.

13. Volume Expansion:

The GCV estimate for this trait was 19.6% (F_1) and 18.1% (F_2) whereas PCV estimate was 22.7% (F_1) and 22.4% (F_2). High heritability values of 74.3% and 65.1% in F_1 and F_2 , respectively accompanied with high genetic advance of 122.9% in F_1 and 105.9% in F_2 was recorded for this trait. Moderate genetic gain over per cent of mean of 40.4% (F_1) and 37.2% (F_2) was observed.

14. Water uptake:

The GCV value for this character was 15.8% in F_1 and 12.8% in F_2 and PCV value was 23.6% (F_1) and 14.2% (F_2). Moderate heritability of 44.9% in F_1 and high heritability of 82.4% in F_2 followed by very high genetic advance of 110.5% in F_1 and high genetic advance of 84.7% in F_2 was recorded for this trait. Moderate genetic gain over per cent mean of 32.5% (F_1) and 26.5% (F_2) was recorded for this character.

15. Kernel elongation:

The GCV for this trait was 9.7% (F_1) and 5.6% (F_2) whereas PCV was 10.8% (F_1) and 12.4% (F_2). Low heritability of 20.4% in F_2 and high heritability of 81.5% in F_1 followed by low genetic advance of 16.4% in F_2 with moderate value of 29.9% in F_1 was recorded for this trait. Low genetic gain

over per cent mean of 20% in F_1 and 11.5% in F_2 was observed for this character.

16. Protein content of brown rice:

PCV estimates were higher than GCV estimates. The GCV for this trait was 12.7% (F_1) and 14.5% (F_2) whereas PCV was 12.9% (F_1) and 16.5% (F_2). High heritability value of 97.2% in F_1 and 77.1% in F_2 accompanied by moderate genetic advance of 31.2% and 28.3% in F_1 and F_2 generations respectively was noticed. Moderate genetic gain over per cent mean of 26.1% in F_1 and 29.9% in F_2 was recorded.

E. CHARACTER ASSOCIATIONS:

Phenotypic and genotypic correlation coefficients between yield, yield components and quality consisting of 16 characters as detailed below were estimated for F_1 s and F_2 s of 21 crosses of 7 x 7 diallel and the results are presented in Tables 20 & 21. In general, the phenotypic correlation coefficients for all the characters were less than genotypic correlation coefficients.

1. Days to 50% flowering:

In F_1 generation, positive and significant association was observed for this trait with plant height (0.7377), panicle length (0.3850) grains per panicle

Table 20: Correlation coefficients between yield, yield components and quality characters in F_1 generation of 21 crosses of 7 x 7 diallel

Characters	Plant height (cm)	EBT/Plant (No.)	Panicle length (cm)	Grains/particle (No.)	Spikelet sterility (%)	100-grain weight (g)	Grain yield/plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling recovery (%)	Volume expansion (No.)	Water uptake (ml)	Kernel elongation (No.)	Protein content of brown rice (%)
Days to 50% flowering	P 0.7377	-0.4477	0.3850	0.4355	-0.5922	0.1829	-0.0161	0.2017	0.0889	0.0164	-0.2072	-0.3149	-0.1669	0.0041	-0.4083
	G 0.7527	-0.4835	0.4681	0.4811	-0.6142	0.2002	-0.0146	0.2085	0.0802	0.1190	-0.2157	-0.3534	-0.2400	-0.0049	-0.4205
Plant height	P	-0.0941	0.6188	0.6488	0.3518	0.3313	0.4303	0.3845	0.0940	0.1560	-0.2655	-0.3082	-0.2382	-0.2975	-0.4934
	G	-0.1080	0.7672	0.6740	0.3634	0.4060	0.4356	0.4022	0.0957	0.8101	-0.3034	-0.3600	-0.3897	-0.3391	-0.4979
E/T/Plant	P	0.0776	-0.1287	-0.3141	0.3958	0.7275	0.1350	0.2988	0.1298	0.2421	0.0072	-0.1384	-0.0498	0.2981	
	G	0.1127	-0.1762	-0.3478	0.4335	0.7657	0.1476	0.3284	0.9986	0.2729	0.0239	-0.1975	-0.0753	0.3179	
Panicle length	P	0.5754	0.1233	0.4334	0.4334	0.4834	0.1635	0.2186	-0.0476	-0.1877	-0.2232	-0.2778	-0.5306	-0.3058	
	G	0.8164	0.1212	0.6271	0.4334	0.5958	0.4374	0.3742	0.7110	-0.2795	-0.3520	-0.3622	-0.6888	-0.3463	
Grains/particle	P	0.1675	0.2879	0.4210	0.6271	0.4210	0.0612	0.2563	0.0699	-0.2209	-0.3985	-0.2973	-0.4470	-0.3671	
	G	0.2008	0.3728	0.4465	0.3728	0.4465	0.0894	0.1236	0.2433	-0.2370	-0.4776	-0.4459	-0.5311	-0.3858	
Spikelet sterility	P	-0.0229	-0.1399	0.2718	0.0407	-0.0323	0.0816	-0.0971	0.0993	-0.0574					
	G	-0.0562	-0.1411	0.0824	0.0450	-0.3156	0.0790	-0.1976	-0.1224	0.1357					
100-grain weight	P	0.6117	0.4026	0.6276	0.1179	0.1034	-0.0587	-0.0680	0.0906	-0.0176					
	G	0.6075	0.4075	0.7650	0.3618	0.1286	-0.0073	-0.1209	-0.1893	-0.0609					
Grain yield per plant	P	0.3051	0.3983	0.1712	0.0225	-0.1942	-0.2933	-0.2935	-0.0455						
	G	0.3135	0.4676	0.1762	0.0227	-0.2160	-0.4388	-0.3146	-0.0467						
Length of grain	P	-0.0898	0.1611	0.0280	0.0926	-0.0174	-0.3232	-0.3359							
	G	-0.0969	1.1247	0.0627	0.1157	-0.0734	-0.3986	-0.3191							
Breadth of grain	P	-0.0988	-0.0380	-0.0131	0.0002	0.3109									
	G	-1.0366	0.4350	-0.0056	-0.1733	0.0216	-0.3563								
L/B Ratio	P	-0.0660	-0.1275	-0.0920	-0.1328	-0.1244									
	G	-0.4875	-1.1257	-0.5387	-0.6488	-0.8422									
Hulling Recovery	P	0.1096	-0.1281	0.0763	0.4536										
	G	0.1201	-0.2023	0.1502	0.4961										
Volume expansion	P	0.2877	0.0518	-0.0970											
	G	0.5675	0.0664	-0.0870											
Water uptake	P	0.3825	-0.2194												
	G	0.5688	-0.3342												
Kernel elongation	P	0.2602													
	G	0.1913													

r table value for 42 D.F. = 5% level = 0.209;

r table value for 82 D.F. = 1% level = 0.279

Table 21: Correlation coefficients between yield, yield components and quality characters in F_2 generation of 21 crosses of 7 x 7 diallel

Characters	Plant height (cm)	SBT/ plant (No.)	Panicle length (cm)	Grains/ panicle (No.)	Spikelet sterility (%)	100-grain weight (g)	Grain yield/ plant (g)	Length of grain (mm)	Breadth of grain (mm)	L/B Ratio (No.)	Hulling recovery (%)	Volume expansion (No.)	Water uptake (ml)	Kernel elongation (No.)	Protein content of brown rice (%)
Days to 50% flowering	P 0.1829	-0.2334	0.1772	0.1683	0.0745	0.3108	-0.0088	0.1526	0.1186	-0.0369	0.0177	0.0085	0.0989	0.1165	-0.1520
	G 0.8354	-0.5150	0.4080	0.3318	0.2955	0.8134	-0.0541	0.4186	0.6410	-0.2020	-0.4263	-0.2453	0.3015	-0.2019	-0.8412
Plant height	P	-0.1747	0.5485	0.5250	0.2459	0.3609	0.1802	0.5578	0.0564	0.2373	-0.3213	-0.2499	-0.2656	-0.2550	-0.2945
	G	-0.1987	-0.8125	0.6594	0.2784	0.4244	0.4004	0.6590	0.1033	0.2447	-0.4870	-0.3451	-0.3018	-0.4336	-0.3584
F/T/Plant	P	0.0187	-0.2118	-0.3103	0.0352	0.6128	0.6128	-0.0678	0.1451	-0.1688	0.3222	0.1185	0.0048	0.0047	0.2517
	G	0.0802	-0.2227	-0.3131	0.1985	0.6825	0.6825	-0.1024	0.2965	-0.1417	0.4459	0.1235	-0.0429	-0.1935	0.3482
Panicle length	P		0.4337	0.1220	0.5228	0.3671	0.3671	0.5522	0.3007	0.0777	-0.0486	-0.0395	-0.1127	-0.3369	-0.2822
	G		0.6444	0.6636	0.8238	0.5372	0.5372	0.7614	0.5735	0.0893	-0.0385	-0.0682	-0.1833	-1.3603	-0.2506
Grains/ panicle	P		-0.0007	0.3983	-0.0007	0.4265	0.4265	0.1226	0.2711	-0.3148	-0.4340	-0.3843	-0.5107	-0.4367	-0.4808
	G		-0.0211	0.5738	-0.0211	0.4700	0.4700	0.1828	0.5797	-0.4314	-0.6678	-0.5470	-0.6184	-1.2317	-0.6387
Sterility	P		0.0316	0.0316	0.0316	-0.1086	-0.1086	0.5750	-0.2272	0.5780	-0.1522	0.1749	0.0264	-0.1506	-0.1914
	G		0.0324	0.0324	0.0324	-0.1560	-0.1560	0.8143	-0.4613	0.6443	0.0298	0.0572	0.1175	-0.2444	-0.2545
100-grain weight	P					9.4887	9.4887	0.3406	0.4909	-0.2665	-0.1487	-0.1614	-0.2403	-0.2349	-0.3817
	G					9.5991	9.5991	0.4640	0.9751	-0.3484	0.2181	-0.1401	-0.2107	-0.6839	-0.6188
Grain yield per plant	P					3.2026	3.2026	0.3170	-0.2082	-0.1337	-0.1337	-0.2109	-0.2994	-0.2852	-0.2638
	G					0.2538	0.2538	0.4423	-0.2427	0.1822	-0.2890	-0.2890	-0.3218	-0.7120	-0.2813
Length of grain	P					-0.1317	-0.1317	0.6089	-0.0399	0.1371	0.0399	0.1371	0.0345	-0.3395	-0.2344
	G					-0.1405	-0.1405	0.7928	0.1511	0.1980	0.1511	0.1980	0.0563	-0.6894	-0.2750
Breadth of grain	P					-0.5408	-0.5408	-0.5408	0.1962	-0.0217	-0.1343	-0.0176	-0.1343	-0.0176	-0.0328
	G					-0.9504	-0.9504	-0.9504	0.1554	-0.1632	-0.2938	-0.5127	-0.2938	-0.5127	0.1266
L/B Ratio	P					0.1229	0.1229	0.2813	0.2813	0.2813	0.2813	0.2813	0.2813	-0.0191	0.0643
	G					0.1612	0.1612	0.2567	0.2567	0.2567	0.2567	0.2567	0.3609	0.1544	0.1033
Hulling Recovery	P					0.2915	0.2915	0.2915	0.2915	0.2915	0.2915	0.2915	0.3363	0.1985	0.6265
	G					0.6526	0.6526	0.6526	0.6526	0.6526	0.6526	0.6526	0.5297	0.5453	1.0023
Volume expansion	P					0.5709	0.5709	0.5709	0.5709	0.5709	0.5709	0.5709	0.5709	0.0733	0.3320
	G					0.6590	0.6590	0.6590	0.6590	0.6590	0.6590	0.6590	0.6590	0.1004	0.5201
Water uptake	P					0.1943	0.1943	0.1943	0.1943	0.1943	0.1943	0.1943	0.1943	0.1943	0.3051
	G					0.5163	0.5163	0.5163	0.5163	0.5163	0.5163	0.5163	0.5163	0.5163	0.3745
Kernel elongation	P					0.3213	0.3213	0.3213	0.3213	0.3213	0.3213	0.3213	0.3213	0.3213	0.3213
	G					0.9243	0.9243	0.9243	0.9243	0.9243	0.9243	0.9243	0.9243	0.9243	0.9243

r table value for 54 D.F. = 5% level = 0.261

r table value for 54 D.F. = 1% level = 0.340

(0.4399) and sterility (0.5922) whereas negative significant association was seen with volume expansion (-0.3149), protein content (-0.4083) and effective tillers per plant (-0.4477).

In F_2 generation, positive and significant association was seen only for 100-grain weight (0.3108) and no significant correlation with other characters was observed.

2. Plant Height:

A positive and significant association in F_1 was observed for this trait with 100-grain weight (0.3513), length of grain (0.3849), panicle length (0.6168), days to 50% flowering (0.7377), grains per panicle (0.6488), spikelet sterility (0.3518) and grain yield (0.4303) whereas negative significant association was noticed with hulling recovery (-0.2895), volume expansion (-0.3082) water uptake (-0.2382), kernel elongation (-0.2975) and protein content of brown rice (-0.4934).

In F_2 generation, positive significant association was observed for this character with 100-grain weight (0.3609), length of grain (0.5578), panicle length (0.5485), grains per panicle (0.5250) and grain yield per plant (0.3802) whereas negative association was seen with remaining characters.

It is observed that this trait has got association with grain yield and with some attributes related to yield but no association was observed with any quality characters.

3. Effective tillers per plant:

A significant positive association of this trait was observed in F_1 with 100-grain weight (0.3958), Breadth of grain (0.2988), hulling recovery (0.2421), protein content (0.2981) and grain yield per plant (0.7275) whereas negative association was seen with the remaining characters. In F_2 generation, positive significant association was seen with hulling recovery (0.3222) and grain yield (0.6128). It is observed that it has got association with grain yield and hulling recovery only.

4. Panicle length:

In F_1 generation, significant positive association was observed for this trait with 100-grain weight (0.4334) length of grain (0.3633), breadth of grain (0.2186), days to 50% flowering (0.3850), plant height (0.6168), grains per panicle (0.5754) and grain yield (0.4834) whereas negative association was seen with other characters.

In F_2 generation, significant positive association was recorded with 100-grain weight (0.5228), length of grain

(0.5522), breadth of grain (0.3002), plant height (0.5458), grains per panicle (0.4377) and grain yield per plant (0.3671) whereas negative association was seen with remaining characters.

It is observed that this trait has got association with grain yield and grain quality characters only.

5. Grains per panicle:

In F_1 generation, positive and significant association was observed for this trait with 100-grain weight (0.2679), breadth of grain (0.2563), days to 50% flowering (0.4399), plant height (0.6488), panicle length (0.5754) and grain yield (0.4210) whereas significant negative association was seen with the remaining characters.

In F_2 generation, a positive and significant association was noticed for this character with 100-grain weight (0.3983), breadth of grain (0.2711), plant height (0.5250), panicle length (0.4337) and grain yield (0.4265) whereas negative association was observed with other characters to this trait.

It is observed that this trait has got association with grain yield and yield attributes viz., 100-grain

weight, plant height and panicle length but no association was seen with quality characters.

6. Spikelet sterility:

In F_1 generation positive and significant association of this trait was noticed with days to 50% flowering (0.5922) and plant height (0.3518) whereas negative significant association was seen with effective tillers per plant (-0.3141). In F_2 generation, a positive and significant association was observed for this character with length of grain (0.5750) and L/B ratio (0.5780) whereas the association was negative with effective tillers per plant (-0.3103). It is observed that this character has no positive association with any of the yield contributing parameters and quality characters.

7. 100-grain weight:

This trait showed positive and significant association with length of grain (0.4026), breadth of grain (0.6276), plant height (0.3513), effective tillers per plant (0.3958), panicle length (0.4334), grains per panicle (0.2679) and grain yield (0.6117) in F_1 whereas in F_2 generation this trait exhibited positive significant association with breadth of grain (0.4909), plant height (0.3609), days to 50% flowering (0.3108), panicle length

(0.5228), grains per panicle (0.3983) and grain yield (0.4887).

It is observed that this trait showed positive association with grain yield and some of its attributes, but no association was noticed with quality characters.

8. Grain yield per plant:

In F_1 generation, a positive and significant association was observed for this character with 100-grain weight (0.6117), length of grain (0.3051), breadth of grain (0.3983), plant height (0.4303), effective tillers per plant (0.7275), panicle length (0.4834) and grains per panicle (0.4210) whereas in F_2 generation positive significant trend was shown for this trait with 100-grain weight (0.4887), breadth of grain (0.3178), plant height (0.3802) effective tillers per plant (0.6128), panicle length (0.3671) and grains per panicle (0.4265). It is observed that this trait has got association with yield attributes only whereas no association was observed with quality characters.

9. Length of grain:

A significant positive association was recorded for this trait in F_1 generation with 100-grain weight (0.4026), plant height (0.3849), panicle length (0.3633) and grain

yield (0.3051) whereas in F_2 positive association was observed with L/B ratio (0.6089), plant height (0.5578), panicle length (0.5522) and spikelet sterility (0.5750). It is observed that this character showed positive association with yield attributes but not with quality characters.

10. Breadth of grain:

In F_1 generation, this trait showed positive and significant association with 100-grain weight (0.6276), hulling recovery (0.3598), protein content of brown rice (0.3109), effective tillers per plant (0.2988), panicle length (0.2186), number of grains per panicle (0.2563) and grain yield (0.3983) whereas in F_2 generation, this trait showed positive and significant association with 100-grain weight (0.4909), panicle length (0.3007), grains per panicle (0.2711), and grain yield (0.3170). It is observed that this trait showed positive association with grain yield and some of its attributes but not with any quality characters.

11. L/B Ratio:

In F_1 generation, no positive association was shown, for this trait with any of the characters whereas in F_2 generation, positive significant association was exhibited by this trait with length of grain (0.6089), volume expansion (0.2833), water uptake (0.2815) and spikelet

sterility (0.5780). It is observed that this trait has got association with cooking quality characters viz., volume expansion and water uptake only.

12. Hulling recovery:

This trait showed significant positive association with breadth of grain (0.3598), protein content of brown rice (0.4536) and effective tillers per plant (0.2421) in F_1 generation whereas in F_2 generation positive significant association was observed with volume expansion (0.2915), water uptake (0.3363), protein content of brown rice (0.6265) and effective tillers per plant (0.3222). It is observed that this trait has got positive association with quality characters viz., volume expansion, water uptake and protein content but not with grain yield.

13. Volume expansion:

In F_1 generation this character expressed significant positive association with water uptake only (0.2877) whereas in F_2 , positive significant association was observed with L/B Ratio (0.2833), hulling recovery (0.2915), water uptake (0.5709) and protein content (0.3320). Further observations revealed that this trait exhibited positive association with quality characters viz., L/B ratio, hulling recovery, water

uptake and protein content only but no association was seen with grain yield.

14. **Water uptake:**

This trait showed significant positive association with volume expansion (0.2877) and kernel elongation in F_1 generation whereas it exhibited positive significant association with L/B Ratio (0.2815), hulling recovery (0.3363), volume expansion (0.5709) and protein content (0.3051) in F_2 . It is observed that this character expressed positive association with quality characters viz., L/B ratio, hulling recovery, volume expansion and protein content only but not with grain yield.

15. **Kernel elongation:**

In F_1 , this trait showed positive significant association with water uptake (0.3829) whereas in F_2 , it exhibited significant positive association with protein content (0.3213) only. It is observed that this character expressed positive association with protein content only and no association was seen with grain yield and its attributes.

16. Protein content of brown rice:

This character recorded significant positive association with breadth of grain (0.3109), hulling recovery (0.4536) and effective tillers per plant (0.2981) in F_1 whereas in F_2 , it exhibited positive significant association with hulling recovery (0.6265), volume expansion (0.3320), water uptake (0.3051) and kernel elongation (0.3213). It is further noticed that this trait showed association with quality characters viz., hulling recovery, volume expansion, water uptake and kernel elongation only but no association was seen with grain yield and its attributes.

In general, correlation studies revealed positive significant association between grain yield and its attributes viz., 100-grain weight, plant height, effective tillers per plant, panicle length and number of grains per panicle both in F_1 and F_2 generations. Whereas quality characters viz., hulling recovery, volume expansion, water uptake, kernel elongation and protein content exhibited significant positive association among themselves both in F_1 and F_2 crosses. Thus there was no direct association between quality characters and grain yield but the grain quality characters viz., length, breadth and L/B ratio were found to influence indirectly both grain yield and quality characters and thus grain quality characters played an important critical role in deciding both grain yield and quality of rice.

F. PATH COEFFICIENT ANALYSIS:

The correlation coefficients do not project the complete picture especially when the casual factors are interrelated. The correlation coefficients between yield and each of its component characters were partitioned into the corresponding direct and indirect effects through path coefficient analysis. The path coefficient analysis of different characters based on yield and phenotypic correlations of F_1 and F_2 generations and their results are presented in Tables 22 and 23. Path diagram showing direct and indirect effects was depicted in Fig. 2 and 3 for F_1 and F_2 generations respectively. The cause and direct effect relationship is diagrammatically depicted in Fig. 4 and 5 both for F_1 and F_2 generations respectively.

1. Days to 50% flowering:

In general negative correlation for yield (-0.0162) was seen with this trait. The effect of this trait on grain yield is negligible (-0.0886) in F_1 . The indirect effect through plant height was positive and moderate (0.2177) on grain yield. The indirect effects of 100-grain weight, L/B ratio, panicle length and grains per panicle were marginal on grain yield for this trait. Effective tillers per plant showed highest negative indirect effect (-0.3034) whereas

Table 22: Direct and indirect effects between yield and yield components in F_1 generation of 21 crosses of 7 x 7 diallel

Characters	Days to 50% Flowering (No.)	Plant height (cm)	E/T/P (No.)	Panicle length (cm)	Grains/ Panicle (No.)	Spikelet sterility (%)	100-grain weight (g)	L/B Ratio (No.)	Correlation with yield
Days to 50% flowering (No.)	-0.0886	0.2177	-0.3034	0.0207	0.1269	-0.0176	0.0282	0.0000	-0.0162
Plant height (cm)	-0.0654	0.2951	-0.0638	0.0332	0.1871	-0.0104	0.0542	0.0003	0.4303
E/T/P (No.)	0.0397	-0.0278	0.6778	0.0042	-0.0371	0.0093	0.0611	0.0002	0.7274
Panicle length (cm)	-0.0341	0.1820	0.0526	0.0538	0.1659	-0.0037	0.0669	-0.0001	0.4833
Grains per panicle (No.)	-0.0390	0.1914	-0.0873	0.0310	0.2884	-0.0050	0.0414	0.0001	0.4210
Spikelet sterility (%)	-0.0525	0.1038	-0.2129	0.0066	0.0483	-0.0297	-0.0035	-0.0001	-0.1400
100-grain weight (g)	-0.0162	0.1037	0.2683	0.0233	0.0007	0.0070	0.1544	0.0002	0.6117
L/B Ratio (No.)	-0.0015	0.0460	0.0880	-0.0026	0.0202	0.0010	0.0182	0.0018	0.1711

Table 23: Direct and indirect effects between yield and yield components in F₂ generation of 21 crosses of 7 x 7 diallel

Characters	Days to 50% Flowering (No.)	Plant height (cm)	E/T/P (No.)	Panicle length (cm)	Grains/ Panicle (No.)	Spikelet sterility (%)	100-grain weight (g)	L/B Ratio (No.)	Correlation with yield
Days to 50% flowering (No.)	-0.0158	0.0425	-0.1773	-0.0252	0.0725	0.0029	0.0942	-0.0025	-0.0087
Plant height (cm)	-0.0029	0.2322	-0.1327	-0.0780	0.2262	0.0097	0.1093	0.0164	0.3802
E/T/P (No.)	-0.0037	-0.0406	0.7596	-0.0055	-0.0912	-0.0122	0.0107	-0.0116	0.6129
Panicle length (cm)	-0.0028	0.1273	0.0294	-0.1422	0.1869	0.0048	0.1584	0.0054	0.3672
Grains per panicle (No.)	-0.0027	0.1219	-0.1608	-0.0617	0.4309	-0.0000	0.1207	-0.0217	0.4266
Spikelet sterility (%)	-0.0012	0.0571	-0.2357	-0.0173	0.0003	0.0393	0.0096	0.0399	-0.1080
100-grain weight (g)	0.0049	0.0838	0.0267	-0.0743	0.1716	0.0012	0.3029	-0.0184	0.4886
L/B Ratio (No.)	0.0006	0.0551	-0.1282	-0.0110	-0.1356	0.0227	-0.0807	0.0690	-0.2081

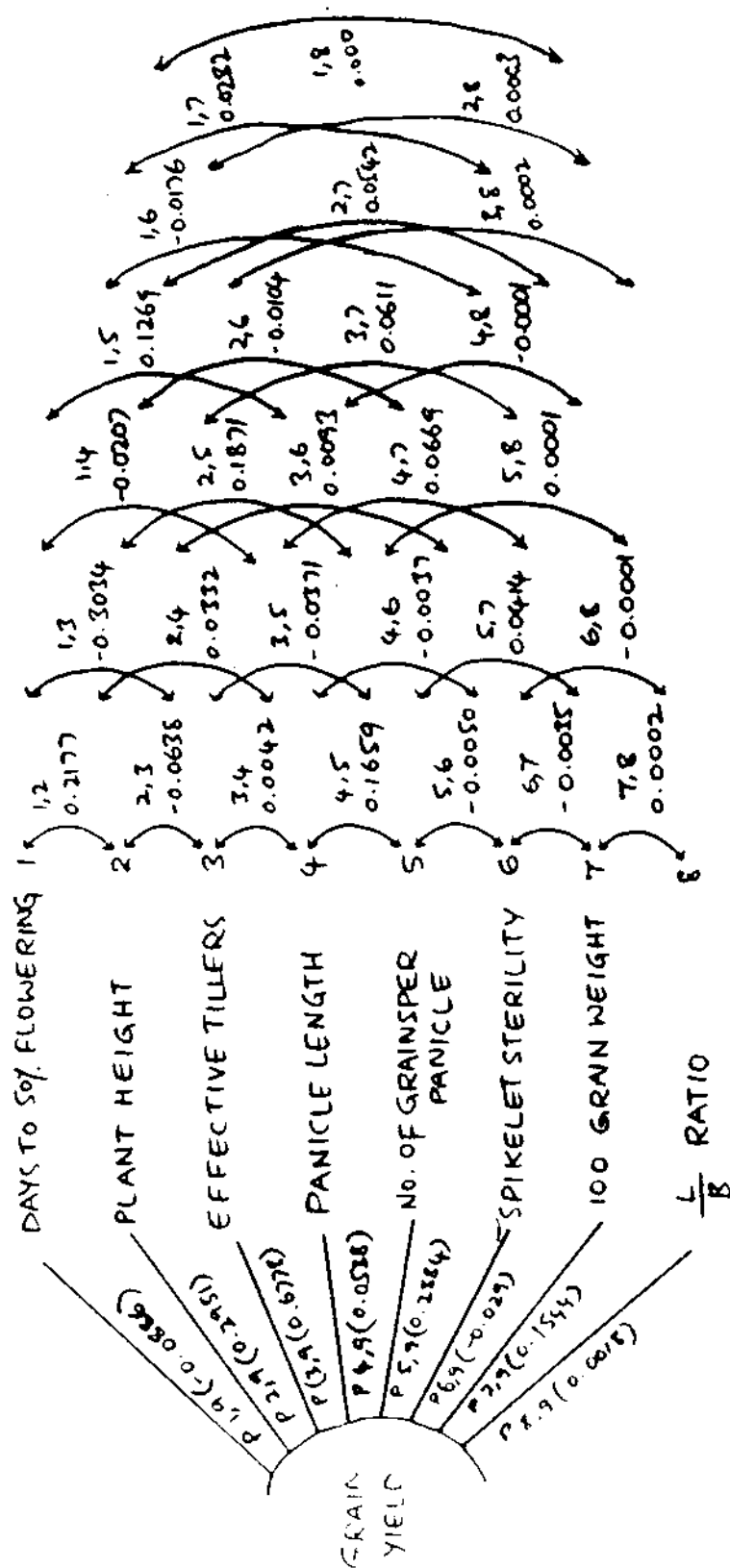


Fig. 2: PATH DIAGRAM SHOWING DIRECT AND INDIRECT EFFECTS ON YIELD IN F₁ GENERATION OF 21 RICE CROSSES OF 7 x 7 DIALLEL

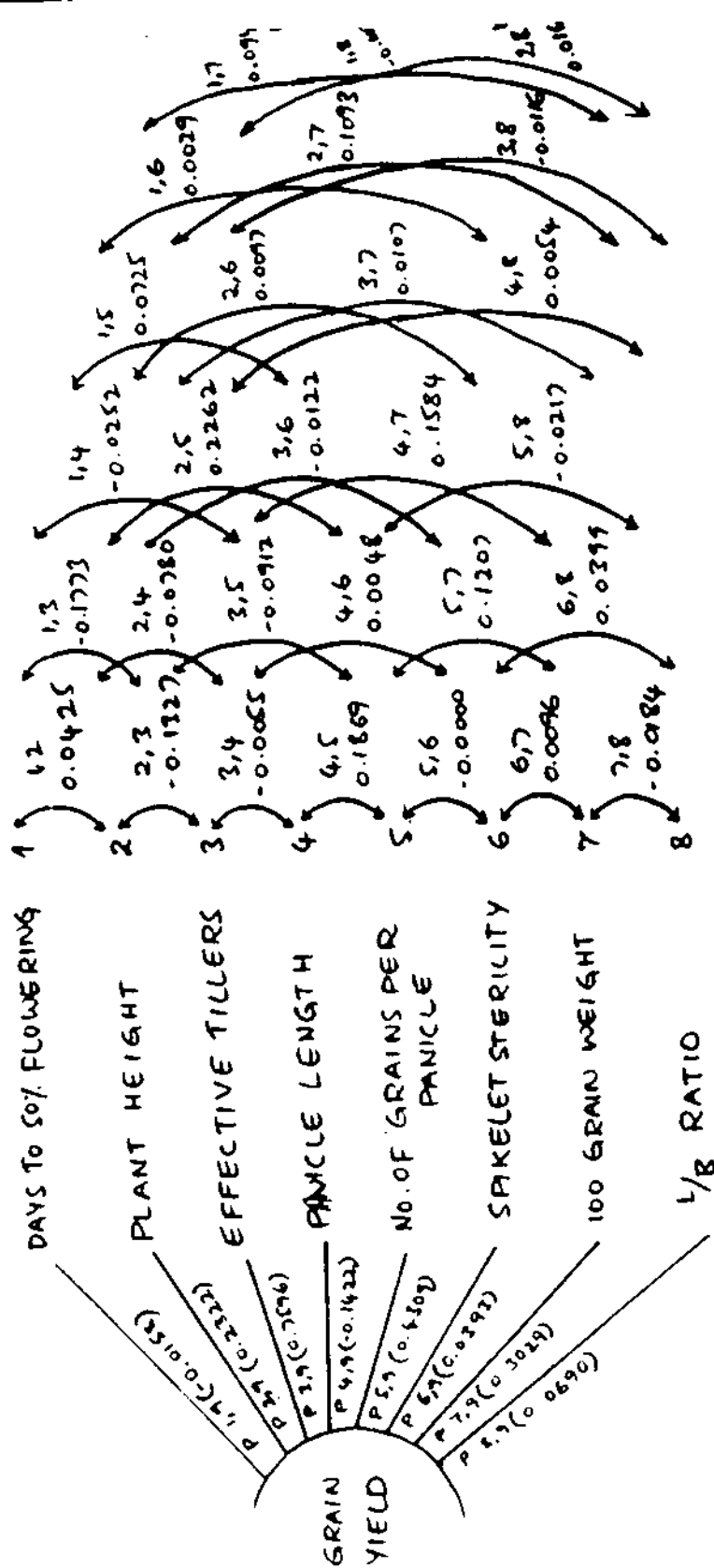


Fig.3: PATH DIAGRAM SHOWING DIRECT AND INDIRECT EFFECTS ON YIELD IN F₂ GENERATION OF RICE CROSSES OF 7 x 7 DIALLEL

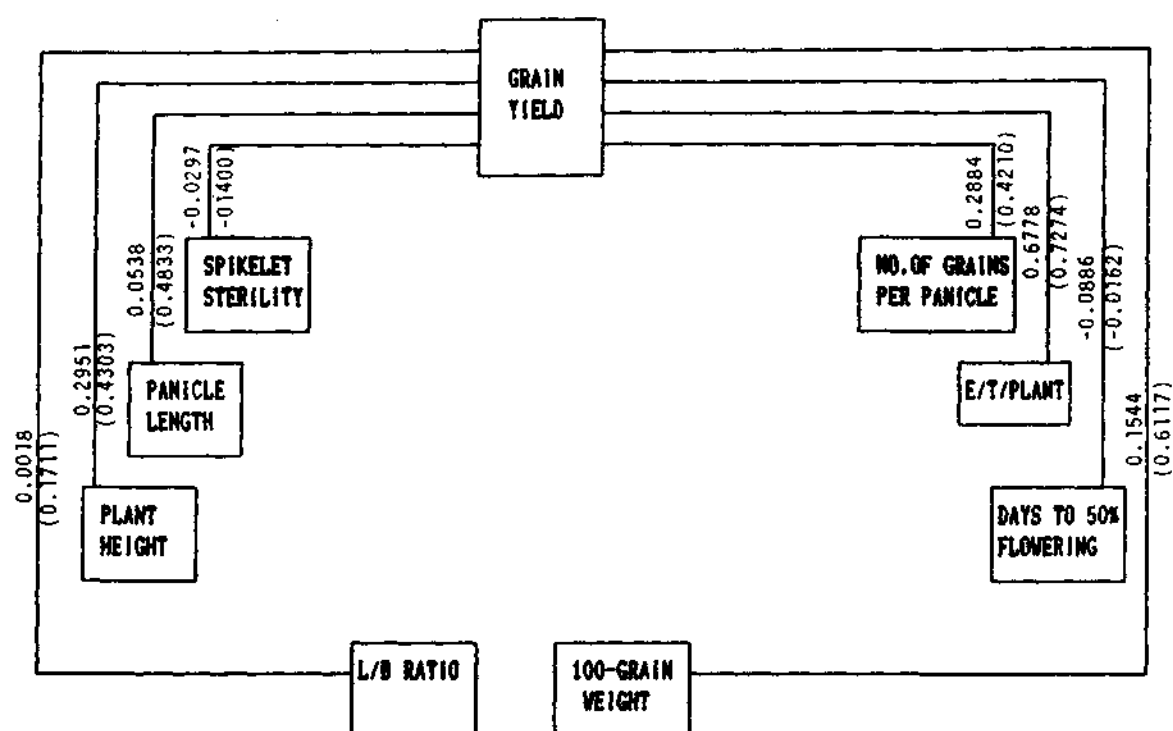


FIG. 4: PATH DIAGRAM SHOWING CAUSE-EFFECT RELATIONSHIP IN F₁ GENERATION (VALUES IN PARENTHESES INDICATE CORRELATION COEFFICIENTS)

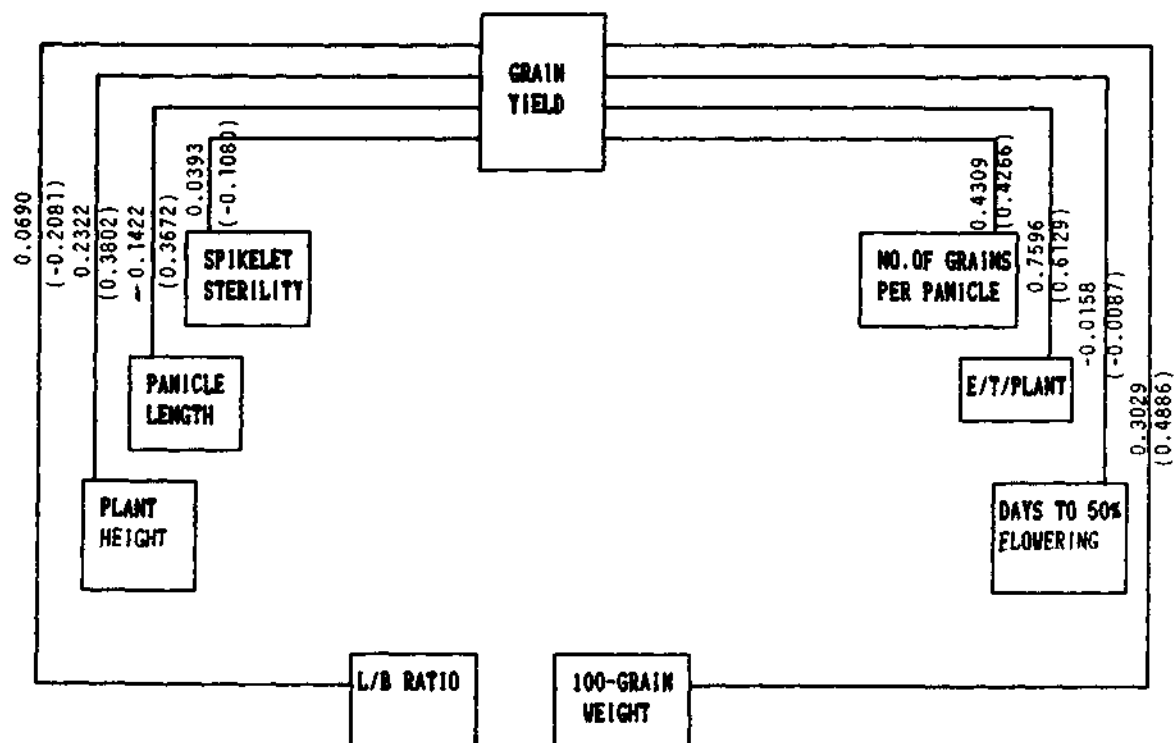


FIG. 5: PATH DIAGRAM SHOWING CAUSE-EFFECT RELATIONSHIP IN F₂ GENERATION (VALUES IN PARENTHESES INDICATE CORRELATION COEFFICIENTS)

spikelet sterility showed negligible indirect effect on grain yield for this trait.

In F_2 generation, the effect of this trait on grain yield was negligible (-0.0158) with negative correlation for yield (-0.0087). The indirect effects through 100 grain weight, plant height, grains per panicle, spikelet sterility were feeble on grain yield whereas L/B ratio and panicle length showed negative indirect effects on grain yield for this trait.

It is noticed that days to 50% flowering had the negative direct effect with negative correlation for yield both in F_1 and F_2 generations.

2. Plant height:

In F_1 generation, direct effect of plant height on grain yield was positive and moderate (0.2951) with positive correlation for yield (0.4303). The indirect effect of plant height through 100-grain weight, L/B Ratio, panicle length were positive and negligible with positive low (0.1871) indirect effect by grains per panicle on grain yield. The indirect effects of plant height through other characters was negative and negligible on yield.

In F_2 , this trait showed positive and moderate (0.2322) direct effect on grain yield with positive correlation for yield (0.3802). The indirect effects through L/B Ratio and spikelet sterility was positive and negligible, by 100-grain weight was positive and low (0.1093), by number of grains per panicle was positive and moderate (0.2262) on grain yield. Negative low indirect effects (-0.1327) by effective tillers per plant with negative, negligible effects through days to 50% flowering and panicle length on grain yield were observed for this trait.

It is observed that plant height showed moderate direct effects with positive correlation for yield both in F_1 and F_2 study.

3. Effective tillers per plant:

In F_1 , the direct effect of this trait was highly positive (0.6778) on grain yield with positive correlation for yield (0.7274). The indirect effects of this trait through 100-grain weight, L/B ratio, days to 50% flowering, panicle length and spikelet sterility were positive and negligible on grain yield whereas remaining characters showed negative, negligible indirect effects on yield.

In F_2 generation also the direct effect of this trait was positive and high (0.7596) with positive correlation for yield (0.6129). The indirect effects of this trait through 100-grain weight, L/B ratio, days to 50% flowering, plant height, panicle length, grains per panicle and spikelet sterility was found negligible on grain yield.

It is observed that effective tillers per plant showed high direct effects with positive correlation for grain yield.

4. Panicle length:

In F_1 generation, the direct effect of panicle length on grain yield was negligible with positive correlation for yield (0.4833). The indirect effect through plant height and grains per panicle on grain yield was positive for this trait whereas negligible indirect effects of this trait on grain yield through 100-grain weight, L/B Ratio, days to 50% flowering, effective tillers per plant and sterility was recorded.

In F_2 generation, the direct effect of panicle length on grain yield showed negative and low (-0.1422) with positive correlation for yield (0.3672). The indirect effect of this trait through 100-grain weight, plant height

and grains per panicle was positive and low on grain yield whereas through L/B ratio, days to 50% flowering, effective tillers per plant and spikelet sterility were having negligible indirect effects on grain yield.

It is observed that panicle length showed negligible direct effects on grain yield with positive correlation for yield both in F_1 and F_2 .

5. Grains per panicle:

In F_1 generation, this trait has positive and moderate (0.2884) direct effects on grain yield with positive correlation for yield (0.4210). The other indirect effects (excepting plant height was with positive and low value (0.1914)) were found to be negligible on grain yield.

In F_2 generation, the direct effect of this trait was positive and high (0.4309) on grain yield with positive correlation for yield (0.4266). The indirect effects through 100-grain weight and plant height was positive and low on grain yield whereas through effective tillers per plant was negative and low (-0.1608) and with remaining characters were found to be negligible on grain yield.

It is observed that grains per panicle showed positive, moderate direct effect in F_1 and high direct effect in F_2 on grain yield with positive correlation for yield both in F_1 and F_2 .

6. Spikelet sterility:

In F_1 the direct effect of this trait on grain yield was negative and negligible with negative correlation for yield (-0.1400). The indirect effects through 100-grain weight, L/B ratio and days to 50% flowering were found to be negligible on grain yield. A negative and moderate (-0.2129) indirect effect was shown by effective tillers per plant on grain yield for this trait.

In F_2 , the direct effect of this character on grain yield was positive and negligible (0.0393) with negative correlation for yield (-0.1080). The indirect effects through 100-grain weight, L/B ratio, days to 50% flowering, plant height, panicle length and grains per panicle were negligible on grain yield with negative and moderate (-0.2357) indirect effect by effective tillers per plant on yield for this trait.

It is observed that spikelet sterility showed negative negligible and positive negligible direct effects

in F_1 and F_2 respectively with negative correlation for grain yield both in F_1 and F_2 is a desirable trend.

7. 100-grain weight:

In F_1 generation, the direct effect of 100-grain weight on grain yield was positive (0.1544) with positive correlation for yield (0.6117). The indirect effect of 100-grain weight through number of effective tillers per plant was positive and moderate (0.2683) and the remaining indirect effects through L/B ratio, grains per panicle, panicle length and spikelet sterility on grain yield were negligible. The indirect effect of plant height was positive and low whereas days to 50% flowering showed negative negligible indirect effect on grain yield.

In F_2 generation, the direct effect of this trait on grain yield was positive and high (0.3029) having positive correlation for yield (0.4886). The indirect effect of 100-grain weight through days to flowering, plant height, effective tillers per plant and spikelet sterility on grain yield were negligible whereas number of grains per panicle showed positive and low indirect effect on yield. L/B ratio and panicle length showed negative negligible indirect effect on grain yield.

It is observed that 100-grain weight exhibited +ve with low direct effect in F_1 whereas positive with high direct effect in F_2 showing positive correlation for yield both in F_1 and F_2 .

8. L/B Ratio:

In F_1 , the direct effect of L/B ratio on grain yield was negligible (0.0015) with positive correlation for yield (0.1711). The indirect effect of L/B ratio through effective tillers per plant was highly positive (0.8850). The indirect effects through 100-grain weight, plant height, grains per panicle and spikelet sterility were negligible on yield whereas indirect effects through days to 50% flowering and panicle length were negative and negligible on yield for this trait.

In F_2 , the direct effect of L/B ratio on grain yield was ^{ve} negligible on yield (-0.2081). The indirect effects through effective tillers per plant showed negative and low (-0.1282) on yield whereas remaining characters exhibited negligible effects on grain yield.

It is further observed that L/B ratio expressed positive, negligible direct effects both in F_1 and F_2

recording positive correlation for yield in F_1 and negative correlation for yield in F_2 .

Overall performance:

High direct effects of plant height, effective tillers per plant and number of grains per panicle on grain yield in F_1 whereas high direct effects of plant height, effective tillers per plant and grains per panicle along with 100-grain weight on grain yield in F_2 were observed.

DISCUSSION AND CONCLUSIONS

DISCUSSION AND CONCLUSIONS

The discussion on ^{the} results obtained (on genetic divergence of 79 genotypes, 7 x 7 diallel (21 F₁ and their 21 F₂) from the present study are presented under the following heads.

- a) Genetic divergence
- b) Analysis of variance
- c) Combining ability analysis
- d) Heterosis
- e) Variability, heritability and genetic advance
- f) Correlation studies, and
- g) Path analysis.

a) Genetic divergence:

Genetic divergence among parents is of paramount importance for obtaining desirable improvements. The Mahalanobis's D^2 statistic provides useful statistical method for measuring the amount of genetic diversity in a given population in respect of characters considered together.

The success and use of Mahalanobis's D^2 analysis in quantifying genetic divergence has been used by Das and

Borthakur (1973), Ratho (1973) and Nanda and Singh (1986) in rice. Environmental variations may also be responsible for this diversity as concluded by many workers (Singh et al, 1979, Singh, 1983 and Ratho, 1984) in rice.

The data on eight characters viz., length and breadth of grain, L/B ratio, hulling recovery, alkali score, protein content of brown rice, 1000-grain weight and grain yield per plant were considered as components of fitness and were collected from 79 genotypes for estimating genetic divergence. The results of analysis of variance showed that the treatmental differences were found to be highly significant for all the characters (except breadth of grain) indicating the existence of high variability in the material. Based on D^2 analysis, the 79 genotypes were grouped into eleven clusters and the inter and intra cluster D^2 values were calculated. The cluster mean values were worked out and the entire information is presented in Tables 1 to 6.

Divergence analysis is performed to identify the diverse genotypes for hybridization purposes. Clustering by D^2 statistics is useful in identifying the magnitude of genetic divergence. The genotypes grouped together are less divergent than the ones which fall into different clusters. With the help of D^2 values or "D" values cluster diagram was

drawn in Fig.1 showing mutual relationship between and within clusters. To get good results and variability, crossing programme may be done between genotypes of clusters showing maximum divergence.

Based on genetic divergence studies and as per the breeding objectives, seven parents viz., Basmati-370 (VIII), DW 8 (VII), IET 1444 (XI), Tellahamsa (III), Prabhat (I), Taichung Native-1 (V) and BPT 1235 (IV) from each of seven different clusters were selected and utilised in 7 x 7 diallel crossing programme to understand the nature of gene action of sixteen characters of yield, yield components and quality characters.

The mean values of selected parents are presented in Table 7.

b) Analysis of variance

The data collected on 16 different characters of yield, yield components and quality characters in respect of the material of 7 x 7 diallel and their 21 F_1 and F_2 progenies was computed for analysis of variance.

From the results of analysis of variance, it is observed that significant differences were found in the

material for the sixteen characters studied with the exception of L/B ratio in F_1 ; kernel elongation and days to 50% flowering in F_2 suggesting that the material used for the study possessed high genetic variability. The results are in accordance with the findings of Ghosh et al (1981), Kotaiah (1983) and Gopinath et al (1984). The mean values and their range of variations from sixteen characters in respect of 7 parents and their 21 F_1 and F_2 progenies also revealed the existence of high genetic variability in the material of the present study.

c) **Combining ability analysis:**

The analysis of diallel cross provides valuable genetic information for deciding efficient breeding procedures leading to rapid improvement in the desirable direction. It also gives an idea about the relative magnitude of additive and non-additive types of gene action in the expression of a trait and helps in partitioning the total genetic variation into the effects due to general and specific combining ability. It serves as a very useful tool in selecting desirable parents for hybridization programme to develop promising material for crop improvement.

In general, the choice of a breeding method primarily depends upon the nature and magnitude of gene action. When

additive effects forms the principle factors for genetic variance, use of pedigree method could be desirable.

When both additive and non-additive gene effects are involved with pronounced non-additive gene effects, reciprocal recurrent selection can be followed.

In F_1 study, the results of combining ability analysis on the material of present study revealed that mean squares due to both GCA and SCA were found to be highly significant for the characters viz., days to 50% flowering, plant height, effective tillers per plant, panicle length, grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant, length of grain, breadth of grain, hulling recovery, volume expansion, water uptake and protein content of brown rice indicating that the characters are under the control of both additive and non-additive gene effects. The character, kernel elongation showed highly significant mean squares of GCA indicating control of additive gene effects. The character, L/B ratio exhibited non-significant mean squares for both GCA and SCA. As regards the magnitude of variance, it is observed that relatively high magnitude of SCA variance over GCA variance was found in respect of characters effective tillers per plant, grains per panicle, spikelet sterility, 100-grain

weight, grain yield per plant, length and breadth of grain, hulling recovery, volume expansion and water uptake indicating that the characters are having predominance of non-additive gene action. The character, L/B ratio also showed predominant non-additive gene action. The characters days to 50% flowering, plant height, breadth of grain and protein content of brown rice showed relatively high magnitude of GCA variance over SCA indicating that the characters are having predominance of additive gene action.

In F_2 study, the results of combining ability analysis on the material revealed that mean squares due to both GCA and SCA were found to be highly significant for the characters plant height, effective tillers per plant, grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice, indicating that the characters are ~~are~~ under the control of both additive and non-additive gene effects. The characters panicle length, breadth of grain and kernel elongation showed highly significant mean squares of GCA indicating control of additive gene effects. The character, days to 50% flowering exhibited non-significant mean squares for both GCA and SCA.

As regards the magnitude of variances ^{in F_2 was} ~~it is~~ observed that relatively high magnitude of SCA variance over GCA variance in respect of characters effective tillers per plant, grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice, indicating that the characters are having predominance of non-additive gene action. The characters panicle length, breadth of grain and kernel elongation showed relatively high magnitude of GCA variance over SCA variance indicating that the characters are having additive gene action. The character, days to 50% flowering also showed predominance of additive gene action.

The differences found in the significance of mean squares due to GCA and SCA for certain traits from F_1 and F_2 generation or vice versa may be attributed to segregation in F_2 and also GxE interaction.

When both F_1 and F_2 results of combining ability analysis were taken into consideration, the common characters which showed additive and non-additive gene effects with predominance of non-additive gene actions both in F_1 and F_2 were effective tillers per plant, grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant,

length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and panicle length suggesting that improvement of these characters is possible by recurrent selection. The results are in agreement with the findings of Dhaliwala and Sharma (1990), Zaman, ^{et al} ~~Siddique and Prasad~~ (1989), Agarwal and Sharma (1988), Sardana and Borthakur (1987), Sarthe, ^{et al} ~~Singh and Perreju~~ (1986), Mahapatra and Mohanty (1985), Sonrexa (1984), Singh and Singh (1982) and Sukanya Subramanian and Rathinam (1984).

The characters days to 50% flowering, plant height and breadth of grain showed additive and non-additive gene effects with predominance of additive gene action ^{while} ~~and~~ kernel elongation ^{showed only} ~~with~~ additive gene action only both in F_1 and F_2 suggesting that improvement of these characters is possible by simple selection through pedigree method. Similar results were reported by Kumar and Sreerangaswamy (1986), Singh and Singh (1985), Mahapatra and Mohanty (1985), Sukanya Subramanian and Rathinam (1984), Panwar and Paroda (1983) and Good, ^{et al} ~~Siddique and Zaman~~ (1983).

For protein content of brown rice, predominance of additive gene action in F_1 and non-additive gene action in F_2 was observed. The difference in predominance of gene

action in F_1 and F_2 may be attributed to segregation ^{and also GE interaction} in F_2 for the trait.

The improvement for higher protein value could be rapidly achieved by kinds of selection which involve certain degree of intercrossing and recurrent selection. Similar views were also reported by Good and Siddique (1983 and 1986), Singh and Singh (1982) and Ghosh ^{et al} ~~Wita~~ ~~and~~ ~~Singh~~ (1976).

GCA and SCA Effects:

The GCA and SCA effects of the parents and their concerned crosses respectively for both F_1 and F_2 are discussed hereunder characterwise. In general, differences were found in GCA and SCA effects for specific parents to some traits from F_1 to F_2 . The inconsistent results of GCA effects over generations could possibly be attributed to genotype x environment interaction effects and also due to the role of non additive gene effects. The inconsistency in SCA effects observed over generations is attributed to dominance x dominance interaction and genotype x environment interaction and this was reported by Kandalkar and Nigam (1993).

1) **Days to 50% flowering:**

The parents, DW 8 and Basmati-370 in F_1 and Basmati alone in F_2 are having significant GCA effects and high per se performances over other parents indicating that they are good combiners.

The SCA effects revealed that three crosses viz., C_1 , C_5 and C_8 derived from the above parents showed significant values in F_1 and non-significant values in F_2 . The cross, C_1 , is a derivative of parents with good GCA effects and also high per se performances, whereas ^{the} cross, C_8 , is a derivative of parents with high per se performance and low per se performance. The results of F_1 indicate that parents with high per se performances and good GCA effects may give good crosses for this trait. Lack of significant SCA effects in F_2 indicates that parents with neither high per se performances nor good GCA effects are responsible for giving good crosses. The results are in agreement with the findings of Mahapatra and Mohanty (1985).

2) **Plant height:**

The two parents viz., Basmati-370 and D.W. 8 showed significant GCA effects both in F_1 and F_2 with high per se performance over other parents indicating that they are good combiners. The SCA effects revealed that ten crosses

viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} and C_{16} in F_1 study derived from the above parents showed positive significant values whereas in F_2 four crosses viz., C_2 , C_4 , C_6 and C_{10} derived from the same parents were positively significant. All the above crosses both in F_1 and F_2 are derivatives of parents with good GCA effects and per se performances. The results indicate that parents both in F_1 and F_2 with good GCA effects and per se performances have given good crosses with significant SCA effects. The results are in conformity with the findings of Mahapatra and Mohanty (1985).

(3) Effective tillers per plant:

The three parents, DW 8, Tellahamsa and TN 1 showed significant GCA effects both in F_1 and F_2 . But high per se performance was seen in two parents viz., Tellahamsa and TN 1 whereas low per se was found in DW 8 indicating that the three parents are good combiners for this trait.

The SCA effects showed that the ^{five} ~~7~~ cross combinations viz., C_7 , C_8 , C_9 , C_{10} and C_{11} in F_1 and four crosses viz., C_7 , C_8 , C_{10} and C_{11} in F_2 were positively significant. The crosses from both F_1 and F_2 are derivatives of parents viz., Basmati and DW 8 which are with low per se performance and the parent, DW 8 only was having significant GCA effect.

The results indicate that parents both in F_1 and F_2 are with low per se performance but one parent among them was ^{with} significant GCA effect and they have given good crosses with significant SCA effects for this trait. Thus it is evident that neither parents with good GCA effect nor per se performance could give combinations with significant SCA effects for this character. Similar results were reported by Mahapatra and Mohanty (1985).

4) Panicle Length:

The parents, Basmati-370 and DW 8 in F_1 were with good GCA effects and high per se performance over other parents whereas in F_2 only one parent i.e., DW 8 alone was with good GCA effect indicating that they are good combiners for this trait.

The SCA effects in five crosses viz., C_2 , C_3 , C_{10} , C_{12} and C_{15} in F_1 exhibited significant positive values whereas in F_2 none of the crosses showed significant SCA effect for this trait. The results in F_1 indicated that parents with good GCA effects and high per se performances when crossed with parent, IET 1444 having negative GCA effect with moderate per se performance has given combinations with significant SCA effects, whereas in F_2 , none of the crosses possessed significant positive SCA effects

indicate^{ing} that neither high per se performance nor good GCA effects of parents are responsible for giving crosses with significant SCA effects for this character. Similar results were reported by Mahapatra and Mohanty (1985).

5) Grains Per Panicle:

The parents, Basmati-370 and DW 8 both in F_1 and F_2 were with good GCA effects. But DW 8 has high per se performance whereas Basmati-370 has low per se performance. But the GCA effects indicate that they are good combiners for this trait.

The SCA effects showed that seven crosses viz., C_1 , C_2 , C_3 , C_4 , C_9 , C_{12} and C_{15} exhibited significant positive values in F_1 whereas in F_2 three crosses viz., C_2 , C_3 and C_4 were with significant SCA effects for this trait. The F_1 results indicate that parents possessing good GCA effects with high or low per se performance when crossed with parent IET 1444 having negative GCA effects with low per se performance has given crosses with significant SCA effects. But in F_2 the parent viz., Basmati-370 with good GCA effect and low per se performance when crossed with other parents has given crosses with significant SCA effects. The results are in conformity with the findings of Mahapatra and Mohanty (1985).

6) Spikelet Sterility:

The parent, Basmati-370 both in F_1 and F_2 showed good GCA effects with high per se performance over other parents whereas IET 1444 expressed negative GCA effect with low per se performance for this trait both in F_1 and F_2 . Negative values for this trait are desirable for improvement. So IET 1444 is a good parent.

The SCA effects recorded that eleven crosses viz., C_1 , C_2 , C_9 , C_{11} , C_{12} , C_{15} , C_{16} , C_{17} , C_{18} , C_{20} and C_{21} expressed significant negative values for this trait in F_1 whereas in F_2 , two crosses viz., C_2 and C_{11} showed significant negative SCA effects. The results indicate that the parent, Basmati-370 possessing good GCA effect and high per se performance gave crosses with significant positive SCA effects both in F_1 and F_2 whereas parent, IET 1444, with negative GCA effect and low per se performance both in F_1 and F_2 gave negative SCA effect crosses only in F_1 but not in F_2 which behaviour can be attributed to segregation in F_2 . The above results were reported by Mahapatra and Mohanty (1985).

7) 100-grain weight:

The two parents viz., DW 8 and Prabhat both in F_1 and F_2 were found to be with good GCA effects possessing high

per se performance indicating that they are good combiners for this trait.

The SCA effects showed that seven crosses viz., C_2 , C_3 , C_5 , C_9 , C_{11} , C_{13} and C_{18} expressed significant positive values for this trait in F_1 whereas in F_2 , the values are confined to only three crosses viz., C_2 , C_5 and C_{18} . The results indicate that only one parent, DW 8 with good GCA effect and high per se performance gave crosses with significant positive SCA effects in F_1 whereas in F_2 , none of the parents with good GCA effect and high per se performance gave good crosses, instead parents viz., Basmati-370 and Tellahamsa having negative GCA effects with low per se performance over other parents both in F_1 and F_2 gave crosses with significant SCA effects in combination with parents having negative GCA effects and low per se performance. The above results further revealed that parents with negative GCA effects and low per se performance also can give good cross combinations with significant SCA effects indicating that selection of parents basing on GCA effects and per se performances alone is not adequate and requires actual study by effecting diallel crossing programme for this trait. The findings are in agreement with Panwar and Paroda (1983), Singh (1984) and Mahapatro and Mohanty (1985).

8) Grain yield per plant:

The two parents viz., DW 8 and Prabhat both in F_1 and F_2 were found to be with good GCA effects and high per se performance over other parents indicating that they are good combiners for this trait.

Eleven crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} , C_{11} , C_{12} and C_{15} exhibited significant positive SCA effects in F_1 whereas in F_2 nine crosses viz., C_2 , C_3 , C_4 , C_6 , C_7 , C_8 , C_9 , C_{10} and C_{11} expressed similar SCA effects. The results also indicate that the above crosses both in F_1 and F_2 are derivatives of parents with good GCA effects and high per se performance for this trait. Similar results were reported by Mahapatro and Mohanty (1985), Sardana and Borthakur (1987), Kuo and Liv (1987) and Kausik and Sharma (1988).

9) Length of Grain:

The parents viz., DW 8, BPT 1235 in F_1 and in F_2 DW 8, Tellahamsa and BPT 1235 recorded significant GCA effects with high per se performances over other parents indicating that they are good combiners for this trait.

Six crosses viz., C_7 , C_8 , C_9 , C_{11} , C_{13} and C_{14} have expressed significant positive SCA effects in F_1 whereas

three crosses viz., C_9 , C_{13} and C_{14} in F_2 showed significant positive SCA effects. The results indicate that only one out of the three parents viz., DW 8 with good GCA effect and high per se performance gave good cross with significant positive SCA effect both in F_1 and F_2 . Whereas the parent, IET 1444 with negative GCA effect both in F_1 and F_2 possessing low per se performance when crossed with parents having negative GCA effects and low per se performances has given good cross combinations both in F_1 and F_2 with positive significant SCA effects. The results further revealed that parents with negative GCA effects and low per se performances when crossed with parents having negative GCA and low per se performances can also give good cross combinations with significant SCA effects for this trait. The above findings are in agreement with the findings of Singh and Richharia (1977), Panwar and Paroda (1983), Singh (1984), Singh and Singh (1985) and Mahapatra and Mohanty (1985).

10) Breadth of Grain:

The three parents viz., DW 8, Prabhat and TN 1 showed significant GCA effects with high per se performance over other parents both in F_1 and F_2 indicating that they are good combiners for this trait.

The SCA effects of six crosses viz., C_2 , C_3 , C_5 , C_{10} , C_{18} and C_{20} exhibited significant positive SCA effects in F_1 whereas there is only one cross viz., C_2 with significant SCA effect in F_2 . The results indicate that in F_1 , parents, DW 8 and Prabhat possessing good GCA effects and high per se performance gave good crosses with significant SCA effects. Further it is observed in F_1 that parents, Basmati and Tellahamsa with negative GCA effects and low per se performance in combination with parents having low per se performance gave good crosses. But parent, TN 1, with significant GCA effect and high per se performance did not give good crosses. In F_2 , the cross C_2 , a derivative of Basmati-370 x IET 1444, was found good indicating that combination of parents with negative GCA effects and low per se performances gave cross combination with significant SCA effect for this trait. The results also indicate that selection of parents with high GCA effects and per se performance alone is not adequate but requires confirmation by actual crossing programme for this trait as none of the parents with high GCA and high per se gave good crosses, instead, parents with negative GCA and low per se performance gave good cross in F_2 for this trait. The results are in confirmity with the findings of Singh and Richharia (1977), Panwar and Paroda (1983), Singh and Singh (1985) and Mahapatra and Mohanty (1985).

11) L/B Ratio:

The parents viz., Basmati-370 and BPT 1235 were with positive significant GCA effects in F_2 but not in F_1 indicating that they are good combiners for this trait only in F_2 . This may be attributed to segregation in F_2 .

The cross C_8 (DW 8./Tellahamsa) showed significant SCA effect in F_1 whereas in F_2 none of the cross combinations showed significant SCA effects. The results indicate that in F_1 , parents possessing non-significant positive GCA effects with low (DW 8) and high (Tellahamsa) per se performances gave cross with significant SCA effect for this trait, eventhough none of the parents showed significant GCA effects. In F_2 none of the crosses recorded significant SCA effects, inspite of two parents viz., Basmati-370 and BPT 1235 possessed significant GCA effects and high per se performances for this trait. Thus it is evident that parents selection basing on GCA effects and per se performances is not sufficient but requires confirmation by actual crossing programme for this character. These findings are in agreement with the findings of Singh and Richharia (1977), Panwar and Paroda (1983), Singh (1984), Sonrexa (1984), Singh and Singh (1985) and Mahapatra and Mohanty (1985).

12) Hulling Recovery:

The parents viz., Prabhat and TN 1 showed positive significant GCA effects having high and moderate per se performances respectively in F_1 over other parents whereas in F_2 , only one parent viz., TN 1 recorded positive significant GCA effect with high per se performance indicating that they are good combiners for this trait. Parent, BPT 1235, though possessed high per se performance did not show significant GCA effect in F_2 , instead it showed negative GCA in F_1 .

The SCA effects of seven crosses viz., C_2 , C_4 , C_7 , C_9 , C_{11} , C_{13} and C_{21} were very interestingly possessed significant SCA effects in F_1 whereas none of the crosses in F_2 showed significant SCA effects for this trait. The results indicate that the parents with high GCA effect may not possess high per se performance and vice versa for this character. In F_1 , only one cross viz., C_{21} (TN 1/BPT 1235) a combination of TN 1 parent with significant GCA effect and high per se performance when crossed with parent, BPT 1235 having negative GCA effect and high per se performance showed significant SCA effect for this trait. The remaining crosses in F_1 , with combinations of parents with negative GCA effect and low per se performance i.e., Basmati-370 when crossed with parents having negative GCA and moderate per se

performance (IET 1444), and another parent (Prabhat) with positive significant GCA and moderate per se performance, gave crosses with significant SCA effects. In F_2 , none of the crosses were with significant positive SCA effects eventhough parent, TN 1, is available with significant GCA effects and high per se performance both in F_1 and F_2 . The results are in confirmity with the findings of Sonrexa (1984) and Mahapatro and Mohanty (1985).

13) Volume Expansion:

The parents viz., Tellahamsa and BPT 1235 recorded significant positive GCA effects with high per se performance both in F_1 and F_2 indicating that they are good combiners for this trait.

Five crosses viz., C_3 , C_7 , C_{16} , C_{18} and C_{20} in F_1 and three crosses in F_2 viz., C_7 , C_{16} and C_{20} exhibited significant positive SCA values. The three crosses viz., C_7 , C_{16} and C_{20} were found to be with good SCA effects both in F_1 and F_2 . The cross C_7 , is a derivative of (DW 8/ IET 1444) parents possessing negative GCA effects and moderate per se performances; C_{16} (Tallahamsa/Prabhat), is a derivative of parents with significant positive GCA and high per se i.e., (Tallahamsa) and negative GCA and low per se performance (Prabhat) and C_{20} , (Prabhat/BPT 1235), is

derivative of parent Prabhat with negative GCA and low per se and parent, BPT 1235, with positive significant GCA and high per se performance indicating that parents with different GCA effects whether negative or positive having different per se performances may also give crosses with significant SCA effects and thus requires confirmation by actual crossing since selection of parents basing on GCA effects and per se performances alone is not adequate for this trait. Similar results were reported by Zaman et al ~~Stedique and Prasad~~ (1989).

14) Water Uptake:

The three parents viz., Tellahamsa, Prabhat and BPT 1235 in F_1 and two parents viz., Tellahamsa and BPT 1235 in F_2 recorded significant positive GCA effects with high (Tellahamsa and BPT 1235) and low (Prabhat) per se performances indicating that the later two parents are good combiners for this trait.

The SCA effects showed that only one cross i.e., C_{20} (Prabhat/BPT 1235) in F_1 and five crosses viz., C_6 , C_{13} , C_{16} , C_{19} and C_{21} in F_2 exhibited significant positive GCA effects for this character. The results indicate that parents with good GCA effects and high per se performances when crossed with parents having negative GCA effects with low to

moderate per se performances can give crosses with good SCA effects and thus requires confirmation by actual crossing besides GCA effects of parental study for this trait. Similar results were reported by Zaman, Siddique and Prasad (1989).

15) **Kernel elongation:**

The three parents viz., Basmati-370, Prabhat and T.N.1 in F_1 and Prabhat alone in F_2 recorded positive significant GCA effects with high (Basmati-370 and Prabhat) and moderate (TN 1) per se performances for this trait indicating that they are good combiners for this trait. The parent, IET 1444, with high per se performance over other parents showed non-significant and negative GCA effects both in F_1 and F_2 for this trait.

Three crosses viz., C_5 , C_{17} and C_{20} in F_1 and none in F_2 showed positive significant SCA values. The results indicate that parents with significant GCA effects and high to moderate per se performances when crossed with parents of significant GCA and non-significant GCA with low per se performance gave significant positive SCA values for this trait in F_1 and none of the crosses in F_2 showed significant SCA values for this trait. Similar results were reported by

Good, Siddique and Zaman (1983) and Mahapatra and Mahanty (1985).

16) **Protein Content of Brown Rice:**

The parents viz., IET 1444 and TN 1 both in F_1 and F_2 were found to be with significant GCA effects and high per se performances over other parents indicating that they are good combiners for this trait.

The SCA effects revealed that eight crosses viz., C_3 , C_5 , C_{10} , C_{11} , C_{12} , C_{14} , C_{19} and C_{20} in F_1 showed significant positive values. In F_2 none of the crosses showed significant positive values for this trait. The results indicate that in F_1 parents with significant GCA values and high per se performances when crossed among themselves or crossed with other parents having non-significant GCA values with moderate to low per se performances gave crosses with significant SCA values. In F_2 , none of the crosses were observed with significant positive SCA effects eventhough parents, IET 1444 and T.N. 1 recording significant positive GCA effects and high per se performances are available for this trait both in F_1 and F_2 . Similar results were reported by Good and Siddique (1986).

D) **HETEROSIS:**

Heterosis breeding is one of the methods of plant breeding to develop high yielding potential hybrids. Heterotic response is normally expressed as deviation of " F_1 " from the mid parental value (Relative heterosis). The degree of heterosis showed may preferably be measured over the superior parent (Heterobeltiosis) and standard parent (Standard heterosis). Such estimates will help in deciding whether the hybrid is of economic value and worth exploiting. MTU 3626 (Prabhat), a popular high yielding variety suitable for both kharif and rabi seasons released from Agricultural Research Station, Maruteru was taken as a standard variety. Though the combining ability analysis is a useful tool in giving clue for selecting the parents and desirable combinations to be used in any breeding programme for the improvement of different traits but requires confirmation whether such of the desirable combinations obtained are actually exhibiting heterotic effects in all the above three classes so that heterotic exploitation of the traits is possible in the desired direction for crop improvement. Heterotic effects were studied for sixteen characters in 21 F_1 s of diallel (7 x 7) and the results are discussed hereunder.

1. Days to 50% flowering:

Out of 21 crosses studied, majority of the crosses showed negative relative as well as negative heterobeltiotic effects whereas very few crosses recorded positive standard heterosis effects for this trait. None of the crosses showed heterotic effects in all the three classes. Three crosses only viz., C_1 , C_5 and C_7 ~~only~~ showed positive heterotic effects both in relative heterosis and standard heterosis. The crosses viz., C_1 and C_5 which showed significant positive SCA effects also showed good heterotic effects for this character indicating that there was relationship between SCA effects and heterotic effects. The results are in agreement with the findings of Kalaimani and Kadambavanasundaram (1988) and Mandal⁴⁶ and Palaniswamy (1989).

2. Plant Height:

Out of 21 crosses studied, most of the crosses showed positive relative and standard heterosis whereas very few crosses showed positive heterobeltiosis for this trait. The crosses which showed positive relative and standard heterosis are more common. Three crosses viz., C_{15} , C_{16} and C_{20} showed common effects in all three classes. C_{16} which showed common heterotic effect also showed significant positive SCA effect indicating relationship between SCA and

heterotic effects. Similar results were reported by Mandal and Palaniswamy (1989).

3. Effective Tillers Per Plant:

Out of 21 crosses studied, six crosses showed positive relative, heterobeltiosis and standard heterosis for this character. The six crosses viz., C_7 to C_{11} and C_{20} which exhibited positive heterotic values in all the three classes, also showed significant positive SCA effects indicating that there is relationship between SCA effects and heterotic effects to this trait. These findings were also reported by Mandal^{et} and Palaniswamy (1989).

4. Panicle Length:

Out of 21, most of the crosses studied showed positive standard heterosis whereas a few crosses showed positive realtive and heterobeltiosis for this trait. The 5 crosses viz., C_2 , C_3 , C_{10} , C_{12} and C_{15} which exhibited positive heterotic values in all the three classes, also recorded significant positive SCA effects indicating that there is relationship between SCA effects and heterotic effects. These results are in accordance with the findings of Sasmal (1988).

5. Grains per panicle:

Out of 21 crosses studied, 11 crosses recorded positive relative, heterobeltiosis and standard heterosis for this trait. The 11 crosses viz., C_1 to C_7 , C_9 , C_{12} , C_{15} and C_{18} which expressed positive heterotic values in all three classes have also recorded significant positive SCA effects indicating that there is relationship between SCA effects and heterotic effects. These results are in conformity with the findings of Man^Ual and Palaniswamy (1989)..

6. Spikelet Sterility:

Out of 21 crosses studied, most of the crosses showed negative relative heterosis whereas only few crosses recorded negative heterobeltiosis and standard heterosis for this character and negative effects for this character are desirable for improvement. Out of 21 crosses, six crosses viz., C_{12} , C_{15} , C_{16} , C_{17} , C_{18} and C_{21} which showed common negative heterotic effects in all three classes also expressed negative SCA effects indicating that there is relationship between negative heterotic effects and negative SCA effects. The results were in accordance with the findings of Sasmal (1985).

7. 100-grain weight:

Out of 21 crosses studied, eight crosses showed positive relative heterosis, heterobeltiosis and standard heterosis for this character. Out of 21 crosses, eight crosses viz., C₅, C₉, C₁₀, C₁₁, C₁₂, C₁₃, C₁₆ & C₂₀ showed positive common heterotic effects in all the three classes. Out of eight crosses, four crosses showed significant positive SCA effects indicating that there is relationship between SCA effects and heterotic effects. The results are in confirmity with the findings of Paramasivan (1986).

8. Grain yield per plant:

Out of 21 crosses studied, ten crosses showed positive relative, heterobeltiotic and standard heterosis for this character. Out of 21 crosses, ten crosses viz., C₃, C₄, C₇, C₉, C₁₀, C₁₁, C₁₂, C₁₅, C₁₆ and C₁₇ showed positive common heterotic effects for all the three classes. Out of ten, seven crosses showed significant positive SCA effects indicating a good relationship between SCA effects and heterotic effects for this trait. The results are in confirmity with the findings of Srivastava and Seshu (1982), Mahapatra and Mohanty (1985), Sasmal (1988) and Man^yal and Palaniswamy (1989).

9. Length of grain:

Out of 21 crosses studied, most of the crosses showed positive relative and standard heterosis but very few crosses showed positive heterobeltiotic effects to this trait. Six crosses viz., C_8 , C_9 , C_{11} , C_{13} , C_{14} and C_{19} showed common heterotic effects for all the three classes. Out of six, five crosses showed positive significant SCA effects indicating that there is some relationship between SCA effects and heterotic effects for this character. Similar results were reported by Paramasivan (1979), Sahai et al (1986), Sasmal (1988) and Man²gal and Sunil Saron (1989).

10. Breadth of grain:

Out of 21 crosses studied, most of the crosses showed positive relative heterosis whereas very few crosses showed positive heterobeltiotic and standard heterotic effects for this trait. Three crosses viz., C_2 , C_{10} and C_{20} recorded positive heterotic effects for all three classes along with significant positive SCA effects indicating that there is relationship between SCA effects and heterotic effects. The results are in agreement with the findings of Singh and Singh (1985), Sahai et al (1986) and Sasmal (1988).

11. L/B Ratio:

Out of 21 crosses, most of the crosses showed positive standard heterotic effects but very few crosses recorded positive relative heterosis, heterobeltiotic and standard heterotic effects for this trait. Four crosses viz., C₇, C₉, C₁₃ and C₁₄ showed positive heterotic effects for all three classes. Only one cross i.e., C₈ showed significant positive SCA effect for this character. In general, there was poor relationship existed between SCA effects and heterotic effects. The results are in confirmity with the results of Paramasivan (1979), Singh and Singh (1985) and Mandal and Sunil Saron (1989).

12. Hulling recovery:

Out of 21 crosses studied, very few crosses recorded positive values for all three classes of heterotic effects for this trait. Five crosses viz., C₂, C₄, C₇, C₉ and C₁₃ expressed positive heterotic effects for all the three classes and also exhibited positive significant SCA effects indicating some relationship between SCA effects and heterotic effects. Similar results were reported by Tomar (1987) and Mandal and Sunil Saron (1989).

13. Volume Expansion:

Out of 21 crosses studied, very few crosses exhibited positive values for all three classes of heterotic effects for this trait. Two crosses viz., C_7 and C_{16} which showed positive heterotic effects for all the three classes showed positive significant SCA effects indicating relationship between SCA effects and heterotic effects. The results are in agreement with the findings of Mandal and Sunil Saron (1989).

14. Water uptake:

Out of 21 crosses, nine crosses showed positive relative and twelve crosses standard heterosis whereas six crosses recorded positive heterobeltiotic effects for this trait. Six crosses viz., C_6 , C_9 , C_{10} , C_{16} , C_{19} and C_{21} showed positive heterotic effects for all three classes also showed positive significant SCA effects. The results indicate that, in general, there was relationship between SCA effects and heterotic effects. Similar results were reported by Sarathe, Singh and Perraju (1986) and Mandal and Sunil Saron (1989).

15. Kernel elongation:

Out of 21 crosses, most of the crosses recorded negative heterotic effects for all three classes to this

trait. Only one cross i.e., C₁₇ showed positive heterotic effect for all the three classes and this cross also showed positive significant SCA effect indicating that there was relationship between SCA effect and heterotic effect for this character. Similar results were reported by Sarathe, ~~Singh and Parraju~~ ^{et al} (1986) and Mandal and Sunil Saron (1989).

16. Protein content of Brown rice:

Out of 21 crosses, most of the crosses expressed positive relative and standard heterosis whereas very few crosses showed positive heterobeltiotic effect for this trait. Ten crosses viz., , C₁, C₄, C₆, C₉, C₁₀, C₁₁, C₁₄, C₁₆, C₁₉ and C₂₁ showed positive common heterotic effects for all the three classes to this trait. Out of ten, five crosses exhibited significant positive SCA effects indicating relationship existed between SCA effects and heterotic effects to this trait. Tomar (1987) and Shailaja Hittalmani (1991) reported similar results.

In general, cross nine (DW 8/ Prabhat) showed heterotic effects to nine characters combining four yield components (effective tillers per plant, grains per panicle, 100-grain weight and grain yield per plant) and five quality characters (length of grain, L/B ratio, hulling recovery, water uptake and protein content of brown rice)

followed by cross, C_{16} (Tellahamsa/Prabhat) with eight characters combining five yield components (plant height, panicle length, spikelet sterility, 100-grain weight and grain yield per plant) and three quality characters (volume expansion, water uptake and protein content of brown rice). The cross C_{10} (DW 8/TN 1) showed heterotic effects for six characters (E/T/plant, 100-grain weight, grain yield, breadth of grain, water uptake and protein content of brown rice) followed by seven crosses viz., C_4 , C_7 , C_8 , C_{11} , C_{12} , C_{13} and C_{15} for five characters combined yield components only. Another seven crosses viz., C_1 , C_2 , C_6 , C_{13} , C_{14} , C_{20} and C_{21} , combined quality and yield components, The crosses C_5 and C_{18} showed ^{heterotic effects} for two characters only ~~for~~ (yield components). The cross C_3 for three characters ~~of~~ (yield components). The cross C_{19} for three characters ~~of~~ (quality components) ^{and} The cross C_{17} for two characters combining yield and quality component i.e., kernel elongation. Thus, it can be concluded that out of 21 crosses, nine crosses viz., C_4 , C_7 , C_8 , C_9 , C_{10} , C_{11} , C_{12} , C_{15} and C_{16} showed ^{heterosis} combining yield, yield components and quality characters indicating that there is possibility to combine yield and quality in a desirable direction in rice.

In general, parent DW 8 with all the parents gave five potential desirable combinations combining quality and yield followed by IET 1444 with two desirable combinations and Basmati-370 and Tellahamsa giving each one cross combination.

Thus, parent, DW 8 which is having significant positive GCA effect for eight characters both in F_1 and F_2 gave maximum number of desirable combinations combining quality and yield and hence ^{could be} considered as the best parent.

E. VARIABILITY, HERITABILITY AND GENETIC ADVANCE:

Success of any breeding programme largely depends upon the knowledge of genetic variability present in the given crop species for the character under improvement. The genotypic coefficient of variation measures the range of variability available in a crop and also enables to compare the amount of variability present in different characters. The phenotypic expression of a character is the result of interaction between the genotype and environment. Hence the total variance needs to be partitioned into heritable and non-heritable components so as to assess the true breeding nature of that particular trait. The measure of transmission of a character from parents to offspring is termed as heritability and the consistence in performance of

selected trait in succeeding generations depends on the magnitude of heritable variation present in relation to observed variation. The estimates of genotypic variation alone would not provide the necessary heritable variation that could be required for selection. Hence, information on heritability is a prerequisite for planning a sound programme which would also provide the information to predict genetic gain obtained by selection. The genetic advance is commonly predicted as a product of heritability ratio and selection differential. High estimates of heritability accompanied by high genetic advance shows that there is additive effect for the character under study. If high heritability is accompanied by low genetic advance, then the epistasis and dominance components would be predominant. Therefore, the estimates of expected genetic gain are important to have an idea of the effectiveness of selection. High heritability values are useful in selection of superior types on the basis of phenotypic performances and low heritability values suggest that they are highly influenced by environment. Heritability with genetic advance is of more value in predicting the effect of selection.

The salient features of the results obtained in the present investigation on these parameters viz., variability,

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heritability, genetic advance and genetic advance over per cent mean are discussed hereunder for the sixteen characters under study.

In general, in the present study, it is observed that the PCV estimates for all characters were higher than GCV both in F_1 and F_2 indicating higher degree of interaction of genotypes (exists with the environment). The heritability, genetic advance and genetic advance over mean were found to be in a decreasing trend from F_1 to F_2 for most of the traits and may be attributed to segregation in F_2 coupled with environmental interaction x genotype and also interactions.

1. Days to 50% flowering:

This trait showed that PCV was higher than GCV both in F_1 and F_2 crosses indicating the higher degree of interaction of genotype, exists with environment. High heritability accompanied by average genetic advance was observed in F_1 whereas low heritability coupled with average genetic advance was seen in F_2 and the decrease in heritability trend from F_1 to F_2 may be attributed to segregation. Thus the results indicate that this character is primarily highly heritable and due to segregation in F_2 tending towards frequency of medium duration segregants (as

seen from F_2 data of Table 11) might have given low heritability values; ^{this} is a desirable trend. Hence response to selection in F_2 might be anticipated to some extent in improving this character. Mahapatra and Mohanty (1985) and Agarwal and Sharma (1988) reported ^{similar} ~~the above~~ findings.

2. Plant Height:

This trait exhibited higher PCV over GCV both in F_1 and F_2 showing higher degree of interaction of genotype with environment. High heritability accompanied by moderate genetic advance in F_1 and moderate heritability coupled with moderate genetic advance in F_2 was observed for this character. The variation in heritability trend may be attributed to segregation in F_2 towards frequency of semi-dwarf types as seen from F_2 data in Table 11 is desirable. The results indicate that the character can be improved by selection in F_2 . Similar findings were reported by Maurya et al (1985), Singh et al (1986), Reddy et al (1986) and Ganeson and Subramanian (1990).

3. Effective tillers per plant:

In general, the PCV values were higher than GCV for this trait indicating higher degree of interaction of genotype with environment. High heritability accompanied by low genetic advance was recorded both in F_1 and F_2 crosses

for this character. The results indicate that the character can be improved by selection though frequency of getting types with less effective tillers per plant as seen from F_2 data in Table 11 are becoming more in F_2 . These results are in confirmity with the findings of Rama Rao (1990), Sreenivasa Rao (1989) and Paramasivan and Sreerangaswamy (1988b).

4. Panicle Length:

Higher PCV over GCV was recorded for this trait indicating the interaction of genotype with environment is at a higher degree. Moderate heritability with low genetic advance in F_1 and average heritability with low genetic advance in F_2 was observed for this trait. The difference in heritability may be attributed to segregation in F_2 towards getting more number of less panicle length types as seen from F_2 data. Hence, improvement of this trait is not possible to desired extent by simple selection in F_2 . Similar results were reported by Paramasivan (1986), Sardana et al (1989) and Deosarkar et al (1989a).

5. Number of grains per panicle:

Higher PCV values over GCV was observed for this trait both in F_1 and F_2 indicating the higher degree of interaction of genotype with environment. High heritability

accompanied by moderate genetic advance was recorded for this trait both in F_1 and F_2 . So, the improvement of this character is possible by selection though the frequency of getting types with more number of grains per panicle as seen from F_2 data in Table 11 are becoming less in F_2 . The results are in accordance with the findings of Gomathinayagam et al (1990) and Paramasivan and Sreerangaswamy (1988b).

6. Spikelet sterility:

This trait was highly influenced by environment (non-genetic factors) as the estimate of PCV was higher than that of GCV. High heritability accompanied by low genetic advance in F_1 and moderate heritability coupled with low genetic advance in F_2 was observed for this character. The variation in heritability trend in F_2 may be explained due to segregation of this trait towards more frequency of spikelet sterility types as seen from F_2 data in Table 11 is not desirable. So improvement of this character in the senese that selection of spikelet fertility types is possible to certain extent though environmental influence is there. Similar results were reported by Ramesh Kumar (1989) and De and Surya Rao (1988).

7. 100-grain weight:

This trait showed high PCV estimates over GCV indicating higher degree of interaction of genotype with environment. High (F_1) to moderate (F_2) heritability accompanied by moderate genetic advance both in F_1 and F_2 was observed for this trait. The difference in heritability trend in F_2 may be attributed to segregation towards more frequency of lesser grain weight types as seen from F_2 data in Table 11. The results indicate that there is scope for improvement by selection for this trait. The results are in agreement with the findings of Deosarkar et al (1989a) and Rao and Jagadish (1986).

8. Grain yield per plant:

In general, the PCV values were higher than GCV for this trait both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. High heritability accompanied by average genetic advance was recorded for this character both in F_1 and F_2 suggesting that improvement of this character by selection is possible even though the frequency of getting high yielding types are becoming less in F_2 as seen from F_2 data of Table 11. The results are in agreement with the findings of Ganesan and Subramanian (1990), Pathak and Patel (1989) and Paramasivan and Sreerangaswamy (1989b).

9. Length of Grain:

The PCV values were higher than GCV for this trait both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. High heritability with higher genetic advance was recorded for this trait both in F_1 and F_2 indicating that improvement can be made through selection for this trait. These results are in agreement with the findings of Dhaliwal and Sharma (1990), Sonarexa (1984), McKenzie (1981) and Jennings et al (1979).

10. Breadth of Grain:

The PCV estimates were more than GCV for this character both in F_1 and F_2 indicates higher degree of interaction of genotype with environment. High heritability with average genetic advance in F_1 and average heritability with average genetic advance in F_2 indicates that improvement can be made to certain extent through selection for this trait. These results are in confirmity with the findings of Singh (1985), Sukanya Subramanian (1984), Q.i.Z.B. et al (1983), Reui (1983), Panwar and Paroda (1983) and Jennings et al (1979).

11. L/B Ratio:

The PCV values were lower than GCV in F_1 whereas GCV values were lower than PCV in F_2 for this trait indicating

higher degree of interaction of genotypes exists with environment in F_2 . Low heritability with very high genetic advance in F_1 and high heritability coupled with high genetic advance in F_2 was observed for this character. This difference in heritability trend may be attributed to segregation of this trait in F_2 towards more of coarse grain types. However improvement may be possible through selection in F_2 generation. These results are in agreement with the findings of Maurya et al (1986), Sukanya Subramaniam (1984), Sonrexa (1984), Panwar and Paroda (1983) and Jennings et al (1979).

12. Hulling recovery:

The PCV values were higher than GCV values for this trait both in F_1 and F_2 but the range of variation is very low indicating that there is interaction of genotype with environment. High heritability coupled with moderate genetic advance in F_1 and average heritability with low genetic advance in F_2 was observed for this character. The variation in heritability trend may be attributed to segregation in F_2 towards more of low hulling types as seen from F_2 data of Table 11. Low genetic advance in F_2 indicates that it is highly influenced by environment. Hence improvement of this trait by selection may be possible to limited extent only. The above findings are in agreement

with the findings of Sonrexa (1984) and Richharia and Govindaswami (1962).

13. Volume Expansion:

The PCV estimates for this character exhibited more than GCV both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. High heritability with very high genetic advance in F_1 and average heritability with very high genetic advance in F_2 was observed for this character. The difference in heritability may be attributed to segregation in F_2 towards more number of low volume expansion types as seen from F_2 data. So improvement of this character may be possible by selection in F_2 . The results are in confirmity with the findings of Tomar (1987 and 1982), Kwo^{and Liw}(1987) and Sonrexa (1984) and Good et al (1983).

14. Water Uptake:

This character showed higher PCV estimates over GCV both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. Average heritability with very high genetic advance in F_1 whereas high heritability with very high genetic advance in F_2 was recorded for this trait. The variation in heritability trend may be attributed to segregation in F_2 towards more number of low water uptake

types. So improvement of this character is possible in F_2 by selection. The above findings are in agreement with the findings of Tomar (1987 and 1982), Sarathe et al (1986) and Good et al (1983).

15. **Kernel Elongation:**

This trait exhibited higher PCV values over GCV both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. High heritability with average genetic advance in F_1 and low heritability with low genetic advance in F_2 was observed for this trait. The difference in heritability trend may be attributed to segregation of this character in F_2 towards more of less kernel elongation types. Hence, improvement cannot be suggested through simple selection for this trait. These results are in agreement with the findings of Rao and Liw (1987), Sarathe et al (1986), Good et al (1983) and Tomar and Nanda (1982).

16. **Protein content of brown rice:**

The character showed higher PCV estimates over GCV both in F_1 and F_2 indicating higher degree of interaction of genotype with environment. High heritability with average genetic advance was observed for this trait both in F_1 and F_2 indicating that this character is highly heritable but more influenced by environment and so improvement may be

possible by selection in F_2 . The results obtained are in confirmity with the findings of Narasamma (1987), Good et al (1986), Mosina (1985), Singh and Singh (1982) and Kaul (1981).

In short, the improvement of the characters viz., plant height, effective tillers per plant, grains per panicle, 100-grain weight, grain yield per plant, length of grain, breadth of grain, L/B ratio, volume expansion, water uptake and protein content of brown rice, is possible by selection in F_2 since high to moderate heritability coupled with high to moderate genetic advance was recorded for the above traits both in F_1 and F_2 .

The remaining characters viz., days to 50% flowering, panicle length, spikelet sterility, hulling recovery and kernel elongation showed varying heritability trends indicating that there is scope to improve days to 50% flowering, spikelet fertility and hulling recovery to certain extent by selection. It is further observed that high PCV estimates were seen more, particularly in F_2 as indicated by more PCV values range than in F_1 . The reverting trends of heritability and genetic advance from high (F_1) to low (F_2) in a desirable direction for any character, if any, can be taken to advantage by breeder to improve such traits by selection.

F. CHARACTER ASSOCIATIONS:

Correlation studies are of primary importance to know the suitability of various characters for selection since selection of a particular trait may cause desirable or undesirable changes in the associated characters. Generally direct selection for yield is not aimed at, due to its complex quantitative nature besides environmental influence. As such, high genotypic and environmental interactions are likely to restrict improvement. Therefore, correlation between yield, quality and yield components are of considerable importance in selection programme.

Further, the component characters of yield and quality show different associations among themselves and with yield. Unfavourable associations between desired attributes under selection may limit genetic advance. Hence, a knowledge of association between yield, quality characters and yield components is highly essential for planning a sound selection programme.

In the present investigation correlation estimates were obtained for eleven quantitative characters and five quality characters and the results obtained are discussed hereunder.

1. Days to 50% flowering:

In F_1 this trait expressed a positive and significant association with grain yield components only viz., panicle length, number of grains per panicle, plant height and spikelet sterility whereas negative association was seen with quality characters viz., volume expansion and protein content whereas in F_2 it showed positive association with 100-grain weight only.

The results indicate that ~~the~~ days to 50% flowering is positively associated with grain yield through panicle length, 100-grain weight and number of grains per panicle whereas it has got negative association with quality characters such as volume expansion and protein content. The results are in agreement with the findings of Reddy and Reddy (1986). Kido et al (1968) reported that early varieties formed kernels rich in protein i.e., negative association with protein.

2. Plant height:

In F_1 , this trait exhibited a positive and significant association with grain yield, 100 grain weight, breadth of grain, days to 50% flowering, panicle length, number of grains per panicle and spikelet sterility and significant negative association with quality characters viz., hulling

recovery, volume expansion, water uptake, kernel elongation and protein content whereas in F_2 , the character showed significant positive association with 100 grain weight, length of grain, grain yield, panicle length and number of grains per panicle. This trait showed significant negative association with quality characters viz., hulling recovery, water uptake and protein content. The results indicate that increase in plant height increased grain yield through 100 grain weight, days to 50% flowering, panicle length and number of grains per panicle. In general, this trait showed negative association both in F_1 and F_2 with quality characters viz., hulling recovery, water uptake and protein content. The results are in confirmity with the findings of Sharma and Reddy (1991), Chauhan et al (1988) and Hsieh and Kwo (1982).

3. Effective tillers per plant:

In F_1 , this trait expressed significant positive association with quality characters (hulling recovery and protein content) and with , grain yield and its components (100-grain weight and breadth of grain) whereas significant negative association was observed with spikelet sterility and days to 50% flowering.

In F_2 , it has recorded positive significant association with grain yield and quality character, hulling recovery only whereas significant negative association was observed with spikelet sterility.

The results indicate that increase in effective tillers per plant increased quality characters (hulling recovery, protein content) and grain yield. The results are in agreement with the findings of Ganesan (1987), Paramasivan and Sreerangaswamy (1988).

4. Panicle length:

In F_1 this trait exhibited significant positive association with grain yield and its components viz., plant height, days to 50% flowering, grains per panicle, 100 grain weight, length and breadth of grain whereas significant negative association was found with quality characters viz., volume expansion, water uptake, kernel elongation and protein content.

In F_2 , the character expressed a positive significant association with grain yield and its components viz., 100 grain weight, plant height, grains per panicle, length of grain and breadth of grain whereas significant negative

association was shown for quality characters viz., kernel elongation and protein content.

The results indicate that increase in panicle length increases grain yield through increase in 100 grain weight, plant height, grains per panicle, length and breadth of grain, whereas increase in panicle length shows decrease in quality characters viz., kernel elongation, volume expansion, water uptake and protein content. The results are in agreement with the findings of Chauhan et al (1986) Dhanraj et al (1987b) and Sadananda, Zaman and Siddique (1989).

5. Number of grains per panicle:

In F_1 , this trait positively associated with grain yield and its components viz., 100 grain weight, days to 50% flowering, plant height, panicle length and breadth of grain whereas negative association was observed with quality characters viz., hulling recovery, volume expansion, water uptake, kernel elongation and protein content.

In F_2 , the trait showed significant positive association with grain yield and its components viz., 100 grain weight, plant height, panicle length and breadth of grain whereas significant negative association was observed

with quality characters viz., hulling recovery, L/B Ratio, volume expansion, water uptake, kernel elongation and protein content.

The results indicated that increase in number of grains per panicle increases grain yield through 100 grain weight, days to 50% flowering, plant height, panicle length and breadth of grain whereas increase of this trait resulted in decrease of quality characters viz., hulling recovery, volume expansion, water uptake, kernel elongation and protein content. The results are in conformity with the findings of Dhanraj et al (1987b), Wilfred Manuel and Palanisamy (1989). Sadananda, Zaman and Siddique (1989) reported association of this trait with volume expansion and water uptake.

6. Spikelet sterility:

A negative and non-significant association was observed for this trait in F_1 with grain yield and its components viz., 100-grain weight and L/B Ratio and quality trait (protein content) whereas no association was seen with any other quality characters.

In F_2 , this trait expressed a negative and non-significant relation with yield and its components viz.,

effective tillers per plant, breadth of grain, days to 50% flowering and L/B Ratio but no association was observed with any quality characters.

The results indicate that decrease in spikelet sterility increases grain yield but has got no effect on quality characters.

The results are in agreement with the findings of Prasad et al (1988). No association studies of this trait with quality characters is available.

7. 100 grain weight:

In F_1 , a positive and significant association for this trait was exhibited with grain yield and its components viz., plant height, panicle length, effective tillers per plant, number of grains pr panicle, length and breadth of grain whereas no significant association was observed with L/B Ratio, hulling recovery, kernel elongation and days to 50% flowering.

In F_2 , this trait expressed a positive, significant association with grain yield and its components viz., days to 50% flowering, plant height, panicle length, grains per panicle and breadth of grain whereas a negative significant

association with L/B ratio and protein content was observed.

The results indicate that an increase in 100 grain weight has got no direct influence on any quality characters but indirectly effects quality characters viz., hulling recovery, cooking quality and protein content through grain quality characters viz., length of grain, breadth of grain and L/B Ratio. In general, increase of this trait influenced increase in grain yield along with length and breadth of grain, plant height, panicle length, effective tillers per plant and grains per panicle. Thus, this trait played a critical role in deciding grain yield and quality through grain quality characters (length, breadth and L/B ratio). Similar results were reported by Chauhan et al (1986), Kalaimani and Kadambavanasundaram (1988), Paramasivan and Sreerangaswamy (1988a), Dhanraj et al (1987b) and Kaul (1983).

8. Grain yield per plant:

In F_1 , this trait showed a positive significant association with 100 grain weight, plant height, panicle length, effective tillers per plant, grains per panicle, length and breadth of grain whereas negative, significant

association was seen with quality characters viz., water uptake and kernel elongation.

In F_2 , this trait expressed a positive significant association with 100 grain weight, plant height, panicle length, effective tillers per plant, grains per panicle and grain breadth whereas significant negative association was seen with quality characters viz., water uptake, kernel elongation and protein content.

The results indicate that increase in grain yield is increased by 100 grain weight, plant height, panicle length, effective tillers ^epr plant, grains per panicle and length of grain but decreases quality characters viz., water uptake, kernel elongation and protein content.

The present results also indicate that selection for higher grain yield in a compromised way with suitable grain quality basing^{ed} on millers and consumers preference would be highly effective in improving grain yield coupled with quality improvement. The findings are in agreement with the reports of Rahangdale and Khorgade (1988), Kalaimani and Kadambavanasundaram (1988), Sharma and Reddy (1991), & Kaul (1983).

9. Length of grain:

This character in F_1 expressed a positive, significant association with grain yield and its components viz., 100-grain weight, plant height and panicle length whereas significant negative association was observed with quality characters such as kernel elongation and protein content.

In F_2 , this trait showed a positive and significant association with yield components viz., days to 50% flowering, panicle length, spikelet sterility and L/B ratio and significant negative association with quality character i.e., kernel elongation.

The results indicate that increase in grain length has no influence on grain yield per plant but indirectly controls yield through plant height, panicle length and L/B ratio. This trait has got negative influence on quality characters such as kernel elongation and protein content. The results are in agreement with the findings of Sarial and Uma Ahuja (1991), Sukanya Subramanian (1984), Soomrith et al (1979), Das et al (1980), Tomar and Nanda (1985) and Jennings et al (1979[~]).

10. **Breadth of grain:**

In F_1 , this trait exhibited a significantly positive association with grain yield and its components (100-grain weight, panicle length, effective tillers per plant and grains per panicle) as well as with quality characters such as hulling recovery and protein content.

In F_2 also, it has expressed significant positive association with yield and its components (panicle length, grains per panicle and length of grain) whereas significant negative association was observed with L/B ratio.

The results indicate that increase of this trait, increases yield through an increase in panicle length, effective tillers per plant and grains per panicle and also quality characters such as hulling recovery and protein content. A decrease in breadth of grain increases grain quality through increase in L/B ratio.

The results are in agreement with the findings of Sasmal (1988), Good et al (1986), Sinha (1987), Das et al (1980).

11. L/B Ratio:

In F_1 , no association with any character was observed for this trait whereas in F_2 , positive significant association was observed with cooking quality characters viz., volume expansion, ~~and~~ water uptake and length of grain. A negative significant association was observed for this trait with grain yield components viz., 100-grain weight, grains per panicle and breadth of grain.

The results indicate that increase in L/B ratio improves cooking quality characters through increase in volume expansion and water uptake. Increase in L/B ratio decreases grain yield through decrease in 100-grain weight, grains per panicle, breadth of grain and increase in length of grain. Simple selection for this trait in early generations may be useful to get good quality types coupled with yield and thus grain quality characters viz., length, Breadth and L/B ratio play an important role in deciding quality and yield acceptable to farming community, trader and consumer. The results are in agreement with the findings of Sukanya Subramanian (1984), Soomrith et al (1979), Mallik et al (1978), Chauhan et al (1982), Siva Subramanian (1973), Tomar and Nanda (1985), Jennings et al (1979)^{av} and Gopalakrishna et al (1982).

12. Hulling recovery:

A positive and significant association in F_1 for this trait was found with yield components (effective tillers per plant and breadth of grain) and quality character i.e., protein content of brown rice. Whereas the association was negative with yield components viz., plant height and grains per panicle.

In F_2 , this trait showed a positive and significant association with yield component i.e., effective tillers per plant, and quality characters viz., volume expansion, water uptake and protein content of brown rice whereas significant negative association was observed with yield components viz., days to 50% flowering and grains per panicle.

The results indicate that increased hulling recovery increases volume expansion, water uptake, protein content of brown rice and breadth of grain and also yield only through effective tillers per plant. The results further indicate the possibility to get high yielding types combined with characters having good volume expansion, water uptake, protein content and hulling recovery through proper selection methods. The above findings are in conformity with the reports of Jennings et al (1979), Siva Subramanian et al (1983) and Hartley et al (1983).

13. Volume expansion:

In F_1 , this trait exhibited a negative significant association with yield components viz., days to 50% flowering, plant height, panicle length and grains per panicle whereas positive significant association was observed with water uptake. In F_2 , this character showed positive, significant association with quality characters viz., water uptake, hulling recovery, L/B ratio and protein content of brown rice, whereas the trait showed significant negative association with yield component i.e., grains per panicle.

The results indicate that increase in volume expansion shows increase in water uptake, hulling recovery, protein content, L/B ratio whereas the increase in volume expansion may result in decreased yield indirectly through grains per panicle, panicle length and plant height. The above studies also indicate the possibility of getting high yielding types combined with good volume expansion and protein content of brown rice by adopting proper selection methods. Similar results were obtained by Primo et al (1962), Pan et al (1954), Singh and Singh (1982) and Sadananda et al (1989).

14. Water Uptake:

In F_1 , this trait showed a positive significant association with quality characters viz., volume expansion and kernel elongation and significant negative association with protein content of brown rice and grain yield components viz., plant height, panicle length and grains per panicle.

In F_2 , this character expressed positive significant association with quality characters viz., volume expansion, hulling recovery, protein content and L/B ratio whereas significant negative association was observed with yield components viz., days to 50% flowering and grains per panicle.

The results indicate that increase in water uptake increases volume expansion, kernel elongation, hulling recovery, protein content and L/B ratio but decreases grain yield through plant height, panicle length and grains per panicle. This character has got good association with quality characters only. Similar results were obtained by Primo et al (1962), Pan et al (1954), Zaman et al (1989), Good and Siddique (1986) and Singh and Singh (1982).

15. Kernel elongation:

In F_1 this character exhibited significant negative association with grain yield components viz., plant height, panicle length, grains per panicle and grain length and positive significant association with water uptake only.

In F_2 , this trait showed a positive, significant association with protein content of brown rice and negative significant association with grain yield components viz., panicle length, grains per panicle and grain length. The results indicate that increase in kernel elongation may result in increased protein content of brown rice but not grain yield. Similar results were obtained by Good and Siddique (1986), Tomar and Nanda (1982), Hsieh and Kwo (1982) and Sarathe et al (1986).

16. Protein content of brown rice:

This character in F_1 showed a positive and significant association with hulling recovery and yield component i.e., breadth of grain whereas significant, negative association was observed with yield components viz., days to 50% flowering, panicle length and grains per panicle, grain length and water uptake.

In F_2 , this trait showed a significant negative^a association with grain yield and its components viz., days to 50% flowering, 100-grain weight, panicle length and grains per panicle whereas positive significant association was observed with quality characters viz., hulling recovery, volume expansion, water uptake and kernel elongation.

The results revealed that increase in protein content of brown rice decreases grain yield through 100-grain weight, panicle length and grains per panicle whereas increases quality characters viz., hulling recovery, volume expansion, water uptake and kernel elongation through increase in breadth of grain and decrease in grain length.

The study revealed that it is not possible to get high protein types combined with high grain yield by simple selection through pedigree method of breeding.

The above findings are in agreement with the findings of Jaros et al (1969), Jennings et al (1979⁶), Kaul (1981), Kambayashi (1984), Tomar and Nanda (1984) and Hartley and Lewis (1983).

In general, correlation studies revealed that grain yield per plant exhibited positive and significant

association among yield components only viz., 100-grain weight, plant height, panicle length, effective tillers per plant and grains per panicle and occasionally with grain characters both in F_1 and F_2 . Similarly quality characters (hulling recovery, volume expansion, water uptake, kernel elongation, protein content) showed positive association among themselves and occasionally with grain quality characters. Thus, it is evident that grain quality characters attained special status and critical role as buffer in deciding grain yield and quality characters. No association was observed directly with grain yield and quality characters but grain yield characters may indirectly influence quality through grain quality characters viz., grain length, breadth and L/B ratio. So selection of plant types combining high yield and quality characters can be achieved through compromised selection of grain quality characters acceptable for trader and consumer for improvement of rice crop in a desirable direction.

G. PATH COEFFICIENT ANALYSIS:

The observed correlation between yield and a particular yield component is the net result of direct effect of that component and indirect effects through the other yield attributes. The direct effect may be different from the observed correlations. The total correlation

between grain yield and component characters may sometimes be misleading since it may over estimate or underestimate due to its association with other characters. Hence direct selection by correlated response may sometimes be not effective. When many characters affect a given trait, it is necessary to split the total correlation into direct and indirect effects of cause as devised by Wright (1921).

If the correlation coefficient between a casual factor and the effect is almost equal to its direct effect, then the correlation explains the true relationship and a direct selection of this trait will be effective. If the correlation coefficient is positive, and the direct effects negative or negligible, the indirect effects seem to be the cause of correlation. In such situations, the other factors have to be considered simultaneously. Correlation coefficient may be negative but if the direct effect is positive and high, then restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.

Based on this, path coefficient analysis was worked out for nine characters along with yield to elicit information on direct and indirect contribution of various

yield components to yield and for evolving a sound basis for selection.

1. **Days to 50% flowering:**

In the F_1 crosses, this trait exhibited a meagre negative direct effect with a negative correlation on grain yield per plant. The positive indirect effect was mainly through plant height. Major negative indirect effect was mainly through effective tillers per plant followed by meagre effect with spikelet sterility.

In F_2 crosses, the major negative indirect effect was mainly through effective tiller per plant followed by L/B ratio and panicle length with very negligible effect on grain yield per plant. Hence, simple selection for this trait would be effective in early generations. These results were in agreement with the findings of Das and Borthakur (1973).

2. **Plant height:**

In F_1 crosses, this character exhibited a high positive direct effect with positive correlation on grain yield per plant. The positive indirect effect was mainly through grains per panicle. Negative indirect effects were

very meagre through days to 50% flowering, effective tillers per plant and spikelet sterility.

In F_2 crosses also, this trait expressed a very high positive direct effect on grain yield per plant. The positive indirect effect was mainly through grains per panicle. Negative indirect effect was mainly through effective tillers per plant followed by meagre effects through days to 50% flowering and panicle length.

The positive direct effect coupled with positive correlation obtained has indicated that the selection could be practiced for plant height for improving grain yield per plant. The results are in agreement with the findings of Gomathinayagam et al. (1988) and Buichibuu and Doxwan Trung (1988) and Reuben and Katuli (1989).

3. **Effective tillers per plant:**

This trait exhibited a very high positive correlation and positive direct effect in all the crosses of F_1 and F_2 generations on grain yield per plant. In F_2 crosses, this character showed very negligible positive indirect effects through 100-grain weight. Negative indirect effects were very meagre through L/B ratio, days to 50% flowering, plant height, panicle length, grains per panicle and spikelet

sterility on grain yield per plant. Hence direct selection for this trait could be effective. These results are in agreement of with findings of Hegde (1987), Reddy and Reddy (1986) and Sardana et al. (1989), Gomathinayagam et al (1988), Reuben and Katuli (1989) and Ibrahim et al (1990).

4. Panicle length:

In F_1 crosses, it showed positive indirect effect mainly through plant height and grains per panicle followed by meagre effect through 100-grain weight and effective tillers with grain yield per plant. In F_2 crosses, panicle length expressed negative direct effect with positive correlation on grain yield per plant. It showed positive indirect effects mainly through grains per panicle, 100-grain weight and plant height followed by meagre effects through L/B ratio, effective tillers per plant and spikelet sterility. Hence simple selection through this trait could be effective. Similar results were reported by Sardana et al (1989) and Bui Chi Buu and Do xuan Trung (1988).

5. Grains per panicle:

In F_1 crosses, this trait showed a high positive correlation with positive direct effect on grain yield per plant. Positive indirect effects were mainly through plant height. Negligible negative indirect effects were observed

through days to 50% flowering, effective tillers per plant and spikelet sterility.

In F_2 crosses also, this trait made the highest contribution to yield and had a high positive correlation as well as positive direct effect. Low indirect effects were observed through 100-grain weight and plant height on grain yield per plant. Hence selection could be exercised for this character in early generations. Reddy and Reddy (1986), Hegde (1987), Bui Chi Buu and Do Xuan Truong (1988), Reuben and Katuli (1989) and Gomathinayagam et al., (1988) reported positive direct effect for this trait.

6. Spikelet sterility:

In F_1 crosses, this trait expressed a negligible negative direct effect and negative correlation with yield. A negative indirect effect was observed mainly through effective tillers per plant followed by meagre effects by 100-grain weight, L/B ratio and days to 50% flowering.

In F_2 crosses, this trait exhibited a low negative correlation with yield. Negative indirect effect was mainly through effective tillers per plant followed by meagre effects through panicle length and days to 50% flowering. The results indicated that selection could be practiced in

the early generations for spikelet fertility for improving the yield. Bui Chi Buu and Do Xuan Trung (1988) reported positive direct effect while Paramasivan and Sreerangaswamy (1988a) observed negative effects for this character with grain yield per plant. This difference in reporting may be due to difference in genetic material studied and also due to environmental effects.

7. 100-grain weight:

In F_1 crosses, the yield components studied for this character exhibited a high positive correlation with moderate positive direct effect on grain yield. The positive indirect effect for this trait was mainly through effective tillers per plant followed by plant height and number of grains per panicle. In F_2 , this trait expressed a high positive correlation with very high positive direct effect on grain yield per plant.

Positive direct path value coupled with positive correlation obtained has indicated that selection could be practiced for more 100-grain weight for improving the yield. Srinivasa Rao (1989) reported positive direct effects whereas negative direct effects of this trait with grain yield per plant was reported by Bui Chi Buu and Do Xuan Truong (1988).

8. L/B ratio:

In F_1 crosses, this trait showed no bearing on grain yield per plant. The positive indirect effects for this trait was found to be high through effective tillers per plant.

In F_2 crosses, this trait exhibited meagre positive direct effect with negative correlation on grain yield. Positive indirect effects for this trait were very negligible. Hence simple selection for this trait would be effective. The results are in agreement with the findings of Rama Rao (1990) and Sreenivasa Rao (1989).

CONCLUSIONS:

From the studies carried out on genetic divergence, combining ability analysis, heterotic effects, variability, heritability and genetic advance, correlation studies and path analysis, the following conclusions are drawn.

Based on genetic divergence studies, the 79 genotypes are formed into 11 clusters based on eight characters. Out of eleven clusters, seven parents from seven different clusters were selected for hybridization programme of 7×7 diallel without reciprocals to understand the nature of gene action for yield and quality characters.

The seven parents, 21 F_1 crosses and their F_2 progenies possessed significant differences for all the sixteen characters studied excepting for L/B ratio in F_1 and for kernel elongation and days to 50% flowering in F_2 indicating existence of high genetic variability for the characters under study.

The combining ability analysis revealed that the characters which showed highly significant mean squares due to both GCA and SCA with relatively high SCA variance over GCA variance in magnitude both in F_1 and F_2 were effective tillers/plant, panicle length, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield/plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice indicating that the above characters are controlled by additive and non-additive gene effects with predominance of non-additive gene action and suggests that improvement of these characters is possible only through recurrent selection. The remaining characters namely days to 50% flowering, plant height, breadth of grain and kernel elongation with predominance of additive gene action suggests that improvement of these characters is possible by simple selection and use of pedigree method is desirable.

The parent, DW 8 showed significant GCA effects for eight characters both in F_1 and F_2 followed by Basmati-370, Prabhat and TN 1 (for four characters), Tellahamsa and BPT 1235 and IET 1444. It is further observed that parents with significant positive GCA effect for a particular character may not possess high per se performance for that particular trait and vice versa. Thus the parents possessing high GCA need not result in a combination of high SCA effect and significant desirable SCA effects are not always associated with high per se performances indicating that the choice of best combination on the basis of high SCA effects may not always necessarily exhibit highest per se performance. Therefore, selection of parents based on genetic divergence studies alone is not adequate but requires confirmation by actual crossing in a diallel manner.

There is some relationship ~~existed~~^{existing} between SCA effects and heterotic effects. Out of 21 crosses, nine crosses (Basmati-370/Prabhat, DW 8/IET 1444, DW 8/Tellahamsa, DW 8/Prabhat, DW 8/TN 1, DW 8/BPT 1235, IET 1444/Tellahamsa, IET 1444/BPT 1235 and Tellahamsa/Prabhat) are superior for yield, yield components and quality characters indicating possibility of combining yield and quality in the desirable direction. The hybrids

derived from the parents viz., DW 8, IET 1444, Tellahamsa and Basmati-370 showed good heterotic effects for different characters.

From the variability, heritability and genetic advance studies, it can be concluded that for all characters higher PCV estimates were seen over GCV both in F_1 and F_2 indicating higher degree of interaction of genotypes exists with environment. The heritability, genetic advance and genetic advance over mean per cent were found to be in a decreasing trend from F_1 to F_2 for most of the characters and may be attributed due to segregation and more play of non-genetic factors (environment) in F_2 . The improvement of the characters viz., plant height, grains per panicle, 100-grain weight, grain yield per plant, length of grain, breadth of grain, L/B ratio, volume expansion, water uptake and protein content of brown rice is possible by selection to some extent since high to moderate heritability coupled with high to moderate genetic advance was recorded both in F_1 and F_2 . The remaining characters viz., days to 50% flowering, effective tillers per plant, panicle length, spikelet sterility, hulling recovery and kernel elongation showed varying heritability trends indicating that there is scope to improve days to 50% flowering, spikelet fertility, hulling recovery and effective tillers per plant to certain

extent by selection. It is further observed that high PCV estimates were seen more particularly in F_2 as indicated by more PCV values range than in F_1 . The reverting trends of heritability percentage and genetic advance from high (F_1) to low (F_2) in a desirable direction for any character, if any, can be taken ~~to~~ ^{as} advantage by breeder to improve the character by selection in F_2 .

Thus, yield components and quality characters are heritable indicating possibility of combining yield and quality for crop improvement, by adopting heterosis breeding and other suitable breeding methodologies such as biparental mating, recurrent selection, pedigree method of breeding and back cross method of breeding.

Correlation studies revealed that grain yield per plant exhibited significant positive association among yield components both in F_1 and F_2 and occasionally with grain quality characters. The quality characters (hulling recovery, volume expansion, water uptake, kernel elongation and protein content) showed positive association among themselves and occasionally associated with grain quality characters.

Thus, grain quality characters attained a special status by playing critical role as buffer in deciding grain yield and quality characters. There was no association of grain yield and quality characters. Hence selection of plant types combining high yield and quality characters can be achieved through compromised grain quality characters acceptable for trader and consumer for improvement of rice crop in a desirable direction.

Path analysis studies indicated that selection based on the traits viz., plant height, effective tillers per plant and number of grains per panicle in F_1 and 100-grain weight, plant height, effective tillers per plant and number of grains per panicle in F_2 results in improving grain yield.

SUMMARY

SUMMARY

From the genetic divergence study of 79 genotypes of rice, 11 clusters were formed. Seven parents (Basmati-370 (VIII), DW 8 (VII), IET-1444 (XI), Tellahamsa (III), Prabhat (I), Taichung Native-1 (V) and BPT-1235 (IV)) were selected keeping in view of breeding objective from seven different clusters. These parents were crossed in 7 x 7 diallel without reciprocals and resulted in 21 F_1 and their F_2 progenies. The above material was studied from kharif 1987 to kharif 1990 at the Rice Research Unit, Agricultural College Farm, Bapatla.

The data collected on 16 characters viz., days to 50% flowering, plant height, effective tillers per plant, panicle length, number of grains per panicle, spikelet sterility, grain yield per plant, length of grain, breadth of grain, L/B ratio, hulling recovery, volume expansion, water uptake, kernel elongation and protein content of brown rice from the material of 7 x 7 diallel and their 21 F_1 and F_2 progenies was computed for analysis of variance, combining ability, heterotic effects, variability, heritability, genetic advance and genetic advance over per cent mean, character associations and path analysis to find

out the nature of gene action for yield, yield components and the quality characters.

The analysis of variance indicated that the differences between the treatments were significant for all the sixteen characters excepting for L/B Ratio in F_1 and days to 50 per cent flowering and kernel elongation in F_2 indicating the existence of high genetic variability in the material for the characters under study.

The combining ability analysis revealed that the characters which showed highly significant mean squares due to GCA and SCA with relatively high SCA variance over GCA variance both in F_1 and F_2 were effective tillers/plant, number of grains per panicle, spikelet sterility, 100-grain weight, grain yield per plant, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake and protein content of brown rice indicating that the above characters are controlled by additive and non-additive gene effects with predominance of non-additive gene action. The results suggest that improvement of these characters is possible ~~by~~ by recurrent selection.

The remaining characters days to 50% flowering, plant height and breadth of grain which showed highly significant

mean squares for both GCA and SCA both in F_1 and F_2 and kernel elongation for GCA alone both in F_1 and F_2 possessing relatively high magnitude of GCA variance over SCA indicates control of additive and non-additive gene effects with predominance of additive gene action and in such a situation improvement of these characters is possible by simple selection in rice crop and use of pedigree method is desirable.

The parent, DW 8 showed significant GCA effects for eight characters with high per se performance both in F_1 and F_2 and ranked first followed by Basmati-370, Prabhat and TN1 for four characters; Tellahamsa and BPT-1235 for three characters and IET-1444 for only one character. It is further observed that parents with significant positive GCA for a particular character may not possess high per se performance for that particular trait and vice versa. It can be further concluded that parents possessing high GCA need not result in high SCA effect and significant positive SCA effects are not always associated with high per se performance. It has further indicated that the choice of best combination on the basis of high SCA effects may not always necessarily exhibit highest per se performance.

From the results, it can be concluded that selection of parents based on genetic divergence studies alone is not adequate but requires confirmation by actual crossing in a diallel manner. The combining ability analysis studies further confirmed the above conclusion from the following points as detailed below.

1. Parents with high GCA effects and per se performance when crossed gave significant SCA effects in respect of plant height, grain yield per plant etc.
2. Parents possessing good GCA effects and high per se performances when crossed have not given good combinations with significant SCA effects in respect of days to 50 per cent flowering, effective tillers per plant, panicle length, grains per panicle, 100 grain weight, length of grain, L/B ratio, hulling recovery, volume expansion, water uptake, kernel elongation and protein content.
3. Parents possessing good GCA effects when crossed with parents having negative GCA effects either with high or low per se performances gave combinations with significant SCA effects in respect of protein content, kernel elongation, volume expansion and hulling recovery.

4. Parents possessing negative GCA effects and low per se performance on crossing with parents having negative GCA and low per se gave combinations with significant SCA effects in respect of panicle length, grains per panicle, 100 grain weight, length of grain, breadth of grain, hulling recovery, volume expansion and water uptake.

The heterotic studies revealed that in general, good to moderate relationship existed between SCA effects and heterotic effects. Based on heterotic effects, nine out of 21 crosses viz., C₄, C₇, C₈, C₉, C₁₀, C₁₁, C₁₂, C₁₅ and C₁₆ were found superior in present study for different characters combining yield, yield components and quality characters in a desirable direction of crop improvement. Crosses derived from the parents viz., DW 8, IET₄ 1444, Tellahamsa and Basmati-370 showed good heterotic effects for different characters. Though some parents viz., IET 1444, Basmati-370 possessed poor GCA for some characters showed high heterotic effects which might be due to their high nicking ability or complementary gene action. Therefore, the choice of parents should be based on four factors i.e., Per se performance, GCA, SCA effects and finally the heterotic effects for further exploitation.

From the variability, heritability and genetic advance studies, it can be concluded that for all characters higher PCV estimates were seen over GCV both in F_1 and F_2 indicating higher degree of interaction of genotypes exists with environment. The heritability, genetic advance and genetic advance over mean per cent were found to be in a decreasing trend from F_1 to F_2 for most of the characters and may be attributed due to segregation and more play of non-genetic factors (environment) in F_2 . The improvement of the characters viz., plant height, grains per panicle, 100-grain weight, grain yield per plant, length of grain, breadth of grain, L/B ratio, volume expansion, water uptake and protein content of brown rice is possible by selection to some extent since high to moderate heritability coupled with high to moderate genetic advance was recorded both in F_1 and F_2 . The remaining characters viz., days to 50% flowering, effective tillers per plant, panicle length, spikelet sterility, hulling recovery and kernel elongation showed varying heritability trends indicating that there is scope to improve days to 50% flowering, spikelet fertility, hulling recovery and effective tillers per plant to certain extent by selection. It is further observed that high PCV estimates were seen more particularly in F_2 as indicated by more PCV values range than in F_1 . The reverting trends of heritability percentage and genetic advance from high (F_1)

to low (F_2) in a desirable direction for any character, if any, can be taken to advantage by breeder to improve the character by selection in F_2 .

Thus, it is imperative that yield components and quality characters are hereditary in nature indicating possibility to combine yield and quality for crop improvement by adopting heterosis breeding and other suitable breeding methodologies such as biparental mating, recurrent selection, pedigree method of breeding and backcross method of breeding.

Correlation studies revealed ~~that~~^{that} grain yield per plant exhibited significant positive association with yield components and occasionally with grain quality traits both in F_1 and F_2 . Similarly quality characters showed positive association among themselves i.e., hulling recovery, volume expansion, water uptake, kernel elongation and protein content and occasionally with grain quality characters. Thus, it is evident that grain quality characters attained a special status and are playing critical role as buffer in deciding grain yield and quality characters. Association was not observed directly with grain yield and quality characters. But grain yield and quality characters were indirectly influenced through grain quality characters viz.,

grain length, breadth and L/B Ratio. Hence selection of plant type possessing high yield and quality characters can be achieved through compromised selection of grain quality characters acceptable for consumer and trader for improvement of rice crop in a desirable direction.

The path analysis indicated that high path coefficients coupled with high positive association for the traits viz., plant height, effective tillers per plant and number of grains per panicle in F_1 whereas in F_2 for traits viz., 100 grain weight, plant height, effective tillers per plant and number of grains per panicle existed suggesting that selection for these characters would be more effective to bring simultaneous improvement of yield and other yield components in rice. Negative correlation for yield was shown by days to 50 per cent flowering, L/B Ratio and spikelet sterility and this may be explained due to getting types with more of early duration (out of seven parents, five parents are of early to medium duration), medium slender to super fine grain types (out of seven parents, three parents are of super fine grain types) respectively and finally to have a negative correlation between yield and spikelet sterility is desirable for any crop improvement.

From the present investigation, it can briefly be concluded that (1) selection of parents for any crossing programme requires study of per se performance, GCA and SCA effects and finally heterosis effects for further exploitation of quality and yield traits in rice crop improvement. (2) Grain yield and quality characters are hereditary in nature indicating possibility to combine grain yield and quality through selection of compromised grain quality characters which are linking factors for yield and quality so that acceptable improvement of rice crop in a desirable direction is possible to the fullest satisfaction of producer, consumer and trader.

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• original not seen.

V I T A

I, P.S.N. Murthy, was born on 1st July 1941. My parents are Sri P.R.K. Murthy and Late Smt. P. Manikyamba and native of Palasa in Srikakulam district of Andhra Pradesh. I obtained my B.Sc.(Ag.) in 1962 from UTKAL UNIVERSITY and M.Sc.(Ag.) in 1965 from Orissa University of Agriculture and Technology, Bhubaneswar, Orissa. I worked for my M.Sc.(Ag.) thesis problem in collaboration with Central Rice Research Institute, Cuttack under late Dr. S.Govindaswamy, Rice Technologist. I worked in Orissa State Department of Agriculture for one year and at C.R.R.I., Cuttack for two years and joined in A.P. Agricultural University service from 1967 onwards, keeping up 27 years of service in Rice Research work dealing with projects on Rice Varietal Development and Resistance Rice Breeding and spent maximum service of 15 years at Agricultural Research Station, Maruteru. As an outcome of my Rice Research work, I became an associate and major team leader for most of the high yielding popular rice varieties released by A.P.A.U. viz., SWARNA, SOWBHAGYA, LAKSHMI, VIJAYA MAHSURI and BPH resistant/tolerant varieties viz., VAJRAM, PRATHIBHA, CHAITANYA, KRISHNAVENI and NANDI and these varieties brought

good name and fame to A.P. Agricultural University with economic benefit in crores of rupees.

My published research work was assessed by expert members nominated by A.P.A.U. and a letter to the effect from Registrar, A.P.A.U. stating that my published research work was found equivalent to that of the Ph.D. degree was given. I was deputed by A.P.A.U. for Ph.D. studies as inservice teacher during 1985 for about 18 months to prosecute my Ph.D. course work at Agricultural College, Rajendranagar which I have successfully completed with Nine O.G.P. Farming community of Krishna-Godavari Zone has honoured me with memento at Golden Jubilee Celebrations of Agril. Research Station, Maruteru which was given to me by Dr. A.Appa Rao, Ex.Vice-Chancellor, APAU. Finally the A.P.A.U. has awarded the "MERITORIOUS RESEARCH AWARD" for the year 1988 at A.P.A.U. convocation held in the February, 1989.

After successful completion of my Ph.D. course work at Agril. College, Rajendranagar, I was posted as Rice Breeder and Head of Office, Rice Research Unit, Agril. College Farm, Bapatla from 1987 July onwards where I have also completed my Ph.D. thesis problem work and thus

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completed six years of my stay at Bapatla. During my stay at Bapatla, promising high yielding, BPH and WBPH resistant cultures of all most all the duration groups were identified by me.

P.S.N. Murthy
[P.S.N. MURTHY]

27/9/84