

**GENETIC ANALYSIS IN RICE (*Oryza sativa* L.)**

**A**

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SUBMITTED TO  
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FOR  
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**OF**

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**IN  
PLANT BREEDING AND GENETICS**

**BY**

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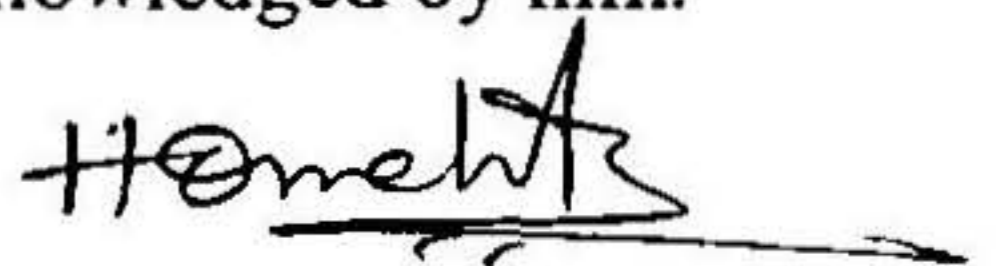
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## C E R T I F I C A T E

This is to certify that the thesis entitled, "**GENETIC ANALYSIS IN RICE (*Oryza sativa* L.)**" submitted by **Mr. CHOUGULE GIRISH RAVASAHEB** in all partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT BREEDING AND GENETICS** of Navsari Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and that the thesis has not been previously formed the basis for the award of any degree, diploma or has been published for other similar title. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

  
(H. D. MEHTA)

Place: Navsari

Date: <sup>30<sup>th</sup></sup> April, 2010

Major Advisor



*ABSTRACT*



**“GENETIC ANALYSIS IN RICE (*Oryza sativa* L.)”**

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**ABSTRACT**

Line x tester analysis using a set of four females (Lines) and ten males (testers) was carried out to estimate the extent of heterosis and combining ability for yield and its components in rice (*Oryza sativa* L.). Experimental material comprising fourteen parents, their forty hybrids were planted in a randomized block design with three replications during *kharif* 2009 at the National Agricultural Research Project farm, Navsari Agricultural University, Navsari.

Analysis of variance for all the characters revealed that parents were highly significant except significant for panicle length and non-significant for grains per panicle, grain yield per plant and amylose content, while differences among hybrids was highly significant for all the characters, indicating considerable amount of genetic variability present in the material studied. Parents vs hybrids comparison was found highly significant for all the characters except non-significant for panicle length, plant height and grain yield per plant.

Among the parents, IET-19044, GR-11, and IET-19046 were the best performing parents for grain yield per plant and some of its related attributes.

High magnitude of heterobeltiosis was observed for grain yield per plant, grains per panicle, panicles per plant, panicle length, days to 50 % flowering, amylose content and 1000 grain weight. Crosses IET-19044 x NVSR-171, IET-19512 x NVSR-181 and IET-19512 x NVSR-178 were found to be most heterotic for grain yield per plant. Simultaneous increase in grains per panicle and panicles per plant had positive effects towards higher grain yield. The *per se* performance of hybrids were, in general related to the heterotic response in majority of characters. This indicated that the selection of crosses on the basis of *per se* performance or heterotic response would be equally important.

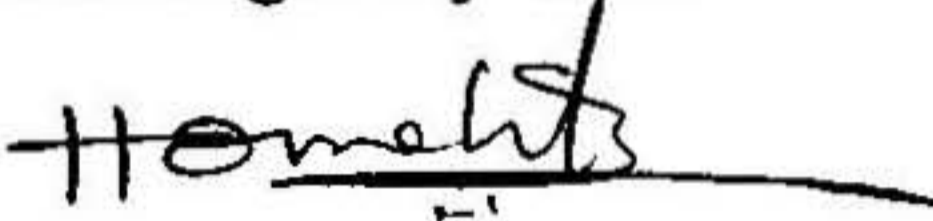
Combining ability analysis revealed that both gca and sca variances were important for inheritance of various traits under study. However, sca variances were higher than gca variances for all the characters, which indicated that non-additive gene action was predominant in the expression of the traits.

The estimation of gca effects for parents revealed that female IET-19044 and GR-11 were observed good general combiners for yield contributing traits, whereas in males IET-19046 was good general combiner for yield and yield contributing characters. The best specific cross combinations were good x average, poor x average and average x average respectively for grain yield per plant.

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## C E R T I F I C A T E

This is to certify that the thesis entitled, “**GENETIC ANALYSIS IN RICE (*Oryza sativa* L.)**” submitted by **Mr. CHOUGULE GIRISH RAVASAHEB** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT BREEDING AND GENETICS** of Navsari Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and that the thesis has not been previously formed the basis for the award of any degree, diploma or has been published for other similar title. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

  
(H. D. MEHTA)

Place: Navsari

<sup>30<sup>th</sup></sup>  
Date: April, 2010  
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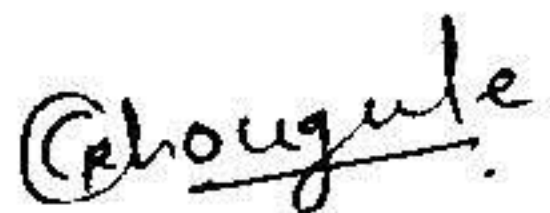
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## DECLARATION

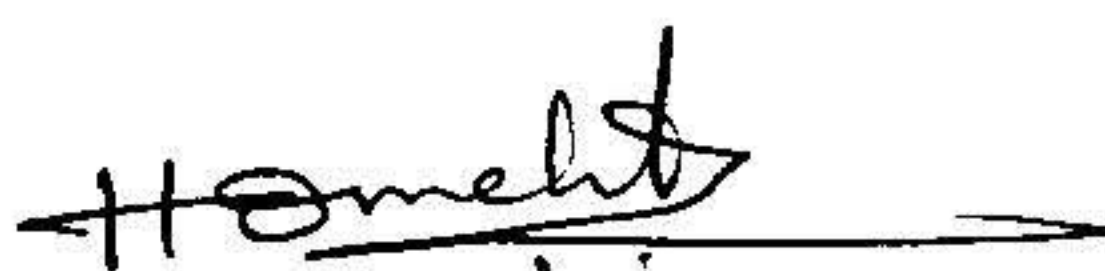
This is to declare that the whole of the research work reported here in the thesis for the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT BREEDING AND GENETICS** by the undersigned is the result of investigation carried by him under direct guidance and supervision of **Dr. H. D. MEHTA**, Associate Research Scientist, Regional Rice Research Station, Navsari Agricultural University, Vyara - 394 650 and no part of the work has been submitted for any other degree so far.

Place : Navsari

Date 30<sup>th</sup> April, 2010

  
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*Every author owes a debt to his teachers. Therefore, I seize this opportunity to express my deep sense of indebtedness and profound gratitude to my major advisor **Dr. H. D. Mehta**, Associate Research Scientist (A.B.) Regional Rice Research Station, Navsari Agriculture University, Vyara, Dist. Tapi for his keen interest, scientific guidance, constructive criticism and inspiration during the course of investigation and preparation of this dissertation.*

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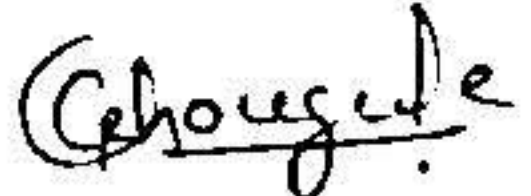
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Place : Navsari

30<sup>th</sup>  
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(Girish R. Chougule)

# CONTENTS

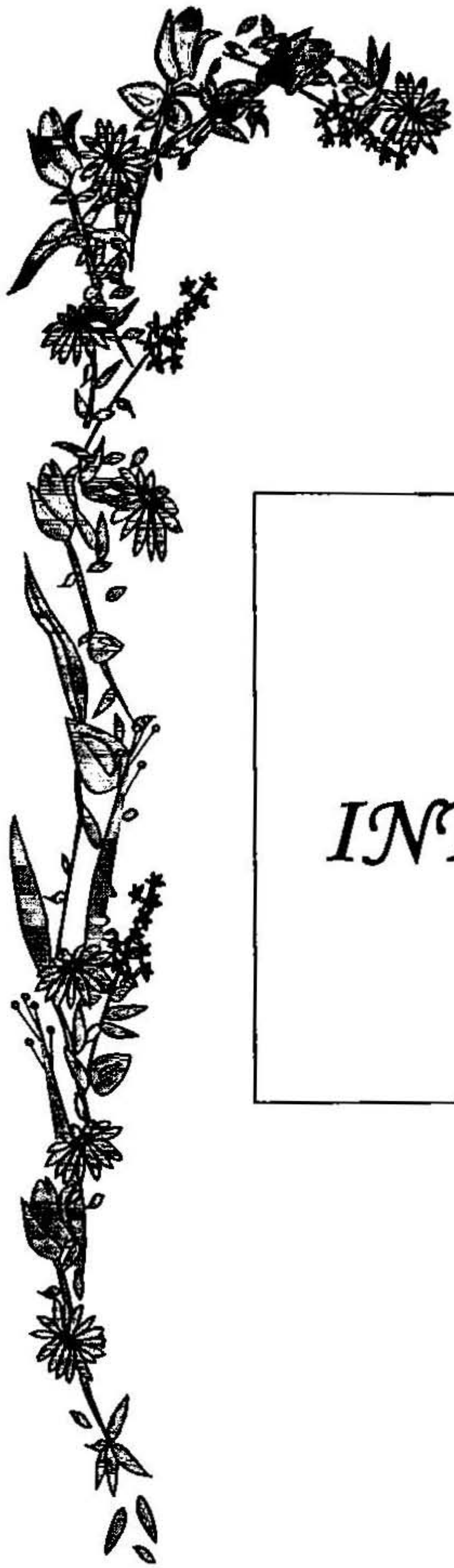
CHAPTER	TITLE	PAGE NO
<b>I</b>	<b>INTRODUCTION</b>	<b>1 - 4</b>
<b>II</b>	<b>REVIEW OF LITERATURE</b>	<b>5 - 31</b>
	2.1 Magnitude of heterosis	5 - 15
	2.2 Combining ability	16 - 31
<b>III</b>	<b>MATERIAL AND METHODS</b>	<b>32 - 41</b>
	3.1 Experimental material	32
	3.2 Experimental procedure	33
	3.3 Experimental design	33
	3.4 Characters studied	34
	3.5 Statistical analysis	35
<b>IV</b>	<b>EXPERIMENTAL RESULTS</b>	<b>42 - 65</b>
	4.1 Analysis of variance for experimental design	42
	4.2 Magnitude of heterosis	48
	4.3 Combining ability analysis	54
<b>V</b>	<b>DISCUSSION</b>	<b>66 - 85</b>
	5.1 Analysis of variance and mean performance	69
	5.2 Magnitude of heterosis	70
	5.3 Combining ability analysis	75
<b>VI</b>	<b>SUMMARY AND CONCLUSION</b>	<b>86 - 89</b>
	<b>BIBLIOGRAPHY</b>	<b>I - XIV</b>
	<b>APPENDICES</b>	<b>XV - XIX</b>

## LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
3.1	Particulars of rice parent material used	32
3.2	Analysis of variance for parents and hybrids	36
3.3	Analysis of variance for combining ability	37
4.1	Analysis of variance (mean sum of squares) for experimental design for different characters in rice	43
4.2	Estimation of heterosis for different characters in rice.	49
4.3	Analysis of variance for combining ability for different characters in rice.	55
4.4	Estimating general combining ability effects of parents for different characters in rice	57
4.5	Estimation of specific combining ability for different characters in rice.	58
5.1	Comparison of top eight promising crosses on the basis of heterobeltiosis for grain yield, sca effects and significant heterotic effect for other character	67
5.2	Summary table showing general combining ability effects of parents for various characters	78
5.3	Summary table showing the best specific combination along with the general combining ability effects of the parents involved the combination for different characters	82

## LIST OF APPENDICES

APPENDINX	TITLE
I	Meteorological observation for the period <i>kharif</i> -2009 at NARP farm, NAU, Navsari.
II	Mean performance of parents and hybrids for various characters in rice



# *INTRODUCTION*



## I INTRODUCTION

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India is the largest rice growing country in the world, but its productivity per unit area as compared to world average is low. Asia is considered as 'Rice bowl' of the world, occupying 90% world's rice area. More than 90 percent of the world's rice is grown and consumed in Asia, where 60 percent of Earth's people live. Rice accounts for 35 percent to 75 percent of the calories consumed by more than 3 billion Asians. In world it is planted on about 155.71 million hectares while production 661.81 million tonnes with productivity 4.25 tonnes per hectare in 2008 (Anon., 2009). In Asia it is planted on 139.61 million hectares with production 600.54 million tonnes and productivity 4.30 tonnes per hectare in 2008 (Anon., 2009). Rice is a major staple food crop of India and accounts for 40% of the total food grain production of the country. In India, it is grown in an area of 44 million hectares with a total production of 99.37 million tonnes and productivity 3.37 tonnes per hectare in 2008 (Anon., 2009). While in Gujarat, rice occupies about 5 percent of the gross cropped area and it is grown in an area of 7.221 lakh hectares which comprises nearly 40 to 45 percent of upland and 55 to 60 percent of lowland situation with a total production of 1.22 million tonnes and the productivity of 1697 kg per hectare (Anon., 2008), while in South Gujarat transplanted rice occupies about 45 percent area with an average productivity of 2.2 tonnes per hectare.

During the last four decades, there have been major advances in rice production due to the adoption of green

revolution technology. Between these periods (1966 to 2005) the population of densely populated low income countries grew by 95 %, but rice production increased by 130 percent from 257 million tonnes in 1966 to 591.7 million tonnes in 2003-2004. In spite of all these achievements of green revolution, serious food problem still exist in the world. Keeping in view, in India the average annual population growth rate of 1.5 percent and per capita consumption estimate of about 400 g of rice per day.

Rice improvement programmers have been in operation across India since the early 1900s. Initially, the improvement was aimed mainly for improvement of popular local varieties through pure line selection. The introduction of the improving plant type concept and the rapid spread of high-yielding, non-lodging, semi-dwarf varieties in the mid-1960s opened new horizons in rice improvement. Exploitation of heterosis in rice has been recognized as practical tool in providing the breeders a mean of improving yield and other important traits for developing promising varieties through hybridization, the choice of parents is a matter of great concern to the plant breeders.

In the past performance and adaptability of genetic stocks has been used as the main criterion in selection of parents for hybridization programme. The importance of combining ability analysis, besides its use in selection of parents, elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. Such information is of practical use in formulating and executing different breeding

program for achieving maximum genetic gain with minimum resource and time.

Various biometrical techniques have been developed to obtain valid information with regards to genetic architecture and inheritance of different yield components, among which Line x tester analysis technique (Kempthorne, 1957) are more systematic approach to assess the combining ability of parents and crosses for different quantitative and qualitative characters. An added advantage of this method is that it gives overall genetic pictures of the materials under investigation in a single generation.

Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability. In breeding high yielding varieties of crop plant, the breeders often face with the problem of selecting parents and crosses. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects indicating good as well as poor combiner and aids in selecting the desirable parents and crosses for the exploitation of heterosis. At the same time, it provides information about nature of gene action involved in the expression of quantitative traits which are important for inheritance of various traits and successful development of crop varieties. [The present investigation in rice (*Oryza sativa* L.) was therefore, planned with the following objectives.

1. To estimate the nature and magnitude of heterosis for grain yield and its components in rice.
2. To estimate general combining ability of parents and specific combining ability of hybrids, for yield and yield contributing characters.
3. To understand nature of gene action for various characters.



*REVIEW OF  
LITERATURE*



## II REVIEW OF LITERATURE

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The present review is an attempt at bringing together some of the findings on rice pertaining to studies on heterosis, combining ability and gene action and presented in this chapter under following sub-heads.

2.1 Magnitude of heterosis.

2.2 Combining ability and Gene action.

**2.1 Magnitude of heterosis**

Heterosis or hybrid vigor is superiority of a hybrid over its parents with respect to any measurable character. The vigour in excess of better parent is termed as heterobeltiosis. Estimation of heterosis will help in identifying genetically potential crosses for further exploitation in plant breeding. It also helps in rejecting large number of crosses in first generation itself.

Exploitation of hybrid vigour through hybrid seed production on commercial scale has been considered as one of the important developments in the field of plant breeding. Heterosis was first reported by Koelreuter (1766). Exploitation of heterosis was first achieved in maize which was followed subsequently in many crops like bajra, cotton, sorghum and others. The term heterosis coined by Shull in 1914, to represent percentage increase or decrease in the mean value of  $F_1$  hybrid over its mid-parent value. Later on Bitzer *et al.* (1968) and

Fonseca and Patterson (1968) coined a new term heterobeltoxis to describe the increase or decrease in the mean value of  $F_1$  hybrid over its better parents.

Stebbins (1957) defined heterosis for crop plant as greater adoptness to human needs, which has been obtained in particular environment through artificial selection followed by hybridization.

The genetic causes of expression of heterosis are dominance, over dominance and epistatic (Mather and Jinks, 1971 and Hayes and Foster, 1976).

Patnaik *et al.* (1990) observed significant heterosis, heterobeltoxis and standard heterosis for grain yield and yield related characters in most of the hybrids studies. Heterosis for grain yield was mainly due to significant heterosis for spikelet per panicle, test weight and total dry matter accumulation. Most of the high yielding hybrids were accompanied by significant negative heterosis for harvest index.

Peng and Virmani (1991) studied seventy five hybrids and eighteen parental lines for heterosis for yield, dry matter, harvest index, days to flowering and plant height. They reported that mean performance of hybrids was superior to that of inbred for all the traits. Heterosis for yield in these hybrids resulted from high dry matter production and harvest index. The best ten hybrids flowered in 90-95 days with 95-115 centimeter height.

Twelve rice hybrids studied by Sahai and Chaudhary (1991) and revealed that reduction in days to fifty per cent heading could be achieved without sacrificing the grain yield. They further reported that most of the hybrids had more than 20 per cent heterosis over better parents and best commercial varieties.

Ram (1992) studied heterotic effect in 45  $F_1$ 's. He represented more than 20 per cent heterobeltosis in 19 crosses for grain yield, while seven crosses gave more than 40 per cent heterobeltosis. Eleven crosses showed significant heterobeltosis for number of tillers per plant and eight gave high heterobeltosis for grain per panicle.

Lokaprakash *et al.* (1992) studied the nature and extent of heterosis and heterobeltiosis for yield and its components in a 7 x 7 half diallel and found that heterosis for all the characters was evident in most of the hybrids studied. Heterosis for yield was mostly due to simultaneous heterosis for number of productive tillers, panicle length, fertile spikelets per panicle, 1000-grain weight and harvest index.

In a study of combing ability and heterosis in rice employing line x tester analysis, Manuel and Prasad (1992) reported significant heterosis for grain yield per plant, straw yield per plant and dry matter production.

In a study for evaluating 50 hybrids involving ten lines and five testers of rice, Bobby and Nandarajan (1994)

reported that 12 hybrids had significant positive standard heterosis for productive tillers and two hybrids had significant positive standard heterosis for grain yield. They further stated that 14 hybrids showed significant long panicle and six hybrids showed significant positive standard heterosis for 100-grain weight.

Deosarkar and Nerkar (1994) reported highly significant positive heterosis over mid-parent in seven crosses for plant height, 1000-grain weight and grain yield per plant, while eight crosses for panicle length and ten crosses for number of grains per panicle exhibited highly significant positive heterosis over mid-parent.

Geetha *et al.* (1994) studied six hybrids for various grain characters and found that the hybrid ADRH-4 recorded the maximum yield of 19.7 g/plant which was due to the higher number of grains per panicle but the standard heterosis was not significant. They further stated that hybrid ADRH-4 had positive significant standard heterosis for panicles per plant, grains per panicle and 100-grain weight.

Ramalingam *et al.* (1994) carried out line x tester analysis with 15 hybrids obtained by crossing five rice lines with three testers and observed the highest standard heterosis for productive tillers per plant followed by grain yield, flag leaf area, panicle length and 100-grain weight.

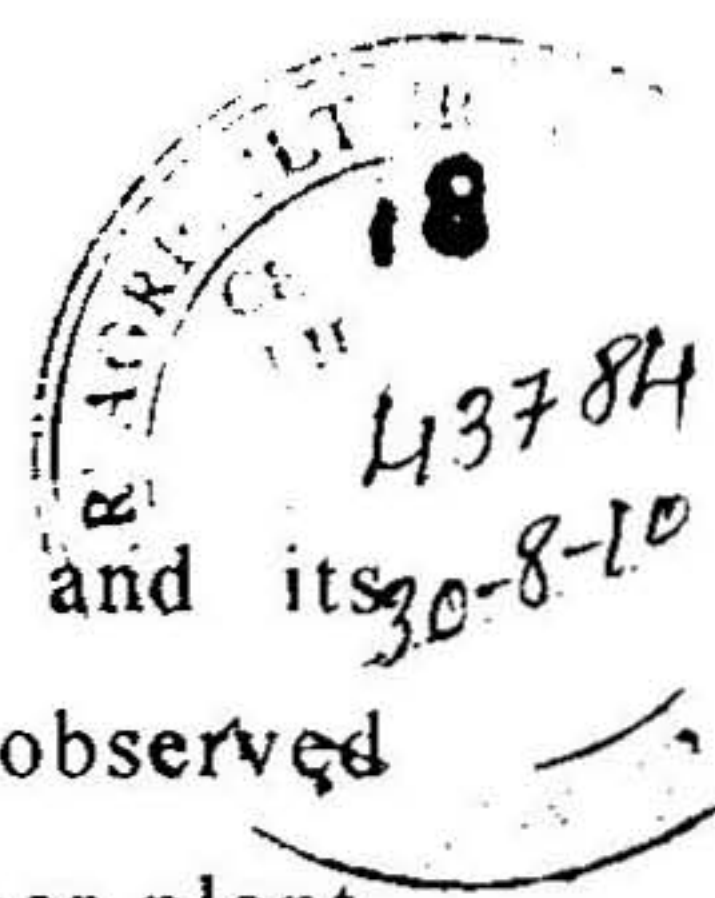
While studying heterosis for grain yield and its components in hybrid rice, Panwar *et al.* (1998) observed significant positive standard heterosis for grain yield per plant, panicles per plant and grains per panicle, whereas negative heterosis was recorded for 1000-grain weight.

Sitaramaiah *et al.* (1998) studied heterosis of 10 rice hybrids and observed that six hybrids had significantly higher yield over standard check. All the hybrids except MTUHR-2006 exhibited a very high positive standard heterosis for number of spikelets per panicle. They also reported that all the hybrids had shown negative and significant standard heterosis for 1000-grain weight.

Vishwakarma *et al.* (1999) reported substantial positive heterosis for grain yield, harvest index, test weight, spikelet fertility, panicle length and effective tillers per plant, while significant negative heterosis was observed for days to fifty per cent flowering and plant height in a study of 65 rice hybrids developed through line x tester design.

Singh (2000) evaluated twenty test hybrids developed by using three cyto-sterile lines and 11 restorers and found that number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield in most of the hybrids.

Janardhanam *et al.* (2001) studied eight strains of rice in a line x tester design to obtain 16 hybrids. Among the three



types of heterosis, relative heterosis was significant for 10 hybrids for plant height, 10 hybrids for numbers of grain per panicle and 13 hybrids for single plant yield. Heterobeliosis was significant for 11 hybrids for plant height, 8 hybrids for panicle length, 3 hybrids for number of spikelets per panicle, 9 hybrids for number of grains per panicle and 12 hybrids for single plant yield. While standard heterosis was significant for all the hybrids for plant height, 6 hybrids for panicle length, 14 hybrid for number of grain per panicle and 15 hybrids for single plant.

During study of average heterosis, heterobeliosis and standard heterosis, Annadurai and Nandarajan (2001) observed that, 12 hybrids recorded significant positive relative heterosis, 13 hybrids showed significant positive relative heterobeliosis and none of the hybrids recorded significant positive standard heterosis. In case of grain yield 20 hybrids out yielded the mid-parent, 12 hybrids recorded significant positive heterobeliosis and nine hybrids showed significant standard heterosis.

Heterosis was studied by Raju *et al.* (2003) using diallel analysis. The resultant twenty one hybrids showed heterosis over better parent for cooking and milling characters, whereas mid parent heterosis was noticed for quality traits. Also they found pre dominance of additive gene action for kernel length and L/B ratio.

Banumathy *et al.* (2003) studied the magnitude of relative heterosis, heterobeltosis and standard heterosis of 100 rice hybrids for grain yield. They registered maximum significant positive relative heterosis (205.29 %) and heterobeltiosis (187.25 %) for grain yield. Further they indicated that most of the high yielding hybrids manifested positive heterosis due to long panicles, filled grain and spikelet fertility.

Joshi *et al.* (2004) studied the magnitude of heterosis and inbreeding depression in 72 genotypes (23 parents, 24 F1s, their F2s and one standard variety) for yield and yield components revealed highly significant differences for all the traits except for total tillers per plant. They observed significant negative heterosis in five hybrids for earliness and four hybrids for dwarfness, while hybrids IR 58025A x UPRI 1063-5-2-1-4 and IR 58025A x CTN 82075-4321 showed significant positive heterosis for panicle length, spikelets per panicle, grain yield per plant and hybrids IR 58025A x HKR 86-217 and PMS 2A x UPRI 1063-5-2-1-4 exhibited significant positive heterosis for total tillers per plant, productive tillers per plant, panicle length and grain yield per plant.

Yadav *et al.* (2004) generated 30 hybrids through line x tester mating design from three lines and ten testers. These hybrids exhibited significant heterosis for panicle length, number of productive tillers per plant, number of spikelets per panicle and harvest index.

Datt and Mani (2004) estimated heterosis in 60 basmati hybrids and observed that the hybrids in general manifested optimum to high magnitude of relative heterosis, heterobeliosis and standard heterosis for grain yield and most of its related agronomic characters. The result indicated that the exploitation of heterosis holds a great promise in increasing the genetic yield potential of Basmati rice.

Reddy (2004) studied 28 crosses involving eight diverse parents of low land rice for grain yield and its component traits. Among the different characters, grain yield per plant recorded higher heterosis (97.0%) followed by biological yield per plant (81.0%) and number of panicles per plant (84.0%).

Bhandarkar *et al.* (2005) studied heterosis over better parent for yield and its components in eight crosses by using line x tester mating design. All the crosses exhibited superiority over their respective parents for grain yield per plant. On the basis of high mean and high heterosis for yield and its components with earliness, cross INRC 140 x Madhuri A-9 has been identified as superior cross followed by ARC 5984 x Madhuri A-9 and Samridhi x Madhuri A-9.

Kshirsagar *et al.* (2005) studied the 40 hybrids developed from four cytoplasmic genetic male sterile lines and ten testers. They stated that the highest heterobeliosis for grain yield per hill was recorded by the cross IR-6888A x IR-56381-

139-2-2 and the cross IR-68888A x IET-16309 had the highest standard heterosis for grain yield per plant.

Veni *et al.* (2005) estimated heterosis, heterobeltiosis and standard heterosis for yield and its attributes for seven important quality characteristics in twenty five crosses generated through line x tester mating design. They found that the estimates of heterosis values were low for quality traits when compared to yield and yield components.

In a study of heterosis involving four lines and six testers, Aananthi and Jebaraj (2006) reported that the hybrid TS-29 x Ponni recorded the maximum standard heterosis (51.65%) followed by TS-6 x Ponni (37.07%), TS-29 x CO-45 (32.00%) and TS-16 x CO-43 (23.06%) for single plant yield.

Pandya and Tripathi (2006) observed that 30 hybrids exhibited significant and positive heterobeltiosis and standard heterosis for grain yield per plant. They further reported that heterosis for grain yield was due to positive and significant heterosis for other yield component characters like number of seeds per panicle, panicles per plant, 1000 seed weight, panicle length, biological yield per plant and harvest index.

Thirty six hybrids developed through two CMS lines and 18 testers were evaluated by Singh (2006) for heterosis in rice. They reported that standard heterosis for grain yield per plant was manifested through more number of ear bearing tillers per plant, fertile grains per panicle, 1000 grain weight,

biological yield and harvest index, while negative standard heterosis was observed for days to fifty per cent flowering due to earliness of the hybrids than standard variety.

Eradasappa *et al.* (2007) studied heterosis for yield and yield components using CMS lines in rice. They observed that two crosses showed significant standard heterosis for dwarfness, 21 crosses for productive tillers per plant, 32 crosses for panicle length, whereas all 33 crosses showed significant standard heterosis for filled grains per panicle and grain yield per plant.

The nature and magnitude of heterosis over better parent and over standard variety in rice was studied by Singh *et al.* (2007) involving 30 lines and two testers in a L x T analysis. They found that the heterosis over better parent and over standard parent was 30.56 per cent and 70.67 per cent for panicle length, 14.62 per cent and 11.07 per cent for total number of spikelets per panicle and 139.43 per cent over better parent and 22.64 per cent over standard parent for grain yield per plant.

Raj *et al.* (2007) studied L x T analysis involving eighteen parents and their forty five crosses for relative heterosis, heterobeltiosis and standard heterosis for yield and its components. The hybrids BR-9 x Cavery, BR-10 x IR-8, Janki x Archana, Birsa Dhan-202 x Cavery and IR-36 x IR-8 were found as the best for exploitation of heterosis while the cross

combinations BR-10 x IR-36 and IR-36 x IR-8 showed highly significant standard heterosis for earliness, number of grains per panicle and panicle length apart from grain yield.

While studying heterosis for economic traits in early, mid early and very early rice cultivars, Issac (2007) reported that the hybrids AD-95134 x TRY-2 and BTCE-23199 x ADT-43 were found suitable for simultaneous improvement of earliness and yield potential through heterosis breeding. These hybrids had desirable *per se* performance for grain per plant, biological yield per plant and earliness.

Venkatesan *et al.* (2008) evaluated thirty two hybrids in L x T mating design for yield and its components in rice. They found that the magnitude of heterosis was low for grain quality character when compared to heterosis for yield and its components, whereas nine hybrids manifested positive and significant heterosis over mid parent and better parent for grain yield per plant.

Parihar and Pathak (2008) studied extent of heterobeltiosis, standard heterosis and the nature of gene action for various quantitative traits using line x tester analysis including 4 lines, 12 testers and their 48 hybrids. Among the parents GR 11, GR 7, NWGR 98002, GR 102, M45-20-1, TN 1, NWGR 9635 and NWGR 97042 were the best performing parent for grain yield per plant and its component traits.

## 2.2 Combining ability

The selection of appropriate parents for hybridization programme could be made on the basis of their ability to transmit desirable performance to their crosses. The combining ability is a powerful tool to discriminate parents as good or poor combiners. It not only helps in choosing out an appropriate parental material but also provide the nature of gene action and for developing suitable breeding methodology for the crop.

The concept of combining ability was given by Sprague and Tatum (1942). The concept helps in assessing the general and specific combining ability of the parents and their hybrids involved in a crossing programme, respectively. This is one of the concepts that had been exploited to great extent by the plant breeders.

Griffing (1956<sup>a</sup>) developed a model in which he proved that additive genetic variance involved in gca variance while sca variance resulted from dominant and epistasis components. Griffing (1956<sup>b</sup>) and Carnaham *et al.* (1960) suggested that gca could included both additive as well as additive x additive interaction.

From the study of 5 x 5 diallel in rice, Haque *et al.* (1981) stressed the importance of additive gene effects for number of days to flowering, plant height, number of effective tillers per plant, number of grains per panicle, 1000 grain weight and grain yield per plant. They further reported that non additive

genetic effects were also important for number of days to flowering, plant height and spikelet sterility.

Amirthadevarathinam (1983) observed that the combining ability variances due to lines, testers and Line x Testers interactions were highly significant for all the characters under study indicating the importance of both additive and non additive gene action in the expression of characters.

While studying combining ability analysis, Panwar and Paroda (1983) revealed that both additive and non additive gene effects played a major role for the expression of 1000 grain weight, kernel length, kernel breadth and kernel shape.

Subramanian and Rathinam (1984) reported that the analysis for combining ability was significant for all the characters indicating the presence of both additive and non additive gene actions. They further reported that the gca variances were higher than sca variances which revealed the predominance of additive gene actions for all the characters.

From the study of line x tester analysis, Anandkumar and Shri Rangaswamy (1984) found significant difference for gca and sca for all the four characters. They further reported predominance of non additive gene action in the expression of plant height, panicle length and yield per plant.

In a 10 x 10 diallel set of rice, Panwar *et al.* (1985) observed highly significant variances for gca and sca for days to

heading, plant height, panicle per plant, panicle length, spikelets per panicle, 1000 grain weight and grain yield per plant.

Sarathe and Singh (1986) studied Combining ability for yield and yield related characters in rice through 8 x 8 diallel analysis and found significant differences for gca and sca indicating the importance of both additive and non additive interaction for all the traits.

In a study of 5 x 5 diallel cross, Sardana and Borthakur (1987) found that gca and sca were significant for grain yield per plant, day to flowering, plant height, effective tillers per plant, panicle length, flag leaf length, flag leaf width, filled grains per panicle and 100-grain weight. Both additive and non additive gene effects were important for all these traits. They further observed predominance of non additive gene effects over additive effects for grain yield per plant, flag leaf length and filled grains per panicle, while predominant additive gene action for 100-grain weight, panicle length and days to flowering.

During combining ability study of seven diverse varieties of rice, Tripathi and Misra (1987) reported predominance of additive gene action for two characters *viz.*, days to flowering and 100-grain weight.

From the study of 7 x 7 diallel analysis in rice, Kalaimani and Sundaram (1988) observed the existence of higher

gca variance than sca variance for all the characters studied, indicating the major role of additive gene action for these traits.

Manuel and Palanisamy (1989) studied combining ability through line x tester analysis and observed that all the nine characters were governed by additive and non additive gene action except panicle per plant. The ratio of gca and sca variance reveled the importance of additive gene action for days to flowering, plant height and panicles per plant and the predominance of non additive gene action for others.

Dhaliwal and Sharma (1990) reported that mean squares due to gca, sca and reciprocal cross effect were significant for days to fifty per cent flowering, plant height, number of panicle per plant, grain thickness, 100-grain weight and grain yield. They also observed that non additive genetic variance was predominant for all these traits except grain density for which additive gene effects were more important.

During the study of combining ability using line x tester analysis, Peng and Virmani (1990) observed that gca and sca variances were significant for yield, dry matter, days to flowering and plant height, while for the harvest index, only sca variance was significant implying that the first four traits were controlled by both additive and dominance gene action, whereas the harvest index was primarily controlled by dominant gene action.

Banumathy and Prasad (1991) studied combining ability for six quantitative traits and found that sca variance was higher than the gca variance for plant height and grain yield per plant, indicating the prevalence of non additive gene action in the expression of these traits. Additive gene action was found to be important for number of productive tillers and length of panicle.

During combining ability study in 7 x 7 diallel cross, Lokaprakash *et al.* (1991) observed that both gca and sca variances were highly significant for all the characters, indicating the importance of both additive and non additive gene action. The preponderance of additive gene action was recorded for plant height, while for all the other characters non additive type was predominant.

In a study of 10 x 10 diallel cross, Ram *et al.* (1991) observed that both additive and non additive type of gene actions were important. Further they suggested that the influence of non additive genetic variance was more than the additive for all the characters except number of sterile spiklets and grain yield per plant.

Singh and Singh (1991) studied 8 x 8 diallel cross in rice and reported that plant height was mainly controlled by additive genetic variance and panicle length, panicle weight and milled rice (%) were controlled by non additive genetic variance, while both additive and non additive genetic variances were important for harvest index.

From the study of line x tester analysis, Manuel and Prasad (1992) found that all the four characters were governed by additive gene action except straw yield per plant. The ratio of *gca/sca* variance revealed the importance of additive gene action for straw yield per plant and dry matter production and non additive gene action for other traits.

Singh *et al.* (1992) carried out the combing ability analysis in an eight parental diallel cross of rice and indicated that both additive and non additive gene effects were important for grain yield and its components. The *gca* effects for different yield components showed significant positive correlations with *gca* effects for grain yield. Similar relationship was found between *sca* effects also.

Through line x tester analysis, Ramalingam *et al.* (1993) observed preponderance of non additive gene action over additive gene action for all the characters except 100-grain weight. They further reported that the superior cross combinations were obtained from high x high, high x low and low x low general combiners. High positive and significant association was obtained between *per se* performance and *gca* effects of the parents.

Employing a nine parental half diallel cross, Shenoy *et al.* (1994) studied genetics of protein in rice and reported that the magnitude of additive effects being larger than that of the non additive effects.

While studying combining ability in  $F_1$  populations of 8 x 8 diallel cross of deepwater rice, Borgohain and Sarma (1998) reported that both gca and sca variances were significant for yield and its component characters. The gca/sca ratio indicated the preponderance of additive gene action for grain yield per plant, plant height, days to fifty per cent flowering and internodes length, while the rest of the characters showed importance of non additive gene action.

Satyanarayana *et al.* (1998) studied combining ability through L x T analysis and reported that variance due to sca was greater than that due to gca, indicating the predominance of non additive gene action governing yield and related traits.

Singh *et al.* (1998) studied combining ability for grain yield and its component traits involving eight diverse parent in a set of diallel crosses in transplanted rice and reported that both gca and sca variances were highly significant for all the characters. However, the magnitude of gca was higher than sca for all the characters except biological yield per plant indicating the preponderance of additive gene effects.

Janardhanam *et al.* (2000) crossed eight strains of rice in line x tester fashion to obtain 16 hybrids and found that the analysis of variances were highly significant for all the characters except for number of productive tiller per plant, also they found that three parents for plant height and number of grain per panicle, two for single plant yield and only one for

number of grains per panicle, as good combiners when both *per se* performance and gca effects were taken simultaneously for consideration. None of the line or tester was found to be superior for all the traits. They also reported significant sca effect for plant height, spikelet per panicle and single plant yield among six hybrids.

Kalita and Upadhyaya (2000) reported that additive gene action played major role in the expression of panicle length, while non additive gene action was predominant for remaining thirteen characters including grain yield in a study of 33 crosses of rice.

Combining ability estimates were obtained by Annadurai and Nadarajan (2001) from L x T analysis of crosses involving five male sterile lines and seven pollinator varieties. They reported that the sca variance was greater than gca variance revealing the predominance of non - additive gene action controlling all the characters studied. They further reported that the crosses showing significant sca for growth yield per plant were obtained from good x good, good x poor, poor x good, poor x poor combinations.

Roy and Mandal (2001) studied 45 hybrids for combining ability analysis and evaluated for days to fifty per cent flowering, plant height, number of panicles per plant, panicle length, number of filled grains per panicle, grain density, 100-grain weight and grain yield per plant. In majority of cases,

good general combiners showed better *per se* performance, which indicates that the parent may be selected on the basis of gca.

Reddy (2002) studied on the basis of combining ability effects on five cross combinations *viz.*, Gayatri x Lunishree, Utkalprabha x CN 718-8-21-10 or 1334-8 x CN 718-8-21-10, Lunishree x 1334-8 and CN 1035-59 x CN 718-8-21-10 which showed significant sca effects for grain yield and some of its component characters and having one of the parent as good general combiner both under normal and late planting situation could be exploited in future breeding program to improve grain yield in lowland rice.

Raju *et al.* (2003) studied combining ability in 7 X 7 diallel crosses (without reciprocals) reported that predominance of additive gene action for L:B ratio and non additive for hulling percentage.

An investigation was undertaken by Prakash *et al.* (2003) on 13 genotypes with their thirty hybrids using line x tester design. They estimated the general and specific combining ability variance and there effects. Based on desirable gca IR-58025A was found good general combiner for most of the character *viz.*, panicle per plant, grains per panicle, 1000 grain weight and grain yield. Among the thirty hybrids, three showed high sca effect for grain and biological yield.

Swain and Nagaraju (2004) studied combining ability and gene action in rice in a set of 7 x 7 diallel cross (excluding reciprocal) for amylase content. The combining ability analysis

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revealed that the variances due to gca were higher than that of the sca variances indicating the preponderance of additive gene action in governing this trait. Sitabhog was good general combiner for intermediate amylose content whereas Gayatri was good general for high amylose content.

During the study of combining ability using line x tester analysis involving five lines and ten testers, Shanthi *et al.* (2004) reported that the gca/sca variance ratio showed preponderance of additive gene action for days to fifty per cent flowering, plant height, test weight and grain yield per plant.

Bisne and Motiramani (2005) observed that the lines DRR 2 A and PMS 10 A and testers BKP 232, R 827-287, R 1060-1674-1-1 and R 714-2-103 were good general combiners for grain yield. The crosses DRR 2 A x R 827-287 and DRR 2 A x R 1060-1674-1-1 exhibited higher specific combining ability with high standard heterosis for grain yield.

In line x tester analysis involving four well adapted CMS lines and eighteen testers, Singh *et al.* (2005) revealed the significant role of non additive gene action for all the characters *viz.*, leaves per seedling, days to fifty per cent flowering, plant height, biological yield per plant, harvest index and grain yield per plant.

Rosamma and Vijayakumar (2005) carried out line x tester analysis using five genetically diverse and widely adaptable rice varieties which were crossed with four stable CGMS lines and observed that grain yield per plant recorded

high sca variance suggesting predominance of non additive genetic variance.

Panwar (2005) studied combining ability analysis by using line x tester design for eleven characters in rice. He reported that non additive gene action was important for majority of the characters, whereas the predominance of sca variance for all the eleven characters suggested that dominance and epistatic gene interaction were important for controlling these traits.

Haripasanna *et al.* (2006) estimated combining ability of parents and hybrids by using Line x Tester design and observed that significant sca effects for grain yield had significant sca effects for one or more yield components, also they found that significant positive effect for particular trait were obtained in average x average, average x low and low x low parental combinations.

Combing ability analysis for earliness, grain yield and it's components in rice were carried out by Issac (2006) in L x T analysis. He reported that preponderance of non additive gene action for all the characters *viz.*, days to flowering, days to maturity, plant height, panicle per plant, panicle length, panicle weight, grain per panicle, 1000 grain weight, biological yield, harvest index and grain yield per plant.

Jagdeesan and Ganesan (2006) studied combing ability using line x tester design. They reported preponderance of non additive gene action for all the traits, where as line

IR-58029-99-3-1-3 and tester BR-4828-2-2-1 showed negative gca effects for days to fifty per cent flowering and plant height, also they reported that the cross IR-44962-161-2-4-4-2 x AS-37800 and IR- 58108-3-1-1-2 x AS-37800 showed high significant result for days to fifty per cent flowering and grain yield per plant respectively.

Combining ability analysis was carried out for grain yield and its contributing traits in line x tester design by Kumar *et al.* (2006) and reported that the predominant role of non additive gene action for the characters *viz.*, numbers of tillers per plant, panicle length and grain yield per plant, whereas additive gene action was predominant for days to flowering, plant height, spikelet fertility per cent, number of spikelets per panicle and 1000-grain weight.

Saravanan *et al.* (2006) carried out line x tester analysis for yield and quality characters in rice. They revealed that majority of characters exhibited non additive variance. They further reported predominance of sca variance for all the characters suggesting that dominance and epistatic gene interactions were important for controlling characters.

Sinha *et al.* (2006) studied combining ability for grain yield and its component traits in rice involving six parents in a set of diallel crosses in upland rice and reported that both gca and sca variances were highly significant for nine characters. However, the magnitude of gca and sca effects for all the traits

indicated both additive as well as non-additive gene action were involved in the expression of the traits.

Verma *et al.* (2006) studied genetic analysis of yield and its components in rice from 7 x 7 half diallel design. They observed that parent NDR-359 was found to be the best general combiner for yield and its components followed by T-21, Sarjoo-52 and Mahsuri. Also they observed the preponderance of non additive type of gene action for traits like days to fifty per cent flowering, panicle length, number of productive tillers per plant, number of spikelets per panicle, 100-grain weight and grain yield per plant.

Singh *et al.* (2007) studied combining ability analysis for grain yield and its components by using seven parental diallel crosses of rice excluding reciprocal. The gca and sca were significant for all the seven characters, indicating the importance of both additive and non additive genetic components for these traits. Among the parents Vaidehi and Rajshree were observed to be good general combiners for grain yield while among the crosses Saket 4 x Vaidehi, Rajshree x Kamini, Prabhat x Rajshree and Sita x Vaidehi were found as superior.

During the study of combining ability of new basmati fertility restorers for grain yield and its components in rice, Sarial *et al.* (2007) observed that the estimates of sca variance were greater in magnitude than gca variance for grain yield per plant, biomass yield per plant, 1000-grain weight, days to fifty

per cent flowering and effective tillers per plant indicating the importance of non additive gene action in this traits.

The combining ability analysis was carried out by Kumar *et al.* (2007) through 9 x 9 diallel fashion. They showed that the gca and sca variances and reciprocal effects were significant for all the six traits viz.; number of productive tillers per plant, number of filled grains per panicle, 100-grain weight, biomass per plant, grain yield per plant and harvest index.

The combining ability and heterosis for yield and component traits in rice studied by Parihar and Pathak (2008) and reported that the crosses in comparison with high sca effects for grain yield per plant had also desirable and significant sca effects for other traits like panicle length, grains per panicle, effective tillers per plant and 1000-grain weight. Also the cross combinations GR-11 x TN-1 and GR-7 x NWGR-9635 had high sca effects for grain yield per plant and both the parents involved were good general combiners for grain yield, such results might be due to interaction of dominant genes contributed by both the parents.

Pradhan and Singh (2008) studied the combining ability and gene action on 30 hybrids generated from three lines and ten testers. They reported that gca and sca effects were significant for all characters, indicating the importance of both additive and non additive genetic components, while among the parental lines three lines were best general combiners for grain yield along with other traits.

Sharma and Mani (2008) studied combining ability analysis for grain yield and its components by using six Basmati lines with three testers and observed that the additive gene action was dominant for flag leaf area, further they reported that Kasturi, Basmati-5853 and Haryana Basmati had good general combining ability for various traits, whereas three crosses showed high sca effect.

Tyagi *et al.* (2008) studied combining ability analysis in rice using L x T design and found that none of the parental line was found excellent for all the characters. Among nine lines, Pusa-1463 was good general combiner for the characters days to fifty per cent flowering, days to maturity, plant height, number of filled grains per panicle, number of sterile grain per panicle, panicle length, biological yield per plant, grain yield per plant, harvest index and test weight.

Dalvi and Patel (2009) studied sixty hybrids developed from crossing four CMS lines with 15 restorers were studied alongwith parents for 13 yield and yield attributing characters. Among the male parental lines, BR-827-35-3-1, RTN-3, IR-46 showed best general combiner for grain yield and most of the component characters. The female line IR-58025A was found to be good general combiner for all the traits except plant height and L:B ratio of grain. The most promising specific combiner were IR 58025A x BR-827-35-3-1, IR-58025A x RTN-3 and IR-68885A x RTN-711 for grain yield hill<sup>-1</sup>.

In an L x T analysis Salgotra *et al.* (2009) observed preponderance of dominance gene action for plant height, effective tillers per plant, panicle length, number of grains per panicle, spikelet sterility, 1000-grain weight and grain yield per plant. Pusa 2517-2-51-1, Sanwaal Basmati, Super Basmati, Ranbir Basmati and Basmati 370 were found to be good general combiner for yield and its components while high sca effects were showed by the Super Basmati x Ranbir Basmati, Pusa-2517-2-51-1 x Pusa Basmati 1, P-1121-92-8-1-1-3-3 x Ranbir Basmati and PAU-29-35-16-3-5-2 x Basmati 370.

Shivani *et al.* (2009) studied eighteen hybrids developed by crossing three lines with six testers were screened for various grain quality traits to assess the combining ability of the parents. For head rice recovery, the crossing involving IR 58025A with MTU 9992 and KMR-3, IR 62829A with MTU 9992 and IR 29723 and IR 68886A with IR 40750R and IR 21567 showed significant positive specific combining ability effects. For kernel length, IR 58025A and IR 68886A among lines and MTU 9992 and IR 21567 among testers showed positive significant general combining ability effects.

### III MATERIALS AND METHODS

The present investigation entitled on 'Genetic analysis in rice (*Oryza sativa* L.)' was carried out at paddy research station, National Agricultural Research Project, Navsari Agricultural University, Navsari during *Kharif* - 2009.

Navsari is situated at coastal region of South Gujarat. Geographically, it is situated at 20°-37' N latitude and 72°-54' E longitude with an altitude of 11.98 meters above the mean sea level. The weather during the growing season was normal and favourable for crop growth. The meteorological data for the cropping season are presented in Appendix-I.

#### 3.1 Experimental material

The experimental material for present investigation consisted of 54 entries including 4 females, 10 males and their 40 crosses. The particulars of rice parents are presented as follows:

**Table 3.1 : Name of parents :**

Line	Source	Tester	Source
1) IET-19044	N.A.R.P.,NAU, Navsari	1) NVSR-171	N.A.R.P.,NAU, Navsari
2) IET-19384	N.A.R.P.,NAU, Navsari	2) NVSR-172	N.A.R.P.,NAU, Navsari
3) IET-19512	N.A.R.P.,NAU, Navsari	3) NVSR-173	N.A.R.P.,NAU, Navsari

4) GR-11	N.A.R.P.,NAU, Navsari	4) NVSR-177	N.A.R.P.,NAU, Navsari
		5) NVSR-178	N.A.R.P.,NAU, Navsari
		6) NVSR-180	N.A.R.P.,NAU, Navsari
		7) NVSR-181	N.A.R.P.,NAU, Navsari
		8) NAUR-1	N.A.R.P.,NAU, Navsari
		9) IET-19046	N.A.R.P.,NAU, Navsari
		10) GR-12	N.A.R.P.,NAU, Navsari

### 3.2 Experimental procedure

The crossing programme was carried out using 4 females and 10 males by hand emasculation and pollination at NARP farm, NAU, Navsari during *summer* 2009, 40 crosses were obtained in line x tester mating design. All the hybrid seeds and selfed parental line seeds were harvested, cleaned and handled properly in seed bag for sowing in the next season.

### 3.3 Experimental design

The experiment was laid out in a randomized block design with three replications during *Kharif* - 2009. Each entry was planted in a single row consist of 10 plant in each row with a spacing 20 x 15 cm. The standard agronomical practices were

followed to raise the good experimental crop. Five competitive plants were randomly selected to record the observations on ten characters and mean values over five plants were subjected to statistical analysis. The procedures adopted for recording observation on various traits are described below.

### **3.4 Characters studied**

#### **3.4.1 Days to 50 per cent flowering**

When 50 per cent of the plants in a plot flowered, the date was recorded as 50 per cent flowering date for the genotype. Then number of days were worked out from the date of seeding in the nursery to that of flowering and recorded as number of days to 50 per cent flowering for each genotype in each replication.

#### **3.4.2 Panicles per plant**

The number of panicles per plant counted at time of harvesting of selected plant.

#### **3.4.3 Panicle length (cm)**

The length of main panicle was measured from base to the tip of panicle in centimeters at time of harvest.

#### **3.4.4 Plant height (cm)**

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

#### **3.4.5 Grains per panicle**

The total numbers of matured grains of five panicles of randomly selected plants were counted and the average number of grains per panicle was derived.

#### 3.4.6 Grain yield per plant (g)

The harvested panicles of the selected plants after sun drying were threshed and total seed weight was recorded in gram.

#### 3.4.7 Test weight (g)

The seed of all panicles per plant were mixed up thoroughly and 1000 grains were taken randomly and weighed in grams.

#### 3.4.8 Amylose content (%)

The amylose content was estimated as per the simplified colorimetric procedure of Juliano (1971).

#### 3.4.9 Protein content (%)

The nitrogen content was estimated from each sample by micro Kjeldahl method and percentage of protein was calculated by multiplying the nitrogen content percentage with factor 5.95 (Stoskopf, 1985).

#### 3.4.10 L/B ratio

The Kernel length: Kernel breadth ratio was counted as  

$$L:B \text{ ratio} = \text{Kernel length (mm)} / \text{Kernel breadth (mm)}.$$

### 3.5 Statistical analysis

Replication wise mean value for all the characters were subjected to statistical analysis at Computer Center, N. M. College of Agriculture, Navsari Agricultural University, Navsari for computing mean, variance, heterosis, general combining ability (gca) and specific combining ability (sca).

#### 3.5.1 Analysis of mean and variance

The data obtained for each character were analysed

the usual standard statistical procedure (Panse and Sukhatme, 1978). To provide comparisons, the treatment sums of squares were partitioned into parents vs hybrids, females vs males, among hybrids, among parents, among male parents and among female parents. The ANOVA table is as under.

**Table 3.2: Analysis of variance for parents and hybrids**

Source	d.f.	M.S.
Replications	(r-1)	
Parents	(p-1)	M <sub>1</sub>
Females	(f-1)	M <sub>2</sub>
Males	(m-1)	M <sub>3</sub>
Females vs. Males	1	M <sub>4</sub>
Hybrids	(h-1)	M <sub>5</sub>
Parents vs. Hybrids	1	M <sub>6</sub>
error	(r-1)(p+h-1)	M <sub>7</sub>
Total	r(p+h-1)	

r = Replication m = Males p = Parents f = Females h = Hybrids

### 3.5.2 Estimation of heterosis

Heterosis, expressed as per cent increase or decrease in the mean value of F<sub>1</sub> hybrid over the better parent (heterobeltiosis) was computed for each characters using following formula.

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \bar{BP}}{\bar{BP}} \times 100$$

Where,  $\bar{F}_1$  = Mean performance of hybrid

$\bar{BP}$  = Mean performance of better parent

The differences in the magnitude of heterosis were tested with the help of following formula,

Critical difference for

$$\text{Heterobeltiosis} = (2Me/r)^{1/2} \times t$$

Where,

- $r$  = Number of replications  
 $M_e$  = Error mean square  
 $t$  = Table value of 't' at degree of freedom corresponding to 5 % or 1 % level of significance

### 3.5.2.1 Test of significance

- Test of significance of hybrids =  $M_5 / M_7$   
 Parents vs hybrids =  $M_6 / M_7$   
 Females vs males =  $M_4 / M_7$   
 Females =  $M_2 / M_7$   
 Males =  $M_3 / M_7$

### 3.5.3 Combining ability analysis

Combining ability analysis was computed as per the procedure developed by Kempthorne (1957). The analysis of variance for combining ability is as follows:

**Table 3.3: Analysis of variance for combining ability**

Source of variation	d.f.	M.S.	Expected mean squares	
			Components	Co-variance
Replications	(r-1)			
Hybrids	(fm-1)			
Females	(f-1)	$M_1$	$\sigma_e^2 + r\sigma^2_{fm} + r m \sigma^2_f$	$\sigma_e^2 + r \text{Cov. (F.S.)} - 2(\text{Cov. (H.S.)} + [mr \text{Cov. (H.S.)}])$
Males	(m-1)	$M_2$	$\sigma_e^2 + r\sigma^2_{fm} + r m \sigma^2_m$	$\sigma_e^2 + r \text{Cov. (F.S.)} - 2\text{Cov. (H.S.)} + [fr \text{Cov. (H.S.)}]$
Females x Males	(f-1)(m-1)	$M_3$	$\sigma_e^2 + r\sigma^2_{fm}$	$\sigma_e^2 + r \text{Cov. (F.S.)} - 2\text{Cov. (H.S.)}$
Error	(r-1)(fm-1)	$M_4$	$\sigma_e^2$	$\sigma_e^2$
Total	(rfm - 1)			

From the expectation of mean squares, covariance of full-sibs and half-sibs were estimated using the sum of squares due to females ( $M_1$ ), males ( $M_2$ ) and females x males ( $M_3$ ) where,

$$\text{Cov.}(H.S.) = (M_1 - M_3) + (M_2 - M_3) / r(f + m)$$

$$\begin{aligned} \text{Cov.}(F.S.) = & (M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4) / 3r \\ & + 6r \text{Cov.}(H.S.) - r(f + m) \text{Cov.}(H.S.) / 3r \end{aligned}$$

Estimates of variance components were obtained in the following manner.

$$\hat{\sigma}^2 f = M_1 - M_3 / r \times m$$

$$\hat{\sigma}^2 m = M_2 - M_3 / r \times f$$

$$\hat{\sigma}^2 fm = M_3 - M_4 / r$$

Estimates of Covariance for half sib (H.S.) and Covariance for full sib (F.S.) would be:

$$\text{Cov.}(H.S.) = (f\hat{\sigma}^2 m + m\hat{\sigma}^2 f) / (f + m)$$

$$\text{Cov.}(F.S.) = [(\hat{\sigma}^2 fm + 2\text{Cov.}(H.S.))]$$

From the above equations, variance due to general combining ability ( $\sigma^2_{gca}$ ) and variance due to specific combining ability ( $\sigma^2_{sca}$ ) were as follows.

$$\hat{\sigma}^2_{gca} = \text{Cov.}(H.S.)$$

$$\hat{\sigma}^2_{sca} = \text{Cov.}(F.S.) - 2 \text{Cov.}(H.S.)$$

$\hat{\sigma}^2_{gca}$  =  $\hat{\sigma}^2_f$  =Cov.1- Covariance between half-sibs plants with only the female parents in common

$\hat{\sigma}^2_{gca}$  =  $\hat{\sigma}^2_m$  =Cov.2- Covariance between half-sibs plants with only the male parents in common

$\hat{\sigma}^2_{sca}$  =  $\hat{\sigma}^2_{fm}$

### 3.5.3.1 Estimation of general and specific combining ability effects

The model used to estimate of general and specific combining ability effects of the  $ij^{th}$  observation was:

$$Y_{ij} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

Where,

$\mu$  = Population mean

$g_i$  = gca effects of  $i^{th}$  female parent

$g_j$  = gca effects of  $j^{th}$  male parent

$s_{ij}$  = sca effects of  $ij^{th}$  combination

$e_{ijk}$  = Error associated with  $ij^{th}$  hybrid

The individual effects were measured as follows:

$$\mu = X_{...} / mfr$$

Where,

$X_{...}$  = Total of hybrid combinations

$$g_i = X_{i..} / mr - X_{...} / mfr$$

Where,

$X_{i..}$  = Total of  $i^{th}$  female over all males and replications

$$g_j = X_{.j} / fr - X_{...} / mfr$$

Where,

$X_{.j}$  = Total of  $j^{\text{th}}$  male parents over all female parents and replications.

$$s_{ij} = X_{ij} / r - X / mr - X_{.j} / fr + X_{...} / mfr$$

Where,

$X_{ij}$  =  $ij^{\text{th}}$  combination total all replications

### 3.5.3.2 Test of significance

The null hypothesis,  $\hat{\sigma}^2_{mf} = 0$  can be tested by  $F(n_3, n_4) = M_3 / M_4$ . If  $M_3$  is significant than test could be  $F(n_1, n_3) = M_1 / M_3$  for  $\hat{\sigma}^2_f = 0$ .  $F(n_2, n_3) = M_2 / M_3$  for  $\hat{\sigma}^2_m = 0$ .

Where,

$M_3$  is not significant, than pooled error is used as denominator.

$$\text{Pooled error} = \frac{\text{S.S.due to error} + \text{S.S.due to } (m \times f)}{\text{d.f.of error} + \text{d.f.of } (m \times f)}$$

### 3.5.3.3. Standard error for general and specific combining ability effects

Standard errors for both the effects were calculated as follows.

$$\text{Variance } (g_i) = \frac{\hat{\sigma}_e^2 (f - 1)}{mfr}$$

$$\begin{aligned} \text{Variance } (g_j) &= \frac{\hat{\sigma}_e^2 (m - 1)}{mfr} \\ \text{Variance } (S_{ij}) &= \frac{\hat{\sigma}_e^2 (f - 1) (m - 1)}{mfr} \\ \text{SE } (g_i - g_j) \text{ (females)} &= \frac{2 \sigma_e^2}{rm} \\ \text{SE } (g_i - g_j) \text{ (males)} &= \frac{2 \sigma_e^2}{rf} \\ \text{SE } (S_{ij} - S_{kl}) &= \frac{2 \sigma_e^2}{r} \end{aligned}$$

Where,

$\sigma_e^2$  = Error variance



*EXPERIMENTAL*  
*RESULTS*



## IV EXPERIMENTAL RESULTS

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The results of present investigation on 'Genetic Analysis in Rice (*Oryza sativa* L.)' are presented as under.

4.1 Analysis of variance for the experimental design

4.2 Magnitude of heterosis

4.3 Combining ability analysis

4.3.1 Analysis of variance for combining ability

4.3.2 Combining ability effects

**4.1 Analysis of variance for the experimental design**

The analysis of variance for all the ten characters under study is presented in Table 4.1

The result revealed that the mean squares due to parents were found highly significant for all the characters except grains per panicle, grain yield per plant and amylose content. The mean squares due to hybrids for all the characters were found highly significant. Parents vs hybrids comparison was found significant for all the characters except panicles length, plant height and grain yield per plant indicating substantial amount of heterosis among hybrids.

Characterwise description of different variance components are made in ensuing paragraphs. The mean performance of parents and hybrids is presented in Appendix-II.

**Table 4.1 : Analysis of variance (mean sum of squares) for experimental design for different characters in rice.**

Sr. No	Characters	Replication	Parents	Females	Males	Females vs Males	Hybrids	Parents vs Hybrids	Error
	d.f.	2	13	3	9	1	39	1	106
1	Days to 50 % flowering	78.52566	395.91439**	155.11425**	217.26535**	2726.15612**	158.03756**	332.14484**	32.2651
2	Panicles per plant	0.68222	4.69089**	4.51281**	3.92091**	12.15501**	9.21258**	5.74385**	0.7125
3	Panicle length (cm)	11.22047	9.71463*	5.51671	12.19278**	0.00508	28.13443**	14.86417	4.3487
4	Plant height (cm)	91.38218	99.77574**	122.47503*	62.46302	367.49226**	137.66254**	19.57536	39.1643
5	Grains per panicle	30.49924	177.84069	8.72750	123.69700	1172.47359**	568.00718**	2038.99839**	111.8234
6	Grain yield per plant (g)	1.33157	5.56490	6.78067	5.74328	0.31215	33.11246**	5.08142	3.7657
7	1000 grain weight (g)	1.51179	4.62927**	7.53911**	3.17211**	9.01414**	31.78664**	29.18699**	0.7462
8	Amylose content (%)	4.67411	2.15971	3.10227	2.06834	0.15429	8.67310**	37.80432**	2.4625
9	Protein content (%)	0.16088	0.18768**	0.18327	0.19899**	0.09905	0.28234**	0.64768**	0.07071
10	L/B ratio	0.00046	0.04593**	0.02320	0.05858**	0.00024	0.08079**	0.08324*	0.0149

\*Significant at 5 %

\*\*Significant at 1 %

#### 4.1.1 Days to 50 per cent flowering

Mean squares due to hybrids were higher than that of parents. Mean squares due to Parents vs hybrids comparison was highly significant indicating greater variation among hybrids for days to 50 percent flowering. Among the parents, males showed much variation for this trait as indicated by highly significant mean squares due to males. This was supported by highly significant mean squares due to females vs males comparison.

The variation for days to 50 per cent flowering in parents ranged from 85.40 days (NVSR-177) to 119.53 days (IET-19044) and in hybrids it ranges from 86.23 days (GR-11 x NVSR-180) to 122.24 days (IET-19044 x NVSR-172).

#### 4.1.2 Panicles per plant

Analysis of variance showed greater contributions of hybrids compared to the parents. The mean squares for Parents vs hybrids comparison was highly significant. The variation for panicles per plant in parents ranged from 7.20 (NVSR-177) to 11.50 (IET-19512), whereas range of variation in hybrids was observed from 6.34 (GR-11 x NVSR-173) to 12.93 (IET-19044 x NVSR-171).

#### 4.1.3 Panicle length (cm)

The contributions of mean squares due to hybrids were more than that the parents. The mean squares for Parents vs hybrids comparison was non-significant. Among the parents, males

and females were found to be significant and non significant respectively.

A perusal of mean values revealed that among parents NVSR-172 (30 cm) had longest panicle length and GR-12 (22.80 cm) had shortest panicle length. The hybrids varied from 20.11 cm (IET-19512 x GR-12) to 32.55 cm (IET-19044 x NVSR-171) for this character.

#### **4.1.4 Plant height (cm)**

The magnitude of mean square due to hybrids was higher than that due to parents. The mean squares due to females vs males were found to be highly significant. The parents vs. hybrids comparison was found non-significant.

The variation for plant height among females was 102.53 cm (IET-19384) to 117.53 cm (IET-19044). Whereas, among males NVSR-181 was dwarfest (92.68 cm). Hybrids varied for plant height from 91.25 cm (IET-19512 x NVSR-181) to 117.12 cm (IET-19044 x NVSR-178).

#### **4.1.5 Grains per panicle**

Analysis of variance showed greater contribution of hybrids compared to the parents. The Parents vs hybrids comparison was highly significant indicating greater variation among hybrids for grains per panicle. Mean squares due to males and females were found non-significant.

The range of mean performance in parents for grains per panicle was from 128.97 (NVSR-178) to 151.30 (GR-11) and in hybrids it varied from 130.25 (IET-19384 x NVSR-180) to 180.60 (IET-19044 X NVSR-171).

#### **4.1.6 Grain yield per plant (g)**

The contribution of mean squares due to hybrids was more than those parents. The Parents vs hybrids comparison was non-significant indicating lesser variation among hybrids for this trait.

Mean grain yield per plant in the parents ranged from 17.87 g (NVSR-181) to 22.75 g (GR-12) and in hybrids it varied from 14.97 g (IET-19512 x GR-12) to 26.77 g (IET-19044 X NVSR-171).

#### **4.1.7 1000 grain weight (g)**

Analysis of variance showed grater contribution of hybrids as compared to parents. Mean squares due to Parents vs hybrids comparison was highly significant indicating greater variation in hybrids for 1000 grain weight. Further breakup of parents mean squares into mean squares due to males and due to females indicated more contribution of females to the parental variation.

The variation for 1000-grain weight in parents was ranged from 17.16 g (NVSR-171) to 21.47 g (GR-11) and in hybrids from 14.23 g (IET-19384 x NVSR-171) to 26.35 g (GR-11 x IET-19046).

#### 4.1.8 Amylose content (%)

Mean squares due to hybrids were higher than that due to parents. The Parents vs hybrids comparison was highly significant indicating higher variation among hybrids for amylose content. Mean squares due to males and due to females were found non-significant.

The variation for amylose content in parents was from 19.02 percent (NVSR-172) to 21.61 percent (NVSR-180). The amylose content in hybrids varied from 19.13 percent (GR-11 X GR-12) to 25.83 percent (IET-19044 x NAUR-1).

#### 4.1.9 Protein content (%)

The contribution of mean squares due to hybrids was more than that due to parents. The Parents vs hybrids comparison was significant indicating variation in hybrids for this trait. Mean squares due to males and due to females were found highly significant and non-significant respectively.

The variation for protein content among parents ranged from 6.23 percent (NVSR-173) to 6.96 percent (IET-19384). The protein content in hybrids varied from 6.24 percent (GR-11 x NAUR-1) to 7.40 percent (IET-19044 x NVSR-177).

#### 4.1.10 L/B Ratio

The contribution of mean squares due to hybrids was more than the parents. The Parents vs hybrids comparison was significant indicating greater variation among hybrids for this

trait. Among the parents both males and females were highly significant and non-significant respectively.

The variation for L/B ratio among parents ranged from 2.90mm (NVSR-177) to 3.35mm (NVSR-172). In case of hybrids varied from 2.93 mm (GR-11 x NVSR-177) to 3.55 mm (IET-19044 X NVSR-171)

#### **4.1 Magnitude of heterosis**

The estimates of heterosis over better parent (heterobeltiosis) for different characters are presented in Table 4.2.

It may be mentioned here that for calculation of heterobeltiosis for days to 50 per cent flowering and plant height, the low scoring parent was considered as better parent.

The magnitude of heterotic effects observed in different characters varied with crosses. The results of each character are narrated in the following paragraphs.

##### **4.2.1 Days to 50 per cent flowering**

The estimates of heterosis for this character revealed that heterobeltiosis ranged from -13.73 per cent (IET-19044 x NAUR-1) to 35.52 per cent (IET-19044 x NVSR-172). Ten crosses showed significant heterobeltiosis for this trait, out of these six crosses exhibited significant negative heterobeltiosis, which is desirable.

Table 4.2 : Estimation of heterosis for different characters in rice.

Crosses	Days to 50 % flowering over better parents	Panicles per plant over better parents	Panicle length (cm) over better parents
1) IET-19044 x NVSR-171	-9.47*	20.81**	22.03**
2) IET-19044 x NVSR-172	35.52**	-32.68**	-11.86*
3) IET-19044 x NVSR-173	6.53	-7.79	5.67
4) IET-19044 x NVSR-177	10.82*	-16.20*	6.83
5) IET-19044 x NVSR-178	4.92	-33.27**	-18.63**
6) IET-19044 x NVSR-180	9.21	-12.71	3.29
7) IET-19044 x NVSR-181	8.85	-10.28	2.66
8) IET-19044 x NAUR-1	-13.73**	19.94**	18.10**
9) IET-19044 x IET-19046	-8.49	-2.80	5.66
10) IET-19044 x GR-12	4.68	0.68	-2.15
11) IET-19384 x NVSR-171	-12.41**	-28.74**	-10.05
12) IET-19384 x NVSR-172	10.00	-2.63	-4.96
13) IET-19384 x NVSR-173	-2.35	10.86	13.23*
14) IET-19384 x NVSR-177	9.75	-6.09	1.16
15) IET-19384 x NVSR-178	9.57	-4.58	0.38
16) IET-19384 x NVSR-180	3.66	-27.50**	-22.55*
17) IET-19384 x NVSR-181	12.11*	-4.21	1.97
18) IET-19384 x NAUR-1	5.35	-0.63	1.66
19) IET-19384 x IET-19046	-12.48**	20.96**	13.04*
20) IET-19384 x GR-12	6.70	-9.66	-2.78
21) IET-19512 x NVSR-171	-0.28	-15.22*	-1.75
22) IET-19512 x NVSR-172	9.76	-7.54	-7.50
23) IET-19512 x NVSR-173	9.61	-10.72	-4.44
24) IET-19512 x NVSR-177	17.68**	-16.23**	-3.89
25) IET-19512 x NVSR-178	2.64	3.39	13.74
26) IET-19512 x NVSR-180	3.52	-8.52	-7.14
27) IET-19512 x NVSR-181	-6.29	12.52*	13.32*
28) IET-19512 x NAUR-1	-4.28	-7.54	-2.79
29) IET-19512 x IET-19046	-6.37	-4.55	-19.28**
30) IET-19512 x GR-12	-12.15**	-10.70	-20.22**
31) GR-11 x NVSR-171	-5.96	-8.92	-4.90
32) GR-11 x NVSR-172	6.43	-1.26	-1.27
33) GR-11 x NVSR-173	6.22	-31.57**	-15.63*
34) GR-11 x NVSR-177	9.48	-10.86	-2.76
35) GR-11 x NVSR-178	7.63	-7.08	-7.02
36) GR-11 x NVSR-180	-4.53	10.68	12.78*
37) GR-11 x NVSR-181	3.18	-4.17	-4.77
38) GR-11 x NAUR-1	7.21	-29.02**	-13.27*
39) GR-11 x IET-19046	-8.27	21.83**	13.44*
40) GR-11 x GR-12	-9.14*	12.96*	13.21
S.Ed.±	4.6379	0.6905	1.7027
C.D. at 5 %	9.2334	1.3748	3.3898
C.D. at 1 %	12.2457	1.8233	4.4957

Contd....

Crosses	Plant height (cm) Over better parents	Grains per panicle Over better parents	Grain yield per plant (g) Over better parents
1) IET-19044 x NVSR-171	-12.87**	20.00**	31.14**
2) IET-19044 x NVSR-172	12.10*	-8.29	-19.93*
3) IET-19044 x NVSR-173	4.35	-1.36	3.59
4) IET-19044 x NVSR-177	1.72	-1.59	2.61
5) IET-19044 x NVSR-178	11.22*	-13.44*	-23.26**
6) IET-19044 x NVSR-180	3.10	-1.96	4.18
7) IET-19044 x NVSR-181	11.68*	-2.19	-1.32
8) IET-19044 x NAUR-1	-11.36*	16.80**	23.22**
9) IET-19044 x IET-19046	0.90	-1.13	4.49
10) IET-19044 x GR-12	4.92	0.07	-0.76
11) IET-19384 x NVSR-171	8.99	-7.99	-21.83**
12) IET-19384 x NVSR-172	2.76	-1.65	-2.58
13) IET-19384 x NVSR-173	-10.53*	15.76**	19.35*
14) IET-19384 x NVSR-177	4.76	-2.71	-0.29
15) IET-19384 x NVSR-178	3.64	-4.17	-1.57
16) IET-19384 x NVSR-180	9.58	-11.69*	-24.78**
17) IET-19384 x NVSR-181	9.48	-3.32	-3.86
18) IET-19384 x NAUR-1	4.95	0.54	-1.24
19) IET-19384 x IET-19046	-7.22	16.51**	21.03**
20) IET-19384 x GR-12	4.42	-1.08	-7.46
21) IET-19512 x NVSR-171	-1.98	-5.06	-0.29
22) IET-19512 x NVSR-172	2.54	-2.89	-5.19
23) IET-19512 x NVSR-173	3.37	-4.57	-3.93
24) IET-19512 x NVSR-177	0.79	-4.80	-2.96
25) IET-19512 x NVSR-178	-10.54*	15.67**	23.84**
26) IET-19512 x NVSR-180	2.16	-5.17	-4.52
27) IET-19512 x NVSR-181	-1.54	15.69**	25.12**
28) IET-19512 x NAUR-1	-0.84	-1.81	-3.88
29) IET-19512 x IET-19046	9.42	-12.11*	-26.03**
30) IET-19512 x GR-12	10.89*	-9.60	-34.22**
31) GR-11 x NVSR-171	-3.81	-3.27	-8.76
32) GR-11 x NVSR-172	0.65	-1.06	-3.65
33) GR-11 x NVSR-173	10.34*	-12.34*	-28.31**
34) GR-11 x NVSR-177	-1.03	-3.24	-1.27
35) GR-11 x NVSR-178	0.03	-4.66	-7.53
36) GR-11 x NVSR-180	-4.36	6.47	14.96*
37) GR-11 x NVSR-181	8.48	-3.75	-9.53
38) GR-11 x NAUR-1	3.51	-7.05	-28.84**
39) GR-11 x IET-19046	-10.74*	16.39**	21.39**
40) GR-11 x GR-12	-2.31	11.59*	16.23*
S.Ed.±	5.10	8.63	1.58
C.D. at 5 %	10.17	17.18	3.15
C.D. at 1 %	13.49	22.79	4.1

Contd.....

Crosses	1000 grain weight (g) over better parents	Amylose content (%) over better parents	Protein content (%) over better parents	L/B ratio
1) IET-19044 x NVSR-171	35.99**	22.90**	0.74	9.67**
2) IET-19044 x NVSR-172	-16.07**	0.27	-1.83	0.90
3) IET-19044 x NVSR-173	4.61	-1.21	-3.36	-0.82
4) IET-19044 x NVSR-177	6.45	1.49	8.40**	-1.54
5) IET-19044 x NVSR-178	-21.16**	5.21	0.64	2.57
6) IET-19044 x NVSR-180	6.65	1.48	0.96	1.65
7) IET-19044 x NVSR-181	3.79	-0.88	-2.96	0.31
8) IET-19044 x NAUR-1	29.42**	19.93**	7.06*	7.72*
9) IET-19044 x IET-19046	3.48	-0.43	-0.82	0.51
10) IET-19044 x GR-12	3.46	1.68	3.70	1.54
11) IET-19384 x NVSR-171	-24.73**	-3.28	-2.11	-0.73
12) IET-19384 x NVSR-172	-0.35	-0.47	-1.72	-7.36*
13) IET-19384 x NVSR-173	22.86**	-5.80	5.08	5.24
14) IET-19384 x NVSR-177	-1.41	-1.51	0.24	-3.98
15) IET-19384 x NVSR-178	0.26	-2.00	-1.29	-0.62
16) IET-19384 x NVSR-180	-24.93**	-0.57	2.20	-0.42
17) IET-19384 x NVSR-181	-3.39	-1.06	-0.91	-7.23*
18) IET-19384 x NAUR-1	0.18	3.99	-6.56*	1.93
19) IET-19384 x IET-19046	18.42**	21.71**	-5.41	-1.68
20) IET-19384 x GR-12	3.47	-0.71	-0.57	2.10
21) IET-19512 x NVSR-171	2.45	-1.69	5.38	-1.71
22) IET-19512 x NVSR-172	0.94	-5.64	0.37	-5.57
23) IET-19512 x NVSR-173	-0.44	0.87	2.46	-4.09
24) IET-19512 x NVSR-177	-6.49	-2.03	3.52	-4.95
25) IET-19512 x NVSR-178	23.96**	12.98*	-0.26	7.63*
26) IET-19512 x NVSR-180	-3.04	-0.02	-1.73	0.95
27) IET-19512 x NVSR-181	20.30**	14.17*	9.46**	-4.30
28) IET-19512 x NAUR-1	2.19	3.54	1.31	-1.32
29) IET-19512 x IET-19046	-22.99**	-1.73	-4.79	-1.39
30) IET-19512 x GR-12	-22.08**	-3.36	-2.19	-2.63
31) GR-11 x NVSR-171	-7.83*	1.89	-7.24*	-2.35
32) GR-11 x NVSR-172	-3.88	-2.09	-4.43	-4.48
33) GR-11 x NVSR-173	-28.68**	2.78	2.95	-2.96
34) GR-11 x NVSR-177	-7.20*	1.48	-0.88	-3.51
35) GR-11 x NVSR-178	-6.44	8.25	-2.17	-4.12
36) GR-11 x NVSR-180	15.85**	2.68	-8.86**	-2.96
37) GR-11 x NVSR-181	-11.58**	5.44	-3.74	-1.94
38) GR-11 x NAUR-1	-31.83**	5.40	-7.88	-2.03
39) GR-11 x IET-19046	22.75**	18.40**	7.22*	9.23**
40) GR-11 x GR-12	21.80**	-10.37	0.24	7.78*
S.Ed.±	0.70	1.28	0.21	0.099
C.D. at 5 %	1.42	2.55	0.43	0.19
C.D. at 1 %	1.86	3.38	0.57	0.26

#### 4.2.2 Panicles per plant

As regards to heterobeltiosis, it varied from -33.27 per cent (IET-19044 x NVSR-178) to 21.83 per cent (GR-11 x IET-19046). With respect to heterobeltiosis, fifteen hybrids recorded significant heterotic effects, of which six hybrids found significant. Positive heterobeltiosis recorded upto 21.83 per cent (GR-11 x IET-19046).

#### 4.2.3 Panicle length (cm)

With respect to heterobeltiosis, fourteen crosses showed significant heterobeltiosis of which seven crosses exhibited significant positive heterobeltiosis, while seven cross combinations expressed significant negative heterosis over their respective better parents. Heterobeltiosis varied from -22.55 per cent (IET-19384 x NVSR-180) to 22.03 per cent (IET-19044 x NVSR-171).

#### 4.2.4 Plant height (cm)

Heterotic effects over better parental values varied from -12.87 per cent (IET-19044 x NVSR-171) to 12.10 per cent (IET-19044 x NVSR-172). For plant height, ten crosses showed significant heterobeltiosis, out of which five cross exhibited significant positive heterosis while five cross combinations exhibited significant negative heterosis over their respective better parents.

#### 4.2.5 Grains per panicle

Grains per panicle are an important component which considerably contributes towards higher grain yield. For this trait, heterosis over better parent varied from -13.44 per cent (IET-19044 x NVSR-178) to 20.00 per cent (IET-19044 x NVSR-171). Under present study, twelve crosses showed significant heterobeltiosis. Out of those twelve crosses, eight crosses exhibited significant positive heterosis while four crosses exhibited significant negative heterosis.

#### 4.2.6 Grain yield per plant (g)

A good number of hybrids were found with high amount of heterobeltiosis for grain yield per plant. The heterobeltiosis ranges from -34.22 per cent (IET-19512 x GR-12) to 31.14 per cent (IET-19044 x NVSR-171). For grain yield per plant seventeen crosses showed significant heterobeltiosis, while out of seventeen crosses nine crosses showed significant positive heterotic effects over their respective better parents

#### 4.2.7 1000 grain weight (g)

In case of 1000 grain weight, heterobeltiosis ranged from -31.83 per cent (GR-11 x NAUR-1) to 35.99 per cent (IET-19044 x NVSR-171). Out of forty crosses, eleven crosses showed significant negative heterobeltiosis, while nine crosses showed significant positive heterobeltiosis for this trait.

#### 4.2.8 Amylose content (%)

Heterotic effects over better parental value varied from -10.37 per cent (GR-11 x GR-12) to 22.90 per cent (IET-19044 x NVSR-171). With respect to heterobeltiosis, six hybrids expressed significant positive heterobeltiosis for this trait.

#### 4.2.9 Protein content (%)

The estimation of heterotic effects for protein content over better parent ranged from -8.86 per cent (GR-11 x NVSR-180) to 9.46 per cent (IET-19512 x NVSR-181). Among seven crosses which showed significant heterobeltiosis, three crosses showed significant negative heterobeltiosis while four crosses showed significant positive heterobeltiosis.

#### 4.2.10 L/B Ratio

Heterotic effects over better parental value varied from -7.36 per cent (IET-19384 x NVSR-172) to 9.67 per cent (IET-19044 x NVSR-171). With respect to heterobeltiosis, seven hybrids showed significant heterotic effects, of which five hybrids showed significant positive heterobeltiosis and only two hybrids expressed significant negative heterobeltiosis for this trait.

### 4.3 Combining ability analysis

#### 4.3.1 Analysis of variance for combining ability

Various genetic variances were estimated from the analysis of variance for combining ability for ten characters as suggested by Kempthorne (1957). The results are presented in

**Table 4.3 : Analysis of variance for combining ability for different characters in rice.**

Source of variation	d.f.	Days to 50 % flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B ratio
Replication	2	77.28	0.54	3.91	106.71	32.83	0.53	0.35	4.81	0.05	0.00033
Female	3	87.21	21.73	46.42	37.65	179.85	35.24	39.02	11.24	0.44	0.27**
Male	9	182.46	7.98	8.47	109.19	190.04	8.29	6.71	12.06	0.23	0.11*
Female x male	27	157.76**	8.22**	32.65**	158.26**	737.12**	41.14**	39.33**	7.25**	0.27**	0.04**
Error	78	30.85	0.72	4.11	39.90	134.99	4.39	0.85	2.57	0.07	0.01
$\sigma^2 f$		-2.35	0.45	0.45	-4.02	-18.57	-0.19	-0.01	0.13	0.005	0.007**
$\sigma^2 m$		2.05	-0.02	-2.01	-4.08	-45.58	-2.73	-2.71	0.40	-0.003	0.005*
$\sigma^2 gca$		-1.09	0.31*	-0.24	-4.04	-26.29	-0.92	-0.78	0.20**	0.003	0.007**
$\sigma^2 sca$		41.83**	2.50**	9.43**	39.70**	208.43**	12.46**	12.86**	1.59**	0.06**	0.01**
$\sigma^2 gca / \sigma^2 sca$		-0.030	0.124	0.0254	-0.101	-0.126	-0.0738	-0.0606	0.1257	0.05	0.7

\*Significant at 5 %

\*\*Significant at 1 %

Table 4.4 : Estimating general combining ability effects of parents for different characters in rice.

Parents	Days to 50 % flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B ratio
<b>Females</b>										
IET-19044	2.111*	0.25	1.034**	1.37	2.27	0.90*	0.78**	0.34	0.102*	0.14**
IET-19384	0.601	-0.79**	-0.591	-0.64	-1.56	-0.59	-0.69**	-0.90**	0.103*	-0.017
IET-19512	-1.018	1.086**	-1.472**	0.40	-2.60	-1.22**	-1.23**	0.16	-0.066	-0.071**
GR-11	-1.694	-0.54	1.029**	-1.13	1.89	0.92*	1.13**	0.39	-0.14**	-0.053*
SE (gi)	1.03	0.15	0.38	1.14	1.93	0.35	0.15	0.28	0.048	0.022
SE (gi-gj)	1.46	0.21	0.53	1.61	2.73	0.50	0.22	0.40	0.068	0.031
<b>Males</b>										
NVSR-171	-0.542	-0.304	-0.274	-1.91	1.71	-0.22	0.0009	0.38	-0.075	0.020
NVSR-172	5.932**	-0.548*	1.041	2.89	-4.40	-1.089	-1.073**	-1.43**	-0.19*	0.024
NVSR-173	-0.953	-0.578*	0.129	-1.01	-0.81	-0.34	-0.20	-0.36	0.053	-0.067
NVSR-177	-2.594	-0.86**	0.002	2.71	-4.35	-0.04	-0.514*	-0.71	0.27**	-0.15**
NVSR-178	-4.947**	-0.637*	-1.521*	0.49	-2.27	-0.71	-0.52*	0.52	-0.096'	0.091*
NVSR-180	-5.187**	-0.485	0.312	1.68	-4.26	-0.06	0.19	0.06	0.022	-0.012
NVSR-181	0.324	0.316	0.354	-6.04**	2.62	0.108	0.06	0.07	0.032	-0.140**
NAUR-1	6.036**	0.462	0.560	1.41	3.44	-0.40	-0.201	1.56**	-0.175*	0.147**
IET-19046	-0.439	1.508**	0.735	-3.26	7.61*	1.771**	1.71**	1.26**	0.056	0.022
GR-12	2.371	1.133**	-1.338*	3.02	0.69	1.017	0.55	-1.36**	0.11	0.072*
SE (gj)	1.63	0.24	0.60	1.80	3.05	0.56	0.24	0.45	0.076	0.035
SE ((gi-gj)	2.31	0.34	0.85	2.55	4.31	0.79	0.35	0.64	0.108	0.050

\*Significant at 5 %

\*\*Significant at 1 %

Table 4.5 : Estimation of specific combining ability for days to 50 per cent flowering, panicles per plant and panicle length (cm).

Crosses	Days to 50 % flowering Over better parents	Panicles per plant Over better parents	Panicle length (cm) Over better parents
1) IET-19044 x NVSR-171	-4.42	3.313**	4.75**
2) IET-19044 x NVSR-172	16.01**	-2.16**	-2.67*
3) IET-19044 x NVSR-173	-0.69	0.527	0.334
4) IET-19044 x NVSR-177	-3.06	-0.086	0.42
5) IET-19044 x NVSR-178	-3.23	-2.141**	-4.84**
6) IET-19044 x NVSR-180	3.53	-0.093	0.88
7) IET-19044 x NVSR-181	2.02	-0.63	-1.03
8) IET-19044 x NAUR-1	-14.71**	2.45**	3.40**
9) IET-19044 x IET-19046	-0.71	-1.026*	-0.61
10) IET-19044 x GR-12	5.27	-0.147	-0.63
11) IET-19384 x NVSR-171	-6.00	-2.241**	-3.30**
12) IET-19384 x NVSR-172	-5.00	0.930	1.02
13) IET-19384 x NVSR-173	-7.41*	1.580**	4.00**
14) IET-19384 x NVSR-177	-2.46	0.331	0.36
15) IET-19384 x NVSR-178	2.36	0.236	0.58
16) IET-19384 x NVSR-180	0.025	-1.783**	-4.81**
17) IET-19384 x NVSR-181	6.60*	-0.684	-0.57
18) IET-19384 x NAUR-1	7.05*	0.610	0.56
19) IET-19384 x IET-19046	-3.53	1.24*	2.55*
20) IET-19384 x GR-12	8.86**	-0.218	-0.39
21) IET-19512 x NVSR-171	8.37*	-0.69	-0.42
22) IET-19512 x NVSR-172	-4.098	0.430	1.14
23) IET-19512 x NVSR-173	5.28	0.094	0.10
24) IET-19512 x NVSR-177	5.92	-0.252	-0.09
25) IET-19512 x NVSR-178	-2.09	1.776**	4.62**
26) IET-19512 x NVSR-180	1.52	0.254	0.35
27) IET-19512 x NVSR-181	-9.11**	1.873**	3.22**
28) IET-19512 x NAUR-1	-1.54	-0.58	0.24
29) IET-19512 x IET-19046	4.70	-1.283*	-5.06**
30) IET-19512 x GR-12	-8.95**	-1.614**	-4.11**
31) GR-11 x NVSR-171	2.05	-0.375	-1.02
32) GR-11 x NVSR-172	-6.41	0.806	0.51
33) GR-11 x NVSR-173	2.82	-2.200**	-4.44**
34) GR-11 x NVSR-177	-0.40	0.007	-0.69
35) GR-11 x NVSR-178	2.96	0.129	-0.37
36) GR-11 x NVSR-180	-5.07	1.623**	3.57**
37) GR-11 x NVSR-181	0.48	-0.555	-1.61
38) GR-11 x NAUR-1	9.20**	-2.484**	-4.21**
39) GR-11 x IET-19046	-0.45	1.070*	3.13*
40) GR-11 x GR-12	-5.17	1.979**	5.14**
SE (Sij)	3.27	0.48	1.20
SE (Sij- Skl)	4.63	0.69	1.70

Contd.....

Crosses	Plant height (cm) Over better parents	Grains per panicle Over better parents	Grain yield per plant (g) Over better parents
1) IET-19044 x NVSR-171	-11.317**	27.347**	5.846**
2) IET-19044 x NVSR-172	6.814	-9.121	-3.712**
3) IET-19044 x NVSR-173	1.144	-2.278	0.343
4) IET-19044 x NVSR-177	0.124	0.916	-0.158
5) IET-19044 x NVSR-178	10.007**	-19.001**	-4.771**
6) IET-19044 x NVSR-180	-0.252	0.282	0.183
7) IET-19044 x NVSR-181	2.934	-6.967	-1.116
8) IET-19044 x NAUR-1	-10.906	20.804**	4.408**
9) IET-19044 x IET-19046	1.994	-10.35	-1.439
10) IET-19044 x GR-12	-0.543	-1.63	0.415
11) IET-19384 x NVSR-171	9.075*	-13.707*	-4.288**
12) IET-19384 x NVSR-172	-2.127	3.498	1.330
13) IET-19384 x NVSR-173	-12.054**	23.855**	4.409**
14) IET-19384 x NVSR-177	0.103	0.152	-0.192
15) IET-19384 x NVSR-178	1.176	-4.082	0.122
16) IET-19384 x NVSR-180	6.070	-13.185*	-4.444**
17) IET-19384 x NVSR-181	2.916	-7.728	-1.143
18) IET-19384 x NAUR-1	1.606	-2.847	0.357
19) IET-19384 x IET-19046	-6.207	16.537**	3.460**
20) IET-19384 x GR-12	-0.558	-2.494	0.391
21) IET-19512 x NVSR-171	1.331	-7.111	-0.535
22) IET-19512 x NVSR-172	-2.132	2.684	1.427
23) IET-19512 x NVSR-173	1.121	-3.853	0.416
24) IET-19512 x NVSR-177	0.098	-0.656	-0.082
25) IET-19512 x NVSR-178	-11.925**	27.724**	4.915**
26) IET-19512 x NVSR-180	-0.261	-1.296	0.263
27) IET-19512 x NVSR-181	-8.339*	22.854**	3.784**
28) IET-19512 x NAUR-1	1.601	-3.991	0.464
29) IET-19512 x IET-19046	11.861**	-23.504**	-5.583**
30) IET-19512 x GR-12	6.644	-12.849*	-5.069**
31) GR-11 x NVSR-171	0.911	-6.529	-1.023
32) GR-11 x NVSR-172	-2.555	2.939	0.955
33) GR-11 x NVSR-173	9.788**	-17.724**	-5.169**
34) GR-11 x NVSR-177	-0.325	-0.411	0.433
35) GR-11 x NVSR-178	0.742	-4.641	-0.266
36) GR-11 x NVSR-180	-5.557	14.199*	3.998**
37) GR-11 x NVSR-181	2.488	-8.160	-1.525
38) GR-11 x NAUR-1	7.698*	-13.966*	-5.228**
39) GR-11 x IET-19046	-7.648*	17.318**	3.562**
40) GR-11 x GR-12	-5.542	16.973**	4.26**
SE (Sij)	3.613	6.105	1.120
SE (Sij- Skl)	5.109	8.634	1.584

Contd.....

Crosses	1000 grain weight (g) over better parents	Amylose content (%) over better parents	Protein content (%) over better parents	L/B ratio
1) IET-19044 x NVSR-171	5.736**	3.078**	-0.007	0.205**
2) IET-19044 x NVSR-172	-3.163**	0.189	-0.058	0.028
3) IET-19044 x NVSR-173	-0.066	-0.427	-0.412**	-0.048
4) IET-19044 x NVSR-177	0.595	-0.271	0.244	0.018
5) IET-19044 x NVSR-178	-4.687**	-0.738	0.007	-0.097
6) IET-19044 x NVSR-180	0.165	-0.222	0.083	-0.023
7) IET-19044 x NVSR-181	-0.489	-1.552	-0.365*	0.061
8) IET-19044 x NAUR-1	4.686**	2.175*	0.519**	0.061
9) IET-19044 x IET-19046	-1.735**	-2.654**	-0.112	-0.094
10) IET-19044 x GR-12	-1.042*	0.421	0.101	-0.111
11) IET-19384 x NVSR-171	-4.627**	-1.174	0.005	-0.034
12) IET-19384 x NVSR-172	1.061*	-0.213	0.154	-0.091
13) IET-19384 x NVSR-173	4.581**	-0.163	0.377*	0.243**
14) IET-19384 x NVSR-177	0.302	0.134	-0.176	0.039
15) IET-19384 x NVSR-178	0.631	-1.593	0.083	-0.049
16) IET-19384 x NVSR-180	-4.478**	0.589	0.209	0.008
17) IET-19384 x NVSR-181	-0.645	-1.341	-0.019	-0.081
18) IET-19384 x NAUR-1	0.290	-0.004	-0.205	0.029
19) IET-19384 x IET-19046	2.676**	2.810**	-0.356*	-0.066
20) IET-19384 x GR-12	0.209	0.955	-0.073	0.004
21) IET-19512 x NVSR-171	-0.215	-1.130	0.287	-0.067
22) IET-19512 x NVSR-172	1.066*	-0.166	-0.123	0.022
23) IET-19512 x NVSR-173	0.640	0.204	-0.241	-0.077
24) IET-19512 x NVSR-177	-0.659	-0.103	0.079	-0.014
25) IET-19512 x NVSR-178	4.119**	1.888*	-0.169	0.271**
26) IET-19512 x NVSR-180	0.304	-0.360	0.064	0.078
27) IET-19512 x NVSR-181	2.886**	2.597**	0.540**	-0.011
28) IET-19512 x NAUR-1	0.861	-1.170	-0.086	-0.024
29) IET-19512 x IET-19046	-4.909**	-2.023*	-0.217	-0.076
30) IET-19512 x GR-12	-4.093**	0.263	-0.134	-0.103
31) GR-11 x NVSR-171	-0.894	-0.774	-0.285	-0.104
32) GR-11 x NVSR-172	1.035*	0.190	0.027	0.042
33) GR-11 x NVSR-173	-5.155**	0.386	0.276	-0.118
34) GR-11 x NVSR-177	-0.238	0.240	-0.147	-0.044
35) GR-11 x NVSR-178	-0.063	0.443	0.079	-0.126
36) GR-11 x NVSR-180	4.009**	-0.008	-0.355*	-0.063
37) GR-11 x NVSR-181	-1.752**	-0.296	-0.156	0.032
38) GR-11 x NAUR-1	-5.837**	-1.001	-0.229	-0.065
39) GR-11 x IET-19046	3.969**	1.867*	0.684**	0.237**
40) GR-11 x GR-12	4.926**	-1.639	0.106	0.210**
SE (Sij)	0.4987	0.906	0.153	0.070
SE (Sij- Skl)	0.7053	1.281	0.217	0.099

Estimation of specific combining ability effects ranged from -14.71 (IET-19044 x NAUR-1) to 16.017 (IET-19044 x NVSR-172) for this trait. The sca effects were significant for ten crosses of which four crosses showed significant negative sca effects for day to 50 % flowering. Cross combination IET-19044 x NAUR-1 (-14.71) exhibited the maximum negative sca effects, followed by IET-19512 x NVSR-181 (-9.11). Both this crosses are best crosses for early flowering.

#### 4.3.2.2 Panicles per plant

While estimating gca effects, six males were significant of which two exhibited significant positive gca effects in desirable direction. IET-19046 showed high gca effect and found as good general combiner, while in females, IET-19512 showed highly significant positive gca effects for this trait.

With regards to sca effects of crosses, eighteen hybrids attributed toward significant sca effects for this trait of which, nine hybrids showed significant positive sca effects. Cross combination IET-19044 x NVSR-171 (3.313) exhibited the maximum positive sca effects.

#### 4.3.2.3 Panicle length (cm)

A study of estimation of gca effects revealed that, Out of four females, two females (IET-19044 and GR-11) showed highly significant positive gca effects and IET-19512 showed highly significant negative gca effects. Estimation of gca effects

for males revealed that, two males (NVSR-178 and GR-12) showed significant negative gca effects.

As regards to sca effects of crosses, seventeen hybrids exhibited significant sca effects for this trait. First five crosses which exhibited highly significant positive sca effects were GR-11 x GR-12 (5.142), IET-19044 x NVSR-171 (4.756), IET-19512 x NVSR-178 (4.628), GR-11 x NVSR-180 (3.575) and IET-19044 x NAUR-1 (3.403) while, cross GR-11 x IET-19046 (3.133) showed significant effect only for this trait.

#### 4.3.2.4 Plant height (cm)

As regard to gca effects, one male possessed significant negative gca effect for plant height. Male NVSR-181 (-6.04) had significant negative gca effects which indicated that it may possessed gene for dwarfness.

Estimation of sca effects ranged from -12.054 (IET-19384 x NVSR-173) to 11.861 (IET-19512 x IET-19046). Ten hybrids showed significant sca effects of which five crosses depicted significant negative sca effects for plant height. The best three specific cross were IET-19384 x NVSR-173 (-12.054) followed by crosses IET-19512 x NVSR-178 (-11.925) and IET-19044 x NVSR-171 (-11.317) for dwarfnees.

#### 4.3.2.5 Grains per panicle

Estimating gca effects for males, only one exhibited significant positive gca effects in desirable direction. Male IET-19046 showed highest gca effect and found as good general

combiner. Among females, IET-19384 and IET-19512 were showed positive but non-significant gca effect.

As regarding to sca effects of crosses, sixteen hybrids attributed toward significant sca effects for this trait, out of which nine hybrids showed significant positive sca effects. Cross combination IET-19512 x NVSR-178 (27.724) exhibited the maximum positive sca effect followed by IET-19044 x NVSR-171 and IET-19384 x NVSR-173.

#### 4.3.2.6 Grain yield per plant (g)

A study of estimates of gca effects out of four females, IET-19512 had highly significant negative gca effect, while only IET-19044 had significant positive gca effect. Among the males, the one male (IET-19046) had highly significant gca effect.

Estimation of sca effects, ranged from -5.583 (IET-19512 x IET-19046) to 5.846 (IET-19044 x NVSR-171). Seventeen hybrids showed significant sca effects of which nine hybrids attributed towards positive direction for grain yield per plant. The best five specific crosses for this trait were IET-19044 x NVSR-171 (5.846) followed by cross, IET-19512 x NVSR-178 (4.915), IET-19384 x NVSR-173 (4.409), IET-19044 x NAUR-1 (4.408) and GR-11 x GR-12 (4.26).

#### 4.3.2.7 1000 grain weight (g)

In a study for estimation of general combining ability effects it was observed that four males showed significant gca effects of which one male (IET-19046) exhibited significant

positive gca effects. Among four females, two females *viz.* GR-11 (1.13) and IET-19044 (0.78) showed highly significant positive gca effects.

Range of sca effects of hybrids varied from -5.837 (GR-11 x NAUR-1) to 5.736 (IET-19044 x NVSR-171). Twelve crosses showed positive gca effect. The best three specific crosses *viz.* IET-19044 x NVSR-171 (5.736), GR-11 x GR-12 (4.926) and IET-19044 x NAUR-1 (4.686) exhibited maximum positive sca effect for 1000 grain weight.

#### 4.3.2.8 Amylose content (%)

While studying the estimation of gca effects for this character, it revealed highly significant positive gca effects for this component. The highest gca effect was manifested by male NAUR-1 (1.56) and IET-19046 (1.26). Female, IET-19384 (-0.90) exhibited highly significant negative gca effect.

Estimation of specific combining ability effects ranged from -2.654 (IET-19044 x IET-19046) to 3.078 (IET-19044 x NVSR-171). Six crosses showed significant positive sca effects. Cross, IET-19044 x NVSR-171 (3.078) exhibited maximum sca effect followed by IET-19384 x I-19046 (2.810) and IET-19512 x NVSR-181 (2.597) for this trait.

#### 4.3.2.9 Protein content (%)

As regard to gca effects, the only male NVSR-177 (0.27) had higher significant positive gca effect. In females, IET-

19044 (0.102) and IET-19384 (0.103) showed significant positive gca effect.

Range of sca effects was varied from -0.412 (IET-19044 x NVSR-173) to 0.684 (GR-11 x IET-19046). The best three specific crosses *viz.* GR-11 x I-19046 (0.684) followed by cross, IET-19512 x NVSR-181 (0.540) and IET-19044 x NAUR-1 (0.519) which exhibited highly significant positive sca effect for protein content.

#### 4.3.2.10 L/B Ratio

Out of four females, three showed high significant gca effects of which, IET-19044 (0.14) showed positive gca effect. While estimating gca effects for males, five males had significant effect of which three exhibited significant positive gca effects in desirable direction. Among males, NAUR-1 (0.147) showed highest gca effect and found as good general combiner also GR-12 (0.072) and NVSR-178 (0.091).

Estimation of sca effects ranged from -0.126 (GR-11 x NVSR-178) to 0.271 (IET-19512 x NVSR-178). Five hybrids showed significant sca effects and all these five hybrids attributed towards positive direction for this trait. Cross, IET-19512 x NVSR-178 (0.271) exhibited maximum sca effect followed by IET-19384 x NVSR-173 (0.243) and GR-11 x IET-19046 (0.237) for this trait.



*DISCUSSION*



## V DISCUSSION

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Plant breeding can be divided into three stages; assembly or creation of a gene pool of variable germplasm, selection of superior individuals from the gene pool and utilization of the selected individuals directly for commercial cultivation or in hybridization to create a superior variety (Dudley and Moll, 1969). The improvement in yield, which is considered as a final product in almost all the crop plants, is usually obtained by screening, spotting and selecting the suitable genes from a huge collection of germplasm, and synthesizing and accumulating them in a productive genotype for commercial cultivation.

In hybridization programme, the choice of right type of parents is a step on which the entire success of the programme rests. The chief aim in any plant breeding programme is to evolve a superior and desirable variety/hybrid having high yield potential. To accomplish this, the breeding programme can efficiently be planned with prior knowledge of the genetic makeup of complex quantitative characters like yield and its components. The knowledge of gene action and combining ability helps in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate fixable genes through selection and in understanding the inheritance of quantitative characters to choose the proper selection method to be followed in breeding programme.

**Table 5.1: Comparison of top eight promising crosses on the basis heterobeltiosis for grain yield, sca effects and significant heterotic effects for other characters**

<b>Hybrids</b>	<b><i>Per se</i> performance</b>	<b>Heterobeltiosis</b>	<b>SCA</b>	<b>Significant heterosis for other traits</b>
IET-19044 x NVSR-171	26.77	31.14	5.846	DFE,PP,PL,PH,GP,TW,AC,LB
GR-11 x IET-19046	26.50	21.39	3.562	PL,PH,GP,TW,AC,PC,LB
GR-11 x GR-12	26.45	16.23	4.26	DFE,GP,TW,LB
IET-19044 x NAUR-1	25.15	23.22	4.408	DFE,PP,PL,PH,GP,TW,AC,PC,LB
GR-11 x NVSR-180	25.10	14.96	3.998	PL,TW,PC
IET-19384 x IET-19046	24.88	21.03	3.460	DFE,PP,PL,GP,TW,AC
IET-19384 x NVSR-173	23.71	19.35	4.409	PL,PH,GP,TW
IET-19512 x NVSR-178	23.22	23.84	4.915	PH,GP,TW,AC,LB

DFE= Days to 50% flowering, PP= Panicles per plant, PL= Panicle length (cm), PH= Plant height (cm), GP= Grains per panicle, GYP= Grain yield per plant (g), TW= Test weight, AC= Amylose content(%),PC= Protein content (%), LB= L/B ratio.

The use of existing variability in a crop species has for a long time served as raw material for breeding better plant types in the crop improvement. Artificial hybridization and mutation are the other means of creating genetic variability. In addition to this, hybridization within the species was found to be an effective mechanism for combining different characters and creating more genetic variability which can be made available for selection. The assembling of different genes in new population and the introduction of the new characters from exotic collection into locally adopted genotypes has been of immense value at all levels of crop breeding.

The phenomenon of heterosis has attracted the attention of plant breeders due to its helpful effect on economic characters. Magnitude of heterosis and combining ability involving diverse breeding materials is of crucial interest for further elevating and stabilizing yield levels in the present day varieties and hybrids.

The knowledge regarding combining ability helps in identifying the best combiner, which may be used in hybridization either to exploit heterosis or to accumulate desirable genes through selection in segregating generations with appropriate breeding procedure. The concept of combining ability has significant practical importance in plant breeding (Sprague and Tatum, 1942 and Jinks and Hayman, 1953). Such information is also important in the choice of parents for hybridization and subsequent selection strategies. Simply phenotypically superior lines may yield poor recombinants; hence the knowledge of general and specific combiners will be more useful.

Selection of the appropriate breeding methodology to achieve maximum genetic gain, studies on the gene effects involving the expression of characters forms an integral part of any breeding programme. The breeding for pure lines is advantageous when major portion of variability is due to additive genetic variance, whereas breeding for hybrids would be advantageous, when major portion of variability is due to non-additive genetic variance.

Keeping these points in view, the present investigation was undertaken to study heterosis, combining ability and gene effects through line x tester analysis. The results obtained for ten characters on fifty four genotypes on these aspects have been presented in the preceding chapter and some of the significant points emerging out from these investigations are discussed below.

### **5.1 Analysis of variance and mean performance**

The analysis of variance exhibited significant differences among parents and hybrids for all the characters. Parents vs hybrids comparison was found significant for all the characters except panicle length, plant height and grain yield per plant indicating substantial amount of heterosis among hybrids.

An examination of mean performance of parents (Appendix-II) for different characters revealed that, none of the females or males showed consistent high performance for all the characters. Among females, GR-11 recorded maximum grain yield per plant with more panicle length, grains per panicle, 1000 grain weight and days to 50 percent flowering. Its performance for protein content, amylose content and plant height was also on second position. Among males,

GR-12 recorded maximum grain yield per plant along with highest number panicles per plant. Among the parent GR-11 recorded highest grains per panicle and 1000 grain weight. Least plant height was recorded by NVSR-181 among the parents. NVSR-177 was earliest in flowering, NVSR-180 recorded highest percentage of amylose content. Parent IET-19384 recorded high percentage of protein content, while NVSR-172 recorded highest L/B ratio.

A perusal of mean performance of hybrids (Appendix-II) indicated that alike parents, none of the hybrids consistently performed better for all the characters studied. Cross combination IET-19044 x NVSR-171 recorded maximum grain yield per plant. It occupied first position for panicle length, grains per panicle and L/B ratio, while second position in panicles per plant and amylose content, while third position in 1000 grain weight. Similarly, cross GR-11 x IET-19046 ranks second for grain yield per plant. It occupied first position for 1000 grain weight, second position for plant height, grains per panicle and protein content, while third position for amylose content. Cross GR-11 x GR-12 occupied third position for grain yield per plant and second position for test weight. Cross IET-19384 x NVSR-173 recorded second rank for days to 50 percent flowering and plant height while third position for protein content.

## 5.2 Estimation of heterosis

The exploitation of heterosis in crop plant is regarded as one of the major breakthrough in the field of plant breeding. The application of heterosis is considered to be an outstanding application of principles of genetics to agriculture. The scope of exploitation of

hybrid vigour depends on directions and magnitude of heterosis and type of gene actions involved.

The knowledge of heterosis with inbreeding depression would help in elimination of poor crosses in early stages. The magnitude of heterosis varied from cross to cross for all the characters studied, of these, the character of economic importance for rice is grain yield and the heterotic response obtained for this character is of greater importance for the purpose of practical plant breeding.

The measures of heterosis over better parent (heterobeltiosis) are better rational parameters for assessing its practical utility. Therefore, in present investigation heterosis is reported over better parent. Negative heterosis is considered as desirable for days to 50 percent flowering and plant height, while for other characters significant positive heterosis was considered as desirable. The present study is an attempt to assess the possibilities of commercial exploitation of heterosis and to develop better varieties and elite lines for further breeding programme. The results in this direction are discussed in following ways.

As regards to heterosis over better parent a good number of crosses registered significant heterobeltiosis in desired direction, for different traits like days to 50 percent flowering in six crosses, panicles per plant in six crosses, plant height in five crosses, panicles length in seven crosses, grains per panicle in eight crosses, test weight in nine crosses, grain yield per plant in nine crosses, L B ratio in five crosses, protein content in four crosses and amylose content in six crosses.

With regards to days to 50 percent flowering, six hybrids showed significant negative heterobeltiosis in desired direction for earliness, and among them four hybrids depicted highly significant. Negative heterosis indicated earliness compared to better parent. The hybrid IET-19044 x NAUR-1 manifested numerically higher negative heterosis over better parent. The result is akin to the finding of Ramalingam *et al.* (1994), Raju *et al.* (2003), Datt and Mani (2004), Bhandarker *et al.* (2005), Eradasappa *et al.* (2007), and Venkatesan *et al.* (2008).

In a study of panicle per plant, six crosses gave significant positive results for heterobeltiosis. The cross showing highest percentage of heterosis over better parent was GR-11 x IET-19046. Raju *et al.* (2003), Datt and Mani (2004), Yadav *et al.* (2004), Bhandarker *et al.* (2005), Pandya and Tripathi (2006), Eradasappa *et al.* (2007), Parihar and Pathak (2008), and Roy *et al.* (2009) also reported similar results in rice.

For panicle length, seven crosses expressed significant positive heterosis over better parent. The hybrid IET-19044 x NVSR-171 exhibited highest heterobeltiosis for this character. The present findings were in close association with the results reported by Ramalingam *et al.* (1994), Yadav *et al.* (2004), Datt and Mani (2004), Pandya and Tripathi (2006), Eradasappa *et al.* (2007), Singh *et al.* (2007), and Roy *et al.* (2009).

The results for plant height indicate that five crosses highlighted significant negative heterosis in desired direction over better parent as dwarfness is desirable for this trait. IET-19044 x

NVSR-171 showed highest heterobeltiosis in negative direction. The present findings were in close association with results reported by Sahai and Chaudhary (1991), Lokaprakash *et al.*(1992), Banumathy *et al.*(2003), Yadav *et al.*(2004), Datt and Mani (2004), Raju *et al.*(2006), Eradasappa *et al.*(2007), Parihar and Pathak (2008), Venkatesan *et al.*(2008) and Roy *et al.* (2009).

With respect to grains per panicle, eight crosses showed significant positive heterosis over better parent. IET-19044 x NVSR-171 was top ranking cross showing highly significant positive heterobeltiosis. The results were in agreement with the findings of Annadurai and Nandaraejan (2001), Banumathi *et al.*(2003), Yadav *et al.*(2004), Pandya and Tripathi (2006), Parihar and Pathak (2008) and Roy *et al.* (2009).

Nine crosses depicted significant positive heterobeltiosis for grain yield per plant. The best performing cross for this trait was IET-19044 x NVSR-171. A comparison of first eight top yielding hybrids and first eight most heterotic hybrids revealed that degree of heterosis was mostly related with the *per se* performance of hybrids. Significant positive heterosis for grain yield has reported by Sahai and Chaudhary (1991), Lokaprakash *et al.*(1992), Annadurai and Nadarajan (2001), Janardhanam *et al.* (2001), Raju *et al.*(2003), Yadav *et al.*(2004), Datt and Mani (2004), Bhandarker *et al.*(2005) Eradasappa *et al.*(2007), Parihar and Pathak (2008), Venkatesan *et al.*(2008) and Roy *et al.* (2009).

For test weight, nine crosses expressed significant heterosis in positive direction. The hybrid IET-19044 x NVSR-171 recorded

maximum heterosis over better parent. These results are in agreement with the findings of Lokaprakash *et al.* (1992), Raju *et al.* (2003), Datt and Mani (2004), Pandya and Tripathi (2006), Singh *et al.* (2007), Parihar and Pathak (2008) and Roy *et al.* (2009).

For amylose content six crosses were excelled for significant heterosis over better parent. The cross IET-19044 x NVSR-171 was top in highest heterobeltiosis percentage. These results were in confirmation with Sarathe *et al.* (1986) and Krishanaveni *et al.* (2004).

For protein content, only four crosses showed significant positive heterosis over better parent. The cross IET-19512 x NVSR-181 exhibited highest positive heterobeltiosis for this trait. Similar results were reported by Chao (1972).

In case of L/B ratio, only five crosses showed significant heterosis over better parent in desired direction. The cross IET-19044 x NVSR-171 exhibited highest positive heterobeltiosis. The results reported by Roy *et al.* (2009) and Venkatesan *et al.* (2008) are in confirmation with this result.

In present study, the magnitude of the heterosis varied from cross to cross. The top five crosses IET-19044 x NVSR-171, GR-11 x IET-19046, GR-11 x GR-12, IET-19044 x NAUR-1 and GR-11 x NVSR-180 showed significant positive heterosis over better parent for grain yield per plant (Table 5.1). The cross IET-19044 x NVSR-171 showed significant positive heterobeltiosis in traits *viz.*, days to 50percent flowering, panicle per plant, panicle length, grains per panicle, test weight, amylose content and L/B ratio, while cross GR-11

x IET-19046 showed significant positive heterobeltiosis for panicle length, plant height, grains per panicle, test weight, amylose content, protein content and L/B ratio. Cross GR-11 x GR-12 showed significant positive heterobeltiosis for days to 50 percent flowering, grains per panicle, test weight and L/B ratio. Cross IET-19044 x NAUR-1 showed significant positive heterobeltiosis for days to 50 percent flowering, panicles per plant, panicle length, plant height, grains per panicle, test weight, amylose content, protein content, and L/B ratio. Cross GR-11 x NVSR-180 showed significant positive heterobeltiosis for panicle length, test weight and protein content, which indicates that the heterosis for yield per plant was due to heterosis for other yield component characters. (Table 5.1)

### **5.3 Combining ability**

The concept of combining ability analysis has significant practical importance in plant breeding as it allows the prediction of the relative efficiency of parents based on early generation performance besides enabling to study the comparative performance of lines in hybrid combinations. Without genetic direction, plant breeders lack the rational basis to guide him in the choice of parents, in the manipulation of progenies and isolation of superior parents. Combining ability analysis provides clues to the usefulness of individuals to be employed as the parents in the hybridization programme as well as simultaneously to screen the hybrids.

In any breeding programme selection of parents is primarily depends on their phenotypic divergence. In quantitatively inherited characters, prediction of ability of the parents to combine

well, generate more variability and transmit desired gene combination to the progeny is rather difficult through parental phenotypes. Recent developments in biometrical genetics have made it possible to make such predictions with ease. Various biometrical methods used to select the right parents, multivariate analysis (Morishima and Oka, 1960; Murty and Arunachalam, 1966; Jawahar Ram and Panwar, 1970) and combining ability analysis (Sprague and Tatum, 1942; Jinks and Hayman, 1953) are some of the widely used ones.

The nature of gene action has a bearing on development of efficient breeding programme. General combining ability effects and additive  $\times$  additive gene action are theoretically fixable. On the other hand, specific combining ability attributed to non additive gene action may be due to dominance or epistasis or both and is not fixable. The presence of non additive genetic variance is primary justification for initiating the hybrid programme (Cockerham, 1961). The success of hybrid programme based on the results of combining ability depends on the extent of genetic parameters remaining stable over environments.

### **5.3.1 Analysis of variance for combining ability**

The analysis of variance for combining ability revealed that general combining ability (gca) variances for females ( $\sigma^2_f$ ) was highly significant for L/B ratio, whereas general combining ability (gca) variances for males ( $\sigma^2_m$ ) was significant for L/B ratio. On the other hand, specific combining ability (sca) variances for f  $\times$  m interaction were significant for all characters. The magnitude of gca variances were lower than sca variances for all the characters indicating the

predominance of non-additive gene action. This was further supported by low magnitude of  $\sigma^2_{gca}/\sigma^2_{sca}$  ratios. The findings are in confirmation with Dhaliwal and Sharma (1990), Satyanarayana *et al.*, (1998), Annadurai and Nadarajan (2001), Singh *et al.* (2005), Panwar (2005), Kumar *et al.* (2006), Sinha *et al.* (2006), Sharma (2006), Kumar *et al.* (2007), Singh *et al.* (2007), Pradhan and Singh (2008), Sharma and Mani (2008) and Salgotra *et al.* (2009) in rice.

For the choice of right breeding method it is necessary to depend upon the nature and magnitude of gene effects involved. In view of this, it became evident that breeding for high yielding varieties in rice may become more effective by appropriate exploitation of additive gene effect alongwith non-additive gene effect. Since the present investigation was conducted only for one season and at a single location, the estimates of genetic variance would be biased due to genotype x environment interaction and this would mislead the breeder in drawing conclusion regarding gene effects. Hence, it is suggested to test the material over environments and/or locations so that clear-cut information can be drawn.

### **5.3.2 Estimates of GCA and SCA effects**

General combining ability effects were estimated for parents and specific combining ability effects were estimated for hybrids. The characterwise categorization of general combining ability effects of the parents has been presented in Table 5.2.

In present study it was observed that none of the parents was good general combiner for all the traits. These results are getting support from the findings of Singh and Singh (1991), Singh *et*

**Table 5.2: Summary table showing general combining ability effects of the parents**

Parents	Days to 50 % flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B ratio
<b>Females</b>										
IET-19044	P	A	G	A	A	G	G	A	G	G
IET-19384	A	P	A	A	A	A	P	P	G	A
IET-19512	A	G	P	A	A	P	P	P	A	P
GR-11	A	P	G	A	A	G	G	A	P	P
<b>Males</b>										
NVSR-171	A	A	A	A	A	A	A	A	A	A
NVSR-172	P	P	A	A	A	A	P	P	P	A
NVSR-173	A	P	A	A	A	A	A	A	A	A
NVSR-177	A	P	A	A	A	A	P	A	G	P
NVSR-178	G	P	P	A	A	A	P	A	A	G
NVSR-180	G	A	A	A	A	A	A	A	A	A
NVSR-181	A	A	A	G	A	A	A	A	A	P
NAUR-1	P	A	A	A	A	A	A	G	P	G
IET-19046	A	G	A	A	G	G	G	G	A	A
GR-12	A	G	P	A	A	A	G	P	A	G

G = Good parent having significant gca effects in desired direction

A = Average parent having either positive or negative but non-significant gca effects

P = Poor parent having gca effect in the undesired direction

*al.*(1992), Kumar *et al.*(2006), Sharma (2006), Singh *et al.*(2007), Parihar and Pathak (2008), Sharma and Mani (2008) and Tyagi *et al.*(2008). The general combining ability effects of different parents for various characters which are presented in Table 5.2 are discussed as follows.

Nature and magnitude of combining ability effects provide guideline in identifying the better parents and their utilization. The summery of general combining ability effects of the parents (Table 5.2) revealed that none of the parents found to be good general combiner for all the characters. An overall appraisal of *gca* effects revealed that among females, IET-19044 was found to be good general combiner for panicle length, grain yield per plant, test weight, protein content and L/B ratio. Female, IET-19384 emerged out as good general combiner for protein content, whereas female, IET-19512 traced out good general combiner for panicles per plant and GR-11 for panicle length, grain yield per plant and test weight. Among the males, NVSR-171 was found to be average general combiner for most of the characters. NVSR-172 was found to be average general combiner for panicle length, plant height, grains per panicle, grain yield per plant and L/B ratio, NVSR-173 was found to be average general combiner for all characters except panicles per plant, NVSR-177 was found to be good general combiner for protein content, NVSR-178 was found to be good general combiner for days to 50 per cent flowering, and L/B ratio, NVSR-180 was found to be good general combiner for days to 50 per cent flowering. NVSR-181 for plant height, NAUR-1 for amylose content and L/B ratio, IET-19046 for panicles per plant, grains per panicle, grain yield per plant,

1000 grain weight and amylose content, while GR-12 for panicles per plant, test weight, L/B ratio.

Perusal of findings indicated that females IET-19044 and GR-11 was observed good general combiner for panicle length, grain yield per plant and test weight. IET-19512 was good general combiners for panicles per plant, whereas in males NVSR-178 and NVSR-180 were good general combiners for days to 50 percent flowering. The male parents, IET-19046 and GR-12 were good general combiners for panicles per plant and 1000 grain weight. NVSR-178, NAUR-1 and GR-12 were good general combiners for L/B ratio. NAUR-1 and IET-19046 were good general combiners for amylose content. This could be considered as the best combining parent of the present study in yield attributes and hence could be initiated in the future breeding programme.

In case of specific combining ability effects, none of the hybrids exhibited favourable SCA effect for all the characters. In the present study positive specific combining ability is desirable for all the characters except days to 50 per cent flowering and plant height. Significant specific combining ability in favourable direction was observed in many crosses for days to 50 per cent flowering (4), panicles per plant (9), panicle length (9), plant height (5), grains per panicle (9), grain yield per plant (9), test weight (12), amylose content (6), protein content (4) and L/B ratio (5). These results are getting support from the findings of Sardana and Borthakur (1987), Peng and Virmani (1990), Banumathy and Prasad (1991), Roy and Mandal (2001), kumar *et al.*(2006), Sinha *et al.*(2006), Sharma *et al.*(2006),

Sarial *et al.*(2007), Singh *et al.*(2007), Parihar and Pathak (2008) and Pradhan and Singh (2008).

High SCA denotes undoubtedly a high heterotic response, but this may be due to poor performance of the parents in comparison with their hybrids. With the same amount of heterotic effect, the SCA may be less, where the mean performance of the parents was higher but this estimate may also be biased (Ziauddin *et al.*, 1979). This suggested that the selection of cross combination based on heterotic response would be more realistic rather than on the basis of SCA effects. Therefore comparative study of first three best specific combinations along with their mean performance and general combining ability effects of the parents in the specific crosses was made and could be summarized as follows.

By examining the summary from Table 5.3 and 4.5, it can be seen that all the crosses having best specific combination for grain yield per plant were obtained either through poor x average, poor x good, average x average, good x good, good x poor, poor x poor parental combination. The best specific combination *viz.*, IET-19044 x NVSR-171 also recorded the desirable significant SCA effects for traits of panicle per plant, panicle length, plant height, grains per panicle, grain yield per plant, 1000 grain weight, amylose content and L/B ratio. The second best cross *i.e.*, IET-19512 x NVSR-178 had desirable significant SCA effects for panicles per plant, panicle length, plant height, grains per panicle, grain yield per plant, test weight amylose content and L/B ratio. Whereas the third best cross IET-19384 x NVSR-173 had significant sca effects for days to 50 per cent

**Table 5.3: A summary table showing the best specific combination along with the general combining ability effects of the parents involved the combination for different characters in rice**

Characters	Best specific combination	SCA	<i>Per se</i> performance	gea effects of the parents involved
Days to 50 % flowering	IET-19044 x NAUR-1	-14.71 **	91.62	P X P
	IET-19512 x NVSR-181	-9.11**	88.37	A X A
	IET-19512 x GR-12	-8.95**	90.58	A X A
Panicles per plant	IET-19044 x NVSR-171	3.313**	12.93	A X A
	IET-19044 x NAUR-1	2.45**	12.83	A X A
	GR-11 x GR-12	1.979**	12.23	P X G
Panicle length	GR-11 x GR-12	5.142**	31.87	G X P
	IET-19044 x NVSR-171	4.756**	32.55	G X A
	IET-19512 x NVSR-178	4.628**	28.67	P X P
Plant height	IET-19384 x NVSR-173	-12.054**	91.53	A X A
	IET-19512 x NVSR-178	-11.925**	94.21	A X A
	IET-19044 x NVSR-171	-11.317**	93.38	A X A
Grains per panicle	IET-19512 x NVSR-178	27.724**	172.12	A X A
	IET-19044 x NVSR-171	27.347**	180.60	A X A
	IET-19384 x NVSR-173	23.855**	170.75	A X A
Grain yield per plant	IET-19044 x NVSR-171	5.846**	26.77	G X A
	IET-19512 x NVSR-178	4.915**	23.22	P X A
	IET-19384 x NVSR-173	4.409**	23.71	A X A
Test weight	IET-19044 x NVSR-171	5.736**	26.07	G X A
	GR-11 x GR-12	4.926**	26.15	G X G
	IET-19044 x NAUR-1	4.686**	24.81	G X A
Amylose content	IET-19044 x NVSR-171	3.078**	25.55	A X A
	IET-19384 x IET-19046	2.810**	24.91	P X G
	IET-19512 x NVSR-181	2.597**	24.57	A X A
Protein content	GR-11 x IET-19046	0.684**	7.38	P X A
	IET-19512 x NVSR-181	0.540**	7.29	A X A
	IET-19044 x NAUR-1	0.519**	7.23	G X P
L/B ratio	IET-19512 x NVSR-178	0.271**	3.48	P X G
	IET-19384 x NVSR-173	0.243**	3.35	A X A
	GR-11 x IET-19046	0.237**	3.39	P X A

flowering, panicles per plant, panicle length, plant height, grains per panicle, grain yield per plant, 1000 grain weight, protein content and L/B ratio.

The high positive or negative specific combining ability effects showed by the crosses involved either good x good, good x average, good x poor, poor x poor and average x poor combining parents. Therefore, information of general combining ability effects alone may not be sufficient to predict the magnitude of heterosis. Hence information on general combining ability effects of the parents needs to be supplemented by that of specific combining ability effects and hybrid performance.

On the basis of heterosis and combining ability, it can be observed that there is some degree of relationship between heterosis and specific combining ability effects. In most of the cases, for most of the characters, the best specific cross combinations for various characters manifested the maximum or near to maximum heterosis for the characters.

On the basis of heterosis and combining ability the most promising parents for yield attributing traits were IET-19044, IET-19046, GR-11 and GR-12 most promising hybrids were IET-19044 x NVSR-171, GR-11 x I-19046 and GR-11 x GR-12.

#### **5.4 Breeding methodology**

Grain yield is a complex character dependent upon the contribution of various component characters affecting directly or indirectly. The existence of total genetic variability and magnitude as

well as nature of gene effects in the population under improvement to a large extent would dictate the choice of breeding methodology.

A population with preponderance of additive genetic variance would lead to the improvement of a character through selection in segregating generations. The presence and magnitude of various components of non-additive gene effect could be justified with heterosis breeding. Whereas, in case of equal magnitude of both additive and non-additive components of genetic variance, population improvement scheme such as reciprocal recurrent selection would be more effective.

From the foregoing discussion of the results obtained in the present study, it is obvious that the magnitude of gca variances were lower than sca variances for all the characters indicating the predominance of non-additive gene action. This was further supported by low magnitude of  $\sigma^2_{gca}/\sigma^2_{sca}$  ratios, thus the breeding methodology for the improvement in this crop for all characters under study should be heterosis breeding.

None of the parents was found to be good general combiner for all the characters. In the present study selection of desirable traits for developing high yielding varieties should be made by crossing NVSR-178 and NVSR-180 for earliness, IET-19044, GR-11 and IET-19046 for yield and yield contributing characters. Taking in to the consideration for an efficient breeding programme, parents with desirable agronomical traits and good general combining ability for grain yield per plant and its component characters which in cross combination may result in high heterosis, high specific combining

ability and high per se performance. The study extended to the estimation of SCA effects revealed that cross combination IET-19044 x NVSR-171, IET-19512 x NVSR-178 and IET-19384 x NVSR-173 were highly promising for yield and most of the yield attributing characters. These crosses were in combinations of either good x average, poor x average and average x average combining parents gca effects and could be exploited for getting desirable recombinants from the segregating population. It was further observed that SCA of crosses for yield was largely depend on their SCA effects for componential characters particularly for panicle length, grains per panicle, panicles per plant and test weigh. This suggested that for imposing high selection intensity, sib- pollination technique originally suggested by Palmar (1953) and subsequently modified by Andrus (1963) can be effectively used.



*SUMMARY*  
&  
*CONCLUSION*



## VI SUMMARY AND CONCLUSION

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The present investigation on 'Genetic Analysis in Rice (*Oryza sativa* L.)' was carried out at experimental farm of National Agricultural Research Project, NAU., Navsari during *kharif* 2009. The experimental material for present investigation consisted of 54 entries including 4 females, 10 males and 40 crosses. The experiment was laid out in a randomized block design with three replications. Observations on ten characters were recorded. The results in brief are summarized as below.

1. General analysis of variance for parents, hybrids revealed that mean squares due to parents for all the characters except grains per panicle, grain yield per plant and amylose content were found significant indicating considerable amount of variability among the parents for various traits. The mean squares due to hybrids for all the characters were found highly significant. Parents vs hybrids comparisons was found highly significant for all the characters except significant for L/B ratio and non-significant for panicle length, plant height and grain yield per plant indicating substantial amount of heterosis among hybrids.
2. An examination of mean values of parents for different characters revealed that among females IET-19044 and GR-11, while among males IET-19046 were the high yielding

parents. Male, NVSR-178 and NVSR-180 were the earliest in days to 50 percent flowering.

3. Sufficiently high magnitude of heterobeltiosis in desirable direction was observed for grain yield per plant, grains per panicle, panicles per plant, panicle length, plant height, days to 50 percent flowering, 1000 grain weight, amylose content and L/B ratio. As many as nine crosses showed significant positive heterosis over their respective better parental value for grain yield per plant. The highest heterobeltiosis for grain yield per plant was registered by the cross IET-19044 x NVSR-171 followed by IET-19512 x NVSR-181 and IET-19512 x NVSR-178.
4. The *per se* performance of hybrids for grain yield and its components was in general related to the heterotic effects. This revealed that selection of hybrids either on the basis of *per se* performance or on the basis of magnitude of heterotic effects would also be reliable.
5. The analysis of variance for combining ability revealed that general combining ability (gca) variances for females ( $\sigma^2_f$ ) and general combining ability (gca) variances for males ( $\sigma^2_m$ ) were highly significant for L/B ratio. On the other hand, specific combining ability (sca) variances for f x m interaction were highly significant for all characters. The

magnitude of sca variances was higher than gca variances for all characters which indicate the predominance of non-additive gene action. This was further supported by low magnitude of  $\sigma^2_{gca}/\sigma^2_{sca}$  ratios.

6. The estimation of gca effects for parents indicating that male IET-19046 and females IET-19044 and GR-11 were the good general combiners for grain yield per plant. For earliness males NVSR-178 and NVSR-180 were the good general combiners. Among the females, IET-19044 had high gca effects for panicle length, grains yield per plant, 1000 grain weight, protein content and L/B ratio, while male, IET-19046 had high gca effects for panicles per plant, grains per panicle, grain yield per plant, 1000 grain weight and amylose content.
7. In the present study, crosses viz., IET-19044 x NVSR-171, IET-19512 x NVSR-178 and IET-19384 x NVSR-173 were the best specific combinations for grain yield per plant and involved good x average, poor x average and average x average combining parents, respectively. For grains per panicle, crosses viz., IET-19512 x NVSR-178, IET-19044 x NVSR-171 and IET-19384 x NVSR-173 were better combinations and involved average x average, average x average and average x average combiners respectively and for panicles per plant, crosses viz., IET-19044 x NVSR-171,

IET-19044 x NAUR-1 and GR-11 x GR-12 were the best specific combinations and involved average x average, average x average and poor x good combining parents, respectively.

8. In the present study, parents IET-19044, IET-19046, GR-11 and GR-12 and crosses, IET-19044 x NVSR-171, GR-11 x IET-19046 and GR-11 x GR-12 could be exploited fully in future rice breeding programme by adopting appropriate breeding technique in order to evolve high yielding hybrids or varieties.



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\*Original not seen



*APPENDICES*



**Appendix I: Meteorological data recorded at Navsari for the period of experiment during *Kharif* 2009**

Month and Year	Standard Week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Rainy Days
		Max	Min	M	Ev.		
June 2009	23	33.9	28.4	82	62	0.0	0
	24	33.8	28.3	78	59	1.0	0
	25	33.9	27.2	82	63	3.0	1
	26	30.6	23.7	92	75	43	4
	27	28.5	25.0	94	78	50.5	5
July 2009	28	31.1	24.8	80	84	118	5
	29	29.9	25.4	95	89	123	7
	30	29.1	25.1	90	85	475	7
	31	29.3	25.3	85	77	335	6
	32	28.3	26.5	95	92	6.2	1
August 2009	33	30.3	26.2	87	76	11.8	2
	34	31.1	26	85	68	10.10	1
	35	33.2	25.9	87	65	13	2
	36	28.6	25.2	91	87	165	5
September 2009	37	29.6	25	92	80	231	5
	38	32.7	25.5	89	65	0.0	0
	39	34.1	25	87	62	0.0	0
	40	33.9	25.5	87	52	0.0	0
October 2009	41	33	25.4	88	67	48	1
	42	31.9	22.5	89	53	36	1
	43	34.8	21.1	85	40	0.0	0
	44	35.2	16.4	80	35	0.0	0
	45	35.7	18.8	70	28	0.0	0
November 2009	46	33.5	20.3	69	45	13	1
	47	28.4	20.9	89	61	6.2	1
	48	31.8	19.4	79	42	0.0	0
	49	32.8	17.3	72	30	0.0	0

Max = maximum, Mini = minimum M = Morning and Ev. = Evening

**Appendix- II: Mean performance of parents and hybrids for various characters in rice.**

Parents/ crosses	Days to 50% flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B Ratio
<b>Females</b>										
1) IET-19044	119.53	10.70	26.68	117.53	150.50	20.41	19.17	20.79	6.75	3.24
2) IET-19384	119.37	8.87	25.42	102.53	147.50	19.36	18.90	19.28	6.96	3.18
3) IET-19512	113.64	11.50	25.21	113.39	148.80	18.31	17.67	21.52	6.37	3.10
4) GR-11	104.22	9.27	28.15	109.37	151.30	21.83	21.47	21.34	6.77	3.04
<b>Males</b>										
1) NVSR-171	105.30	7.60	25.31	107.18	133.27	18.22	17.16	20.72	6.57	3.12
2) NVSR-172	90.20	9.50	30.00	103.77	149.27	20.42	18.13	19.02	6.32	3.35
3) NVSR-173	92.60	8.90	27.00	102.30	136.20	19.87	18.82	21.56	6.23	2.94
4) NVSR-177	85.40	7.20	26.50	107.60	135.50	19.47	18.32	20.56	6.82	2.90
5) NVSR-178	87.80	7.90	24.30	105.30	128.97	18.75	17.45	20.17	6.47	3.23
6) NVSR-180	90.32	9.10	28.33	104.80	134.13	20.12	19.39	21.61	6.92	3.15
7) NVSR-181	94.30	8.30	25.72	92.68	133.70	17.87	16.35	19.77	6.66	3.09
8) NAUR-1	106.20	10.00	27.12	109.57	145.10	19.85	18.56	21.54	6.34	3.28
9) IET-19046	108.33	9.60	26.30	104.40	137.33	20.56	19.62	20.47	6.88	3.11
10) GR-12	103.11	10.83	22.80	103.99	144.83	22.75	18.95	20.57	6.84	3.17

## Appendix- II contd.....

Crosses	Days to 50% flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L B Ratio
1) IET-19044 x NVSR-171	95.33	12.93	32.55	93.38	180.60	26.77	26.07	25.55	6.80	3.55
2) IET-19044 x NVSR-172	122.24	7.20	26.44	116.32	138.02	16.35	16.09	20.85	6.63	3.38
3) IET-19044 x NVSR-173	98.64	9.87	28.53	106.75	148.45	21.14	20.05	21.30	6.52	3.21
4) IET-19044 x NVSR-177	94.64	8.97	28.50	109.45	148.10	20.94	20.41	21.10	7.40	3.19
5) IET-19044 x NVSR-178	92.12	7.14	21.71	117.12	130.27	15.66	15.11	21.87	6.79	3.32
6) IET-19044 x NVSR-180	98.64	9.34	29.27	108.05	147.55	21.26	20.68	21.93	6.99	3.29
7) IET-19044 x NVSR-181	102.64	9.60	27.39	103.50	147.20	20.14	19.90	20.61	6.55	3.25
8) IET-19044 x NAUR-1	91.62	12.83	32.03	97.12	175.78	25.15	24.81	25.83	7.23	3.54
9) IET-19044 x IET-19046	99.14	10.40	28.19	105.35	148.80	21.48	20.30	20.70	6.83	3.26
10) IET-19044 x CIR-12	107.94	10.90	26.10	109.10	150.60	22.58	19.83	21.14	7.09	3.29
11) IET 19384 x NVSR-171	92.23	6.32	22.86	111.75	135.71	15.13	14.23	20.04	6.81	3.16
12) IET 19384 x NVSR 172	99.22	9.25	28.51	105.36	146.80	19.89	18.83	19.19	6.84	3.10
13) IET 19384 x NVSR 173	90.42	9.87	30.58	91.53	170.75	23.71	23.22	20.31	7.31	3.35

Appendix- II contd.....

Appendix- II contd.....

Crosses	Days to 50% flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B Ratio
14) IET-19384 x NVSR-177	93.72	8.33	26.81	107.41	143.50	19.41	18.63	20.25	6.98	3.05
15) IET-19384 x NVSR-178	96.21	8.47	25.51	106.26	141.35	19.06	18.95	19.76	6.87	3.21
16) IET-19384 x NVSR-180	93.62	6.60	21.94	112.35	130.25	15.14	14.56	21.48	7.11	3.17
17) IET-19384 x NVSR-181	105.72	8.50	26.23	101.46	142.60	18.61	18.26	19.56	6.90	2.95
18) IET-19384 x NAUR-1	111.88	9.94	27.57	107.61	148.30	19.60	18.93	22.40	6.50	3.35
19) IET-19384 x IET-19046	94.81	11.62	29.73	95.12	171.86	24.88	23.23	24.91	6.58	3.13
20) IET-19384 x GR-12	110.02	9.78	24.71	107.06	145.90	21.06	19.60	20.42	6.92	3.25
21) IET-19512 x NVSR-171	105.00	9.75	24.87	105.05	141.27	18.26	18.10	21.16	6.93	3.07
22) IET-19512 x NVSR-172	99.00	10.63	27.75	106.40	144.95	19.36	18.30	20.31	6.39	3.16
23) IET-19512 x NVSR-173	101.50	10.27	25.80	105.75	142.00	19.09	18.74	21.75	6.53	2.97
24) IET-19512 x NVSR-177	100.50	9.63	25.47	108.45	141.65	18.89	17.13	21.08	7.06	2.95
25) IET-19512 x NVSR-178	90.12	11.89	28.67	94.21	172.12	23.22	21.90	24.31	6.45	3.48
26) IET-19512 x NVSR-180	93.50	10.52	26.23	107.06	141.10	19.21	18.80	21.60	6.80	3.18

Appendix- II contd.....

Appendix- II contd....

Crosses	Days to 50% flowering	Panicles per plant	Panicle length (cm)	Plant height (cm)	Grains per panicle	Grain yield per plant (g)	1000 grain weight (g)	Amylose content (%)	Protein content (%)	L/B Ratio
27) IET-19512 x NVSR-181	88.37	12.94	29.15	91.25	172.15	22.91	21.25	24.57	7.29	2.97
28) IET-19512 x NAUR-1	101.66	10.63	26.37	108.65	146.11	19.08	18.97	22.30	6.45	3.24
29) IET-19512 x IET-19046	101.43	10.98	21.23	114.24	130.78	15.21	15.11	21.15	6.55	3.06
30) IET-19512 x GR-12	90.58	10.27	20.11	115.31	134.51	14.97	14.76	20.80	6.69	3.09
31) GR-11 x NVSR-171	98.00	8.44	26.77	103.09	146.35	19.92	19.79	21.74	6.28	3.05
32) GR-11 x NVSR-172	96.00	9.38	29.62	104.44	149.70	21.03	20.63	20.89	6.47	3.20
33) GR-11 x NVSR-173	98.36	6.34	23.75	112.88	132.63	15.65	15.31	22.16	6.97	2.95
34) GR-11 x NVSR-177	93.50	8.26	27.37	106.49	146.40	21.55	19.92	21.66	6.76	2.93
35) GR-11 x NVSR-178	94.50	8.61	26.17	105.34	144.25	20.19	20.08	23.10	6.62	3.10
36) GR-11 x NVSR-180	86.23	10.26	31.95	100.23	161.10	25.10	24.87	22.19	6.31	3.06
37) GR-11 x NVSR-181	97.30	8.88	26.81	100.54	145.63	19.75	18.98	22.50	6.52	3.03
38) GR-11 x NAUR-1	111.73	7.10	24.41	113.21	140.64	15.53	14.63	22.70	6.24	3.22
39) GR-11 x IET-19046	95.60	11.70	31.93	93.19	176.10	26.50	26.35	25.27	7.38	3.39
40) GR-11 x GR-12	93.68	12.23	31.87	101.59	168.83	26.45	26.15	19.13	6.86	3.42

# CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference services in a library or documentation centre.

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Date: <sup>30<sup>th</sup></sup> April, 2010

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Chougule  
(Chougule G.R.)