"COMBINING ABILITY ANALYSIS AND ESTIMATION OF HETEROSIS FOR DEVELOPMENT OF AROMATIC RICE HYBRIDS"

M. Sc. (Ag.) Thesis

By

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“COMBINING ABILITY ANALYSIS AND ESTIMATION OF HETEROSIS FOR DEVELOPMENT OF AROMATIC RICE HYBRIDS”

Thesis

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CERTIFICATE-I

This is to certify that the thesis entitled **"Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids"** submitted in partial fulfilment of requirements for degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Harish Kumar Pandey** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

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

Date: 28.08.2020

Chairman 28.8.2020

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This is to certify that the thesis Viva-voce in respect of **Mr. Harish Kumar Pandey** student of **M.Sc. (Ag.)** has been conducted under the chairmanship of Head of the Department/Dean (in case of out campii) along with Advisory committee on **06-10-2020.** The necessary corrections have also been made as per comments/suggestions made by the Advisory Committee and Head of the Department/Dean.

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This is to certify that the thesis entitled **"Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids"**submitted by **Harish Kumar Pandey** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Genetics and Plant Breeding** has been approved by the external evaluator and Student's Advisory Committee after oral examination, under the chairmanship of Head of Department.

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Date: 28.08.2020

(Harish Kumar Pandey)

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LIST OF ABBREVIATIONS

ABBREVATIONS		FULL FORM
%	-	Percent
Approx.	-	Approximately
Df	-	Degree of freedom
ANOVA	-	Analysis of Variance
et al.	-	and others
Viz.,	-	Namely
G/g	-	Gram
Ha	-	Hectare
i.e.	-	that is
S.D.	-	Standard Deviation
S.E.	-	Standard Error
GCV	-	Genotypic Coefficient of Variation
PCV	-	Phenotypic Coefficient of Variation
ANOVA	-	Analysis of Variance
RCBD	-	Randomized Complete Block Design
Mm	-	Millimeters
CD	-	Critical differences
cm	-	Centimeters

THESIS ABSTRACT

Title of the thesis	:	**"Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids "**
Full name of the student	:	Harish Kumar Pandey
Major subject	:	Genetics and Plant Breeding
Name and address of the major advisor	:	Dr. A.K. Sarawgi, Professor and Head, Department of Genetics and Plant Breeding, College of Agriculture, IGKV Raipur.
Degree to be awarded	:	M. Sc. (Agriculture, Genetics and Plant Breeding)

Harish Pandey
Signature of Student

Signature of Major Advisor

Signature of Head of the Department

Date : 28.08.2020

ABSTRACT

The experiment having the title **"Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids"** was conducted at "research cum instructional farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Kharif* 2019". The concerned investigation that has been kept under the supervision was 48 rice genotypes and was grown in the

design of Randomised block design with 2 replications. Data were recorded for thirteen yield and its contributing traits for the analysis of the given objective i.e, Varaiblity, combining ability and Heterosis.

The analysis of variance for the 48 genotypes disclosed the fact that significant differences were available for all the concerned characters that has been taken in the experiment. This signifies that there is large amount of the variability present among the rice genotypes/hybrids for the concerned traits.

The prevalence of the effect of specific combining ability (SCA) variance for various characters indicates the preponderance of non-additive or dominant and epistatic gene action, this is really essential in order to regulate the manifestation of these characters. Therefore, on analogy with different findings obtained in this analysis, it can be concluded that the heterosis is significant for the grain yield traits and can be utilized commercially

Non-additive gene action came out to be significant for all the thirteen characters in this research work that has been based on the significant SCA variances. As SCA variances tends to stand out in performance as compared to GCA variances for all the characters, it means that for all the characters probability of utilising heterosis is beneficial for thirteen characters as compared to normal selection.

Six noteworthy crosses, comprising CG Zinc rice / Jaggithyali sannalu, Samleshwari / UPR3565-10-1-1, Indira aerobic / HUNG MI TSAING MA, Indira aerobic / Muskan, Rajeshwari / Kanakjeera andIR-64 / HUNG MI TSIANG MA this were found as the best hybrids that produce significant results for grain yield per plant based on results of mean output, heterosis estimate, SCA effects and GCA effects

शोधसारांश

अ. शोध का शीर्षक	:	"सुगंधित चावल संकर के विकास के लिए क्षमता विश्लेषण और विषमता का आकलन"।
ब. छात्र का पूरा नाम	:	हरीश कुमार पांडे
स. प्रमुख विषय	:	अनुवांशिकी एवं पादप प्रजनन
द. प्रमुख सलाहकार का नाम और पता	:	डॉ ए.के. सरावगी, प्रोफेसर और प्रमुख, अनुवांशिकी एवं पादप प्रजनन विभाग, अनुवांशिकी पादप प्रजनन विभाग, कृषि महाविद्यालय, इ. गा.कृ. वि. रायपुर (छ. ग.).
इ. उपाधि से सम्मानित किया गया	:	एम. एस. सी. (कृषि)अनुवांशिकी एवं पादप प्रजनन

Harish Pandey
छात्र का हस्ताक्षर

प्रमुख सलाहकार के हस्ताक्षर

विभाग के प्रमुख का हस्ताक्षर

दिनांक: 28·08·2020

सारांश

खरीफ2019 के दौरान "सह-सुगंधित चावल संकर के विकास के लिए संयोजन क्षमता विश्लेषण और सुगंधित चावल संकर के विकास का अनुमान" शीर्षक का प्रयोग किया गया था। प्रायोगिक तौर पर जो निगरानी के तहत रखा गया है, उसमें 48 चावल के जीनोटाइप थे जिन्हें 2 प्रतिकृति के साथ रैंडमाइज्ड ब्लॉक डिजाइन के रूप में उगाया गया था। डेटा को तेरह पैदावार के लिए दर्ज किया गया था और इसके दिए गए उद्देश्य के विश्लेषण के लिए महत्वपूर्ण योगदान अर्थात्, वराइबैलिटी, संयोजन क्षमता और हेटेरोसिस।

48 जीनोटाइप्स के लिए विचरण के विश्लेषण ने इस तथ्य का खुलासा किया कि प्रयोग में लिए गए सभी संबंधित पात्रों के लिए उल्लेखनीय मात्रा में अंतर उपलब्ध था। यह दर्शाता है कि संबंधित लक्षणों के लिए चावल जीनोटाइप / संकर के बीच बड़ी मात्रा में परिवर्तनशीलता मौजूद है।

विभिन्न वर्णों के लिए विशिष्ट संयोजन क्षमता (एससीए) विचरण के प्रभाव की व्यापकता गैर-योजक या प्रमुख और एपिस्टैटिक जीन कार्रवाई के पूर्वसुधार को इंगित करती है, यह वास्तव में इन पात्रों की अभिव्यक्ति को विनियमित करने के लिए आवश्यक है। इसलिए, इस विश्लेषण में प्राप्त विभिन्न निष्कर्षों के साथ सादृश्यता पर, यह निष्कर्ष निकाला जा सकता है कि चावल की संकरता के मामले में बीज की उपज तय करने में हीटरोसिस की प्रक्रिया एक महत्वपूर्ण भूमिका निभाती है और व्यावसायिक रूप से उगाई जा सकती है।

गैर-एडिटिव जीन एक्शन इस शोध कार्य में पूरे तेरह सूचीबद्ध किस्मों को नियंत्रित करता है जो एससीए संस्करण के उल्लेखनीय प्रभाव पर आधारित है। जैसा कि SCA संस्करण सभी वर्णों के लिए GCA संस्करण के सामने खड़ा होता है। इसका अर्थ है कि इस वर्ण के लिए, तेरह वर्णों के लाभ उठाने की संभावना लाभकारी है क्योंकि साधारण चयन के माध्यम से, कुछ वर्णों में सुधार किया जाना चाहिए।

छः उल्लेखनीय संकर, जिसमें सीजी जिंक चावल / जग्गिथ्याली सन्नालु, समलेश्वरी / UPR3565-10-1-1, इंदिरा एरोबिक / HUNG MI TSAING MA, इंदिरा एरोबिक / मुस्कान, राजेश्वरी / कनकजीरा और आईआईआर -64 / HUNG MI TSIANG MA शामिल हैं मीनिंग आउटपुट, हेटेरोसिस अनुमान, एससीए प्रभाव, और जीसीए प्रभाव (उनके संबद्ध माता-पिता के) के परिणामों के आधार पर प्रति पौधे अनाज की उपज के लिए गहन परिणाम उत्पन्न करने वाली मोहक संकर।

CHAPTER – I
INTRODUCTION

Rice (*Oryza sativa L.*) is one of the major crop within the cereals which suffice the extreme need of the calorie in this coming neoteric world and being the chief or in other meaning the major food crop for about half of that of total population in today's world and thus this crop being the most significant cereal crop in our earth. Rice being the semi aquatic that it lives in the condition where major portion of life cycle came out to be submerged in water and half of it on land and it is being classified as grass crop, belongs to the family of Poaceae. Rice is the crop which has the genus *Oryza* and having the well read cultivated species that is *Oryza sativa* and *Oryza glabbberima* and also having about 22 species that are categorized as the wild species but the major portion of the rice that is being cultivated in half of the world population isone and only *Oryza sativa L.* (annual species) where as the other species *i.e.Oryza glaberrima* comes out to be the perennial species that could be cultivated in the West Africa

Rice is the crop which has the great significance or calls it one of the most important crop whether it is south east asia or whole world with respect to area and production. As per the new estimates it is being believed that out of the three people one of them should depends on rice for satiating there need of the diet over the day or over the period of time . It also being researched that about Ninety percent of the total of our planet population does depends on the rice for satisfying the varying need to satisfy the hunger and tackling ravenous condition over the worldinperiod of time .

Rice is being produced in different countries of neoteric developing world and major part of the South East Asia like China, India, Korea, Japan, Thailand *etc*. out of them china came out to be the country which is acing in rice production as compared to other country over decades. Whereas India came out to be the second in the production of rice next to China emerging as the major producer of rice in the world. In our country rice is being taken as major crop almost covering considerable portion of the states, covering about 30 percent land that of total cultivated area and having the major portion in the total production of the grain *i.e.* about 40 percent in total country. The production of rice in our country for year 2015-2016 came out to be 104.41 million tones, having the productivity of about 2400 kg/hectare enveloping an area of about 434.99 lakhs hectares. Whereas in the year of 2016-17 the total acerage or the total area covering decreased to be 431.94 lakh hectare with rise in the production that is about110.15 million tonnes (Anonymous, 2018).

Chhattisgarh state is being acknowledged as "Rice bowl of India". The affluent diverseness in the biodiversity of rice in Chhattisgarh is the corroboration of this certitude that Rice belongs to the category of major crop during the Kharif season glancing maximum area over our state. This biodiversity becomes the pioneering origin of source and provide immense scope for confirming the presence of the diverseness or wide variability. In Chhattisgarh, rice is being cultivated in total area of 3.79 million hectares, with the production estimate came out to be around the total of the 6.91 million tonnes (Anonymous, 2018)

As it is been globally known that rice is came out to be the self pollinated crop and it follows such mode of pollination even though strong heterosis is being reported in the F_1 hybrids in those self pollinating crops. Heterosis or in other words we could spell it hybrid vigour could be made significant as surplus performances for the F_1 hybrids that has been generated by involving the cross between the two suitable inbred lines. Heterosis in today's generation can also be defined in quantitative way, in quantitative way it could be understood in such of upward deviation to that of the mid-parent,that has been based on the value of those mean values of those two parents that has been involved. Heterosis could be divided in that of those two categories namely positive heterosis and other name be the negative heterosis. And through different research and analogies it is been conclusive that positive heterosis came out to be good for the yield factor and in comparison of this negative heterosis is being desirable for the early maturity. Heterosis is being measured in simple 3 ways that to with the basis that has been used to differentiate the performance of the hybrid and by this it is easy to compare them. But with certain researches done by plant breeder's, fact is conclusive that better parent or in the simple terms we could insist standard variety is more than effective. And the better parent performance that has been discussed above in more advance term could be pronounced as heterobeltiosis. (Fanesco and Peterson,1968) and the later part that has discussed above in terms of standard variety is called as standard heterosis.(Virmani,1994). Practically, standard heterosis is more significant because it is preferred to develop hybrids that desired to be excessively high yielding in comparison to those of the commercial varieties.

Before starting any of the breeding programme when the course of action is for selection then for its effectiveness, the existence of the variability came out to be with the role of utmost importance. The aggregate of genetic variability existing in any of the material is being properly wielded before commencing any of the varietal development experiment. The extent of variability present in any condition could be evaluated with the help of certain genetic parameters such as Genetic Coefficient of Variation (GCV) and the other parameter that is being utilized is Phenotypic Coefficient of Variation (PCV). "Heritability estimates provide information about a particular genetic attribute which will be transmitted to the successive generations and direct the breeders in the choice of parents for the crop improvement programmes". However, lonely the heritability in broad sense could not be significant in selection of those which are base upon the phenotype, because the heritability itself is influenced by the factor determined by the environment. Thus calculation of the heritability along to that of the genetic advance is not only significant in estimating the gain that is under the selection but also estimating the extent of environment factor on appearance of the respective genotype.

Genetic amplification or genetic improvement is one of the major drive in bringing significant enhancement and improvement in case of the productivity. Hybrid techniques has been majorly applauded and acknowledged to magnify the genetic potentiality of the different major crop species. Before initiation of any of the breeding programme the major requirement is of the good parents that combine well and to define the potential of the parents that combine well in the population could be analyzed by general combining ability and specific combining ability and gene action comes to the rescue. Choice of the parent which amalgamates well in a sequence of crosses may be utilized in exploiting the major important character of the commercial hybrids. The investigation of the combining ability provides the measures by which it is easy to determine the potential parent and there selection and by such investigation we could determine the breeding procedure that could flourish the coming breeding programme. Such examination also provides the significant information about the extent of the additive variance as well as about the non additive variances for study of different characters like yield and its major components. The major equipments in analyzing the gene effects are Diallele and the other method that came up in account is the Line × Tester analysis techniques. Nevertheless Line×Tester analysis method (Kempthrone, 1957) becomes more achievable with the large no of the parents involved. An included significance of this method is that it gives complete genetic image of the material under single umbrella in a single generation.

Keeping the above discussed views into the consideration. The present investigation was carried out with the following objectives:-

1. **To estimate the magnitude of heterosis for yield and its contributing traits**
2. **To estimate the general combining ability, specific combining ability and gene action for yield and its contributing traits**
3. **To estimate variability for yield and its contributing traits**

CHAPTER-II
REVIEW OF LITERATURE

Appearance of the genetic variability in the foundation population is the major factor that is needed for advancement of a crop species. The calculation of the different required genetic parameters aids to know and briefly understand the extent and nature of the genetic variability and also genetic diversity and also provide information about connection within different characters comprising their respective direct or their indirect effects on certain variable like yield and other parameter like quality of the grain so that selection could be done according to those respective analysis. Thus, knowledge about this parameters in relation to that of above aspects is useful to draw a blueprint of a breeding program for respective enhancement in the base population.

The literature that is present in rice related to current perspective was checked and summarized under the heading beneath:

2.1 Genetic variability.

2.2 Combining ability and Gene action.

2.3 Heterosis.

2.1 Genetic variability.

Variability may be described as the existence of variations between the individuals of a population arising either from discrepancies in a population's genetic makeup or from the environment in which they are raised.Developing a successful breeding system and selection performance based on the extent or amount of the genetic variation that has been present in the population. Therefore it is necessary to state a judicious breeding system awareness of the variation present in the population. Renowned taxonomists like Linnaeus (gave the common name '*Oryza*') performed the pioneering research on genetic diversity. Other notable scientists are De Candolle (1886),Camus (1920), Roschevicz (1931), Chatterjee (1947) and Porter (1956).

Sinha and Bhattacharya (1980) evaluated 40 rice varieties and observed a Genotypic coefficient of variation range from 8.54% (for panicle length) to 28.15% (for per plant yield of grain).Chauhan and Tandon (1984) came to know about the enhancing results for the GCV for effective tillers and significant heritability, Awasthi and Borthakur (1986) and Sardana and Sasikumar (1987) for length of panicle, per plant number of fertile/filled grains, weight of 1000 seeds and per plant yield of grain,Hussain (1987) and De and Rao (1988) for sterility percentage, Choubey *et al*. (1988) for alkali spreading benefit, elongation ratio and weight of 1000 grains in various kinds of investigational rice content. Deosarkar *et al*. (1989) obtained non significant results for the parameters like GCV for grain shape (L / B ratio).

Sarawgi *et al*. (1994) mentioned variability for quality traits along with a high heritability. A broad range of variation was recorded by Mani *et al*. (1997) in basmati class of rice for the fertile spikelets per panicle, grain produce and 100 seed weight. Balan *et al*. (1999) reported a strong value of the genotypic coefficient of variability for yield of grain per plant, Chikkalingaiah *et al*. (1999) for amylase content, effective tillers and elongation ratio and Sadukhan and Chattopadhyay (2000), along with moderate to that of the high rate of heritability were obtained for parameters such as per plant grain yield weight and weight of 1000 grains.

Sivasubramanian and Madhavamenon (1973), Bhattacharya (1978) showed significant heritability for crop yield, Paramasivan (1981) for grain size and grain weight of 1000 seeds , Shamsuddin (1982) for yield of grain, Nee (1982) for the gelatinization temperature, Chauhan and Nanda (1983), Chauhan and Tandon (1984) for tillers, Maurya *et al*. (1986) and Sarawgi *et al*. (1994) for size of grain and weight of 1000 grains,De and Rao (1988), Reddy and De (1996) for grain production, Nath and Talukdar (1997) for fertility of the spikelet Sadukhan and Chattopadhyay (2000), for yield of grain per plant , content of amylase and 1000 grain weight, reported the range of moderate to high heritability.

Maurya *et al*. (1986) recorded high genetic advances for grains per panicle and panicle length, De and Rao (1988) and Sharma *et al*. (1996) recorded it significant for effective tillers, Choubey and Singh (1994) documented high genetic advances for the grain yields per plant.Nath and Talukdar (1997) reported the range of moderate to high heritablity for grain yield, sterility percentage and weight of 1000 grains.

Das *et al*. (2001) reported significant estimate of PCV for all the traits under study in 29 boro rice genotypes. Some of the traits showed high heritability along with high genetic advance and some of the traits showed high heritability along with the moderate to low genetic advance. Kavitha and Reddi (2002) reported significant heritablity along with increased genetic advance for the spikelets per panicle and the total number of the fertile grains per panicle.

Chaudhary and Motiramani (2003) noticed a wide range of variations in 54 conventional aromatic rice accessions.The significant PCV and GCV were documented for percentage of spikelet sterility. Significant heritability along with increased genetic advance shown by all characters except for the harvest index. Chaudhary *et al*. (2004) documented high heritability and genetic advance for the traits of the plant that are under analysis. High range of the GCV and PCV were shown by grain yield, harvest and biological index as described by Singh and Singh (2005). High heritability as well as significant impact of genetic advance for the height of plant was also noticed.

For all the characters which are included for the study by Veni and Rani (2006) tracked low range to moderate range of the variability results, that are coupled with moderate range to high range of the heritability and along with low genetic advance.An investigation performed by Mustafa and Elsheik (2007) showed the existence for many characters of large degree of variation and higher heritability with higher genetic advance for the character such as stature of plant along with days to 50 percent of flowering and another parameters like grain weight of 1000 seeds

Singh *et al*. (2011) performed research where all the characters displayed significant differences excluding the flag leaf length, where they found high range of PCV and GCV for the parameters like total number of the spikelets per panicle. Traits like biological yield per hill showed high broad sense heritability. High range of heritability and genetic advance were recorded for the traits like number of spikelets per panicle.

Kumar *et al*. (2013) identified high variability for the all the traits amongst these genotypes. The phenotypic coefficient of variation (PCV) was little greater as compared to that of the Genotypic coefficient of variation (GCV). All concerned traits showed high value of the heritability in the mode of the broad sense. Significant genetic advance coupled along with greater heritability was obtained for traits such as plant stature,grain yield per plant , harvest index, 1000 seed weight *etc*. Lower value of the genetic advance along with strong heritability was obtained for the parameter such aspanicle length,days to maturity anddays to 50% flowering.

Vanisree *et al*. (2013) examined 50 aromatic and basmati short grain rice genotypes and discovered that genotypes showed greater variation observed for the traits that contribute to yield and characters like grain quality. Parameters like fertile grain and effective tillers per plantshowed highest variability along with theother parameters panicle length, days to 50% flowering, kernel breadth and kernel elongation ratio had lower value for variability.

Seventy two genotypes of upland rice examined by Limbani *et al*. (2017) for the extent of genetic variability. The parameters like harvest index, per plot yield of grain, sterile grain per panicle and effective tillers per plot showed high value of phenotypic and genetic coefficient of variation and also marked high heritability along with significant value of genetic advance.

Iqbal *et al*. (2018) tested eighteen evolved lines of green super rice (GSR) for genetic variation, heritability and genetic advance. Significant amount of the differences were reported amongst GSR lines for different characters. The valueof phenotypic coefficient of variation (PCV) better thanthat of value of the genotypic coefficient of variation (GCV) suggesting marginal effect by the parameter of environment on the yield and its attributing traits.Likewise, greater amount heritability as well as the greater amount of the genetic advance was depictedfor all parameters studied except for length of panicle which shows selection was utilized for the enhancement ofconcerned parameters.

Tiwari *et al*. (2019) evaluated the 7 genotypes involving the hardinath 1 as the check and observed that greater heritability (broad sense) value came out for characters like maturity days and the high value of the heritability were obtained for the plant stature. Forphenotypic and genotypic parameters positive correlation being reported for characters like days to heading and and other character being the maturity days. Likewise, for the plant stature and other character like weight of the 1000 grain has the record of negative and significant correlations. Thus this kind of results shows that characters like heading days, maturity days, yield of the grain, 1000-grain test weight shows high range of the heritability and significant genetic advance and this could be accepted as significant traits for enhancement and selection of the trait to get fixed and good yielding genotypes that tend to have the character of high yield under rainfed environments.

2.2 Combining ability and Gene action.

Knowledge on the essence of combining ability of parents and hybrid capacity promotes parent selection or call it aids in the choice of the parents in a breeding programme and in deciding the significance of the breeding strategies that about to be done.The combining ability is the potential of an inbred or a parent to express favourable output of their hybrid progeny. A parent's average or inbred output in a sequence of cross combinations is regarded as its 'general combining ability' and two unique inbreds output in a specific cross combination is recognized as their 'specific combining ability.'

Davis (1927) was the first one to propose using inbreds top cross to report the hybrids general combining ability.Sprague andTatum (1942) are two scientist who made pioneering work in combining ability concept and distinguished between general combining ability and specific combination ability as the average line effectiveness in a sequence of crosses and then further presumed that GCA was reliant on additive gene effects.The specific combining ability (SCA) was used in certain situations where those cross-combinations do comparatively better or even worse than predicted based on the total lines output.The SCA relies on dominant genes and epistatic impact.

The information on the process of combining ability in the crop of rice is discussed in below:

2.2.1 The GCA and SCA effects

Singh *et al*. (1980) identified TET 3618 as a cultivar that has ability of good general combiner for character of grain yield/plant and for the character like days to 50% flowering and Saket 4 as an effective combiner for the character of effective number of tillers, flowering days and stature of the plant.

Rahman *et al*. (1981) proclaimed variety Dular which came out to be good general combiner.

Singh (1982) identified Saket 4 and Sona as the strong general combiners for the traits like paddy length and paddy L/B ratio and CH 4 and Saket 4 for the traits like yield of the grain. Four of hybrids namely, Saket 4 x FH 562, Saket 4 x Padma, CH 4 x Sona and CH 4 x Padma have been described as successful cross-combinations to be used in rice breeding.

Devarathinam (1983) considered Chitariyan as a cultivar which shows significant geneal combining ability for improved plant stature, efficient tillers, fertile grain per panicle, yield of plants and days to 50% flowering and Chandikar for the character such as yield of grain.Poongar X IR 8 and Chitariyan x Kannagi have been reported as successful cross combinations yield per panicle of plants and fertile panicle per plant.

Kumar and Rangaswamy (1984) identified cultivar 07414 and 07107 as significant general combiner for the traits like per plant yield and 06184 for small stature.

Singh and Singh (1985) discovered CP 231 and T9 assignificantgeneral combinerfor parameters like paddy length, paddy width and their respective ratios.

Sarathe and Singh (1986)observed Kalimooch 64 and IR 43 varieties which came out to be significant general combinerfor traits like harvest index, grain production, grains per panicle and other character being reducd rate of the sterlity, while for the variety like Basmati 370 came out to show strong combination for the traits like harvest index,stature of the panicle, reduced rate of sterility and weight of the 1000 of the grains. Similar kind of results for varieties like Kalimooch 64. Kalimooch 64 x Mahsuri, IR 443 x Dubraj, Madhuri x Laloo 14and Basmati 370 x Dubraj cross groupings were found to be good specific combiners.

Sharma *et al*. (1987) identified varieties like PL 16, cross B2, IR 54, IR 36 as good general combiners while specific cross combiner significant for the varieties such as IR 36 x Safri 17 and IR 5 x Pragati for plant stature.

Kalaimani and Sundaram (1988) grabbed excellent general combining in the variety of IR8 for the trait of yield and its other significant contributing components, for traits like grainweight and earlinessADT 3 came out to be significant , for yieldCO 37 and for grains per panicle it isIR 20 .

Manuel and Palaniswamy (1989) examined that as good general combiners for grain yield per plant the varieties that stand out are ASO 16 between lines and IR 50 among tester. For traists like plant height,days to 50% flowering,panicles per plant,grains per panicle, length of panicle, sterilitypercentage and 100 grain weightASD-1 and IR 50 were significant. Cross combinations ADT 30 xADT

36,ASD 1 x CO 33, ASD 16 x IR 50 andTKM 9 x CO 33 shows specific combiner for economic yield/plant.

Paramasivan (1990) pioneered that the SCA variance stands out in comaparisionto GCA for trait like panicle length, plant height and economic yield per plant which easily signifies that presence of non additive gene action. The genotypesUtrirajappan and ADT 31 came out to be significant general combiner for yield and for those cross combinations having both of these parents reported significant SCA effects.

Singh and Singh (r) excelled general combiners for panicle length, panicle weight and harvest index in varieties of IR 36 and HKR-1. IR 36x RP 2136-92-2, IR 36x PR 106, HKR x RP 2151-21-1 amongst cross combinations and Jaya x DV 85 showed good specific combiners for panicle weight, stature of panicle and harvest index.

Murthy and Shivashankar (1992) recorded substantial variation due to both GCA and SCA for all the traits suggesting the significance of both additive and non-additive gene effects. For grain yield, total dry matter content, photosynthetic rate and net assimilation ratecrop likeGowisanna and Halubbalu identified as significant general combiners.

Singh *et al*. (1993) identified impact of non additive gene forL/B ratioandkernel breadth. Parental impact was found to be a great significance forthe GCA effects. The cross Pusa 33 x BR 34and IET 7564 x BG 90-2 were significant specific combiners.

Gravois (1994) reported the effects of GCA were better than that of effects of SCA for traits like head rice percentage.

Sharma *et al*. (1996) recorded the impact of non additive gene action for stature of the plant and yield of the grain and to that of additive gene action came out to be significant for traits like panicle length,panicle bearing tillers per plant andfertile spikelets per panicle.

Meenakshi and Amirthadevarathinam (1999) identifiedgenetic varianceandcombiningability for yield and physiological components in a ten of the total number of the genotypes and recorded that KallusundaikarandAnnada came out to be the significant general combiner for all the concerned characters except to that of the weight of 100 seed grains. Annada / Chandikaand Annada/ Kalusundaikar came out to be best of the specific combiners.

Kalitha and Upadhaya (2000) investigated 33 of the characters for process of combining ability via line x testers method comprising 11 lines and 3 testers and propounded the significance of the non additive gene action for all the characters except length of panicle.

Munhot *et al*. (2000) implemented analysis of combining ability for yield and its attributes and traits comprising quality parameter via line x tester method and explained that the parents RP 2151-33-2, Dubraj, Mahamaya, R302-111 and Abhaya came out to be excellent general combiners for character like yield and its attributing components. The cross R 302-111 / Dubraj,RP 2151-33-2/ Pusa Basmati-1, Mahamaya x Basmati-370, RP2151-33-2/ Dubraj ,PR-111/ Pusa Basmati-1 and PR106/ Tarori Basmati figured out good specific combiners for traits like yield.

Satayanarayana *et al*. (2000) reported combining ability using L x T cross combinations comprises 3 of the CMS lines and 33 of the restorer lines and exclaimed that the CMS lines V20A came out to be significant general combiner for trait of earliness whereas, IR 62829AandIR 58025A were good general combiners the trait of the yield.

Annadurai and Nadarajan (2001) investigated the 7 restorers and five of the CMS lines and there 35 cross combinations. IR-8866-20-3-1-4-1, Ponni, IR6289A, IR 58025A and PMS9 came out to be good general combiners. IR 58025A x Ponni, comprised the better specific combiners and it does not show useful SCA effects for grain yield.

Sharma and Mani (2001) conducted combining ability analysis in a 9 x 9 diallel cross including seven basmati and two non-basmati genotypes adopting Griffings methodology (method 2, model 1). Haryana Basmati,Basmati 370, Pusa Basmati and Kasturi have emerged as a good general combiners for grain yield and other characters. UPR85-71-8-1 was successful combiner for traits like earliness and small plant height.They also identified crosses with good specific combining ability.

Banumathy *et al*. (2003) investigated combining ability in hybrids involving 20 testers and 5 CMS lines. The lines IR 69616A, IR-58025A and IR-70364 A and testers IR 65515-472-1-19 CB 950566, IR 10198-66-2R, TNAU-841434, TNAU 94301 and TNAU 94241 came out to be good general combiners for yield of grain per plant. The cross combination IR-68888A/ IR-1019866-2R,IR-68888A/ CB95066, IR 70370 A/ CO 47 , IR0364A/ TNAU 80030 andIR69616A/ TNAU 841434 good specific combining ability trait like the yield of the grain.

Bhave *et al*. (2003) for yield and its different components analysed combining ability using 16 restorer lines , 32 F1 hybrids and 2maintainer lines of rice crop.RTN 68, KJT 14-7 andIR-62829A showed good general combining ability for the traits liketotal number of tillers per plant.KJT-4 RTN-73, KJT-1 and IR-62829A, came to show significant general combining ability for traits like maturityand 50 per cent flowering.IR-58025 and RTN-68 were the best combiner forpanicle characteristics., RTN 68 ,KJT-4-7 andIR-58025A best combiners for yield of grain per panicle. , IR-58025A x PNL 1, IR-62829A x PNL2 andIR-58025A/ RTN 68 showed significant specific combining ability..

Prakash *et al*. (2003) investigated combining ability of rice for10 traits using 13 parental genotypes and femaleparents which are cytoplasmic male sterile. IR-58025A came out to be significant general combiner for traits like dwarfness, number of tillers per plant, number of panicle bearing tillers per plant and significant traits like earliness.Among hybrids PMS 10A x NDRK-5028,IR-58025A x Annada, IR58025Ax Sarjo 52 showed good specific combining ability for traits like biological yield and yield of grain.

Liu-Wei *et al*. (2004) used9 ecotypeand its41 japonica rice varities to design cross combination in a manner of the diallele set. GCA variances are more significant than that of the SCA. Additive gene effect has major impact on those comprised characters. North west Taiwan ecotype and ecotype of cultivar ITA showed heterotypic relation among hybrids and GCA and it tends to be significant.

Panwar (2005) conducted analysis of combining ability in L x T design comprising ten testers and3 lines with 30 possible cross combinations. Testers Basmati 370, Kasturi, PusaBasmati-1,IR 64 and Tarori Basmati and the line IET-13846 showed good general combiing ability for traits like yield of grain per plant. Crosses like, IET 13856 x IR64, IET-13846 x PusaBasmati-1, JET 13846 xTarori Basmati andIET 13846 x Kasturi produced significant specific combiningability effects for yield of grains, heterosis that ranges moderate to high and both of those parents tends out to show significant general combining ability.
Sao and Motiramani (2006) researched the combination of rice capability employing L x T mating design for yield and its supporting characteristics finding DRR 22A showing better general combining ability for the trait stature of plant.IR62829A came out to be good general combiner for traits like panicle number of spikelets and grain yield per plant, IR67684A came up with good general combining ability for the traits like per plant productive tiller, total number of fertile spikelet per panicle, spikelet fertility percentage and pollen sterility percentage. Swarna tester came out to be best combiner for grain yield per plant.

P*etc*hiammal and Anandakumar (2007) have analyzed combining ability with forty-two rice hybrids generated from seven different genotypes, particularly three Assam rice crops with full diallel pairing feature.Compared with the results and GCA impact,ARC 18214 and ARC15759 have been the significant parents to enhance yield and its attributing traits.

Five testers and six lines and their cross combinations were reviewed by Karthikeyan *et al*. (2009) for combining ability under salt affected circumstance.Lines IR65192-4B-8-1 and IR65847-3B-6-2 demonstrated good general combining ability for effective tiller, panicle length and economic yield per plant. The IR65847-3B-6-2 / ADT45 hybrids reported non-additive impact of dominance x dominance particularly.

Bagheri and Jelodar (2010) analyzed the combining ability in hybrid rice and showed maximum SCA variances than GCA variances for almost all of the characteristics. TheCMS line IR 50 and IR62829A were also found to be good general combiners and four crosses to be better specific cross combiners for yield components and many of the characters analyzed.

Waghmode and Ingole (2011) identified among lines RTN3A and RTN2A as well as among males IR63879-195-2-2-3-2, NVSR20, BL184AR, GR7 and IR8866 as a good general combiner for yield and much of the characters. The crosses namely, RTN13A/GR7, RTN2A/NVSR20 andRTN3A/BL184ARshowed good specific general combining ability on grain yield per plant and some associated characteristics.

The two CMS lines, PMS12A and11A and six of the restorers were described by Gautam *et al*. (2012) like PAU1106-5-4, PAU2024, IR59566, PAU1226-1-4, PAU1106-6-2 and IR32841 as nice general combiners.

The parents Malida, IR64 and Ujala Depama were identifed by Shiva Prasad *et al*. (2013) as good general combiners.The significant specific combiners are MTU-1010 / Ujala Depama, IR64 / Malida and IR64 / Ujala Depama.

Sarial(2014) crossed 45 aromatic and non-aromatic genotypic germplasm lines with four CMS lines like; IR 58025A, PMS3A, PMS10A andIR62829A.The Basmati 385 restorer was classified as a good general combiner for both qualities of grain and physiochemical characteristics whereas, Karnal Local was classified for quality of grain and HKR 241 for physical chemical qualities. Heterotic grain yield hybrids IR58025A / Karnal Local and IR58025A / Basmati 385 with significant SCA effects were recognized as specific grain performance and physicochemical characteristics combinations, respectively.

Thalapati *et al*. (2015) analysed thirty six hybrids for yield and its contributing
attributes.A group of best general combiners for yield componentstraits IL350-12, IL86-18, IL50-7and CMS lines: APMS6A andIR79156A were identified. APMS10A/IL363-5, IL86-18 and IR79156A/IL50-13showed promising increase in the extent of specific combination and also enhanced effect for the conventional heterosis.

Sahu *et al*. (2016) studied twenty one crosses for combining ability analysis comprising three CMS lines and seven testers in LxT design. IR79156A indicated good GCA effect, so it was identified as a better general combiner for the grain yield per plant. Important general combiners for yield of the grain perplant and other related characters found in the testers like TOX981-11-2-3, Bagdidhan, Suraksha and Karmamahsuri. IR58025A / Inger-2114, IR58025A / Suraksha, CRMS32A / Karmamahsuri, IR79156A / RIL-62 and IR79156/Karmamahsuri identified as superior combination of grain yield and its attributing traits

Devi *et al* (2017) evaluated 54 F1 performance established by crossing 18 lines with three testers.The significant SCA effect has been analyzed and non additive impact being reported for various yield and its contributing traits.

2.2.2 Gene action:

Johannson (1909) first found the evidence relevant to genetic control of quantitative traits.Fisher (1918) was the one to divide the genetic variance mainly into the three parts namely additive, dominance and epistatic variance.Additive variance could be understood as the portion of genetic variation that is generated at all the segregating loci by the differences attributable to average effects of the gene alleles.Dominance variance occurred as a result of the deviation from the additive gene action scheme resulting from predominant intra-allied interaction.The epistatic variance occurs as a result of the inter-allelic interactions due to the deviations.Hayman and Mather (1955) separated the epistatic variance further into three variables

- additive x additive,
- additive x dominance
- dominance x dominance interactions.

In the absence of epistasis, the Line x tester analysis (Kempthorne, 1957) was reported to become the greatest in estimating impartial additive and dominance components.Experiments on predicting genetic variation in rice using linex tester study was analyzed as follows:

Singh *et al*. (1980) revealed that non-additive gene activity predominated for grain yield, flowering days, plant stature and productive tillers.

Rahman *et al*. (1981) identified prevalence of additive gene effect in flowering days, plant height, panicle length and spikelet count.

Devarathinam (1983) noticed that the activity of both of the additive and non-additive genes was essential for yield and its associated characters.

Kumar and Rangawamy (1984) identified stature of plant, yield and panicle length showed effect of non-additive gene action.

Singh and Singh (1985) observed additive gene effects for maturity days as well as additive influences for grain width and grain weight in their experiment of half diallel cross.

Kuo and Liu (1986) reported additive gene effects significant for number of panicles, number of spikelets and plant height.

Kalaimani and Sundaram (1987) recorded the prevalence of non additive gene for character plant height and 100 grain weight and non-additive gene effect for days to flowering, effective tillers per plant and grains per panicle.

Cheema *et al*. (1988) mentioned that the effects of both additive and non-additive genes influenced plant height, spikelets per panicle and flowering days, however the impact of non-additive genes alone significantly effected the productive tiller.

Manuel and Palanisamy (1989) observed significantadditive gene effects for effective number of tiller and plant height and the prevalence of non-additive gene action to grains per panicle, flag leaf area, spikelet sterility, grain weight of 100 seeds and yield of grain per plant, while both non-additive and additive gene effects were significant for panicle length.

Peng and Virmani (1990) observed significant additive gene action for days to flowering, stature of plant and dry matter and both the additive and non-additive components were significant for yield components.

Sarawgi*et al*. (1991) recorded the significant effect of non-additive gene action for fertile spikelets per panicle, tiller number per plant, grain width, spikelet sterility, biological yield , L / B ratio, yield of grain per plant, harvest index.While the traits like stature of plant, panicle length, days to 50 percent flowering, density of spiklelet , test weight and length of paddy were recorded to be controlled more by action of additive genes.The existence for non-additive gene action for total dry matter, yield of grain and harvest index was stated by Murthy and Shivashankar (1992).

Singh *et al*. (1993) mentioned the prevalance of the non additive gene action in the character of length of kernel, additive gene effect was significant for length and breadth ratio of kernel and breadth of kernel.

Geetha *et al*. (1994) reported predominance of additive gene action for paddy length and weight of 100 grain and non-additive gene action to panicles per plant and yield of grain per plant.

The kernel characters reported by Vivekanandan and Giridharan (1995) (*i.e.* kernel length after cooking,length, breadth and its respective ratio, breadth after cooking, linear elongation ratio, expansion ratio and elongation index) were controlled by action of additive gene.

Sharma*et al*. (1996) found predominant action of non addititve genes for yield of grain per plant, stature of plant and the action of additive genes for panicle bearing tillers per plant, fertile spikelets per panicle and panicle length was found significant.

Manomani and Ranganathan (1998) examined the existence of additive gene action as well as other characteristics in the L x T method and found that GCA: SCA variance ratio revealed the value of non-additive gene action for plant height,days to flowering, paniclelength,number of productive tillers, total number of grains/primary ears, yield andweight of 100 grains.

Meenakshi and Amirthadevarathinam (1999) stated that the additive gene action was dominant with grain yield per plant and days to 50% flowering.Both gene actions*i.e.*additive and non-additive were examined for productive tiller.

Lavanya (2000) suggested that the dominant gene impact was prevalent for characteristics such as filled grains per panicle,effective tillers per plant, percent spikelet fertility, yield of grainsandharvest index.

Satyanarayana *et al*. (2000) observed that, for all characters tested, the variation due to specific combining capacity (SCA) was higher than the general combining ability (GCA), suggesting the growing influence of non-additive gene activity within yield and associated characteristics.

For stature of the plant, spikelet sterility percentage, weight of panicle, harvest index and other traits, Munhot *et al*. (2000) observed predominance of dominance gene action.Additive gene effect for fertile spikelet and spikelet density was also observed.

Liao *et al*. (2000) analyzed the predominance of additive influence for length of grain, breadth and their respective ratios, chalky region, chalky rice percentage, gelatinization temperature, while non-additive effects tended to be significant than additive effects for brown rice percentage.

Jiang Rong Lin *et al.* (2001) researched that length of brown rice , ratio of brown rice length to breadth were mainly influenced by additive effects

Hong*et al*. (2002) suggested that there were various ecological forms of japonica rice.For the three characteristics in rice heading date, panicle length and productive panicles per plant, additive effects were far more essential than that to non-additive effects. Non-additive effect was much more essential than that of additive effects for the character of 1000 seed grain weight.

Liang *et al*. (2002) found that the dominance action predominated for the number of tillers.Environmental and genotype influence additive effect of gene, but the expressions of dominant gene were not affected. The additive effects and the non additive gene effects were selectively expressed in the tillering stage.

The high prevalence of non-additive gene action were reported by Swain *et al*. (2003) for days to 50% flowering, number of panicles per plant and yield of grain per plant, while the additive form of gene action predominated for the remaining traits.

Shanthi *et al*. (2003) mentioned the non-additive gene effect was prevalent for the traits such as panicle length and for productive tillers/plant.The additive and non-additive gene activity is prevalent in the number of spikelets per panicle.

The gene effects were estimated by Rao and Kulkarni (2004) in fine inter subspecific crosses (indicax japonica), of which additive and dominance effect determined for economic yield, stature of plant, filled grains per panicle harvest index and length of panicle.

Panwar (2005) analysed ten testers and three lines with 30 cross combinations using L × T method. For these fourteen of the crosses exhibited significant SCA results,8 cross includes one parent with significant GCA results and another with higher or low effect of combining ability , suggesting both additive and non-additive genetic effect prevailing in crosses.

Murugan and Ganesan (2006) recorded that the additive gene activity was quite relevant for yield of grain per plant.

Narasimman *et al*. (2007) demonstrated that with all the six traits, ADT44 was a significant general combiner.Also, it was found that the parent CR1009 was a good combiner for all traits excluding the harvest index.The ADT44 / CR1009 cross combination demonstrated significant favourable SCA results with respect to the amount of productive grains per panicle, biomass per plant and grain yield per plant.

Kumar (2008) established the prevalence of non-additive gene action for all the character being studied like,head rice recovery, productive tiller per plant,plant height, length of panicle,flag leaf area, spikelets sterility percent, fertile grain per panicle, yield of grain per panicle and days to 50% flowering, respectively.

Jayasudha and Sharma (2009) analysed 33 hybrids utilising the cross combination of the three lines and eleven testers together with significant specific combining ability and gene action were found for all the characters.

As a consequence of the SCA effect, Kumar *et al*. (2010) recorded dominant gene action for plant stature, per panicle grain yield, grains/panicle, effective tillers per plant, hundred grain weight and days to 50 percent flowering.

Waghmode and Ingole (2011) performed gene-action research in rice (*Oryza sativa L)* applying various CGMS sources. The SCA variability was greater than that of the GCA variances in the yield of grain per plant, productive tillers per plant, plant stature, spikelets fertility rate, spikelets number per panicle, panicle stature, hundred grain weight and days to 50 percent flowering showing the prevalence of non-additive gene activity.

Padmavathi (2012) reported the prevalence of non-additive gene activity for many of the contributing yield and yield characteristics.

Malik and Singh (2013) found predominance of non additive gene effects forall the traits studied*viz*.,panicle weight, length of panicle, stature of the plant, number of panicle per plant , number of tillers per plant, thousand grain weight, spikelet number per panicle, grain number per panicle, spikelet fertility percentage harvest index and days to 50% flowering.

Pratap *et al*. (2013) revealed that greater SCA variances as compared to GCA variances showing the prevalence of non-additive gene influences suggested heterosis breeding significance for enhancing the contributing yield and yield characteristics.

Dar *et al*. (2014) examined general and specific combinations for yield and yield contributing rice characteristics.For most of the traits, large SCA variances prevaledas compared to that of GCA variances, suggesting the preponderance of non-additive gene activity.

In order to pick the right genotype, Ramesh *et al*. (2018) examined the 24 variants with 11 parents (8 male lines and 3 female CMS lines) in L X T Mating system.SCA variability was more than GCA for character such as number of the productive tillers per plant, days to the 50 percent flowering; non productive tillers per plant, breadth of flag leaf and grain weight of the 1000 seeds and duration of the grain. The fraction of the breadth which suggested that the non-additive genes dominated them. The performance of the lines and testers was more relative than the results of line x tester. High GCA variation suggested tester and lines had additive gene activity.

2.3 Heterosis

Heterosis describes the phenomenon where the hybrid of two genetically divergent parents shows a low or high yield at least above the parental value of the mid parentJones (1926) documented heteroesis in rice.Heterosis is the main factor for improving the hybrid's yield capability.Heterosis based analysis is summarized as follows:

In the crosses Karunax HP 235 and IR 28 x HP 235, Singh and Shrivastava (1982) reported highest heterosis for yield and some of its components.

Kumar and Saini (1983) registered significant heterosis over a better parent for grain yield per plant (223.2%),for grain per panicle (87.6%) , for 100 grain weight (25.4%).andvolume of panicle came out to be 21.8%,

Singh *et al*. (1984) recorded significant heterosis over better parents for grain yield per plant (-37.48 to 133.71 per cent).

Kaw and Khush (1985) examined usefulheterosis for character like low rice temperature resistance and found an overall cold resistant index heterosis of 163.0 per cent.

Kaushik and Sharma (1986) recorded that 2 crosses such as China 988 x Himadhan and Himalaya xPherlatas 72 hadheterobeltiosis around 32.3 and 26.9 per cent, respectively for grain yield.

Sarwagi and Shrivastava (1988) revealed significant mean heterosis over better parent for biological yield (25.62 percent),tiller number (22.48 percent),and yield per plant (28.41 percent)under irrigated conditions and for biological yield (10.72 percent),flag leaf region (21.88 percent), and tiller number (9.12 percent) under rainfed condition in partial diallele studies involving total sixteen varieties.

Qi *et al*. (1990) analyzed cross variations of 6 japonica varieties and5 indica rice varieties. Heterosis levels were shown to be important for amylose content and gelatinisation temperature.

Peng and Virmani (1991) studied seventy four of the hybrids and 18 parenting lines for heterosis of yield, harvest index, flowering days, grain yield, dry matter and plant height.One hybrid (IR-19746-27-3-3-1-2x IR 2797-105-2-2-3) displayed a significant improvement over check by 33.6 percent

Vivekanandan *et al*. (1992) explored 6 TKM6, IR 50 and CO 29 crosses and found the TKM6x CO 29 cross as heterotic for earliness, number of productive tillers, number of grains per panicle, panicle length and yield of grain.

Heterosis for the character like yield ranging from 16% to 68% was mainly due to heterosis for the panicle weight rather than panicle number studied by the scientist Gravois and Mc New (1993).

Gravois (1994) documented non-significant mean heterosis in head rice value, but significant heterosis in rough rice yield and head rice percentage, respectively, averaged 21, -5 and 22%.The strong heterotic combination for grain yield was found to be APMS IA / IET-10021 and IR58025A / IET-10021.

Khan *et al*. (1998) stated that in the harvest index involved significant heterosis for grain yield.

Singh and Haque (1999) noticed grain yield involves positive heterosis per plant, ear bearing tillers per plant and the number of grains per panicle in the test produced in 10 x 10 part of the diallel crosses.

Singh and Maurya*et al*. (1999) revealed significant standard heterosis for earliness in 5 hybrids and for dwarfness in 4 hybrids. For effective tillers, spikelets per panicle, panicle length andtotal number of tillers positive normal heterosis was noticed. All of the hybrids exhibited negative heterosis for percentage seed setting and test weight.

The hybrids IR-62829A / IR276-301-06-01R, IR-6289A / WGL 3962, APMS 2A / IET 9762, IR-62829A / MTU-9992 yield and number of effective tillers per plant and 100 grain weight (over SV1 only) were analyzed by Babu *et al*. (2000) in line x tester study. In cross combinations the strong heterotic effect for grain yield per plant was observed in the cross combination of Mahsuri/TR24,NDR 359/T21, IR 24/NDR 359,Sarjoo52/NDR 359, and NDR 359/Jai Lahri.

Tang *et al*. (2002) analyzed Pei-ai 645 / Javanica rice and reported positive heterobeltiosis in height of culm, panicle length, yield per plant, grains per plant and spikelets per panicle,negative heterobeltiosis in flower days, seed setting rate and weight of 1000 seeds.The Indica / Javanica hybrids have positive standard heterosis for height of culm , length of panicle, *etc*.

In a L×T analysis Durai (2002) explored 35 rice hybrids.The IR-62829A / BR-736-20-3-1 combination had the highest relative heterosis, better parent heterosis and normal heterosis.IR-A / Ponni had the maximum index for the leaf area and the average yield for grain per plantIR-62829A / BR 738-20-3-1, achieving the maximum yield for grain per plant.The hybrids namely PMS 10A / Poni, IR-62829A / BR-736-20-3-1, IR58025A / BR-736-20-3-1, IR-58025A / Ponni and V 20A / IR-50400-64-1-2-2-22 were superior hybrids, recording >20 percent Standard heterosis for grain yield per plant with derived magnitude and directional physiological characteristics.

Verma *et al*. (2002) researched 7 separate rice ecotypes for various characters, along with their Fi and F2 community.Most crosses have shown considerable heterobeltiosis and standard heterosis over standard grain variety(SV2, Sarjoo 52) and (SV1, Mahsuri)

Fifteen rice crosses were tested for yield and its attributing traits, other physiological and grain consistency characters by Satish and Ramaiah (2003) and their six parents.The extent of heterobeltiosis and heterosis for grain yield ranged from -25.63 to 5.27 per cent and -4.56 to 17.89 per cent respectively. The top heterotic combination identified foryield evaluation was: ARC 5780 x NLR33641,ARC 5780 x BPT 1768, BPT 5204 x BPT 4358, BPT 5204 x BPT 1768,NLR 33641 x BPT 4358 and MTU 2067 x BPT4358.

Rao and Kulkarni (2004) studied heterosis and standard heterosis involving atleast 7 indica / javanica and 21 indica/ indica cross combination. Heterobeltiosis for grain yield ranged in intersubspecific combinations from 34 percent in dry season to 36.2 percent in wet season with an average of 35.2 percent and normal heterosis ranged from 32.2 percent in dry season to 81.4 percent in wet season with an average of 56.8 percent While heterobeltiosis ranged in intrasubspecific (I / J) hybrids from -2.5 percent in dry season to 21.2 percent in wet season with an average of 9.3 percent and standard heterosis ranged from 4.5 percent to 34.4 percent .The cross combination Chaitanya/ Gendaji beton displayed more than 66 per cent standard heterosis in the dry season with an maximum of 19.5 per cent and 106 per cent in rainy season.Between intersubspecific hybrids (Indica / Japonica) 71.4 percent of dry season hybrids and 85.7 percent of wet season hybrids demonstrated significantly better performance although only 19.0 percent of dry and wet season hybrids in intrasubspecific (Indica / Indica) hybrids reported significantly better output over the general mean.

In C x T architecture Malar*viz*hi *et al*. (2004) studied 4 and 5 testers and lines respectively and their cross combination. Five hybrids indicated a positive heterobeltiosis and eight hybrids displayed substantial positive significant heterosis for 100 grain weight panicle duration varying from 3.39 per cent to 46.76 per cent.Standard heterosis ranged from-29.59 (IR-58025A /IR-36) to 47.30 (IR-58025A / ADT-39) for productive tillers. High grain yield involving heterosis over normal control was found in IR-58025A / IR-54742-22-19-3 (63.70%), accompanied by IR-68888Ax IR-54742-22-19-3 (39.32%) and IR-58025Ax ADT-39 (52.8%)

Singh (2004) reported 39 of the total F1s involving total of 16 parents.The highest heterobeltiosis for grain yield per plant (99.40 per cent) was registered in the V20Ax Sugandha cross accompanied by IR-54752Ax Sugandha (74) and V20Ax Rajshree (65.99).

Raju *et al*. (2005) researched rice heterosis for yield portion and kernel features including parents for fertile grains per panicle and grain weight of the 100 seeds of medium x medium or lowx low *per se* results just at medium value and also in negative magnitude in the shape of kernel.

Issac (2007) noticed that the BTCE2399 / ADT and AD95134 / TRY hybrids were ideal for enhancement of yield capacity and earliness by process of the heterosis , because such hybrids provided favorable results for earliness and grain yield plants .

Parihar and Pathak (2008) presented a study using L x T approach to estimate the magnitude of heterobeltiosis and the nature of expression of genes for various analytical characteristics.High intensity of heterobeltiosis and standard heterosis was ascertained for harvest yield index, plant stature, grain weight of the thousand seeds, effective tillers plant, panicle grains and grain per plant.The Gurjari / Jaya, GR 7 / IR64, Gurjari / GR 102, GR 7 / Narmada, GR 11 / TN 1 and GR 104 / NWGR 97042 cross combinations displayed extremely important heterosis over GR 7.

Jayasudha and Sharma (2009) analysed 33 of the hybrids created by making cross combinations between three lines with eleven testers.High heterotic crosses CRMS31A / RPHR 203-3, CRMS31A / IR68830-NDR-1-1, CRMS32A / R1130-102-3-88-1,IR58025A / R 304-34 and. IR58025A / OR1898-18RAU729-12-44were reported.

Soni and Sharma (2011) calculated heterosis and heterobeltiosis for yield of grain and its contributing traits to establish heterotic hybrids in 27 cross combinations like, IR58025A/IRFAN-115,IR58025A/SR-6-SW-8, IR58025A/ET1-13, APMS6A/ET1-12 and APMS6A/NPTR-2 exhibited significant grain yield heterosis and seven hybrids showed negative early heterosis and three hybrids could be exploited for breeding with heterosis and yield stability screening should be carried out.

Jarwar *et al*. (2012) assessed different lines and testers namely; LR2, Sugdasi and Rataria; Basmati 370 and Pandan as the testers and analysed them in two different environmental conditions. In lowland and upland conditions the hybrids DR65 / Vertin, Sugdasi / Pandan and Bengalo / Pandan showed the highest mid parent heterotic values.Substantial negative heterosis has been ascertained in traits like days to maturity, days to 50 percent flowering and plant height desirable for early maturation and semi dwarf stature.

Prasad *et al*. (2013) made cross combination between the 4 lines in line x tester design involving 4 testers.The resulting sixteen F1's were used for the heterosis determination. Krishna Hamsa / Parwa Panki ,IR64 / Ujala Depama and IR64 / Malida, are the best heterotic character lines for yield and its attributing traits.

Ghara *et al*. (2014) conducted an analysis to determine the best heterotic hybrids in L x T mating architecture.The maximum heterosis was observed in the cross combination of the Amol3A / IR9 assisted by eight other yield crosses and many of its associated traits.

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CHAPTER – III
MATERIALS AND METHODS

The present investigation entitled, "**Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids"**was conducted in *Kharif*, in 2019. The methodology adopted & materials used during the study are listed under:

3.1 Experimental site:

The study was conducted at Research cum Instructional farm, Department of Genetics and Plant Breeding, College of Agriculture, IGKV, Raipur, Chhattisgarh.

The state of Chhattisgarh rests among 17°14' N and 24°45'N latitudes and 79°16' E and 84° 15' E longitudes. Raipur is the state capital of Chhattisgarh. It lies between latitude 21 ° 16 'N and longitude 81 ° 36' E at a height of 289.60 meters just above sea - level.

3.2 Experimental season and weather:-

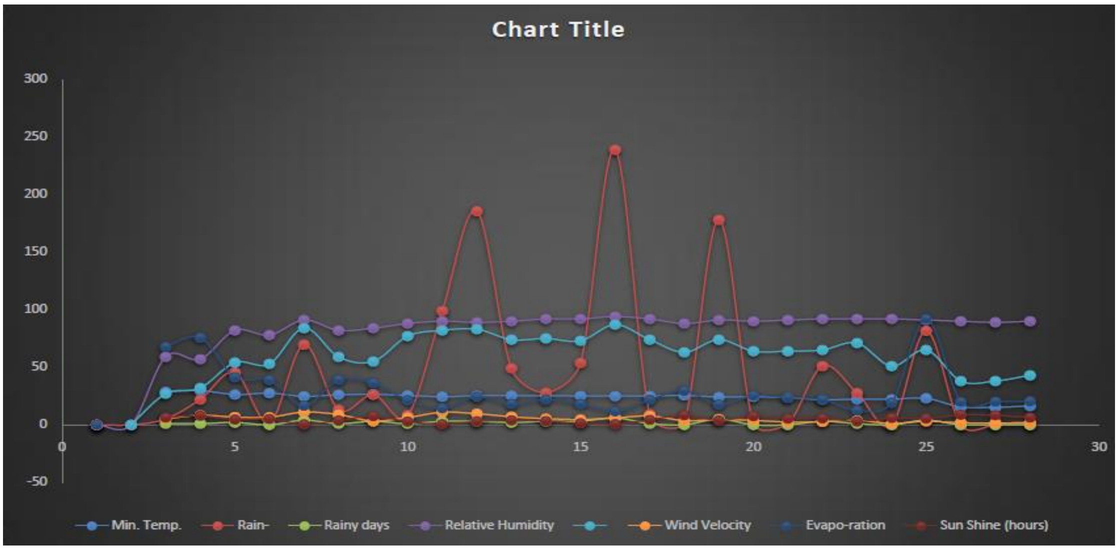

Fig 3.1: Meteorological data recorded during crop growth season (26 June to 31 November, 2019)

3.3 Experimental material:-

The experimental material comprise of seven genotypes of aromatic rice as lines and five varieties of rice as testers. During ***Kharif* 2018** seven lines were crossed with the five testers in line×tester fashion to generate a total of thirty five F_1 hybrid combinations

In *Kharif* 2019 thirty five F_1 along with twelve parents along with the one check variety were evaluated in Randomised Complete Block Design (RCBD) in two replications. Standard agronomical package and practices were applied to raise good crop.

Table: 3.1 Genotypes used as experiment material during *Kharif* 2019.

Lines	**Testers**
1. INDIRA BARANI (LINE 1)	1.KANAK JEERA (TESTER 1)
2. C.G ZINC RICE(LINE 2)	2.UPR3565-10-1-1 (TESTER 2)
3. SAMLESHWARI(LINE 3)	3.JAGGITHYALI SANNALU (TESTER 3)
4. INDIRA AEROBIC 1(LINE 4)	4.HUNG MI HSIANG MA (TESTER 4)
5. DURGESHWARI (LINE 5)	5.MUSKAN (TESTER 5)
6. RAJESHWARI (LINE 6)	**Check variety**
7.IR-64 (LINE 7)	1.RAJESHWARI (CHECK)

Fig 3.2: Figure depicting sowing of the genotypes in the season of *Kharif* 2019

Fig 3.3: Figure depicting transplanting of the genotypes in season of *Kharif* 2019

3.4 Observations recorded:

To fulfill the goal and intent of the analysis, various yield and yield attributing traits were observed and registered.Randomly 5 plants are chosen by each row to obtain information on different attributes during optimum plant growth cycle. Average results from the sampled plant in respect of different traits are being used for statistical analysis.

3.4.1 Days to 50 percent flowering:

The number of days was recorded in fifty percent of the plants for each replication from the date of seed sowing in nursery to the date of first panicle emergence and expressed as in days.

3.4.2 Plant height(cm)

The height of the plant was measured in centimeters by measuring the plant from the ground level to top of the most spikelet using measuring scale.

3.4.3 Effective tillers per plant (number)

In individual plants the overall number of panicle carrying tillers has been measured and recorded.

3.4.4 Panicle length(cm)

By measuring it from the base to the tip of the last or top most spikelet at the time of plant maturity or before harvesting, panicle length was recorded.
It's recorded also in centimetres.

3.4.5 Number of filled grains per panicle

Manually taking 5 random panicles was counted after harvesting the total number of filled grains per panicle and registered.

3.4.6 Number of unfilled grains per panicle

In 5 random panicles, the total amount of unfilled grains was reported in the same way by recording it manually as filled grains were recorded.

3.4.7 100 seed weight (g)

At random, 100 whole grains or seeds were collected from every accession of the germplasm and weighed in grams using a calibrated balance.

3.4.8 Biological yield(g)

Above that the ground part of the each plant was measured in grams which is called biological yield, *i.e.* straw and grains except roots.

3.4.9 Harvest index(%)

The grain yield ratio to biological yield is referred to as the harvest index and is expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{Biologicalyield} \times 100$$

3.4.10 Grain yield/ Economic yield per plant (g)

The grains from each plant was harvested and weighed separately in grams. This is known as grain yield per plant.

3.4.11 Paddy length(mm)

10 randomly selected grains with husk were taken and average length wasmeasured by using graph paper and scale and recorded.

3.4.12 Paddy breadth (mm)

Again the width was measured of the same 10 randomly selected grains in same manner as length was recorded.

3.4.13 Paddy L/B ratio

This was calculated as-

$$\text{Paddy L/B ratio} = \frac{\text{Paddy length}}{\text{Paddy breadth}} \times 100$$

3.5 Statistical Analysis:

3.5.1 Range:

Range is estimated from a character's minimum and maximum value.

Range = Maximum value - Minimum value

3.5.2Mean:

Could be measured as:

$X = Xi / N$, Where,

Xi = sum of all the observations

N = Total no. of observations.

3.5.3 Coefficient of variation (CV %)

CV %=*SD/M* ×100

Where, SD= standard deviation

M= Mean

Based upon the magnitude CV has been divided into the 3 categories i.e high (>20%),

Moderate (20%- 10%) and low (<10%).

3.5.4 Phenotypic coefficient of variation (PCV %):-

PCV%= $\frac{\sigma p}{\bar{X}} \times 100$

Where,

PCV (%) = Phenotypic coefficient of variation

σp = Phenotypic variance

$\bar{X}$= Mean of the character

3.5.5Genotypic coefficient of variation (GCV %): -

GCV=$\frac{\sigma g}{\bar{X}} \times 100$

Where,

GCV (%) = Genotypic coefficient of variation

σg = Genotypic variance

X = Mean of the character

3.5.6 Heritability (Broad sense):-

In a broad sense, heritability was calculated using the following formula specified beneath, that is the proportion of genotypic variance ($\sigma^2 g$) with the phenotypic variances($\sigma^2 p$).

$$h^2 \text{(bs)}\% = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

$\sigma^2 g$= Genotypic variance

$\sigma^2 p$= Phenotypic variance

Johnson *et al*(1955) provided information that heritability values could beClassifiedas low(<30%),moderate (30 - 60%) and high (>60%).

3.5.7 Genetic advance (GA) : -

The expected genetic advance was estimated by using formula:

$$G\ A = K.\sigma_p.h^2(bs)$$

Where,

GA = Genetic advance under selection

k = Selection differential (value of k at 5% selection intensity is 2.06)

σp = Phenotypic standard deviation

h2 = Heritability value of the character

3.5.8 Genetic advance% of mean:-

The genetic advance could be measured as a percentage of the mean with the formula given beneath:

$$G\ A \text{ as percentage of mean} = \frac{\text{Genetic Advance}}{\text{Genetical Mean}} \times 100$$

The range could be understoodin following manner as reviewed byJohnson *et al.*, (1955)

GA > 20 per cent High

GA = 10 – 20 per cent Moderate

GA < 10 per cent Low

3.5.3. Analysis of Variance

The characters examined were evaluated using the variance strategies given by Panse and Sukhatme (1978) for study.

Table 3.2 Analysis of variance (ANOVA)

Source	d. f.	Mean sum of squares	
		Observed	**Expected**
Replications	r-1	M_r	$\sigma^2 r+\sigma^2 e$
Genotypes	g-1	M_g	$\sigma^2 g+\sigma^2 e$
Error	(r-1) (g-1)	M_e	$\sigma^2 e$

3.5.4. Heterobeltiosis and Standard Heterosis

The degree of heterosis in F1s was determined by adopting the procedures described by Liang *et al*. (1972) in relation to better parent and checks as a percentage increase or decrease in F1 over better parent (Heterobeltiosis) and checks (standard / commercial heterosis)

i). Heterobeltiosis $=\frac{F1-BP}{BP}\times 100$

Where,

F1 = Mean performance of single cross

BP = Mean performance of better parent

ii). Standard heterosis $=\frac{F1-SC}{SC}\times 100$

Where,

SC = Mean performance of the standard check

The significance was also evaluated by using t-test proposed by Snedecor and Cochran (1967), as continues to follow:

Heterobeltiosis ‘t cal’ $=\frac{F1-BP}{\sqrt{2EMS/r}}$

Standard heterosis ‘t cal’ $=\frac{F1-SC}{\sqrt{2EMS/r}}$

Mid parent heterosis 't cal' $= \frac{F1-MP}{\sqrt{3EMS/r}}$

Where,

EMS = Error mean squares in the ANOVA table

r = Number of replications

At the corresponding degrees of freedom of error, measured't' values were contrasted and compared to that of the tabulated value of 't.'

3.5.5 Combining ability analysis

The method suggested by Kempthorne (1957) performed the combining ability analysis.Mean sum of squares that arise from different variation sources have been estimated and their expected genetic values have been calculated. A model analysis of variance (ANOVA) table for Line × tester analysis was given below:

Table 3.3 ANOVA table for Line × tester Analysis

Sources of variation	Degree of freedom	Sums of squares	Mean sums of squares	Expected mean sums of squares
Replication	(r-1)	SSR	-	-
Hybrids	(*l*t-1)	SS(h)	-	-
Lines	(*l*-1)	SS(l)	Ml	Me+r[Cov.(FS-2Cov.(HS)+rl(Cov.(HS)]
Testers	(t-1)	SS(t)	Mt	Me+r[Cov.(FS-2Cov.(HS)+rl(Cov.(HS)]
Line x testers	(*l*-1) (t-1)	SS (l ×t)	M(l × t)	Me+r[Cov.(FS 2Cov.(HS)]
Error	(r-1) (t-1)	ESS	Me	-
Total	(rt-1)	-	-	-

Where,

r = number of replications

l = number of lines

t = number of testers

Estimates of the covariance of complete sib and half sib were determined from mean squares using the following equations:

$$=\frac{Ml+Mt-2M(l\times t)}{r(l\times t)}$$

$$=Me+mt+m(l\times t)-3Me+6rCov.(HS)-(l\times t)\ Cov.\ (HS)/3r$$

(FS) was used to estimate variance as a result of General Combining Ability (GCA) and variance as a result of Specific Combining Ability (SCA)as in:

Variance of GCA = Cov. (HS)

Variance of SCA = Cov. (FS) -2 Cov. (HS)

3.5.6. Estimation of GCA and SCA effects

The results of ijkth observation on GCA and SCA were calculated by following the model below.

Xijk = μ + gi + gj + sij + eijk

Where,

i =1, 2 …ith line

j =1, 2 …ith tester

k =Number of replications

μ =Mean

gi =GCA effect of ith line gj =GCA effect of jth tester

sij =SCA effect of hybrid of ith line with jth tester eijk =Error effect associated with the ijkth observation

Significance of GCA effects of In lines is tested as:

$$t=\frac{gi}{SE(gi)}$$

Significance of GCA effects of testers is tested as:

$$t=\frac{Sij}{SE(Sij)}$$

Standard error for testing the significance of difference between GCA effects of two lines:

$$SE(g_i - g_i) = \sqrt{\frac{\sigma^2}{P^2}}$$

Standard error for testing the GCA effects of testers =

$$SE(g_i) = \sqrt{\frac{(p-1)\,\sigma^2}{2p^2}}$$

CHAPTER – IV
RESULTS AND DISCUSSION

The present research was performed taking 48 rice genotypes (i.e 7 lines, 5 testers and their 35 cross combinations along with one check variety) for **"Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids"** for evaluation of variablity, combining ability effects and heterosis studies,are described in detail under the following heads:

4.1 Analysis of Variance.

4.2 Assesment of Variablity

4.3 Combining ability and Gene action.

4.4 Heterosis.

4.1 Analysis of Variance

The outcome of variance analysis shows that all the characters under review were considered to be extremely significant (*i.e.* at 1% level of significance). For the above mentioned 13 characters, the occurrence of relevant values of mean sum of square suggested strong variation among the characters of genotypes. This significant amount of variability may be due to diverse experimental material used in the present study (Table 4.1).

4.2 Assessment of Variability

48 genotypes were used for determining variablity. The averages of mean values of these germplasm accessions for various traits were utilized for estimation of variability parameters. The mean performances of these 48 genotypes for different yield and yield contributing traits are presented in the Appendix B and C and Table. 4.2, 4.3 and 4.4 showing the mean, minimum and

Table 4.1 Analysis of Variance based on RBD

Source of variation	DF	Mean sum of square												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Replication	1	1.260	1.801	1.801	0.135	0.007	39.527	4.770	0.016	0.001	0.014	18.174	2.190	0.041
Treatments	34	49.744**	15.133**	15.133**	3.078**	0.383**	2808.207**	2035.95 **	1.285**	0.065**	0.642**	91.483**	13.145**	8.668**
Error	34	1.388	0.963	0.963	0.720	0.007	14.333	5.166	0.003	0.003	0.004	6.203	3.412	4.040

1 = Days to 50% flowering , 2 = Plant height, 3= Panicle length, 4 = number of effective tillers ,5 = Test Weight of 100 seeds ,6 = Filled grain/panicle , 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 = Biological yield, 12=Economical Yield, 13 = Harvest index

** Significant at p=0.01% level

maximum values, Coefficient of variation(CV) of parents and their respective cross combination, Genotypic coefficient of variation(GCV), Phenotypic coefficient of variation(PCV), Heritability and Genetic advance respectively.

4.2.1 Mean performance of genotypes for different characters taken under study

The observations were recorded for the 48genotypes *i.e.*seven lines and five testers, thirty five hybrids and one checks in two replications for thirteen different characters and were used for calculation of the mean performance. The observations were first averaged for five plants taken randomly for each genotype in each replication and further were averaged over both replication.

The mean performance of parents and hybrids for different quantitative and quality characters is presented inTable 4.2 and Table 4.3 respectively. The mean performance of different characters is described as below:

4.2.1.1Days to 50% flowering

The mean performance of parents for days to 50% flowering ranged from 79.00 (C.G. Zinc rice) to 98.50 days (Jaggithyali sannalu), with overall mean of 89.88 days. In the hybrids it ranged from80 days (C.G. Zinc rice/Kanakjeera) to 98.50 days (Samleshwari/HUNG MI TSIANG MA) with an overall average of 91.51 days. Considering the performance among the entire cross combinations, three combinations *viz.*, Rajeshwari/Kanakjeera, C.G. Zinc rice/Jaggtihyali sannalu and Indira aerobic/Jaggithyali sannalu were identified as good performing hybrids for days to 50% flowering on the basis of early flowering.

4.2.1.2Plant height (cm)

The value of parents for plant height ranged from 94.06 cm in C.G. Zinc rice to highest in the Kanak jeera comprising 148.66 cm and mean came out to be 115.67 cm, whereas in the hybrids the value ranged from 108.57 in cross combination of Samleshwari/Muskan to 170.63 in the Rajeshwari/Jaggithyali sannalu cross

Table 4.2: Mean performance of different parents and checks

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
Parents Lines/Female													
I.Barani	89.00	109.56	25.63	7.30	2.55	167.70	11.60	9.26	2.37	3.91	83.37	30.80	36.94
C.G. ZINC	79.00	94.06	23.69	6.60	2.30	154.30	20.20	8.66	2.44	3.55	78.10	30.22	38.69
SAMLESHWARI	87.00	101.19	25.69	6.40	2.30	139.70	21.70	8.73	2.47	3.53	82.61	30.10	36.43
I.Aerobic	94.50	112.13	26.21	4.50	2.15	163.90	14.40	9.16	2.34	3.91	75.80	27.06	35.69
DURGESHWARI	88.00	103.37	24.83	5.50	2.85	147.60	41.70	7.30	2.92	2.50	67.45	23.62	35.01
Rajeshwari	89.00	106.41	25.49	6.80	2.60	156.00	15.50	9.13	2.25	4.06	82.83	31.12	37.56
IR-64	95.00	110.58	23.86	6.30	3.05	156.20	19.50	9.12	2.68	3.40	76.35	26.66	34.83
Average	88.79	105.33	25.06	6.20	2.54	155.06	20.66	8.77	2.50	3.55	78.07	28.51	36.45
Testers /Male													
K.Jeera	93.00	148.66	27.71	6.20	1.95	78.20	46.60	8.47	2.01	4.22	88.80	32.94	37.10
UPR3565	95.00	113.73	25.70	4.90	2.20	85.20	47.10	12.06	2.20	6.15	84.10	30.64	36.45
J.Sannalu	98.50	100.56	25.23	6.30	1.65	179.60	45.00	7.56	2.14	3.53	83.02	32.40	39.02
Hung	83.50	144.74	24.33	7.40	2.45	122.50	9.60	8.38	2.72	3.08	84.70	32.69	38.60
Muskan	88.00	148.23	30.61	7.00	2.60	99.50	32.20	9.91	2.07	4.63	86.68	32.64	37.66
Average	91.13	126.87	26.44	6.33	2.23	120.01	33.53	9.19	2.27	4.19	84.23	31.64	37.55
Checks													
RAJESHWARI©	89.00	110.58	23.86	6.30	3.07	156.20	19.50	9.12	2.68	3.40	83.68	30.12	35.98
Average	89.00	110.58	23.86	6.30	3.07	156.20	19.50	9.12	2.68	3.40	83.68	30.12	35.98
Overall parental average	**89.88**	**115.67**	**25.60**	**6.26**	**2.44**	**138.96**	**26.50**	**8.98**	**2.40**	**3.83**	**81.34**	**30.07**	**36.91**
Lowest Range	79.0000	94.0600	23.6900	4.5000	1.6500	78.2000	9.6000	7.3000	2.0100	2.4950	67.4500	23.6200	34,83
Highest Range	98.50	148.66	30.61	7.40	3.07	179.60	47.10	12.06	2.92	6.15	88.80	32.94	39.02
SEm +	1.0727	0.9591	0.5229	0.6597	0.0697	1.6566	1.4385	0.0364	0.0253	0.0552	1.3948	1.1581	1.0591
CV	1.6877	1.1725	2.8881	14.8824	4.0423	1.6858	7.6747	0.5728	1.4842	2.0356	2.4249	5.4452	4.057

1 = Days to 50% flowering , 2= Plant height, 3 = Panicle length, 4 = number of effective tillers ,5 = Test Weight of 100 seeds ,6 = Filled grain/panicle , 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 = Biological yield, 12=Economiical Yield, 13 = Harvest index

Combination and mean came out to be 138.66, the other three cross combination like Indira aerobic/Muskan, IR-64/HUNG MI TSIANG MA and IR-64/Jaggithyali sannalu were identified as the good crosses for the height of the plant

4.2.1.3Panicle length (cm)

The value of parents for the panicle length ranged from 23.69 cm in C.G. Zinc rice to 30.61cm in the Muskan and mean came out to be 25.60, whereas in the hybrids the value of panicle length ranges from 23.08 cm in Rajeshwari/Muskan to 33.75 cm in Durgeshwari/HUNG MI TSIANG MA. Other three best performing hybrids that have been noted out are Samleshwari/UPR3565-10-1-1, C.G. Zinc rice/Muskan and Rajeshwari/UPR3565-10-1-1.

4.2.1.4 Number of effective tiller

The mean of effective tillers per plant for parents ranged from 4.5 (Indira Aerobic) to 7.40 (HUNG MI TSIANG MA) with the overall parental mean of 6.26. The mean value of the hybrids ranged from 4.9 (Rajeshwari/UPR3565-10-1-1) to 11.3 (IR-64/Muskan) with an overall average of 7.17. Three cross combinations *viz.,* Indira aerobic/Jaggithyali sannalu, Indira aerobic/HUNG MI TSIANG MA and C.G. Zinc rice/ Kanak jeera were identified significant hybrids for effective tillers per plant.

4.2.1.5 Test weight/ 100 seed weight (g)

The mean of 100 seeds weight for parents ranged from 1.65 g (Jaggithyali sannalu) to 3.07 g (Rajeshwari) with an overall parental average of 2.44 g. Among hybrids, 100 seed weight ranged from 1.05g (C.G. Zinc rice/Kanakjeera) to 3.30 g (IR-64/Jaggithyali sannalu) with an overall mean of 2.66 g. Among the entire cross combinations, three cross combinations *viz.,*Indira aerobic/Muskan, IR-64/UPR3565-10-1-1 were identified as significant hybrids for 100 grain seed weight

4.2.1.6Filled or fertile spikelets per panicle

The mean value for filled spikelets per panicle among the parents ranged from 78.20 grains (Kanakjeera) to 179.60 grains (Jaggithyali sannalu) with an overall parental mean of 138.96. In hybrids it ranged from 79.3 grains (IR-64/Muskan) to 289.3 grains (Samleshwari/HUNG MI TSIANG MA)with an overall average of 154.35. Among the entire cross combinations, three cross combinations *viz.*,Samleshwari/Muskan, C.G. Zinc rice/Jaggithayali sannalu and Indira barani/UPR3565-10-1-1 were identified as best hybrids for fertile spikelets /panicle.

4.2.1.7 Sterile or unfilled spikelets per panicle

The mean of sterile spikelets per panicle for parents ranged from 9.60 grains (HUNG MI TSIANG MA) to 47.10 grains (UPR3565-10-1-1) with an overall parental mean of 26.50, while in the hybrids it ranged from 12.4 grains (Durgeshwari/UPR3565-10-1-1) to 192 grains (C.G. Zinc rice/Kanakjeera) with an overall average of 44.15 grains. Among the entire cross combinations, three cross combinations *viz.*, C.G. Zinc rice/Muskan, IR-64/Muskan and Durgeshwari/HUNG MI TSIANG MA were recorded as good performing hybrids for sterile spikelets/ panicle.

4.2.1.8 Paddy Length

The range of paddy length value came out to be 7.30 cm for the parent Durgeshwari to 12.06 cm for the parent UPR3565-10-1-1 and the overall mean came out to be 8.98. While for the hybrid it ranges from 8.38 cm(Samleshwari/HUNG MI TSIANG MA) to 10.82 cm (Rajeshwari/Muskan), mean came out to be 9.15 and other three hybrids which stands out for the character paddy length are Indira aerobic/Muskan,Indira barani/UPR 3565-10-1-1 and Indira aerobic/UPR 3565-10-1-1.

4.2.1.9 Paddy Breadth

The range of the paddy breadth value came out to be 2.01 cm (Kanak jeera) to 2.92 cm (Durgeshwari) overall mean value was 2.40cm. In the case of the hybrid the value of paddy breadth ranges from 2.27 cm (Indaira barani/UPR3565-10-1-1) to 2.79 cm (Indira aerobic/Jaggithyali sannalu) and over all mean value 2.49 cm and other three hybrids which shows superior performances are Indra barani/HUNG MI TSIANG MA, IR-64/UPR 3565-10-1-1 and the last hybrid value that stands out is cross combination of Durgeshwari/HUNG MI TSIANG MA.

Table 4.3 Mean performance of hybrids for different characters

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
INDIRA BARANI													
I.Barani*K.Jeera	93.50	167.91	28.57	8.20	3.05	137.60	38.40	8.74	2.45	3.56	84.30	31.54	37.42
I.Barani*UPR3565	92.00	139.22	28.97	6.60	2.60	194.70	38.60	10.74	2.27	4.73	84.20	32.80	38.97
I.Barani*J.Sannalu	95.50	140.78	29.02	5.40	2.95	152.30	19.80	8.78	2.45	3.58	80.60	29.53	36.48
I.Barani*Hung	87.00	133.58	29.17	7.60	2.85	112.80	18.80	8.85	2.74	3.23	75.50	28.70	38.01
I.Barani*Muskan	90.00	143.45	30.30	6.50	2.65	146.30	54.70	9.52	2.50	3.80	77.80	29.78	38.41
Average	91.60	144.99	29.21	6.86	2.82	148.74	34.06	9.33	2.48	3.78	80.48	30.47	37.86
CG ZINC RICE													
CGZ*K.Jeera	80.00	149.94	30.26	8.60	1.05	100.10	192.00	8.47	2.52	3.36	91.90	33.00	35.88
CGZ*UPR3565	86.50	148.60	30.94	5.60	2.70	119.50	72.80	9.16	2.54	3.60	80.60	25.20	31.33
CGZ*J.Sannalu	86.00	152.25	30.48	7.00	2.75	195.90	33.30	8.62	2.55	3.38	101.70	35.17	34.60
CGZ*Hung	97.00	131.40	26.58	6.10	2.65	139.30	40.20	9.72	2.27	4.28	78.07	31.54	40.40
CGZ*Muskan	96.50	168.32	33.19	8.10	1.95	181.00	106.90	8.47	2.46	3.44	85.00	30.94	36.37
Average	89.60	149.25	30.11	7.04	2.32	147.42	79.88	8.96	2.47	3.64	86.29	31.05	36.07
SAMLESHWARI													
SMR*K.Jeera	95.00	134.05	28.06	7.50	2.20	192.00	32.80	8.56	2.55	3.35	84.20	30.43	36.20
SMR*UPR3565	92.00	166.68	33.38	8.30	2.20	183.00	25.70	8.90	2.38	3.74	101.70	33.00	32.47
SMR*J.Sannalu	96.50	126.84	28.36	7.30	2.70	167.80	25.40	9.24	2.42	3.81	93.30	34.17	36.61
SMR*Hung	98.50	118.02	25.84	5.40	2.05	289.30	19.00	8.38	2.40	3.49	87.56	33.72	38.51
SMR*Muskan	97.00	108.57	28.44	6.50	2.40	199.20	23.70	8.53	2.41	3.54	77.34	29.83	38.57
AVERAGE	94.77	133.90	29.03	7.01	2.31	196.45	34.41	8.76	2.44	3.59	88.40	32.03	36.40

INDIRA AEROBIC													
I.Aerobi*K.Jeera	87.00	127.70	27.59	6.00	3.10	99.30	16.60	9.20	2.66	3.46	80.03	31.60	39.50
I.Aerobi*UPR3565	87.50	128.12	27.93	6.20	2.55	133.30	27.90	9.82	2.47	3.98	86.56	33.76	39.00
I.Aerobi*J.Sannalu	86.00	147.66	28.74	9.40	3.05	133.80	24.00	9.21	2.79	3.30	84.10	32.34	38.50
I.Aerobi*Hung	87.00	147.98	28.42	9.10	3.05	145.00	42.40	9.48	2.50	3.79	99.40	36.26	36.50
I.Aerobi*Muskan	93.00	108.98	27.54	6.20	3.20	184.70	25.70	10.78	2.37	4.54	86.92	34.78	40.01
AVERAGE	89.21	132.39	28.21	7.32	2.88	148.76	28.50	9.54	2.54	3.77	87.57	33.46	38.32
DURGESHWARI													
DGR*K.Jeera	95.00	114.25	26.95	8.00	2.70	162.80	66.50	8.44	2.46	3.43	101.07	33.48	33.12
DGR*UPR3565	87.00	149.23	25.60	6.50	2.75	164.00	12.40	8.85	2.52	3.51	83.90	31.36	37.40
DGR*J.Sannalu	91.00	153.00	30.73	6.70	2.60	147.80	35.20	9.60	2.46	3.90	86.60	32.23	37.27
DGR*Hung	93.50	162.08	33.75	6.90	2.85	163.20	83.70	8.87	2.70	3.28	86.48	32.15	37.18
DGR*Muskan	90.00	125.15	30.55	6.80	2.95	121.00	44.20	8.86	2.47	3.59	89.17	33.74	37.83
AVERAGE	90.95	139.35	29.30	7.04	2.79	151.26	45.08	9.03	2.52	3.58	89.13	32.73	36.85
RAJESHWARI													
RJR*K.Jeera	82.00	153.48	30.45	6.70	2.70	157.00	27.80	8.69	2.55	3.41	86.54	35.60	41.15
RJR*UPR3565	87.50	121.19	31.90	4.90	2.65	117.60	78.90	8.95	2.37	3.77	76.10	29.42	38.65
RJR*J.Sannalu	96.00	170.63	31.13	7.60	2.70	155.60	82.60	9.08	2.47	3.67	86.13	31.10	36.10
RJR*Hung	97.00	132.51	28.63	6.30	3.10	169.40	16.70	9.72	2.48	3.92	84.10	27.72	33.00
RJR*Muskan	97.00	117.09	23.08	7.40	2.40	149.90	27.80	10.82	2.32	4.66	81.40	31.12	38.23
AVERAGE	91.74	139.04	29.08	6.66	2.72	150.13	46.48	9.38	2.45	3.83	83.90	31.28	37.33
IR 64													
IR-64*K.Jeera	86.00	139.63	31.44	8.50	3.00	101.40	19.40	8.94	2.55	4.66	83.90	33.56	40.01
IR-64*UPR3565	97.00	161.72	31.36	7.10	3.10	183.80	16.50	9.37	2.73	3.43	85.20	29.20	34.27
IR-64*J.Sannalu	92.50	113.85	25.80	7.10	3.30	144.50	24.30	9.31	2.46	3.78	87.20	32.40	37.17

IR-64*Hung	97.00	109.42	30.61	7.70	2.70	178.20	44.00	9.07	2.39	3.79	87.28	33.91	38.86
IR-64*Muskan	91.00	139.85	30.30	11.30	2.10	79.30	86.80	8.80	2.64	3.33	83.30	31.89	38.25
AVERAGE	92.54	133.92	29.76	8.06	2.82	139.55	39.58	9.15	2.54	3.80	85.13	32.04	37.65
Overall average	91.51	138.6	29.25	7.17	2.66	154.35	44.15	9.15	2.49	3.71	85.97	31.91	37.20
Lowest range	80	108.57	23.07	4.9	1.05	79.30	12.40	8.38	2.27	3.22	75.49	25.2	31.32
Highest range	98.5	170.6	33.75	11.3	3.3	289.3	192	10.82	2.79	4.73	101.7	36.26	41.15
SEm +	0.69	1.16	0.744	0.51	0.058	2.98	1.68	0.03	0.04	0.04	1.89	1.37	1.54
CV	1.06	1.18	3.59	10.16	3.09	2.73	5.38	0.60	2.51	1.56	3.11	6.07	5.87

1 = Days to 50% flowering , 2 = Plant height, 3 = Panicle length, 4 = number of effective tillers ,5 = Test Weight of 100 seeds 6 = Filled grain/panicle ,
7 = Unfilled grain/Panicle , 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 = Biological yield, 12 =Economical Yield, 13 = Harvest index

4.2.1.10 Paddy L/B ratio

The mean performance of parents for paddy L/B ratio ranged from 2.49cm (Durgeshwari) to 6.15 cm (UPR3565-10-1-1), with overall mean of 3.83cm. In the hybrids it ranged from 3.23 cm (Indira barani/HUNG MI TSIANG MA) to 4.73 cm (Indira barani/UPR 3565-10-1-1) with an overall average of 3.71 cm. Considering the performance among the entire cross combinations, three combinations *viz.*, IR-64/Kanak jeera,Rajeshwari/Muskan and Indira aerobic/Muskan were considered better.

4.2.1.11 Biological yield per plant (g)

The mean value of biological yield for parents ranged from 67.45 g (Durgeshwari) to 88.80 g (Kanak jeera) with an overall parental mean value of 81.34 g. while in case of hybrids, biological yield per plant ranged from 75.5 g (Indira barani/HUNG MI TSIANG MA) to 101.7g (Samleshwari/UPR3565-10-1-1) with an overall mean of 85.97g. Three cross combinations *viz.*, Durgeshwari/Kanakjeera, Indira aerobic / HUNG MI TSIANG MA and other hybrid namely Samleshwari/Jaggithyali sannalu were identified as good performing hybrids for biological yield per plant.

4.2.1.12 Grain yield /Economic yield per plant (g)

The mean parental value for the character of grain yield per plant, ranged from 23.62g (Durgeshwari) to 32.94 g (Jaggithyali sannalu) with overall parental mean of 30.07 g. Among hybrids, grain yield per plant ranged from 25.2 g (C.G. Zinc rice) to 36.26g (Indira aerobic/HUNG MI TSIANG MA) with an overall mean of 31.91g. For this trait, three cross combinations *viz.*,Rajeshwari/Kanak jeera, C.G. Zinc rice/Jaggithyali sannalu, Indira aerobic/Muskan were identified as good performing hybrids.

4.2.1.13 Harvest Index (%)

The mean of harvest index in parents, ranged from 34.83% (IR-64) to 39.02% (Jaggithyali sannalu) with an overall average of 36.91%. Among hybrids, harvest index ranged from 31.32% (C.G. Zinc rice/UPR 3563-10-1-1) to 41.15% (Rajeshwari/Kanak jeera) with an overall mean of 37.20%. Among the entire cross combinations, three cross combinations *viz.*,C.G, Zinc rice/UPR 3565-10-1-1, IR-

64/Kanak jeera and Indira aerobic/Muskan were identified as best performing hybrids for harvest index.

4.2.2 Estimation of Genotypic coefficient of variation and Phenotypic coefficient of variation:

The range of phenotypic coefficient of variation was found to be very wide varyingfrom 5.55% for Days 50% flowering to 81.13%% for number of unfilled grains per panicle.

Highest magnitude of phenotypic coefficient of variation was recorded as 81.13%for number of unfilled grains per panicle followed by filled grain per panicle (25.01%).

Moderate values of PCV were recorded as 19.89% for total effective tiller, 16.97%for 100 seed weight, 15.89% for height of the plant, 15.17% for paddy L/B ratio and 10.04% for panicle length.

Lower estimates of phenotypic coefficient of variation were shown by economic yield (9.16%), paddy length (8.81%), biological yield (8.25%), paddy breadth (7.48%), harvest index (6.79%) and days to 50% flowering (5.55%).

The values of genotypic coefficient of variation varied widely ranging from4.1% for days to 50% flowering to 80.92 % for number of unfilled grains per panicle.

Higher estimates of genotypic coefficient of variation were recorded in number ofunfilled grains per panicle (80.92%) followed by filled grain per panicle (24.89%)

Traits having moderate values of Genotypic coefficient of variation were number of effective tiller (16.64%), 100 grain seed weight (15.85%), plant height (15.67%) and paddy L/B ratio (15.07%).Lower estimates of GCV were exhibited by panicle length (9.42%), economic yield(8.79%), paddy length(7.71%), biological yield(7.12%), paddy breadth(7.02%), harvest index(5.4%) and days to 50% flowering(4.1%).

"The estimates of phenotypic coefficient of variation were found to be higher thanthat of genotypic coefficient of variation indicating the influence of environment(Das *et al.* 2001, Kumar *et al.* 2013and Iqbal *et al.* 2018). The values of PCV andGCV were found to be in close agreement for unfilled grain per panicle, filled grain per panicle , 100 seed grain weight, plant height, panicle length, paddy length, paddy breadth, days to 50% flowering and biological yield indicating less influence of environment on these traits”.

“For some the traits like harvest index, economic yield and number of effective tiller,considerabledifference was observed between PCV and GCV indicating influence ofenvironment on these traits thus, showing expressions of these traits are result ofGxE interaction”.

″Higher estimates of genotypic coefficient of variation and phenotypic coefficientof variation in general were recorded in number of unfilled grains per panicle,followed by number of filled grains per panicle (Limbani *et al.*2017), indicating presence of sufficientvariability in the germplasm material and thereby suggesting that selection of thesetraits will be useful for genetic improvement”.

4.2.3 Estimates of Heritability and Genetic advance as a percent of mean:-

All the traits under study except Harvest index showed higher estimates of heritability (i.e > 60% as suggested by Johnson *et al.* 1995) in broad sense (Chaudhary and Motiramani, 2003).The values of heritability for all the 13 characters ranged from 36.4% for the Harvest index to 99.5% in the paddy length and for the character like unfilled grain per panicle the heritability came out to be the high in the extent . The high rate of the heritability shown by the following: plant height (99.44%), filled grain per panicle (99%), paddy L/B ratio (98.7%), 100 seed weight (96.2%), days to 50% flowering (94.6%), paddy breadth (90.6%), panicle length (88%), biological yield (87.3%) and number of the effective tiller (62.1%).

Moderate range of the heritability was being exhibited by the grain yield that came out to be about 58.8%.Low range of the heritability was exhibited by the character harvest index that came out to be 36.4%.

High degree of the genetic advance as a percent of mean observed for the given characters like unfilled grain per panicle (83.91%), filled grain per panicle (65.37%), 100 seed weight (43.1%), plant height (41.72%), paddy L/B ratio (39.52%), number of the effective tiller (32.61%), panicle length (23.33%), paddy length (23.14%).

Trait exhibiting moderate values for genetic advance as a percent of mean reported for the characters like paddy breadth (17.89%), biological yield (16.11%) and days to 50% flowering (13.86%).

"High heritability coupled with the high genetic advance as a percent of mean was reported for the traits like plant height, panicle length, number of the effective tiller, 100 seed weight, filled grain per panicle, unfilled grain per panicle and paddy length indicating that the expression of such characters controlled by the additive gene action and thus simple selection will be effective for the improvement of this characters"

"High heritability coupled with the moderate genetic advance as a percent of mean was observed for the characters like days to 50% flowering, paddy breadth and biological yield suggesting that control of expressions by both additive and non additive gene action suggesting that the selection cannot be practiced for improving these traits thus heterosis breeding could be successful.

"The moderate heritability coupled with lowest genetic advance are observed in the characters like grain yield per plant and the other one being the harvest index indicates that character is influenced by the environmental effects and selection came ineffective".

Das *et al.* 2001, Chaudhary and Motiramani (2003), Mustafa and Elsheik 2007, Kumar *et al.* 2013, Limbani *et al.* 2017, Iqbal *et al.* 2018 reported similar findings in their research.

Table: 4.4 Genetic parameter for 13 yield and its contributing traits

Characters	PCV (%)	GCV (%)	H^2 (bs) %	GA(%)
1	5.55	5.40	94.60	13.86
2	15.89	15.85	99.44	41.72
3	10.04	9.42	88.00	23.33
4	19.89	15.67	62.10	32.61
5	16.97	16.64	96.20	43.10
6	25.01	24.89	99.00	65.37
7	81.13	80.92	99.50	83.91
8	8.81	8.79	99.50	23.14
9	7.48	7.12	90.60	17.89
10	15.17	15.07	98.70	39.52

11	8.25	7.71	87.30	16.11
12	9.16	7.02	58.80	4.47
13	6.79	4.10	36.40	2.42

1 = Days to 50% flowering, 2 = Plant height, 3 = Panicle length, 4 = number of effective tillers, 5 = Test Weight of 100 seeds, 6 = Filled grain/panicle , 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 = Biological yield, 12=Economical/Grain Yield, 13 = Harvest index

4.3 Combining ability

Data recorded on 35 hybrids, 7 lines and 5 testers was used for combining ability analysis using line x tester design proposed byKempthorne (1957).

The results of analysis are discussed under the following subheads:

4.3.1 ANOVA for line x tester

4.3.2 Combining ability analysis for GCA and SCA effects

4.3.1Analysis of variance (ANOVA) for Line x Tester

The analysis of variance for combining ability of all the traits under the present study has presented in the Table 4.5. Significant variation was found among treatments for all the characters taken under the study.The variance due to parents were significant for all the characters under study. The variance due tohybrids was also found significant for most of the characters. For all of the charactersthe variance due to parent vs. hybrids was also found significant except for number of the effecrive tiller.The variance due to lines was found significant for most of the traits under study except harvest index.The variance due to testers was found significant for all characters except harvest index. The variance due to line x tester was recorded significant for all the characters. This suggested that sufficient variability is available in the material used for study.

Similar finding were also reported by Saleem*et al.* (2010), Jarwar*et al.* (2012) for treatments, parents, parents vs. crosses and hybrids, Saidaiah*et al.* (2010) for treatments, parents, parents vs. crosses, Veeresha *et al*. (2013) for treatments and hybrids and testers except panicle length and lines vs. testers and Ghara*et al.* (2012), Shiva Prasad *et al.* (2013), Srikrishna*et al.* (2013) for treatments, hybrids, testers and line x tester, Ghara*et al.* (2014) and Gahtyari *et al.*(2017) for genotypes, crosses, lines, testers and line x tester interaction for tiller number, plant

Table 4.5 ANOVA for L x T

	Df	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Replication	1	2.394	0.002	1.469	0	0.009	39.326	3.602
Treatments	46	50.635 **	881.272 **	14.599 **	3.128 **	0.382 **	2867.650 **	2062.672 **
Parents	11	60.678 **	765.976 **	7.038 **	1.616 *	0.294 **	2251.492 **	421.220 **
Parents (Line)	6	56.976 **	80.285 **	1.867	1.720 *	0.209 **	177.419 **	197.739 **
Parents (Testers)	4	69.850 **	1011.106 **	12.542 **	1.826 *	0.292 **	3345.970 **	513.960 **
Parents (L vs T)	1	46.201 **	3899.602 **	16.047 **	0.149	0.811 **	10318.020 **	1391.144 **
Parents vs Crosses	1	43.269 **	9095.541 **	220.182 **	14.723 **	1.383 **	5056.879 **	5204.970 **
Crosses	34	47.603 **	676.977 **	10.999 **	3.276 **	0.381 **	3002.606 **	2501.310 **
Line Effect	6	61.648	521.859	5.44	3.217	0.829 *	5531.987	4691.691
Tester Effect	4	77.3	583.809	2.543	3.139	0.289	2249.628	1303.448
Line * Tester Eff.	24	39.142 **	731.285 **	13.798 **	3.313 **	0.284 **	2495.758 **	2153.358 **
Error	46	1.22	2.459	0.969	0.613	0.008	14.642	5.206
Total	93	25.674	437.114	7.716	1.85	0.193	1426.073	1022.86

*Significant at p=0.05% level, **Significant at p=0.01% **level**

Cont.

Table 4.5 ANOVA for L x T

	Df	**8**	**9**	**10**	**11**	**12**	**13**
Replication	1	0.013	0.001	0.013	17.03	1.514	0.196
Treatments	46	1.313 **	0.065 **	0.651 **	93.423 **	13.355 **	8.798 **
Parents	11	2.932 **	0.154 **	1.639 **	67.710 **	16.611 **	3.867
Parents (Line)	6	0.940 **	0.106 **	0.549 **	64.076 **	15.649 **	3.917
Parents (Testers)	4	6.275 **	0.161 **	2.815 **	10.519	1.715	2.227
Parents (L vs T)	1	1.519 **	0.419 **	3.471 **	318.275 **	81.969 **	10.124
Parents vs Crosses	1	0.578 **	0.214 **	0.430 **	416.174 **	60.412 **	0.763
Crosses	34	0.811 **	0.031 **	0.337 **	92.250 **	10.918 **	10.629 **
Line Effect	6	1.213	0.027	0.179	107.752	12.492	10.25
Tester Effect	4	1.079	0.016	0.169	62.894	8.82	10.576
Line * Tester Eff.	24	0.666 **	0.035 **	0.405 **	93.267 **	10.874 **	10.733 **
Error	46	0.003	0.003	0.004	6.329	3.429	4.066
Total	93	0.651	0.034	0.324	49.523	8.318	6.365

*Significant at p=0.05% level, **Significant at p=0.01% level

1 = Days to 50% flowering, 2 = Plant height, 3 = Panicle length, 4 = number of effective tillers, 5 = Test Weight of 100 seeds, 6 = Filled grain/panicle, 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 =Biological yield, 12=Economical yield/Grain yield, 13 = Harvest index

height, days to 50% flowering, panicle length, number of spikelet per panicle, spikelet fertility and grain yield traits.

4.3.2 Combining ability analysis for GCA and SCA effects

The GCA effects of 12 parentages *i.e.,* seven lines and five testers and the SCA effects of 35 hybrids combinations was estimated according to procedure described by Kempthorne(1957, L x T mating design) and Singh and Chaudhary, (1985).The estimates of general combining ability (GCA) effects of lines and testers arepresented in Table 4.6 and specific combining ability (SCA) effects of hybrids for different charactersare presented in Table4.7 and Gene action (Additive or Non additive gene action) are presented in Table 4.8 and out performing parents (lines and testers) and hybrids are presented in Table 4.9.Character wise results of combining ability effects described below:

4.3.2.1 Days to 50% flowering

Among the lines, Indira aerobic (-3.414**) and CG Zinc rice (-2.314**) had shown negative significant effect. Among the testers, Kanakjeera (-3.157)and UPR 3565-10-1-1 (-1.586) showed negative significant GCA effects. The negative GCA effects indicate their usefulness in breeding for early maturity.

Among the 35 hybrids, twelve hybrids came up with the significant SCA effects. Twelvehybrids have shown the negative significant SCA effects and other fourteen crosses shows positive significant value. The highest negative significant SCA effects have shown by cross Indira barani/HUNG MI TSIANG MA (-6.943), Rajeshwari/Kanakjeera (-6.743) and CG Zinc rice/Kanakjeera (-6.043) Negative values indicate that these are good combinations for early flowering.

SCA variance was higher than GCA variance signifying the presence of non additive gene action as the indicator of heterosis breeding for improvement of this trait (). Similar results also reported by Sharma *et al.* (2012), Ghara, *et al.* (2012), Hasan *et al.* (2013), Dharwal *et al.* (2017) and Ramesh *et al.* (2018).

Table 4.6 General combining ability effects of parents for different characters

	1	2	3	4	5	6
I.Barani	0.086	6.327 **	-0.052	-0.314	0.154 **	-5.614 **
C.G. ZINC	-2.314 **	11.441 **	1.031 **	-0.094	-0.446 **	-7.194 **
SAMLESHWARI	4.286 **	-7.829 **	-0.443	-0.174	-0.356 **	51.906 **
I.Aerobic	-3.414 **	-6.573 **	-1.214 **	0.206	0.324 **	-15.134 **
DURGESHWARI	-0.214	2.081 **	0.258	-0.194	0.104 **	-2.594*
Rajeshwari	0.386	0.319	-0.221	-0.594*	0.044	-4.454 **
IR-64	1.186 **	-5.767 **	0.642*	1.166 **	0.174 **	-16.914 **
K.Jeera	-3.157 **	2.333 **	-0.213	0.469*	-0.123 **	-18.611 **
UPR3565	-1.586 **	6.305 **	0.753 **	-0.717 **	-0.016	2.203*
J.Sannalu	0.414	4.912 **	-0.078	0.04	0.199 **	2.460*
Hung	2.343 **	-5.091 **	-0.259	-0.16	0.084 **	16.674 **
Muskan	1.986 **	-8.459 **	-0.203	0.369	-0.144 **	-2.726*
CD 95% GCA(Line)	0.71	1.008	0.633	0.503	0.056	2.459
CD 95% GCA(Tester)	0.6	0.852	0.535	0.425	0.047	2.078

	7	8	9	10	11	12	13
I.Barani	-10.097 **	0.168 **	-0.011	0.064 **	-5.496 **	-1.443*	0.651
C.G. ZINC	44.883 **	-0.270 **	-0.025	-0.105 **	1.479	-0.744	-1.490*
SAMLESHWARI	-18.837 **	-0.436 **	-0.061 **	-0.132 **	2.844 **	0.317	-0.734
I.Aerobic	-16.837 **	0.540 **	0.064 **	0.096 **	1.425	1.836 **	1.497*
DURGESHWARI	4.243 **	-0.235 **	0.029	-0.175 **	3.468 **	0.677	-0.649
Rajeshwari	2.603 **	0.294 **	-0.055 **	0.169 **	-3.123 **	-0.923	0.219
IR-64	-5.957 **	-0.060 **	0.061 **	0.082 **	-0.599	0.279	0.507
K.Jeera	12.057 **	-0.438 **	0.041*	-0.113 **	1.445*	0.831	0.406
UPR3565	-5.186 **	0.240 **	-0.026	0.107 **	-0.51	-1.236*	-1.196*
J.Sannalu	-9.214 **	-0.038*	0.021	-0.084 **	2.543 **	0.508	-0.529
Hung	-6.329 **	-0.003	0.004	-0.035	-0.493	0.086	0.287
Muskan	8.671 **	0.239 **	-0.040*	0.126 **	-2.985 **	-0.189	1.032
CD 95% GCA(Line)	1.466	0.035	0.037	0.042	1.617	1.19	1.296
CD 95% GCA(Tester)	1.239	0.029	0.031	0.036	1.366	1.006	1.095

1 = Days to 50% flowering, 2 = Plant height, 3 = Panicle length, 4 = number of effective tillers, 5 = Test Weight of 100 seeds, 6 = Filled grain/panicle , 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 =Biological yield, 12=Economical yield/Grain yield, 13 = Harvest index

Table 4.7 Specific Combining Ability Effects of Hybrids for Different Characters

	1	2	3	4	5	6
I.Barani*K.Jeera	5.057 **	20.589 **	-0.423	0.871	0.353 **	7.471 **
I.Barani*UPR3565	1.986 *	-12.073 **	-0.989	0.457	-0.204 **	43.757 **
I.Barani*J.Sannalu	3.486 **	-9.120 **	-0.108	-1.500 *	-0.069	1.1
I.Barani*Hung	-6.943 **	-6.317 **	0.223	0.9	-0.054	-52.614 **
I.Barani*Muskan	-3.586 **	6.921 **	1.297	-0.729	-0.026	0.286
CGZ*K.Jeera	-6.043 **	-2.495 *	0.183	1.051	-1.047 **	-28.449 **
CGZ*UPR3565	-1.114	-7.807 **	-0.102	-0.763	0.496 **	-29.863 **
CGZ*J.Sannalu	-3.614 **	-2.764 *	0.269	-0.12	0.331 **	46.280 **
CGZ*Hung	5.457 **	-13.611 **	-3.453 **	-0.82	0.346 **	-24.534 **
CGZ*Muskan	5.314 **	26.677 **	3.103 **	0.651	-0.126 *	36.566 **
SMR*K.Jeera	2.357 **	0.885	-0.543	0.031	0.013	4.351
SMR*UPR3565	-2.214 **	29.543 **	3.811 **	2.017 **	-0.094	-25.463 **
SMR*J.Sannalu	0.286	-8.904 **	-0.377	0.26	0.191 **	-40.920 **
SMR*Hung	0.357	-7.721 **	-2.716 **	-1.440 *	-0.344 **	66.366 **
SMR*Muskan	-0.786	-13.803 **	-0.175	-0.869	0.234 **	-4.334
I.Aerobi*K.Jeera	2.057 *	-6.721 **	-0.241	-1.849 **	0.233 **	-21.309 **
I.Aerobi*UPR3565	0.986	-10.273 **	-0.867	-0.463	-0.424 **	-8.123 **
I.Aerobi*J.Sannalu	-2.514 **	10.660 **	0.774	1.980 **	-0.139 *	-7.880 **
I.Aerobi*Hung	-3.443 **	20.983 **	0.635	1.880 **	-0.024	-10.894 **
I.Aerobi*Muskan	2.914 **	-14.649 **	-0.301	-1.549 **	0.354 **	48.206 **
DGR*K.Jeera	6.857 **	-28.825 **	-2.353 **	0.551	0.053	29.651 **

DGR*UPR3565	-2.714 **	2.183	-4.669 **	0.237	-0.004	10.037 **
DGR*J.Sannalu	-0.714	7.346 **	1.292	-0.32	-0.369 **	-6.420 *
DGR*Hung	-0.143	26.429 **	4.493 **	0.08	-0.004	-5.234
DGR*Muskan	-3.286 **	-7.133 **	1.237	-0.549	0.324 **	-28.034 **
RJR*K.Jeera	-6.743 **	12.167 **	1.625 *	-0.349	0.113	25.711 **
RJR*UPR3565	-2.814 **	-24.095 **	2.109 **	-0.963	-0.044	-34.503 **
RJR*J.Sannalu	3.686 **	26.738 **	2.171 **	0.98	-0.209 **	3.24
RJR*Hung	2.757 **	-1.379	-0.148	-0.12	0.306 **	2.826
RJR*Muskan	3.114 **	-13.431 **	-5.757 **	0.451	-0.166 *	2.726
IR-64*K.Jeera	-3.543 **	4.403 **	1.752 *	-0.309	0.283 **	-17.429 **
IR-64*UPR3565	5.886 **	22.521 **	0.707	-0.523	0.276 **	44.157 **
IR-64*J.Sannalu	-0.614	-23.956 **	-4.022 **	-1.280 *	0.261 **	4.6
IR-64*Hung	1.957 *	-18.383 **	0.966	-0.48	-0.224 **	24.086 **
IR-64*Muskan	-3.686 **	15.415 **	0.597	2.591 **	-0.596 **	-55.414 **
CD 95% SCA	1.587	2.254	1.415	1.125	0.125	5.499

*Significant at p=0.05% level, **Significant at p=0.01% level

	7	8	9	10	11	12	13
I.Barani*K.Jeera	-7.717 **	-0.148 **	-0.073	-0.106 *	2.376	0.24	-0.841
I.Barani*UPR3565	9.726 **	1.174 **	-0.187 **	0.844 **	4.231 *	3.567 *	2.306
I.Barani*J.Sannalu	-5.046 **	-0.508 **	-0.053	-0.115 *	-2.422	-1.447	-0.846
I.Barani*Hung	-8.931 **	-0.474 **	0.254 **	-0.519 **	-4.491 *	-1.86	-0.137
I.Barani*Muskan	11.969 **	-0.045	0.058	-0.105 *	0.306	-0.5	-0.482
CGZ*K.Jeera	90.903 **	0.02	0.011	-0.142 **	3.001	1.001	-0.24
CGZ*UPR3565	-11.054 **	0.032	0.097 *	-0.117 *	-6.344 **	-4.732 **	-3.193 *
CGZ*J.Sannalu	-46.526 **	-0.230 **	0.061	-0.146 **	11.703 **	3.494 *	-0.585
CGZ*Hung	-42.511 **	0.835 **	-0.202 **	0.705 **	-8.891 **	0.281	4.394 **
CGZ*Muskan	9.189 **	-0.657 **	0.033	-0.301 **	0.531	-0.044	-0.376
SMR*K.Jeera	-4.577 **	0.276 **	0.077	-0.120 *	-6.064 **	-2.63	-0.676
SMR*UPR3565	5.566 **	-0.062	-0.027	0.045	13.391 **	2.007	-2.809
SMR*J.Sannalu	9.294 **	0.556 **	-0.031	0.311 **	1.938	1.433	0.669
SMR*Hung	0.009	-0.340 **	-0.036	-0.063	-0.771	1.405	1.748
SMR*Muskan	-10.291 **	-0.431 **	0.018	-0.174 **	-8.494 **	-2.215	1.068
I.Aerobi*K.Jeera	-22.777 **	-0.06	0.062	-0.243 **	-8.815 **	-2.979 *	0.393
I.Aerobi*UPR3565	5.766 **	-0.118 **	-0.066	0.062	-0.335	1.248	1.49
I.Aerobi*J.Sannalu	5.894 **	-0.450 **	0.212 **	-0.432 **	-5.843 **	-1.916	0.328
I.Aerobi*Hung	21.409 **	-0.216 **	-0.061	0.009	12.493 **	2.426	-2.488
I.Aerobi*Muskan	-10.291 **	0.843 **	-0.147 **	0.603 **	2.5	1.221	0.277
DGR*K.Jeera	6.043 **	-0.045	-0.103 *	-0.002	10.182 **	0.055	-3.846 *
DGR*UPR3565	-30.814 **	-0.314 **	0.023	-0.137 **	-5.033 **	0.002	2.036
DGR*J.Sannalu	-3.986 *	0.715 **	-0.083 *	0.444 **	-5.386 **	-0.867	1.239
DGR*Hung	41.629 **	-0.051	0.174 **	-0.225 **	-2.475	-0.525	0.333

DGR*Muskan	-12.871 **	-0.305 **	-0.012	-0.081	2.712	1.335	0.238
RJR*K.Jeera	-31.017 **	-0.324 **	0.071	-0.366 **	2.238	3.775 **	3.321 *
RJR*UPR3565	37.326 **	-0.742 **	-0.042	-0.221 **	-6.242 **	-0.338	2.418
RJR*J.Sannalu	45.054 **	-0.334 **	0.011	-0.130 **	0.73	-0.397	-0.794
RJR*Hung	-23.731 **	0.270 **	0.038	0.066	1.741	-3.360 *	-4.715 **
RJR*Muskan	-27.631 **	1.129 **	-0.078	0.650 **	1.533	0.32	-0.23
IR-64*K.Jeera	-30.857 **	0.280 **	-0.045	0.976 **	-2.921	0.538	1.888
IR-64*UPR3565	-16.514 **	0.032	0.202 **	-0.479 **	0.334	-1.755	-2.245
IR-64*J.Sannalu	-4.686 **	0.250 **	-0.115 **	0.067	-0.719	-0.299	-0.012
IR-64*Hung	12.129 **	-0.025	-0.168 **	0.028	2.397	1.633	0.862
IR-64*Muskan	39.929 **	-0.537 **	0.127 **	-0.593 **	0.909	-0.117	-0.493
CD 95% SCA	3.279	0.078	0.082	0.095	3.615	2.661	2.898

*Significant at p=0.05% level, **Significant at p=0.01% level

1 = Days to 50% flowering, 2 = Plant height, 3 = Panicle length, 4 = number of effective tillers, 5 = Test Weight of 100 seeds, 6 = Filled grain/Panicle, 7 = Unfilled grain/Panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 =Biological yield, 12=Economical yield/Grain yield, 13 = Harvest index

4.3.2.2 Plant height (cm)

Among the lines, Samleshwari (-7.829), Indira aerobic (-6.573)and IR-64 (-5.767) showed negative significant GCA effect. Among the testers, Muskan (-8.459) and HUNG MI TSIANG MA (-5.091) showed negative significant GCA effects.Negative effects of these lines indicate their usefulness in breeding of developing dwarf and semi dwarf hybrids. Samleshwari and Muskan came out to be good general combiner among lines and testers respectively.

Among the 35 hybrids eighteen hybrids shows the negative significance value, the crosses which shows high negative significant value is Rajeshwari/Muskan(-28.825), Rajehswari/UPR3565-10-1-1(-24.1), IR-64/Kanakjeera(-23.96),

SCA variance was higher than GCA variance indicating the non additive gene action, therefore heterosis breeding method is appropriate for this trait. Similar results also reported by El-Rewainy *et al.* (2011), Ghara, *et al.* (2012), Hasan *et al.* (2013) and Ali *et al.* (2017).

4.3.2.3Panicle length (cm)

Among the lines, CG Zinc rice has the value 1.031 and other one is IR-64 has the value 0.642 and among the testers the positive significant value 0.753 was shown by UPR3565-10-1-1. Among the thirty five hybrids, five hybrids shows positive SCA effect and other six hybrids shows negative SCA effect, the crosses which shows significant positive value of the panicle length are Samleshwari/UPR 3565-10-1-1(3.811) and other one is CG Zinc rice/Muskan (3.103)

SCA variance was higher than GCA variance therefore heterosis breeding is appropriate for this trait. Similar results also reported by Zhu *et al.*(2009) and Ali *et al.* (2017).

4.3.2.4 Number of effective tillers per plant

Among the lines IR-64 (1.166) and shows positive significant GCA effect and in testers Kanakjeera (0.469) shows positive significant GCA effect.

Among the hybrids, four of themshows the positive significant SCA effect and other 5 hybrids shows the negative significant SCA effect. The hybrids which shows high positive SCA effects are IR64/Muskan(2.591), Samleshwari/UPR

3565-10-1-1 (2.017), Indira aerobic/Jaggithyali sannalu (0.98) and other one be Indira aerobic/HUNG MI TSIANG MA(1.88)

"SCA variance was higher than the GCA variance therefore heterosis breeding is suitable for this trait. Similar results obtained by Ghara *et al*.(2014)."

4.3.2.5 Test Weight/ hundred seed weight (g)

Among the lines, Indira aerobic 1 (0.324), IR-64 (0.174), Indira barani (0.154) and Durgeshwari (0.104) showed positive significant GCA effect whereas, among the testers, Jaggithyali sannalu (0.199) and HUNG MI TSIANG MA (0.084) showed positive significant GCA effects.

Among the thirty five hybrids, 22 hybrids have shown significant SCA effects. Ten hybrids have shown the positive significant and twelve have shown the negative significant SCA effects. The highest positive significant SCA effects have shown by cross CG Zinc rice/UPR 3565-10-1-1 (0.496), Indira barani/Kanakjeera (0.353), CG Zinc rice/HUNG MI TSIANG MA (0.346)CG Zinc rice/Jaggithyali sannalu(0.331), Rajeshwari/HUNG MI TSIANG MA (0.306) .These hybrids came out to be as best specific combiner for 100 seed weight.

The SCA variance came out to be higher than the GCA variance, indicating the role of non-additive gene action. Similar findings were also supported by Zhu *et al*(2009), Satheesh *et al.* (2010), El-Rewainy *et al.* (2011), Ghosh *et al.* (2013), Ali*et al.* (2017) and Ramesh *et al.* (2018).

4.3.2.6Filled grain/Fertile spikelets per panicle

Among the lines, Samleshwari (51.906) showed positive significant GCA effect. Among the testers, HUNG MI TSIANG MA (16.674), Jaggithyali sannalu (2.460) and UPR 3565-10-1-1 showed positive significant GCA effects. Samleshwari and HUNG MI TSIANG MA were recorded good general combiners for fertile spikelets per panicle among the line and testers respectively.

Among the hybrids, only 25 hybrids have shown significant SCA effects. Eleven hybrids have shown the positive significant SCA effects and fourteen hybrid has shown the negative significant SCA effects. The highest positive significant SCA effect has shown by cross Indira aerobic/Muskan (48.206) CG

Zinc rice/Jaggithyali sannalu (46.280), IR-64/UPR 3565-10-1-1 (44.17) and Indira barani/UPR 3565-10-1-1(43.757).

SCA variance was higher than GCA variance hence heterosis should be rewarded for improvement of such traits. Similar results were also supported by Sao and Motiramani (2006), Mirarab *et al.* (2011) and Tiwari *et al.* (2011) and Ramesh *et al.* (2018).

4.3.2.7 Unfilled grain/ Sterile spikelets per panicle

Within the lines, only one line stands out in performance *i.e.* Samleshwari (-18.837), Indira aerobic (-16.837) and Indira barani (-10.097)showed negative significant GCA effect and positive effect is being shown by the line CG Zinc rice (44.883), Durgeshwari (4.243) and Rajeshwari (2.603). And in case of the testers, Jaggithyali sannalu (-9.214), HUNG MI TSIANG MA (-6.329) and UPR 3565-10-1-1 (-5.957) showed negative significant GCA effects and positive effect has been shown by the Kanakjeera (12.057) and Muskan (8.671)

Within the hybrids, thirty hybrids have shown significant SCA effects. Fourteen hybrids have shown the positive significant SCA effects, whereas nineteen hybrids have shown the negative significant SCA effects. The negative significant SCA effect has shown by CG Zinc rice/Jaggithyali sannalu (-46.526) and CG Zinc rice/HUNG MI TSIANG MA (-42.511). These hybrids were recorded as best specific combiners for less number of sterile spikelets per panicle.

The SCA variance was found higher than the GCA variance, indicating the role of non-additive gene action and heterosis breeding. The present finding had also been supported by Jayashudha and Sharma (2009) and El-Rewainy *et al.* (2011) and Ramesh *et al*. (2018).

4.3.2.8 Paddy Length

Within the line positive significant GCA effect shown by the Indira barani (0.168), Indira aerobic (0.540) and Rajeshwari (0.294), within testers the positive significant GCA effect is being shown by the UPR 3565-10-1-1 and Muskan (0.239).

In the case of the hybrids out of the 35 hybrids the hybrid which show significant SCA effects are twenty six in number , negative significance shown by sixteen hybrids and positive SCA significance has been shown by the ten hybrids. Those which show high SCA effects were Indira barani/UPR 3565-10-1-1 (1.174), Rajehswari/Muskan (1.129) and CG Zinc rice/HUNG MI TSIANG MA (0.825).

In this case as well SCA variance tends to be higher than that of the GCA variances, signifying the use of heterosis breeding for the further generations.

4.3.2.9 Paddy Breadth

In the lines Indira aerobic shows the positive effect with value 0.064 and in the testers the positive GCA effect is being show by the Kanak jeera (0.041)and the negative SCA significant effect is shown by the Muskan (-0.040).

In the hybrids eleven hybrids shows the significant SCA effect and out of which seven hybrids shows negative significant effect and four shows the positive significant SCA effect. The positive significant SCA effect is shown by the Indira aerobic/Jaggithyali sannalu (0.212), IR-64/UPR3563-10-1-1 (0.202), Durgeshwari/HUNG MI TSIANG MA (0.174) and IR-64/Muskan (0.127).SCA variances tends to be higher than that of the GCA variances, indicating the role of non additive gene action.

4.3.2.10 Paddy L/B Ratio

The lines that perform and show the positive significant GCA effects are Rajeshwari (0.169), Indira aerobic (0.096), IR-64 (0.082) and Indira barani (0.069). Testers that show the significant positive GCA effect are Muskan (0.126) and other being the UPR 3565-10-1-1 (0.107).

In case of hybrids 26 hybrids shows the significant SCA effect and the positive significant effect was being shown by the seven hybrids whereas in case of the negative significant SCA effect is being shown by the nineteen hybrids. The hybrids that had shown positive SCA effects are IR-64/Kanakjeera (0.976) , Indira barani/UPR 3565-10-1-1 (0.844) and CG Zinc rice/HUNG MI TSIANG MA (0.705)

SCA variances came out to be more significant than that of the GCA variances signifying the impact of the non additive gene action and heterosis breeding.

4.3.2.11 Biological yield per plant (g)

Within the lines, positive significant GCA effect had shown by Durgeshwari (3.468) and Samleshwari (2.844). Among the testers, Jaggithyali sannalu (2.543) and Kanakjeera (1.445) showed positive significant GCA effects.

Within the hybrids, fourteen hybrids shows the significant SCA effect out of which five hybrids have shown the positive significant SCA effects whereas, nine hybrids have shown negative significant SCA effects. The positive significant SCA effect has shown by Samleshwari/UPR 3565-10-1-1 (13.391), Indira aerobic 1/HUNG MI TSIANG MA (12.493), CG Zinc rice/Jaggithyali sannalu (11.703) and Durgeshwari/Kanakjeera (10.182).

The SCA variance was found higher than the GCA variance, indicating the role of non-additive gene action and heterosis breeding. Similar findings were also supported by Kumar *et al*. (2007), Tiwari *et al.* (2011), Ghosh *et al.* (2013) and Belhekar *et al.* (2017).

4.3.2.12 Grain yield per plant (g)

Within the lines, Indira aerobic showed significant GCA effect. Among the testers, no significant testers showed the positive significant GCA effects.

Within the thirty five hybrids, six hybrids have shown significant SCA effects. Three hybrids have shown the positive significant SCA effects and three hybrids have shown the negative significant SCA effects. The highest positive significant SCA effect has shown by crossRajeshwari/Kanakjeera (3.775) Indira barani/UPR 3565-10-1-1 (3.567) andCG Zinc rice/Jaggithyali sannalu (3.494). These hybrids were identified as good specific combiner for the trait.

The SCA variance was found higher than the GCA variance, indicating the role of non-additive gene action therefore hetetrosis breeding will be rewarded for improvement of this trait. Similar findings were also supported by Singh *et al*. (2007), Satheesh *et al.* (2010), Mirarab *et al*. (2011), El-Rewainy *et al.* (2011), Shrivastava*et al.* (2012), Ghara *et al.* (2012), Pratap *et al.* (2013), Utharasu and

Table 4. 8 Estimates of gene action for the yield and yield contributing traits

S. No.	Characters	Additive Variance	Dominance Variance	Additive Dominance ratio	Gene Action
1	Days to 50% flowering	5.68	18.96	0.29	Non-additive
2	Plant height	45.86	364.41	0.13	Non-additive
3	Panicle length	0.25	6.41	0.04	Non-additive
4	Number of effective tillers	0.21	1.35	0.16	Non-additive
5	100 seed weight	0.046	0.1384	0.33	Non-additive
6	Feritile or Filled grain	323.01	1240.55	0.26	Non-additive
7	Sterile or Unfilled grain	249.36	1074.07	0.23	Non-additive
8	Paddy length	0.0952	0.3313	0.29	Non-additive
9	Paddy breadth	0.0015	0.0157	0.1	Non-additive
10	Paddy L/B ratio	6.58	43.8	0.15	Non-additive
11	Biological yield	0.6	3.72	0.16	Non-additive
12	Grain or economic yield	0.52	3.33	0.16	Non-additive
13	Harvest index	0.0142	0.2003	0.07	Non-additive

Table.4.9 Identification of best general and specific combiners for yield and its contributing traits

S.No.	Characters	Best General Combiners		Best Specific Combiners
		Lines	Testers	
1	Days to 50% flowering	Indira aerobic	Kanakjeera	Indira barani x HUNG MI TSIANG MA Rajeshwari x Kanakjeera CG Zinc rice x Kanakjeera
2	Plant height	Samleshwari	Muskan	Rajeshwari x Muskan Rajeshwari x UPR 3565-10-1-1 IR-64 x Kanakjeera
3	Panicle length	CG zinc rice	UPR 3565-10-1-1	Samleshwari x UPR 3565-10-1-1 CG Zinc rice x Muskan
4	Number of effective tiller	IR-64	Kanakjeera	IR -64 x Muskan Samleshwari x UPR 3565-10-1-1 Indira aerobic x Jaggithyali sannalu
5	Hundred seed weight	Indira aerobic	Jaggithyali sannalu	CG Zinc rice x HUNG MI TSIANG MA CG Zinc rice x UPR 3565-10-1-1 CG Zinc rice x HUNG MI TSIANG MA Rajeshwari x HUNG MI TSIANG MA
6	Filled or Fertile grain	Samleshwari	HUNG MI TSIANG MA	Indira aerobic x Muskan CG Zinc rice x Jaggithyali sannalu IR-64 x UPR 3565-10-1-1
7	Unfilled or Sterile grains	Samleshwari	Jaggithyali sannalu	CG Zinc rice x Jaggithyali sannalu

				CG Zinc rice x HUNG MI TSIANG MA
8	Paddy length	Indira barani	UPR 3565-10-1-1	Indira barani x UPR 3565-10-1-1 Rajehswari x Muskan CG Zinc rice x HUNG MI TSIANG MA.
9	Paddy breadth	Indira aerobic 1	Kanak jeera	Indira aerobic x Jaggithyali sannalu IR -64 x UPR 3565-10-1-1 Durgehswari x HUNG MI TSIANG MA IR-64 x Muskan
10	Paddy L\B Ratio	Rajeshwari	Indira aerobic	IR -64 x Kanakjeera Indira barani x UPR 3565-10-1-1 CG zinc rice x HUNG MI TSIANG MA
11	Biological yield	Durgeshwari	Jaggithyali sannalu	Samleshwari x UPR -3565-10-1-1 Indira aerobic x HUNG MI TSIANG MA CG Zinc rice x Jaggithyali sannalu
12	Economic/Grain yield	Indira aerobic	-	Rajeshwari x Kanakjeera Indira barani x UPR 3565-10-1-1
13	Harvest Index	Indira aerobic	-	CG Zinc rice x Muskan Rajeshwari x Kanak jeera

Table 4.10 Best cross combinations for multiple traits in rice genotypes

S. No.	Cross Combination	Multiple traits
1	I.Barani*K.Jeera	100 seed weight, Filled/Fertile grain per panicle, Unfilled /Sterile grain per panicle
2	I.Barani*UPR3565	Plant height, Filled grain/ Fertile grain per panicle, Paddy length, Paddy L/B ratio, Biological yield, Economic/ Grain yield
3	CGZ*J.Sannalu	Days to 50% flowering, Plant height, 100 seed weight, Filled/Fertile grain per panicle, Biological yield, Economic/ Grain yield
4	CGZ*Hung	Plant height, 100 seed weight, Unfilled/Sterile grain per panicle, Biological yield, Economic/Grain yield.
5	SMR*UPR3565	Days to 50% flowering, Panicle length, Number of effective tiller, Biological yield.
6	RJR*K.Jeera	Days to 50% flowering, Panicle length, Filled/ Fertile grain per panicle, Unfilled/Sterile grain per panicle, Economic/ Grain yield per panicle, Harvest index

Anandakumar (2013), Ghosh *et al.* (2013), Hasan *et al.* (2013), Gahtyari*et al.* (2017) and Kishor*et al*. (2017).

4.3.2.13 Harvest Index (%)

Among the lines, Indira aerobic 1 (1.836) showed significant GCA effects. Among the testers, no one showed positive significant GCA effects.

Among the hybrids, five hybrids have shown significant SCA effects. Three hybrids have shown negative significant SCA effects.Only two hybrid CG Zinc rice/Muskan and other one is Rajehswari/Kanakjeera has shown the positive significant SCA effect.

SCA variance was higher than GCA variance resulting the non additive gene action and heterosis breeding programme. Similar findings were also supported by Panwar (2005), Kumar*et al.*(2007), Malik and Singh (2013) and Srijan *et al.* (2016).

"Cross combinations which showed better results for multiple traits in rice genotypes are Indira barani/Kanakjeera, Indira barani/UPR 3565-10-1-1, C.G. Zinc rice/Jaggithyali sannalu, CG Zinc rice/HUNG MI TSIANG MA, Samleshwari/UPR 3565-10-1-1 and Rajeshwari/ Kanakjeera.(Table 4.10)"

4.4 Heterosis

Investigations on heterosis provides fundamental information regarding the utility of the cross combinations and its use for commercial exploitation. The magnitude of heterosis for yield, yield components and quality traits depends to a large extent on genetic variation, genetic base and adaptability of parents. The presence of significant amount of non additive gene action is a prerequisite for the commercial exploitation of heterosis in rice.

A programme to produce hybrid population may be initiated for a number of reasons. A partial listing of these would include existence of a significant amount of dominance variance, a requirement for high degree of uniformity in the harvested product, a need for flexibility in the programme and the availability of cytoplasmic sterility. The demonstration of heterosis in crop is not adequate justification for the establishment of a programme to produce hybrids. The existence of heterosis demonstrates two things, some degree of genetic diversity between parents and some degree of dominance. Heterosis can arise when many loci are involved, if for each locus, the heterozygote is slightly super to the mid-parental value. The existence of therefore, provides no guide as to the degree of dominance. Such information must be derived from specifically designed experiments.

The Heterosis over mid parent (Relative heterosis), over better parent (heterobeltiosis) and over standard check (standard heterosis/ useful heterosis) was estimated for all the characters under study. The estimates of mid parent, better parent and standard heterosis are given in Table 4.11. The results of heterosis are described below:

4.4.1 Days to 50% flowering

The relative heterosis for the given trait ranged from -10.88 % (Indira aerobic/Jaggithyali sannalu) to 19.38% (CG Zinc rice/HUNG MI TSIANG MA). Among hybrids, twelve hybrids showed significant negative heterosis and fifteen hybrids showed significant positive heterosis for this trait. Highest significant negative heterosis over mid parent recorded by cross combination of Indira aerobic/Jaggithyali sannalu(-10.88%).One of the cross show no improvement over heterosis *i.e.* Indira barani/Kanakjeera as parental and mid parent mean were same.

The heterobeltiosis ranged from –13.98 % (CG Zinc rice/Kanakjeera) to 16.17 % (CG Zic rice/HUNG MI TSIANG MA). Among hybrids, eighteen hybrids showed significant negative heterosis for this trait and seven hybrids shows the positive significant value.

The standard heterosis (over Rajeshwari) ranged from -10.11% (CG Zinc rice/Kanakjeera) to 10.67% (Samleshwari/HUNG MI TSIANG MA). Among hybrids, five hybrids showed significant negative heterosis and nineteen hybrids showedsignificant positive heterosis for this trait.

Negative heterosis is desirable for days to 50% flowering as this signifies that respective hybrid will mature early than other hybrids. Testers Kanak jeera and Jaggithyali sannalu showed significant negative value for all heterotic estimates. Kanak jeera and Jaggithyali sannalu with CG Zinc rice showed heterobeltiosis, relative heterosis and standarad heterosis in negative direction. It can also be used

Table 4.11 Mid parent Heterosis, Heterobeltiosis and Standard Heterosis

	Days to 50% flowering			Plant height (cm)		
Cross	**Mid**	**Better**	**Standard** RAJESHWARI©	**Mid**	**Better**	**Standard** RAJESHWARI©
I.Barani*K.Jeera	2.75 *	0.54	5.06 **	30.05 **	12.95 **	51.84 **
I.Barani*UPR3565	0.00	-3.16 *	3.37 *	24.70 **	22.41 **	25.90 **
I.Barani*J.Sannalu	1.87	-3.05 *	7.30 **	34.00 **	28.50 **	27.31 **
I.Barani*Hung	0.87	-2.25	-2.25	5.06 **	-7.71 **	20.80 **
I.Barani*Muskan	1.69	1.12	1.12	11.29 **	-3.22 **	29.73 **
CGZ*K.Jeera	-6.98 **	-13.98 **	-10.11 **	23.55 **	0.86	35.59 **
CGZ*UPR3565	-0.57	-8.95 **	-2.81 *	43.03 **	30.66 **	34.38 **
CGZ*J.Sannalu	-3.10 **	-12.69 **	-3.37 *	56.46 **	51.40 **	37.68 **
CGZ*Hung	19.38 **	16.17 **	8.99 **	10.05 **	-9.22 **	18.83 **
CGZ*Muskan	15.57 **	9.66 **	8.43 **	38.94 **	13.55 **	52.22 **
SMR*K.Jeera	5.56 **	2.15	6.74 **	7.30 **	-9.83 **	21.22 **
SMR*UPR3565	1.1	-3.16 *	3.37 *	55.11 **	46.56 **	50.73 **
SMR*J.Sannalu	4.04 **	-2.03	8.43 **	25.74 **	25.35 **	14.70 **
SMR*Hung	15.54 **	13.22 **	10.67 **	-4.02 **	-18.46 **	6.73 **
SMR*Muskan	10.86 **	10.23 **	8.99 **	-12.94 **	-26.76 **	-1.82
I.Aerobi*K.Jeera	-7.20 **	-7.94 **	-2.25	-2.07	-14.10 **	15.48 **
I.Aerobi*UPR3565	-7.65 **	-7.89 **	-1.69	13.45 **	12.65 **	15.86 **
I.Aerobi*J.Sannalu	-10.88 **	-12.69 **	-3.37 *	38.85 **	31.69 **	33.53 **
I.Aerobi*Hung	-2.25 *	-7.94 **	-2.25	15.22 **	2.24 *	33.82 **
I.Aerobi*Muskan	1.92	-1.59	4.49 **	-16.29 **	-26.48 **	-1.45
DGR*K.Jeera	4.97 **	2.15	6.74 **	-9.34 **	-23.15 **	3.32 *

DGR*UPR3565	-4.92 **	-8.42 **	-2.25	37.48 **	31.21 **	34.95 **
DGR*J.Sannalu	-2.41 *	-7.61 **	2.25	50.05 **	48.01 **	38.36 **
DGR*Hung	9.04 **	6.25 **	5.06 **	30.65 **	11.98 **	46.57 **
DGR*Muskan	2.27 *	2.27	1.12	-0.52	-15.57 **	13.18 **
RJR*K.Jeera	-9.89 **	-11.83 **	-7.87 **	20.34 **	3.24 **	38.80 **
RJR*UPR3565	-4.89 **	-7.89 **	-1.69	10.10 **	6.56 **	9.59 **
RJR*J.Sannalu	2.40 *	-2.54 *	7.87 **	64.88 **	60.35 **	54.30 **
RJR*Hung	12.46 **	8.99 **	8.99 **	5.52 **	-8.45 **	19.83 **
RJR*Muskan	9.60 **	8.99 **	8.99 **	-8.03 **	-21.01 **	5.89 **
IR-64*K.Jeera	-8.51 **	-9.47 **	-3.37 *	7.72 **	-6.07 **	26.27 **
IR-64*UPR3565	2.11 *	2.11	8.99 **	44.19 **	42.20 **	46.25 **
IR-64*J.Sannalu	-4.39 **	-6.09 **	3.93 **	7.84 **	2.96 *	2.96 *
IR-64*Hung	8.68 **	2.11	8.99 **	-14.29 **	-24.40 **	-1.05
IR-64*Muskan	-0.55	-4.21 **	2.25	8.07 **	-5.65 **	26.47 **

	Panicle Length			Effective Tiller		
Cross	**Mid**	**Better**	**Standard** RAJESHWARI©	**Mid**	**Better**	**Standard** RAJESHWARI©
I.Barani*K.Jeera	7.12 *	3.1	19.74 **	21.48 *	12.33	30.16 *
I.Barani*UPR3565	12.88 **	12.72 **	21.42 **	8.2	-9.59	4.76
I.Barani*J.Sannalu	14.12 **	13.23 **	21.63 **	-20.59 *	-26.03 *	-14.29
I.Barani*Hung	16.77 **	13.81 **	22.25 **	3.4	2.7	20.63
I.Barani*Muskan	7.75 *	-1.01	26.99 **	-9.09	-10.96	3.17
CGZ*K.Jeera	17.74 **	9.20 *	26.82 **	34.38 **	30.30 *	36.51 **
CGZ*UPR3565	25.29 **	20.39 **	29.67 **	-2.61	-15.15	-11.11
CGZ*J.Sannalu	24.61 **	20.81 **	27.75 **	8.53	6.06	11.11
CGZ*Hung	10.69 **	9.24 *	11.39 **	-12.86	-17.57	-3.17
CGZ*Muskan	22.25 **	8.43 *	39.10 **	19.12	15.71	28.57 *
SMR*K.Jeera	5.09	1.26	17.60 **	19.05	17.19	19.05
SMR*UPR3565	29.91 **	29.88 **	39.90 **	46.90 **	29.69 *	31.75 *
SMR*J.Sannalu	11.39 **	10.39 *	18.86 **	14.96	14.06	15.87
SMR*Hung	3.32	0.58	8.3	-21.74 *	-27.03 *	-14.29
SMR*Muskan	1.02	-7.10 *	19.19 **	-2.99	-7.14	3.17
I.Aerobi*K.Jeera	2.34	-0.43	15.63 **	12.15	-3.23	-4.76
I.Aerobi*UPR3565	7.61 *	6.56	17.06 **	31.91 *	26.53	-1.59
I.Aerobi*J.Sannalu	11.74 **	9.65 *	20.45 **	74.07 **	49.21 **	49.21 **
I.Aerobi*Hung	12.47 **	8.43 *	19.11 **	52.94 **	22.97 *	44.44 **
I.Aerobi*Muskan	-3.06	-10.03 **	15.42 **	7.83	-11.43	-1.59
DGR*K.Jeera	2.59	-2.74	12.95 **	36.75 **	29.03 *	26.98 *
DGR*UPR3565	1.33	-0.39	7.29	25	18.18	3.17

DGR*J.Sannalu	22.77 **	21.80 **	28.79 **	13.56	6.35	6.35
DGR*Hung	37.31 **	35.92 **	41.45 **	6.98	-6.76	9.52
DGR*Muskan	10.21 **	-0.2	28.04 **	8.8	-2.86	7.94
RJR*K.Jeera	14.47 **	9.89 **	27.62 **	3.08	-1.47	6.35
RJR*UPR3565	24.63 **	24.12 **	33.70 **	-16.24	-27.94 *	-22.22
RJR*J.Sannalu	22.75 **	22.12 **	30.47 **	16.03	11.76	20.63
RJR*Hung	14.93 **	12.31 **	19.99 **	-11.27	-14.86	0.00
RJR*Muskan	-17.73 **	-24.61 **	-3.28	7.25	5.71	17.46
IR-64*K.Jeera	21.93 **	13.46 **	31.77 **	36.00 **	34.92 **	34.92 **
IR-64*UPR3565	26.55 **	22.02 **	31.43 **	26.79 *	12.7	12.7
IR-64*J.Sannalu	5.11	2.26	8.13	12.7	12.7	12.7
IR-64*Hung	27.03 **	25.80 **	28.28 **	12.41	4.05	22.22
IR-64*Muskan	11.24 **	-1.03	26.97 **	69.92 **	61.43 **	79.37 **

	100 seed weight (Test weight)			Filled Grain		
Cross	Mid	Better	Standard RAJESHWARI©	Mid	Better	Standard RAJESHWARI©
I.Barani*K.Jeera	35.56 **	19.61 **	-0.65	11.92 **	-17.95 **	-11.91 **
I.Barani*UPR3565	9.47 **	1.96	-15.31 **	53.97 **	16.10 **	24.65 **
I.Barani*J.Sannalu	40.48 **	15.69 **	-3.91	-12.29 **	-15.20 **	-2.5
I.Barani*Hung	14.00 **	11.76 **	-7.17 *	-22.26 **	-32.74 **	-27.78 **
I.Barani*Muskan	2.91	1.92	-13.68 **	9.51 **	-12.76 **	-6.34 *
CGZ*K.Jeera	-50.59 **	-54.35 **	-65.80 **	-13.89 **	-35.13 **	-35.92 **
CGZ*UPR3565	20.00 **	17.39 **	-12.05 **	-0.21	-22.55 **	-23.50 **
CGZ*J.Sannalu	39.24 **	19.57 **	-10.42 **	17.34 **	9.08 **	25.42 **
CGZ*Hung	11.58 **	8.16 *	-13.68 **	0.65	-9.72 **	-10.82 **
CGZ*Muskan	-20.41 **	-25.00 **	-36.48 **	42.63 **	17.30 **	15.88 **
SMR*K.Jeera	3.53	-4.35	-28.34 **	76.23 **	37.44 **	22.92 **
SMR*UPR3565	-2.22	-4.35	-28.34 **	62.74 **	30.99 **	17.16 **
SMR*J.Sannalu	36.71 **	17.39 **	-12.05 **	5.10 *	-6.57 **	7.43 **
SMR*Hung	-13.68 **	-16.33 **	-33.22 **	120.67 **	107.09 **	85.21 **
SMR*Muskan	-2.04	-7.69 *	-21.82 **	66.56 **	42.59 **	27.53 **
I.Aerobi*K.Jeera	51.22 **	44.19 **	0.98	-17.97 **	-39.41 **	-36.43 **
I.Aerobi*UPR3565	17.24 **	15.91 **	-16.94 **	7.03 *	-18.67 **	-14.66 **
I.Aerobi*J.Sannalu	60.53 **	41.86 **	-0.65	-22.10 **	-25.50 **	-14.34 **
I.Aerobi*Hung	32.61 **	24.49 **	-0.65	1.26	-11.53 **	-7.17 **
I.Aerobi*Muskan	34.74 **	23.08 **	4.23	40.24 **	12.69 **	18.25 **
DGR*K.Jeera	12.50 **	-5.26	-12.05 **	44.20 **	10.30 **	4.23
DGR*UPR3565	8.91 **	-3.51	-10.42 **	40.89 **	11.11 **	4.99 *

DGR*J.Sannalu	15.56 **	-8.77 **	-15.31 **	-9.66 **	-17.71 **	-5.38 *
DGR*Hung	7.55 *	0.00	-7.17 *	20.84 **	10.57 **	4.48
DGR*Muskan	8.26 **	3.51	-3.91	-2.06	-18.02 **	-22.54 **
RJR*K.Jeera	18.68 **	3.85	-12.05 **	34.07 **	0.64	0.51
RJR*UPR3565	10.42 **	1.92	-13.68 **	-2.49	-24.62 **	-24.71 **
RJR*J.Sannalu	27.06 **	3.85	-12.05 **	-7.27 **	-13.36 **	-0.38
RJR*Hung	22.77 **	19.23 **	0.98	21.65 **	8.59 **	8.45 **
RJR*Muskan	-7.69 *	-7.69 *	-21.82 **	17.34 **	-3.91	-4.03
IR-64*K.Jeera	20.00 **	-1.64	-2.28	-13.48 **	-35.08 **	-35.08 **
IR-64*UPR3565	18.10 **	1.64	0.98	52.28 **	17.67 **	17.67 **
IR-64*J.Sannalu	40.43 **	8.20 **	7.49 *	-13.94 **	-19.54 **	-7.49 **
IR-64*Hung	-1.82	-11.48 **	-12.05 **	27.88 **	14.08 **	14.08 **
IR-64*Muskan	-25.66 **	-31.15 **	-31.60 **	-37.97 **	-49.23 **	-49.23 **

	Unfilled Grain			Paddy Length		
Cross	Mid	Better	Standard RAJESHWARI©	Mid	Better	Standard RAJESHWARI©
I.Barani*K.Jeera	31.96 **	-17.60 **	96.92 **	-1.41 *	-5.62 **	-4.17 **
I.Barani*UPR3565	31.52 **	-18.05 **	97.95 **	0.75	-10.95 **	17.76 **
I.Barani*J.Sannalu	-30.04 **	-56.00 **	1.54	4.40 **	-5.18 **	-3.73 **
I.Barani*Hung	77.36 **	62.07 **	-3.59	0.34	-4.43 **	-2.96 **
I.Barani*Muskan	149.77 **	69.88 **	180.51 **	-0.68	-3.94 **	4.39 **
CGZ*K.Jeera	474.85 **	312.02 **	884.62 **	-1.11	-2.19 **	-7.13 **
CGZ*UPR3565	116.34 **	54.56 **	273.33 **	-11.58 **	-24.05 **	0.44
CGZ*J.Sannalu	2.15	-26.00 **	70.77 **	6.29 **	-0.46	-5.48 **
CGZ*Hung	169.80 **	99.01 **	106.15 **	14.08 **	12.24 **	6.58 **
CGZ*Muskan	308.02 **	231.99 **	448.21 **	-8.78 **	-14.53 **	-7.13 **
SMR*K.Jeera	-3.95	-29.61 **	68.21 **	-0.47	-1.95 **	-6.14 **
SMR*UPR3565	-25.29 **	-45.44 **	31.79 *	-14.38 **	-26.20 **	-2.41 **
SMR*J.Sannalu	-23.84 **	-43.56 **	30.26 *	13.44 **	5.84 **	1.32 *
SMR*Hung	21.41	-12.44	-2.56	-2.05 **	-4.01 **	-8.11 **
SMR*Muskan	-12.06	-26.40 **	21.54	-8.48 **	-13.93 **	-6.47 **
I.Aerobi*K.Jeera	-45.57 **	-64.38 **	-14.87	4.37 **	0.44	0.88
I.Aerobi*UPR3565	-9.27	-40.76 **	43.08 **	-7.45 **	-18.57 **	7.68 **
I.Aerobi*J.Sannalu	-19.19 **	-46.67 **	23.08	10.17 **	0.55	0.99
I.Aerobi*Hung	253.33 **	194.44 **	117.44 **	8.10 **	3.49 **	3.95 **
I.Aerobi*Muskan	10.3	-20.19 **	31.79 *	13.06 **	8.78 **	18.20 **
DGR*K.Jeera	50.62 **	42.70 **	241.03 **	7.04 **	-0.35	-7.46 **
DGR*UPR3565	-72.07 **	-73.67 **	-36.41 **	-8.57 **	-26.62 **	-2.96 **

DGR*J.Sannalu	-18.80 **	-21.78 **	80.51 **	29.21 **	26.98 **	5.26 **
DGR*Hung	226.32 **	100.72 **	329.23 **	13.14 **	5.85 **	-2.74 **
DGR*Muskan	19.62 **	6	126.67 **	2.93 **	-10.62 **	-2.88 **
RJR*K.Jeera	-10.47	-40.34 **	42.56 **	-1.25 *	-4.82 **	-4.71 **
RJR*UPR3565	152.08 **	67.52 **	304.62 **	-15.53 **	-25.79 **	-1.86 **
RJR*J.Sannalu	173.06 **	83.56 **	323.59 **	8.81 **	-0.55	-0.44
RJR*Hung	33.07 *	7.74	-14.36	11.02 **	6.46 **	6.58 **
RJR*Muskan	16.56	-13.66	42.56 **	13.66 **	9.18 **	18.64 **
IR-64*K.Jeera	-41.30 **	-58.37 **	-0.51	1.65 **	-1.97 **	-1.97 **
IR-64*UPR3565	-50.45 **	-64.97 **	-15.38	-11.52 **	-22.31 **	2.74 **
IR-64*J.Sannalu	-24.65 **	-46.00 **	24.62 *	11.63 **	2.08 **	2.08 **
IR-64*Hung	202.41 **	125.64 **	125.64 **	3.66 **	-0.55	-0.55
IR-64*Muskan	235.78 **	169.57 **	345.13 **	-7.51 **	-11.20 **	-3.51 **

	Paddy Breadth			Paddy L/B Ratio		
Cross	Mid	Better	Standard RAJESHWARI©	Mid	Better	Standard RAJESHWARI©
I.Barani*K.Jeera	11.87 **	3.38	-8.58 **	-12.32 **	-15.54 **	4.71 *
I.Barani*UPR3565	-0.66	-4.22	-15.30 **	-5.92 **	-23.09 **	39.12 **
I.Barani*J.Sannalu	8.65 **	3.38	-8.58 **	-3.70 *	-8.32 **	5.29 **
I.Barani*Hung	7.70 **	0.81	2.24	-7.59 **	-17.41 **	-5.15 *
I.Barani*Muskan	12.61 **	5.49 *	-6.72 **	-10.95 **	-17.93 **	11.76 **
CGZ*K.Jeera	13.26 **	3.28	-5.97 **	-13.53 **	-20.40 **	-1.32
CGZ*UPR3565	9.48 **	4.1	-5.22 *	-25.73 **	-41.46 **	5.88 **
CGZ*J.Sannalu	11.35 **	4.51	-4.85 *	-4.45 **	-4.65 *	-0.59
CGZ*Hung	-11.98 **	-16.48 **	-15.30 **	29.31 **	20.73 **	25.88 **
CGZ*Muskan	9.09 **	0.82	-8.21 **	-15.96 **	-25.81 **	1.03
SMR*K.Jeera	13.84 **	3.24	-4.85 *	-13.49 **	-20.52 **	-1.47
SMR*UPR3565	1.93	-3.64	-11.19 **	-22.83 **	-39.27 **	9.85 **
SMR*J.Sannalu	5.10 *	-1.92	-9.61 **	7.93 **	7.93 **	12.06 **
SMR*Hung	-7.48 **	-11.70 **	-10.45 **	5.53 **	-1.27	2.5
SMR*Muskan	6.17 **	-2.43	-10.07 **	-13.36 **	-23.65 **	3.97 *
I.Aerobi*K.Jeera	22.30 **	13.68 **	-0.75	-14.95 **	-18.03 **	1.62
I.Aerobi*UPR3565	8.59 **	5.34 *	-8.02 **	-20.87 **	-35.28 **	17.06 **
I.Aerobi*J.Sannalu	24.55 **	19.23 **	4.1	-11.42 **	-15.73 **	-3.09
I.Aerobi*Hung	-1.15	-8.02 **	-6.72 **	8.38 **	-3.2	11.32 **
I.Aerobi*Muskan	7.48 **	1.28	-11.57 **	6.32 **	-1.94	33.53 **
DGR*K.Jeera	-0.2	-15.75 **	-8.21 **	2.09	-18.74 **	0.74
DGR*UPR3565	-1.56	-13.70 **	-5.97 **	-18.80 **	-42.93 **	3.24

DGR*J.Sannalu	-2.77	-15.75 **	-8.21 **	29.46 **	10.48 **	14.71 **
DGR*Hung	-4.22 *	-7.53 **	0.75	17.77 **	6.67 **	-3.53
DGR*Muskan	-1	-15.41 **	-7.84 **	0.63	-22.57 **	5.44 **
RJR*K.Jeera	19.72 **	13.33 **	-4.85 *	-17.65 **	-19.22 **	0.15
RJR*UPR3565	6.52 **	5.33 *	-11.57 **	-26.11 **	-38.70 **	10.88 **
RJR*J.Sannalu	12.53 **	9.78 **	-7.84 **	-3.23 *	-9.49 **	7.94 **
RJR*Hung	-0.16	-8.76 **	-7.46 **	9.82 **	-3.45 *	15.15 **
RJR*Muskan	7.41 **	3.11	-13.43 **	7.31 **	0.65	37.06 **
IR-64*K.Jeera	8.74 **	-4.85 *	-4.85 *	22.39 **	10.56 **	37.06 **
IR-64*UPR3565	11.89 **	1.87	1.87	-28.27 **	-44.31 **	0.74
IR-64*J.Sannalu	2.07	-8.21 **	-8.21 **	9.09 **	7.08 **	11.18 **
IR-64*Hung	-11.45 **	-12.07 **	-10.82 **	17.07 **	11.47 **	11.47 **
IR-64*Muskan	11.16 **	-1.49	-1.49	-17.06 **	-28.08 **	-2.06

	Biological Yield			Economic Yield		
Cross	Mid	Better	Standard RAJESHWARI©	Mid	Better	Standard RAJESHWARI©
I.Barani*K.Jeera	-2.07	-5.07	0.74	-1.04	-4.25	4.73
I.Barani*UPR3565	0.56	0.12	0.62	6.77	6.49	8.92
I.Barani*J.Sannalu	-3.12	-3.32	-3.68	-6.54	-8.84	-1.94
I.Barani*Hung	-10.16 **	-10.87 **	-9.78 **	-9.6	-12.21 *	-4.72
I.Barani*Muskan	-8.49 **	-10.24 **	-7.03 *	-6.12	-8.76	-1.11
CGZ*K.Jeera	10.13 **	3.49	9.82 **	4.5	0.18	9.58
CGZ*UPR3565	-0.62	-4.16	-3.68	-17.19 **	-17.75 **	-16.32 *
CGZ*J.Sannalu	26.25 **	22.51 **	21.53 **	12.34 *	8.57	16.79 **
CGZ*Hung	-4.09	-7.83 *	-6.70 *	0.26	-3.52	4.72
CGZ*Muskan	3.17	-1.93	1.58	-1.57	-5.22	2.72
SMR*K.Jeera	-1.75	-5.18	0.62	-3.46	-7.62	1.05
SMR*UPR3565	22.01 **	20.93 **	21.53 **	8.66	7.7	9.58
SMR*J.Sannalu	12.67 **	12.39 **	11.50 **	9.35	5.48	13.47 *
SMR*Hung	4.67	3.37	4.63	7.41	3.17	11.97
SMR*Muskan	-8.62 **	-10.77 **	-7.58 *	-4.93	-8.62	-0.96
I.Aerobi*K.Jeera	-2.76	-9.88 **	-4.36	5.33	-4.07	4.93
I.Aerobi*UPR3565	8.26 **	2.92	3.44	17.02 **	10.18	12.1
I.Aerobi*J.Sannalu	5.91 *	1.31	0.5	8.79	-0.17	7.39
I.Aerobi*Hung	23.86 **	17.36 **	18.79 **	21.38 **	10.94	20.41 **
I.Aerobi*Muskan	6.99 *	0.28	3.87	16.52 **	6.56	15.49 *
DGR*K.Jeera	29.37 **	13.82 **	20.78 **	18.37 **	1.62	11.16
DGR*UPR3565	10.72 **	-0.24	0.26	15.57 *	2.33	4.12

DGR*J.Sannalu	15.11 **	4.32	3.49	15.08 *	-0.51	7.02
DGR*Hung	13.67 **	2.1	3.34	14.20 *	-1.64	6.76
DGR*Muskan	15.71 **	2.88	6.56 *	19.93 **	3.35	12.02
RJR*K.Jeera	0.84	-2.55	3.41	11.13 *	8.06	18.20 **
RJR*UPR3565	-8.82 **	-9.51 **	-9.06 **	-4.74	-5.48	-2.32
RJR*J.Sannalu	3.86	3.75	2.92	-2.07	-4	3.27
RJR*Hung	0.4	-0.71	0.5	-13.13 *	-15.21 *	-7.97
RJR*Muskan	-3.96	-6.09 *	-2.72	-2.38	-4.66	3.34
IR-64*K.Jeera	1.61	-5.52	0.26	12.62 *	1.88	11.44
IR-64*UPR3565	6.20 *	1.31	1.82	1.92	-4.7	-3.04
IR-64*J.Sannalu	9.44 **	5.04	4.21	9.73	0.02	7.59
IR-64*Hung	8.39 **	3.05	4.3	14.28 *	3.75	12.60 *
IR-64*Muskan	2.2	-3.89	-0.45	7.54	-2.31	5.88

	Harvest Index		
Cross	Mid	Better	Standard RAJESHWARI©
I.Barani*K.Jeera	1.08	0.86	4.02
I.Barani*UPR3565	6.19	5.48	8.31
I.Barani*J.Sannalu	-3.95	-6.51	1.4
I.Barani*Hung	0.62	-1.54	5.64
I.Barani*Muskan	2.96	1.98	6.75
CGZ*K.Jeera	-5.31	-7.25	-0.26
CGZ*UPR3565	-16.62 **	-19.03 **	-12.93 *
CGZ*J.Sannalu	-10.95 *	-11.33 *	-3.82
CGZ*Hung	4.54	4.42	12.29 *
CGZ*Muskan	-4.72	-5.98	1.1
SMR*K.Jeera	-1.54	-2.43	0.63
SMR*UPR3565	-10.91 *	-10.93	-9.76
SMR*J.Sannalu	-2.96	-6.18	1.77
SMR*Hung	2.64	-0.25	7.03
SMR*Muskan	4.12	2.42	7.21
I.Aerobi*K.Jeera	8.54	6.47	9.8
I.Aerobi*UPR3565	8.12	6.98	8.39
I.Aerobi*J.Sannalu	3.07	-1.33	7.02
I.Aerobi*Hung	-1.73	-5.44	1.46
I.Aerobi*Muskan	9.1	6.24	11.22
DGR*K.Jeera	-8.15	-10.74	-7.95
DGR*UPR3565	4.66	2.59	3.95

DGR*J.Sannalu	0.68	-4.5	3.59
DGR*Hung	1.01	-3.69	3.34
DGR*Muskan	4.1	0.44	5.14
RJR*K.Jeera	10.23 *	9.56	14.38 *
RJR*UPR3565	4.43	2.89	7.42
RJR*J.Sannalu	-5.72	-7.48	0.35
RJR*Hung	-13.35 **	-14.52 **	-8.28
RJR*Muskan	1.64	1.5	6.25
IR-64*K.Jeera	11.23 *	7.83	11.2
IR-64*UPR3565	-3.84	-5.98	-4.74
IR-64*J.Sannalu	0.66	-4.74	3.32
IR-64*Hung	5.84	0.67	8.02
IR-64*Muskan	5.53	1.57	6.32

for developing early maturing hybrids. Heterosis in both negative and positive direction for days to flowering has also been reported by Peng and Virmani (1991) and Murthy and Kulkarni (1996).

4.4.2 Plant height (cm)

The mid parent heterosis ranged from -16.24% (Indira awerobic/Muskan) to 64.88% (Rajehswari/Jaggithyali sannalu). Among hybrids, six of them have showed the negative significant value and twenty seven of them have showed the positive significant value for this trait.

The heterobeltiosis ranged from -26.76% (Samleshwari/Muskan) to 60.35% (Rajeshwari/Jaggithyali sannalu). Among hybrids, fourteen of them have showed the negative significant heterosis and the other nineteen of them have shpwed the positive significant value for better heterosis for this trait.

The standard heterosis (over Rajeshwari) ranged from -1.82% (Samleshwari/Musakn) to 54.3% (Rajeshwari/Jaggithyali sannalu). Among hybrids, two of them have showed negative significant value and tbirty two have showed positive significant heterosis for this trait.

The negative heterotic effects indicating that the hybrids were shorter than their mid parents and positive heterotic effects showed that hybrids were taller with their mid parents. Cross Samleshwari/Muskan showed highest significant negative estimates of relative, better parent and for standard check which indicate that this cross can be used for breeding dwarf hybrid. The testers Muskan and Jaggithyali sannalu showed significant negative estimate for all heterosis along with the line Samleshwari.

Similar results have also been reported byIssac (2007),Gawas *et al*. (2007),Saidaiah *et al*. (2010), Kumar *et al*. (2012), Patil *et al*. (2012), Jarwar*et al*. (2012), Srikrishna *et al.* (2013), Huang *et al.* (2015) and Sahu *et al.*(2016).

4.4.3 Panicle length (cm)

The mid parent heterosis ranged from -17.73% (Rajeshwari/Muskan) to 37.31% (Durgeshwari/HUNG MI TSIANG MA). In hybrids,the twenty six of them have showed the positive significant value and only one of the hybrid have shown the negative significant value in relative heterosis for this trait.

The heterobeltiosis ranged from -24.61% (Rajeshwari/Muskan) to 35.92% (Durgeshwari/HUNG MI TSIANG MA). Twenty one of the hybrids showed significant positive better heterosis while two of the hybrids showed significant negative better parent heterosis for this trait.

The standard heterosis (over Rajeshwari) ranged from -3.28% (Rajehswari/Muskan) to 41.45% (Durgeshwari/HUNG MI TSIANG MA). Among the hybrids, Thirty one hybrids showed significant positive standard heterosis for this trait.

Those hybrids which has the large panicles signifies that it has the better impact and better capability in partitioning of the material that have been assimilated by the plant to their respective reproductive part of the plant. Panicle length is the attribute that has major impact in the gaining the higher yield hence positive heterotic effects are more fruitful for such traits. Highest significant positive heterotic effects were shown in crosses Durgehswari/HUNG MI TSIANG MA and Rajeshwari/UPR 3565-10-1-1. Testers HUNG MI TSIANG MA, UPR 3565-10-1-1 and Jaggithyali sannalu with line Durgeshwari and Rajeshwari have shown positive significant estimate over all the three checks.

Similar findings reported by Singh *et al*. (2007), Sreedhar *et al*. (2012), Patil *et al*. (2012), Utharasu and Anandakumar (2013), Veeresha *et al.* (2013), Srikrishna *et al.* (2013), Ghara *et al.* (2014), Shinde and Patel (2014) and Nayak *et al.* (2015).

4.4.4Number of Effective tillers per plant

The mid parent heterosis ranged from -21.74% (Samleshwari/HUNG MI TSIANG MA) to 74.07% (Indira aerobic/Jaggithyali sannalu). Within hybrids, Ten of them have showed positive significant heterosis and other two of them have showed the negative significant value.

The heterobeltiosis ranged from -27.94% (Rajeshwari/UPR 3565-10-1-1) to 61.43% (IR-64/Muskan).In hybrids seven of them have showed the positive heterotic value and three of them have showed the negative heterotic value

The standard heterosis (over Rajeshwari) ranged from -21.22% (Rajeshwari/UPR 3565-10-1-1) to 79.37% (IR-64/Muskan). Nine of the hybrids have shown the positive significant standard heterosis for this trait and one of them have showed zero value and no improvement over heterosis *i.e.* Rajeshwari/HUNG MI TSIANG MA.

Number of the effective tillers per plant is known to be a competent trait towards grain yield and thus it could be exploited very well. Hence, heterosis over better parent and standard check in the positive direction is very well desiravvle for this trait.

Similar results have been reported by Kumar *et al*. (2012), Jarwar *et al*. (2012), Sreedhar *et al*. (2012), Patil *et al*. (2012), Utharasu and Anandakumar (2013), Srikrishna *et al.* (2013), Ghara *et al.* (2014), Shinde and Patel (2014) and Sahu *et al.*(2016).

4.4.5Hundred Seed weight (g)

The mid parent heterosis ranged from -50.59% (CG Zinc rice/Kanakjeera) to 60.53% (Indira aerobic/Jaggithyali sannalu). In hybrids, twenty five hybrids showed significant positive relative heterosis and four of the hybrids showed significant negative relative heterosis for this trait.

The heterobeltiosis ranged from -54.35% (CG Zinc rice/Kanakjeera) to 44.19% (Indira aerobic/Kanakjeera). Within hybrids, fourteen hybrids showed significant positive better heterosis and eight of them showed significant negative better parent heterosis for this trait.One cross *viz*., Durgeshwari/HUNG MI TSIANG MA showed no improvement over heterosis.

The standard heterosis (over Rajeshwari) ranged from -65.8% (CG Zinc rice/Kanakjeera) to 7.49% (IR-64/Jaggithyali sannalu). Within hybrids, only one of them has shown the positive significant effect and twenty four hybrids showed significant negative standard heterosis for this trait.

Hundred seed grains weight is an remarkable yield component in the final yield, as the bold varities generally yield out better than the other types. In the present study positive significant values are reported which were in agreement with the earilier findings by Rahimi *et al.* (2010), Krishna *et al.* (2011), Kumar *et al.* (2012), Pratap *et al.* (2013), Singh *et al.* (2013), Latha *et al.* (2013) and Sahu *et al.*(2017).

4.4.6 Fertile spikelets/ Filled grain per panicle

The mid parent heterosis ranged from -37.97% (IR-64/Muskan) to 120.67% (Samleshwari/HUNG MI TSIANG MA).Twenty of the hybrids showed significant positive relative heterosisand ten of them have shown significant negative relative heterosis for this trait.

The heterobeltiosis ranged from -49.23% (IR-64/Muskan) to 107.09% (Samleshwari/HUNG MI TSIANG MA). Within hybrids, fourteen of them showed positive significant value and other seventeen of them have shown significant negative better heterosis for this trait.

The standard heterosis (over Rajeshwari) ranged from -49.23% (IR-64/Muskan) to 85.21% (Samleshwari/HUNG MI TSIANG MA). Within hybrids sixteen of them showed significant positive standard heterosis and thirteen of them showed significant negative standard heterosis for this trait.

The number of fertile spikelets directly impact the seed yield therefore the positive heterotic effect would be desirable. In the present study, more number of fertile spikelets is closely associated with high yield per plant resulting high productivity. Therefore, the main interest is to find out the cross combinations with more number of long and heavy panicle bearing tillers. Samleshwari/HUNG MI TSIANG MA recorded higher values of heterotic expression for better parent, mid parent andone check. Virmani *et al.* (1981 and 1982) reported that heterosis in yield was primarily due to increased number of spikelets panicle^{-1} further supported by Patel *et al.* (1994) and Reddy (1996) that confirms the present trend in this traits.

Significant positive heterosis for number of fertile spikelets per panicle was reported by Singh *et al*. (2007), Tiwari *et al.* (2011), Saidaiah *et al.* (2012), Sreedhar *et al.* (2012), Patil *et al.* (2012), Issac (2007), Premkumar *et al.* (2017) and Ramesh *et al.* (2018).

4.4.7 Sterile spikelets/Unfilled grain per panicle

The mid parent heterosis ranged from -72.07% (Durgeshwari/UPR 3565-10-1-1) to 474.85% (CG Zinc rice/Kanakjeera).Hybrids that has the positive significant heterotic effect are seventeen in number and other ten hybrids has the negative significant relative heterotic effect.

The heterobeltiosis ranged from -73.67% (Durgeshwari/UPR 3565-10-1-1) to 312.02% (CG Zinc rice/Kanakjeera). Within hybrids thirteen of them have showed significant positive better heterosis and eighteen of the hybrids showed significant negative better heterosis for this trait.

The standard heterosis (over Rajeshwari) ranged from -36.41% (Durgeshwari/UPR 3565-10-1-1) to 884.62% (CG Zinc rice/Kanakjeera). Among those of the hybrids, only one of the hybrids have shown negative significant standard heterosis, twenty five hybrids showed significant positive standard heterosis, three hybrids showed significant positive standard heterosis for this trait.

Result revealed that promising crosses were IR 58025A/ Kdamphool, CRMS 32A/ Kadamphool, CRMS 32A/ Bakramudi showed heterosis in negative direction over mid parent and better parent. IR 58025A/ Kadamphool and IR 58025A/ Siyar showed heterosis in negative direction over standard checks *viz.,* KRH-4 and Arize 6444 respectively. Similar results have been reported by Singh *et al.* (2007), Singh *et al.* (2013) and Ramesh *et al.* (2018).

4.4.8 Paddy length

The mid parent heterosis ranged from -15.53% (Rajeshwari/UPR 3565-10-1) to 29.21% (Durgeshwari/Jaggithyali sannalu). Among those of the hybrids, Eighteen hybrids showed significant positive better heterosis twelve of hybrids showed significant negative better heterosis for this trait..

The heterobeltiosis ranged from -26.62% (Durgehswari/UPR 3565-10-1-1) to 26.98% ((Durgehswari/Jaggithyali sannalu).In the hybrids, Nine of them have shown the positive significant effect and twenty among them have showed the negative significant value of betterparent heteosis

The standard heterosis (over Rajeshwari) ranged from -8.11% (Samleshwari/HUNG MI TSIANG MA) to 18.64% (Rajeshwari/Muskan). Twelve of the hybrid have shown the negative significant standard heterotic value and eighteen of them have shown the posititve significant effect

Result provided the information that remarkable cross that has significant positive value for the mid parent and standard heterosis is Rajeshwari/Muskan. Similar results have been reported by Singh *et al.* (2007), Singh *et al.* (2013) and Ramesh *et al.* (2018).

4.4.9 Paddy breadth

The mid parent heterosis ranged from -11.98% (CG Zinc rice/HUNG MI TSIANG MA) to 24.55% (Indira aerobic/Jaggithyali sannalu). In the hybrids twenty one of them hasd the positive significant effect and other fours has the negative mid parent heterotic effect.

The heterobeltiosis ranged from -16.48% (CG Zinc rice/HUNG MI TSIANG MA) to 19.23% (Indira aerobic/Jaggithyali sannalu).In the hybrids,six of them have shown the positive significant effect and twelve among them have showed the negative significant value of betterparent heteosis

The standard heterosis (over Rajeshwari) ranged from -15.3% (CG Zinc rice/HUNG MI TSIANG MA) to 4.1% (Indira aerobic/Jaggithyali sannalu). None of the hybrids have shown the positive significant effect for the standard herterosis and twenty njine of them have shown the negative heterotic effect.Similar results have been reported by Singh *et al.* (2007), Singh *et al.* (2013) and Ramesh *et al.* (2018).

4.4.10 Paddy L/B ratio

The mid parent heterosis ranged from -28.27% (IR-64/UPR 3565-10-1) to 29.46% (Durgeshwari/Jaggithyali sannalu). Among those of the hybrids, thirtteen hybrids showed significant positive better heterosis twenty of hybrids showed significant negative better heterosis for this trait..

The heterobeltiosis ranged from -44.31% (IR-64/UPR 3565-10-1) to 20.73% (CG Zinc rice/HUNG MI TSIANG MA).In the hybrids, seven of them have shown the positive significant effect and twenty four among them have showed the negative significant value of betterparent heteosis

The standard heterosis (over Rajeshwari) ranged from -5.15% (Indira barani/HUNG MI TSIANG MA) to 39.12% (Indira barani/UPR 3565-10-1-1). Twenty one of the hybrid have shown the positive significant standard heterotic value and only one of them have shown the negative significant effect

. Similar results have been reported by Singh *et al.* (2007), Singh *et al.* (2013) and Ramesh *et al.* (2018).

4.4.11Biological yield per plant (g)

The mid parent heterosis ranged from -10.16% (Indira barani/HUNG MI TSIANG MA) to 29.37% (Durgeshwari/Kanakjeera). Sixteen hybrids showed significant positive relative heterosis and four hybrids showed significant negative relative heterosis for this trait.

The heterobeltiosis ranged from -10.87% (Indira barani/HUNG MI TSIANG MA) to 22.51% (CG Zinc rice/jaggithyali sannalu). Within the hybrids five of them have shown the positive significant effect and other seven of the hybrids have shown the negative significant negative heterosis.

The standard heterosis (over Rajeshwari) ranged from -9.78% (Indira barani/HUNG MI TSIANG MA) to 21.53% (CG Zinc rice/jaggithyali sannalu). Seven of thehybrids have shown the positive significant standard heterotic effect and other five of the have shown the negative heterotic effect.

Similar results have been reported by Issac (2007), Tiwari *et al.* (2011), Kumar *et al.* (2012), Pratap *et al.* (2013) and Srikrishna *et al.* (2013).

4.4.12 Grain yield per plant (g)

The mid parent heterosis ranged from -17.19% (CG Zinc rice/UPR 3565-10-1-1) to 21.38% (Indira aerobic 1/HUNG MI TSIANG MA). Withinhybrids, eleven hybrids showed significant positive relative heterosis and two of the hybrids showed significant negative relative heterosis for this trait.

The heterobeltiosis ranged from -17.75% (CG Zinc rice/UPR 3565-10-1-1) to 10.94% (Indira aerobic 1/HUNG MI TSIANG MA). Within hybrids none of them have showed positive significant heterotic effect and three of the hybrid have shown negative significant heterotic better parent heterotic effect

The standard heterosis (over Rajeshwari) ranged from -16.32% (CG Zinc rice/UPR 3565-10-1-1) to 20.41% (Indira aerobic 1/HUNG MI TSIANG MA). Among hybrids, six hybrids showed significant positive standard heterosis while only one of the hybrids showed significant negative standard heterosis for thistrait.

Grain yield is one of the complicated trait that is multiplicative end product of several attributes of yield. Hybrid showing high heterosis for grain yield per plant, also helpful in manifesting the heterotic effects for productive tillers per plant, panicle length, number grains per panicle and 1000 grain weight.Remarkable positive relative heterosis, heterobeltiosis and standard heterosis has been depicted by the cross Indira aerobic 1/HUNG MI TSIANG MA

Increased yield in rice due to various component traits as observed in the present investigation is in close conformity the finding observed by the other workers Issac (2007), Li *et al.* (2008), Vaithiyaligan and Nandarajan (2010),Tiwari *et al.* (2011), Patil *et al*. (2012), Sreedhar *et al.* (2012), Pratap *et al.* (2013), Srikrishna Latha *et al.* (2013), Veeresha *et al.* (2013),Ghara *et al.* (2014), Shinde and Patel (2014), Seesang *et al.* (2014), Sahu *et al.*(2017) and Thorat *et al.*(2017).

4.4.13 Harvest Index (%)

The mid parent heterosis ranged from -16.62% (CG Zinc rice/UPR 3565-10-1-1) to 11.23% (IR-64/Kanakjeera). Among those of thehybrids, two of them showed significant positive relative heterosis and four of themhybrids showed significant negative relative heterosis for this trait.

The heterobeltiosis ranged from -19.03% (CG Zinc rice/UPR 3565-10-1-1) to 9.56% (Rajeshwari/Kanakjeera).Among the whole of the hybrids, three of those hybrids showed significant negative better heterosis for this trait and none of the hybrids showed positive heterosis.

The standard heterosis (over Rajeshwari) ranged from -12.93% (CG Zinc rice/UPR 3565-10-1-1) to 14.38% (Rajeshwari/Kanakjeera). Two hybrids showed significant positive standard heterosis while only onehybrid showed significant negative standard heterosis for this trait.

Similar results have been reported by Bansal *et al*. (2000), Issac (2007), Tiwari *et al*. (2011), Kumar *et al.* (2012), Pratap *et al.* (2013), Utharasu and Anandakumar (2013) and Bedi and Sharma. (2016).

Table 4.12 Promising hybrids based on Mean performance, Heterosis and Combining Ability for Grain Yield per plant.

Hybrids	Mean value (g/plant)	Heterosis			GCA Effect		SCA Effect
		MP	BP	Rajeshwari	LINE	TESTER	HYBRIDS
CG Zinc Rice × Jaggithyali sannalu	35.17	12.34*	8.57	16.79**	-0.744	0.508	3.494**
Samleshwari × Jaggithyali sannalu	34.17	9.35	5.48	13.47**	0.317	0.508	1.433
Indira aerobic 1 × HUNG MI TSIANG MA	36.26	21.38**	10.94	20.41**	1.836**	0.086	2.426
Indira aerobic 1 × Muskan	34.78	16.52**	6.56	15.49**	1.836**	-0.189	1.221
Rajeshwari × Kanakjeera	31.12	11.13**	8.06	18.20**	-0.923	0.831	3.775**
IR-64 × HUNG MI TSIANG MA	33.91	14.28**	3.75	12.6	0.279	0.086	-3.36

*Significant at p=0.05% level, **Significant at p=0.01% level

CHAPTER – V
SUMMARY AND CONCLUSION

The recent investigation having the title, **“Combining ability analysis and estimation of heterosis for development of aromatic rice hybrids”** got accomplished using 48 of the rice genotypes i.e. 7 lines, 5 tester and their respective cross combinations along with single check variety namely Rajeshwari at the “Research cum Instructional farm, Department of Genetics and Plant Breeding, College of Agriculture, IGKV, Raipur, Chhattisgarh” during season *of Kharif* 2019. Through "Randomized Block Development (RCBD)," the experiment was outilined to meet the purpose of "variability assessment. Combining ability analysis and heterosis estimation in the given rice genotype. The findings that were obtained are outlined below:

- The result of the variation analysis showed the existence of highly significant variations for all of the listed variety under investigation.
- “The estimates of phenotypic coefficient of variation were found to be higher than that of genotypic coefficient of variation indicating the influence of environment. The values of PCV and GCV were found to be in close agreement for unfilled grain per panicle, filled grain per panicle , 100 seed grain weight, plant height, panicle length, paddy length, paddy breadth, days to 50% flowering and biological yield indicating less influence of environment on these traits”.

For certain characters such as harvest index, economic yield, and number of successful tiller, significant differences were found between PCV and GCV suggesting environmental impact on these characteristics as a result of G×E interaction exhibiting manifestations of these characteristics.

“Higher estimates of Genotypic coefficient of variation and Phenotypic coefficient of variation in general were recorded in number of unfilled grains per panicle, followed by number of filled grains per panicle, indicating presence of sufficient variability in the germplasm material and thereby suggesting that selection of these traits will be useful for genetic improvement".

- "High heritability coupled with the high high genetic advance as a percent of mean was reported for the traits like plant height, panicle length, number of the effective tiller, 100 seed weight, filled grain per panicle, unfilled grain per panicle and paddy length indicating that the expression of such characters controlled by the additive gene action and thus simple selection will be effective for the improvement of this characters"

  "High heritability coupled with the moderate genetic advance as a percent of mean was observed for the characters like days to 50% flowering, paddy breadth, and biological yield suggesting that control of expressions by both additive and non additive gene action suggesting that the selection cannot be practiced for improving these traits thus heterosis breeding could be successful."Whereas the moderate heritability coupled with lowest genetic advance are observed in the characters like grain yield per plant and the other one being the harvest index shows that character is strongly affected by environmental effects and ineffective selection has been made.

- The assessment of L x T combination and the combining ability provides the subsequent variance due to the parents and it was very much relevant to all characters brought into this study. Also for all characters under study, the variations that have been occured due to cross combinations have been found to be statistically significant.
- Depending on the outcomes we gathered, the SCA value shows a remarkable and better value than the GCA value, all thirteen of the characters that kept under study have shown the non additive effect, which means that the utilisation of heterosis would be more beneficial for the future perspective.
- Considering total lines, out of them Indira aerobic 1 demonstrates good General combining capability for characters such as Economic yield per plant, Days to 50 percent flowering, Plant height, Hundred grain weight, Unfilled grain, Paddy breadth, Paddy L / B ratio and even Harvest index.

- Considering total testers, out of them Kanakjeera stands out in the performance and shows remarkable general combining ability for the traits like Economic yield and Days to 50% flowering.
- The efficacy of the heterosis in any cross combination is determined by the SCA effect of the given cross. Indira barani / UPR 3565-10-1-1, CG Zinc rice / Jaggithyali sannalu, Rajeshwari / Kanakjeera are the crosses which showed premium value of SCA for the trait of economic yield.
- Six remarkable crosses that includes following crosses viz., CG Zinc rice/Jaggithyali sannalu, Samleshwari/UPR3565-10-1-1, Indira aerobic/HUNG MI TSAING MA, Indira aerobic/Muskan,Rajeshwari/Kanakjeera and IR-64/HUNG MI TSIANG MA, this were spotted as the enticing hybrids that produce profound results for grain yield per plant based on results of mean output, heterosis estimate, SCA effects, and GCA effects (of their associated parents).Promising hybrids were discussed in the Table 5.1

CONCLUSION

- The analysis of variance for the 48 genotypes disclosed the fact that there is remarkable amount of difference are available for all the concerned characters that has been taken in the experiment. This signifies that there is large amount of the variability is being present among the rice genotypes/hybrids for the concerned traits.
- The prevalence of the effect of specific combining ability (SCA) variance for various characters indicates the preponderance of non-additive or dominant and epistatic gene action, this is really essential in order to regulate the manifestation of these characters. Therefore, on analogy with different findings obtained in this analysis, it can be concluded that the process of heterosis plays a crucial role in deciding seed yield in the case of rice hybrids and can be grown commercially.
- Non-additive gene action regulates whole of the thirteen listed varieties in this research work that has been based on the remarkable effect of the SCA variances. As SCA variances tends to stand out in front of GCA variances for all the characters. It

means that for this characters probability of leveraging heterosis is beneficial for thirteen characters because through simple selection, certain characters should be improved.

- Six noteworthy crosses, comprising CG Zinc rice / Jaggithyali sannalu, Samleshwari / UPR3565-10-1-1, Indira aerobic / HUNG MI TSAING MA, Indira aerobic / Muskan, Rajeshwari / Kanakjeera andIR-64 / HUNG MI TSIANG MA this were spotted as the enticing hybrids that produce profound results for grain yield per plant based on results of mean output, heterosis estimate, SCA effects, and GCA effects (of their associated parents).

SUGGESTION FOR THE FUTURE RESEARCH WORK

- More line and tester set should be integrated for the further breeding programme.
- Throughout most of the traits the line, Indira aerobic described as a strong general combiner and can be used to create better combinations in further study.
- Throughout most of the traits the tester, Kanakjeera described as a strong general combiner and can be used to create better combinations in further study.
- Six primary cross combinations includes CG Zinc rice / Jaggithyali sannalu, Samleshwari / UPR3565-10-1-1, Indira aerobic / HUNG MI TSAING MA, Indira aerobic / Muskan, Rajeshwari / Kanakjeera andIR-64 / HUNG MI TSIANG MA should indeed be reassessed in the retested cross nursery to validate the outcome. Such effective hybrids provide more room for more strategic use of hybrid vigour

REFERENCES

Ali, K., Chand, P., Imran, M. and Ahmad, A. 2017. Gene action studies for qualitative and quantitative traits in rice (*Oryza sativa L.*). Bangladesh J. Agril. Res., 39(1):1-12.

Annadurai, A. and Nadarajan, N. 2001. Combining ability for yield component and physiological traits in hybrid rice. Madras Agric. J., 88(4/6): 300-303.

Anonymous. 2018. Annual Report. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Gol, Krishi Bhawan, New Delhi-110 001.

Anonymous. 2018. Selected State-wise Area and Production of rice in India (2017-18), Indiastat.

Awasthi, R.P. and Borthakur, D.N. 1986. Agronomic evaluation of rice varieties in upland terraces of Meghalaya, Indian J. Agric. Sci., 56(10): 700-703

Babu, S.M., Satyanarayana, P.V., Madhuri, J. and Kumar, R.V. 2000. Combining ability analysis for identifying elite parents for heterosis rice hybrids. Oryza., 37(1):19-22.

Baghri, N. and Jelodar, N. B. 2010 Heterosis and Combining ability analysis for yield and related traits in hybrid rice. International J. Biology., 2(2):222-26

Balan, A., Muthiah, A.R. and Boopathi, S.N.M.R. 1999a. Genetic variability, correlation and path coefficient analysis in upland early rice genotypes. Madras Agric. J., 86(1-3):79-80.

Balan, A., Muthiah, A.R. and Boopathi,S.N.M.R. 1999b. Genetic variability, character association and path coefficient analysis in rainfed rice, under alkaline condition. Madras Agric. J., 86(1-3) : 122-124.

Banumathy, S., Thiyagarajan, K. and Vidyanathan, P. 2003. Combining ability for yield and yield components in three line hybrid rice. Oryza., 40(3&4): 75-77.

Bedi, S. and Sharma, D. 2016. Heterosis studies in hybrid rice (*Oryza sativa L.*). Inter.. J. Forestry Crop Improv., 7(1):1-6.

Bhattacharya, R.K. 1978. Estimation of genetic parameters of some quantitative characters in rice under stress soil conditions. Oryza., 15(2) : 146-150.

Bhave, S.G., Dhonukshe, B.L. and Bendale, V.W. 2003. Combining ability in hybrid rice (*Oryza sativa L.*). J. Soils Crops., 13(1):41-46.

Chahuhan, J.S. and Nanda, J.S. 1983. Genetic variability for physico-chemical characters of rice grain ion segregating rice (*Oryza sativa L.*) *Oryza*., 20:209-215

Chatterjee, D. 1947. Botany of the wild and cultivated rice. Nature., 160: 234-237.

Chaudhary, M. and Motiramani, N.K. 2003. Variability and association along yield attributes and grain quality in traditional aromatic rice accessions. Crop Imp., 30(1): 84-90.

Chaudhary, M., Sarawgi, A.K. and Motiramani, N.K. 2004. Genetic variability of quality, yield and yield attributing traits in aromatic rice (*Oryza sativa L.*). Adv. Pl. Sci.., 17(2): 484-90.

Chauhan, J. S. and Nanda, J.S. 1984. Varietal identification in rice (*Oryza sativa L.)* by physico-chemical characters of the grain and electrophoretic variants of salt soluble seed proteins. Seed Res., 12(1):78-79

Chauhan, V.S. and Tandon, J. P 1984. Genetic variability and character association in hill rices. Oryza., 21 : 138-142.

Cheema, A.A., Awan, M.A., Tahir, G.R. and Aslam, M. 1988. Heterosis and combining ability studies in rice. Pakistan J. Agric. Res., 9(1):41-45.

Chikkalingaiah, Shridhara, S., Lingaraju, S. and Radhakrishna, R.M. 1999. Genetic variability of plant and quality traits in promising genotypes of scented rice (*Oryza sativa L.*), Mysore J. Agri.Sci., 33(4):338-341..

Choubey, P.K.; Nanda, B.B. and Richharia, A.K. 1988. Quality attributing characters of scented and non-scented rice. Oryza., 25(2) : 325-328.

Choubey, P.K. and Singh, R.P. 1994. Genetic variability correlation and path analysis of yield component of rice. Madras Agric., 81(9): 468-470

Dar S.H., Rather, A.G., Ahanger, M.A., Sofi, N.R. and Talib S. 2014 Gene action and combining ability studies for yield and its contributing traits in rice (*Oryza sativa L.*): Agriculture review J. of plant and pest science., 1(3):110-127

Das, P.K., Chakraboty, S., Barman, B. and Samrah, K.K. 2001. Genetic variation for harvest index, grain yield and yield components in bore rice. Oryza., 38(3&4): 149-150.

Davis, R.L. 1927. Report of plant breeding. Annual Report. Puerto Rica Agr. Expt. Sta., pp. 14-45.

De Candolle, A. 1886 Plants cultivated for their seeds. Origin of Cultivated Plants. Int. Sci. Series., 2:376-384

De, R.N. and Rao, A.V.S. 1988. Genetic variability and correlation studies in rice under semi-deep water logged situation., Oryza. 25(4) : 360-364.

Deosarkar, D.B., Misal, M.B. and Nerkar, Y.S. 1989. Variability and correlation studies for grain quality characters in breeding lines of rice. J.Mah.Agric. Univ., 14:124-125.

Devarathinam, A.A. 1983. Combining ability and heterosis in dry and semi-dry paddy. Madras Agric. J., 70(4):233-237.

Devi, Archana., Kumari, Preeti., Dwivedi, Ranjan, Verma, O.P. and Dwivedi, D.K. 2017.Gene action and combining ability ability analysis foryield and its components over environment. J. Pharmacogynosy and Phytiochemistry., (3) 662-671

Dharwal, G., Verma, O. P. and Verma, G. P. 2017. Combining ability analysis for grain yield and other associated traits in rice. Int. J. Pure App. Biosci., 5(2): 96-100.

Durai, A.A. 2002. Heterosis for physiological traits in hybrid rice (*Oryza sativa L.*). Indian J. Genet., 62(4):331-333.

El-Rewainy, I. M. O., Hassan, H. M. and El-Abd, A. B. 2011. A study on heterosis and combining ability for grain yield and some its related traits in rice under water stress conditions. J. Agric. Res. Kafer El-Sheikh Univ., 37(4): 583.

Fanseco, S. and Peterson, F.L., 1968. Hybrid vigor in a seven parent diallel cross in common wheat (*T. aestivum L.*). Crop Sci., 8:85-88.

Fisher, R.A. 1918. The correlation on the supposition of Mendelian inheritance. Trans Royal Science Education., 52:399-433.

Gahtyari, N.C., Patel, P.L., Choudhary, R., Kumar, S., Kumar, N. and Jaiswal, J.P. 2017. Combining ability for yield, associated traits and quality attributes in rice for South Gujrat (*Oryza sativa L.*). J. Appl. Nat. Sci., 9(1):60-67.

Gautam, R.K, Sekhon, R.S. and Bharaj, T.S. 2012 Commercial heterosis and Combining ability in rice hybrid involving bacterial blight resistant and susceptible CMS lines Tropical Agric. (Trinidad)., 89(1):25-32

Gawas, Y. K., Bhave, S. G., Bendale, V. W., Sawant, S. S. and Jadhav, B. B. 2007. Nature and magnitude of heterosis for growth yield and yield components in hybrid rice. J. Maharashtra. Agric. Univ., 32(1): 52-56.

Geetha, S., Soundararaj, K., Palanisamy, S. and Karim, A.A. 1994. Combining ability analysis and gene action relating to grain characters among medium duration rice genotypes. Crop Research., 7(2):239-242.

Ghara, A. G., Nematzadeh, G., Bagheri, N., Ebrahimi, A. and Oladi, M. 2014. Evaluation of general and Specific Combining Ability in parental lines of hybrid rice. Int. J. Agri. Res. Rev., 2(4): 455-460.

Ghara, A. G., Nematzadeh, G., Bagheri, N., Oladi, M. and Bagheri, A. 2014. Heritability and heterosis of agronomic traits in rice lines. Int. J. Farm. and Alli. Sci., 3(1): 66-70.

Ghosh, S. C., Chandrakar, P. K. and Rastogi, N. K. 2013. Gene action and fertility restoration behavior of the tropical japonica/ indica, japonica/ indica derived restorers in rice (Oryza sativa L).Oryza., 50(1):52-57.

Gravois, K.A. 1994. Dialllel analysis foe head rice percentage, total milled rice percentage and rpough rice yield. *Crop Science.*. 34(1):42-45

Gravois, K.A. and Mc New, R.W. 1993. Combining ability and heterosis in U.S. Southern Long grain rice, Crop Science., 33:83-88.

Hasan, M.J., Kulsum, U.K., Lipi, L.F. and Shamsuddin, A.K.M. 2013. Combining ability studies for developin new rice hybrids in Bangladesh. Bangladesh J, Bot., 42(2):215-222.

Hayman, B.I. and Mather, K. 1955. The description of gene interaction in continuous variation. Biometrics., 11:69-82.

Hong, D.L., Yang, K.Q. and Pan, E.F. 2002. Heterosis of F_1's derived from different ecological types and combining ability of their parents in japonica rice (*Orvza sativa*). Chinese J. Rice Science.,16(3):216-220

Huang, Z., Zhao, B. Qi-ming, L. V., Xi-qin, F. U., Xin, Y. and Yuan, L. 2015. Heterosis expression of hybrid rice in natural- and short-day length conditions. Rice Science., 22(2): 81−88.

Hussain, A.A. 1987. Studies on quality status of indigenous upland rice(*Oryza sativa L.*) Genetics., 47(2):145-51.

Iqbal, T., Majeed, A., Khattak, S.I., Ali, F., Malik, S.N., Ahmed, N., Nauman, M., Ali. M. 2018. "Genetic Variability and Interrelationship Studies in "Green Super Rice". Research in Plant Biology., 8:37-41.

Issac, S. 2007. Heterosis for economic traits in early, mid early and very early rice cultivars for the cauvery delta zone. Indian J. Agril. Res., 41(4): 249-255.

Jarwar A.D., Delacruz. Q.D. and Juneja G.S. 2012. Heterosis of some agronomic character in aromatic rice varieties and their F_1 hybrids under newland and upland environment Pak.J. Agri. Engg. Vet. Sci.,20(2):131-40

Jayashudha, S. and Sharma, D. 2009. Combining ability and gene action analysis for grain yield and its components in rice (*Oryza sativa L.*). J. Rice Res., 2(7): 105-111.

Jian Rong Lin, Lin, J.R., Guo, W.M., Hai, S.C., Lin-J.R., Wu-M.G. and Shi-C.H. 2001. Analysis on genetic effects of appearance quality traits in japonica hybrid rice. Chinese J. Rice Science.,2:93-96.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1995 Estimation of genetic and environmental variability in soyabeans. Agro. J., 47:314-318.

Jones, J.W. 1926. Hybrid vigour in rice. J. American Soctety Agronomy., 18:423-428.

Kalaimani, S. and Sundaram, M.K. 1987. Genetic analysis in rice (*Oryza sativa L.*). Madras Agric. J., 74(8-9):369-372.

Kalaimani, S. and Sundaram, M.K. 1988. Combining ability for yield and yield component in rice (*Oryza sativa L.*). Madras Agric J., 75(3-4):99-104.

Kalitha, U.C. and Upadhaya, L.P. 2000. Line x tester analysis of combining ability in rice under irrigated lowland condition. *Oryza*., 37(1):15-19

Karthikeyan, P., Snbuselvam, Y., Palaniraja, K. and Elangaimannan, R.2009. Combining ability of rice genotypes under coastal saline soils. Electronic J. Plant Breed., 1(1):18-23

Kaushik, R.P. and Sharma, K.D. 1986. Extend of heterosis in rice (*Oryza sativa L.*) under cold stress conditions for yield and its components. TAG., 73(1):136-140.

Kavitha, S. and Reddi, N.S.R. 2002. Variability and heritability and genetic advance of some important traits in rice (*Oryza sativa L.*). Andhra Agric. J., 49(3-4): 222-224.

Kaw, R.N. and Khush, G.S. 1985. Heterosis in traits related to low temperature tolerance in rice. Philippines J. Crop Science., 10(2):93-105.

Kempthorne, O. 1957. An introduction to Genetic Statistics. John Wiley and Sons Inc., New York.

Khan, M.N.A., Auryama, S., Tsuzuki, E., Scacisbrick, D.H., Ishimine, Y. and Nakamura, I. 1998. Dry matter accumulation and heterosis in photosynthesis in Fi hybrids of rice (*Oryza sativa L.*). Japanese J. Tropical Agriculture., 42(4):272-281.

Kishor, R., Devi, A., Kumari, P., Dwivedi, S., Giri, S.P., and Pandey, U.P. 2017. Gene action and combining ability in rice (*Oryza sativa L.*) involving indica and tropical japonica genotypes. Int. J, Curr. Microbiol. App. Sci., 6(7):8-16.

Kumar, A., Rangare, N. R. and Vidyakar, V. 2013. Study of genetic variability of Indian and exotic rice germplasm in Allahabad agroclimate. The bioscan., 8(4): 1445-1451.

Kumar, C., Vishwanath, K., Shivakumar, N., Prasad, R.S., Radha, B.N. and Gowda, R. 2012. Utilization of SSR Markers for Seed Purity Testing in Popular Rice Hybrids (*Oryza sativa L.*) Annals of plant sci., 1(1): 1-5.

Kumar, C.R.A. and Rangaswamy, S.R.S. 1984. Combining ability of dwarf lines of Indica rice. *Oryza.*, 21(4):218-284.

Kumar, I. and Saini, S.S. 1983. International heterosis in rice. Genetica Agrasi., 37(3/4):287-297.

Kumar, P. 2008. Combining ability analysis and heterosis for grain yield and its related characters in rice. M.Sc. (Ag.) Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur., 135-136.

Kumar, S., Sigh, H.B., Sharma, J.K. and Sood, S. 2010. Heterosis for morphophysiological and qualitative traits in rice. Oryza., 47(1):17-21.

Kumar, S., Singh, H. B. and Sharma, J. K. 2007. Combining ability analysis for grain yield and other associated traits in rice. Oryza., 44: 108-114.

Kuo, Y.C. and Liu, C. 1986. Genetic studies on large grain in rice. I. Inheritance of heading date, plant height, panicle number and spikelet number. J. Agriculture Research China., 35(1):1-10.

Latha, S., Sharma, D. and Sanghera, G. S. 2013. Combining ability and heterosis for grain yield and its component traits in rice (*Oryza sativa L.*). Not. Sci. Biol., 5(1): 90-97.

Lavanya, C. 2000. Combining ability for yield and its components in hybrid rice. Oryza., 37(1):11-14.

Li, Y.J., Fang, S.H., Lu, Y.g., Li, J.Q., Chen, X.H. and Liu, X.D. 2008. Heterosis analysis on main agronomic traits in autotetraploid rice. J. South China Agril. Uni., 29(3): 117-119

Liang, G.H., Reddy, C.R. and Dayton, A.D. 1972. Heterosis, Inbreeding Depression and Heritablity Estimates in a Systematic Series of Grain Sorghum Genotypes. Crop Sciences., 12(4): 409-411.

Liang, K.J., Lin, W.X., Wang, X.R., Chen, Z.X., Guo, Y.C., Leang Y.Y., Chen, F.Y. and Li, YJ. 2002. Studies on the developmental genetics of tiller number in three line indica hybrid rice. Agricultural Science in China., 1(8) : 837-844.

Liao, F.M., Zhou, K.L, Yang, H.H., Xu, Q.S. and Long, H.P. 2000. Combining ability and heritability of grain quality character in indica hybrid rice. J. Human Agricultural University.,26(5):323-328.

Limbani, P.L., Gangani, M.K., Pandya, M.M., 2017. Genetic variability, heritability and genetic advance in rice (*Oryza sativa L.*). Int. J. Pure App. Biosci., 5(6): 1364-1371.

Liu, W., Zhang, G.Q., Dung, X.H., Zuo, Q.F. and Zhang, J.Z. 2004. Combining ability analysis of major agronomic character of indica-japonica lines in rice. J. South China Agric. Uni., 24(2):1-5.

Malar*viz*hi, D., Thiyagarajan, K. and Manonmani, S. 2004. Prospects of three line system for exploring heterosis and combining ability in rice. International Symposium on Rice - Extended Summarizes.,1:137-138.

Malik, S. and Singh, S. 2013. Combining ability analysis for yield and related traits in rice (*Oryza sativa L.*) The Bioscan., 8(4): 1417-1420.

Mani, S.C., Verma, S.K. and Sharma, R.K. 1997. Genetic variability and character association for panicle traits in Basmati rice. Agricultural Science Digest., 17(3):155-157.

Manonmani, S. and Ranganathan, R.B. 1998. Genetic analysis in early lies of indica rice. Oryza.. 35(4):358-360.

Manuel. W.W. and Palanisamy. S. 1989. Line x tester analysis of combining ability in rice. Oryza., 26(1):27-32.

Maurya, D.M.; Singh, S.K. and Singh, R.S. 1986. Genetic variability in 48 land rice cultivars of Uttar Pradesh, India. IRRN., 11(4) : 13.

Meenakshi, T. and Amirthadevarathinam, A. 1999. Combining ability for yield and physiological characters in semi-dwarf rice. Oryza.. 36(2): 111-113.

Mirarab, M., Ahmadikhah, A. and Pahlavani, M.H. 2011. Study on combining ability, heterosis and genetic parameters of yield traits in rice. Afr. J. Biotechnol., 10(59): 12512-12519

Munhot, M.K., Sarawgi, A.K. and Rastogi, N.K. 2000. Gene action and combining ability for yield, grain quality and other related characters in rice. Oryza., 37(1):1-6.

Murthy, N. and Kulkarni, R.S. 1996. Heterosis in relation to combining ability in rice. Oryza., 33: 153-156.

Murthy, N. and Shivashankar, G. 1992. Combining ability analysis for yield and some physiological traits in rice (*Oryza sativa L.*). Indian J. Genetics., 52(3):321-324.

Murugan, S. and Ganeshan, J. 2006. Combining ability studies in the rice. J. of Interacademicia., 10(1):1-4

Mustafa M.F. and Elsheikh M.A. 2007, Variablity, Corelation and path coefficient analysis for yield and its component in rice. African crops Sci. J., 15(4):183-89

Narsimman, R. Kumar, Thirugnana S., Eswari, R., Kumar, S., Praveen, S. and Anandan, A. 2007 Combining ability and heterisis for grain yield and its component character in rice (*Oryza sativa L.*) crop improvement., 34(2) 16-18

Nath, N. and Talukdar, P. 1997. Genetic variability and correlation of indigenous scented x high yielding non-scented crosses in rice. *Oryza.*, 34(2): 92-93.

Nayak, G., Sreedhar, P., Raju, Surendra Ch. and Vanisree, S. 2015. Heterosis studies of arromatic lines for yield and grain quality in rice (*Oryza sativa L.*) Int. J.App. Bio. Phar. Tech., 6(1):232-239.

Nee T. T. 1982. Genetic variability of physio-chemical traits in rice. M.Sc.(Ag.) Thesis (Unpublished). Punjab Agriculture University, Ludhiana, Punjab.

Padmavathi, P. V., Satyanarayana, P. V., Ahamed, M., Rani, Y. and Rao, V. S. 2012. Studies for yield and yield components trait in hybrid rice (Oryza sativa L.). Electron. J. Plant Breed., 3(3): 836-842.

Panwar, L.L. 2005. Line x tester analysis for combining ability in rice (*Oryza sativa L.*). Indian J. Genet., 65(1):51-52.

Paramasivan K.S.1981. Heritablity and genetic advance in hybrids of tall and indigenous rice (*Oryza sativa L.*). Madras Agric. J., 68(2):135-137

Paramasivan, K.S. 1990. Combining ability in rice. Madras Agric. J., 77(9-12):447-449.

Parihar A and Pathak A.R.2008 Heterosis for varieties quantitative traits in rice. Oryza., 45(3):181-187

Patel, S.R., Desai, N.M. and Kukadia, M.U. 1994. Heterosis for yield contributing characters in upland rice. GAU Research J., 20:162-163

Patil, S. R., Vashi, R. D. Patil, S. S. and Varpe, P. G. 2012. Heterosis for yield and its components in Rice (*Oryza sativa L.*). Agric. Sci. Digest., 32 (2): 111-116.

Peng, J.Y. and Virmani, S.S. 1990. Combining ability for yield and four related traits in relation to breeding in rice. Oryza., 27(1):1-10.

Peng, J. Y. and Virmani, S. S. 1991. Heterosis in some international crosses of rice. Oryza., 28: 31-36.

Petchiammal K.I. and Anand Kumar, C. R, 2007. Combining ability analysis for yield and its attributing traits in Rice (*Oryza sativa L.*)involiving the Assam rice hybrids Int. J. Agric. Sci., 3(2):234-36

Porter, R. 1956. Types de ramification de inflorescence dans le genere, Oryza., 3: 248-264.

Prakash, N., Mishra, C.H., Giri, S.P. and Dixit, S. 2003. Combining ability analysis for yield and other yield contributing traits in rice (*Oryza sativa L.*) CMS system. Annals Agricultural Research., 24(3):552-558.

Prasad S.G., Subba rao, L.V., Sujatha, M. and Chaitanya, U. 2013. Heterosis and combining ability analysis for few wild tolerant rice germplasm at there seedling stage. Int. J. Developmental research., 3(8):010-012

Pratap, N., Shekhar, R. and Soni, S.K. 2013. Combining ability, gene action and heterosis using CMS line in hybrid rice (*Oryza sativa L.*). The Bioscan ., 8(4): 1521-1528

Premkumar, R., Gnanamalar, R. P., and Anandakumar, C. R. 2017. Heterosis analysis for grain yield and yield component traits in rice (*Oryza sativa L.).* J. Pharmacogn. Phytochem., 6(6): 881-884.

Qi, Z.B., Li, B., Wu, Q.Y. and Cai, Y.T. 1990. Heterosis of physiological characters and rice quality characters of F_1 hybrids between indica and japonica crosses. Hereditas., 12(3):7-10.

Rahimi, M., Rabiei, B., Samizadeh, H. and Kafi Ghasemi, A. 2010.Combining ability and heterosis in rice (*Oryza sativa L.*) cultivars. J. Agri. Sci. Tech., 12: 223-231.

Rahman, M., Patwary, A.K. and Miah, A.J. 1981. Combining ability in rice. Indian J. Agric. Sciences., 51(8):543-546.

Raju, C.H.S., Rao, M.V.B., Sudarshanam, A. and Reddy, G.L.K. 2005. Heterosis and inbreeding depression for yield and kernel characters in rice. Oryza.,42(1):14-19.

Ramesh, Ch., Raju, Ch. D., Raju, Ch. S. and Varma, N. R. G. 2018. Combining ability and gene action in hybrid rice. Int. J. Pure App. Biosci., 6(1): 497-510.

Rao, S. and Kulkarni, N. 2004. Heterosis and gene effects for gain yield in inter sub-specific crosses of rice (*Oryza sativa L.*). *Extended Summary.*

Reddy, J.N. and De, R.N. 1996. Variability in lowland rice. Madras Agric. J., 83(4) : 260-270.

Roschevicz, R.I. 1931 A contribution to the study of rice. Turdy Prikl. Bot. Genet. Selek., 27(4):3-133.

Sadukhan, R.N. and Chattopadhyay, P. 2000. Variability and character association between yield and grain quality in aromatic rice. J.Interacad., 4(4) : 494-497.

Sahu, P. K., Sharma, D., Mondal, S., Kumar, V., Singh, S., Baghel, S., Tiwari, A., Vishwakarma, G. and Das, B. K. 2017. Genetic variability for grain quality traits in indigenous rice landraces of Chhattisgarh, India. J. Exp. Bio. Agril Sci., 5(4): 439-455.

Sahu, P., Sharma, D., Singh, S. P., Khute, I. K. and Sao, F. C. 2017. Heterotic expressions evaluation for grain yield and quality traits in CMS based rice hybrids. Int. J. Genet., 9(3): 257-262.

Sahu, P., Sharma, D., Singh, S.P. and Sahu, P. 2016. Gene action and combining ability analysis in CMS based hybrid rice for grain yield and quality attributing traits. Inter. J. Agri. Sci.,8(48): 2024-2029.

Saidaiah, P., Kumar, S. and Ramesha, M. S. 2010. Combining ability studies for development of new hybrids in rice over environments. J. Agri. Sci., 2(2): 226-233.

Saleem, M. Y., Mirza, J. I., and Haq, M. A., 2010. Combining ability analysis of some morphological traits in basmati rice. Pak. J. Bot., 42 (5): 3113-3123.

Sao, A. and Motiramani N.K. 2006. Combining ability analysis for yield and its contributing traits using CMS lines, fertility system restoration system in the rice hybrids. Jordan J. of Agri., 2(1):29-34

Sarathe, M.L. and Singh, S.P. 1986. Combining ability for yield and related characters in rice. Oryza., 23:224-228.

Sarawgi, A.K. and Shrivastava, M.N. 1988. Heterosis in rice under irrigated and rainfed conditions. Oryza., 25(1):10-15.

Sarawgi, A.K.; Soni, D.K. and Shrivastava, M.N. 1994. Variability analysis in rice under irrigated and rainfed situations. Current Research., 23(3/4):33-35.

Sardana, S. and Sasikumar, B. 1987. Genetic variability in cold tolerant genotypesof rice. *Oryza.*, 24 :119-122..

Sarial, A. K. 2014. Heterosis and combining ability analysis for grain quality and physiochemical traits involving fertility restorers with basmati background in Rice (Oryza sativa L.). Electron. J. Plant Breed., 5(4): 615-625

Satheesh, P., Kumar, K., Saravanan and Sabesan, T. 2010. Combining ability for yield & yield contributing chraractrs in rice (Oryza sativa L.). Electron. J. Plant Breed., 1(5): 1290-1293.

Satish, Y. and Ramaiah, K.V.S. 2003. Heterosis for yield and grain quality characters in rice (*Oryza sativa L.*). Annals of Biology., 19(1):7-16

Satyanarayana, P.V., Reddy, M.S.S., Kumar, I. and Madhuri, J. 2000. Combining ability studies on yield and yield components in rice.Oryza., 37(1):22-25.

Seesang, J., Sripichitt, P. and Sreewongchai, T. 2014. Heterosis and inheritance of fertility-restorer genes in rice. Science Asia., 40: 48-52.

Shamsuddin, A.K.M. 1982. Analysis of genetic variation for panicle and grain characterization in relation to grain yield in rice. Pakistan J. Sci. Res., 34(3/4) : 75-78.

Shanthi P., Shanmugasundaram, P. and Nagarajan P. 2003. Combining ability analysis in rice . Oryza., 40(1/2):11-13

Sharma, D.K., Shrivastava, M.N. and Tiwari, D.K. 1987. Line x tester analysis for harvest index and related character in rice (*Oryza sativa L.*). Indian J. Genet., 47(2):211-218.

Sharma, M.K., Richharia, A.K. and Agrawal, R.K. 1996. Variability, heritability, genetic advance and genetic divergence in upland rice. IRRN Res. Notes., 21 : 1, 25-26.

Sharma, R.K., Karanne, K.D. and Dube, S.D. 1996. Combining ability analysis for yield and yield components in rice. Oryza., 33(1):18-20.

Sharma, R.K. and Mani, S.C. 2001. Combining ability studies for grain yield and other associated characters. Crop Improvement., 28(2):236-243.

Sharma, S. K., Singh, S. K., Nandan, R. and Kumar, M. 2012. Identification of restorers and maintainers for CMS lines of rice (*Oryza sativa L.*). Indian J. Plant Genet. Resour., 25(2): 186-188.

Sharma, S. K., Singh, S. K., Singh, S., Kumar, V., Singh, A. and Nandan, R. 2012. Combining ability analysis for yield and its components in hybrid rice. Oryza., 49(3): 171-177.

Shinde, D. A., and Patel, P. B. 2014. Study of heterosis for improvement in aerobic rice (*Oryza sativa L*.)., The bioscan., 9(2): 739-743.

Shivaprasad, G., Subbarao, L.V., Sujatha, M. and Chaitanya, V. 2013. Heterosis and combining ability analysis for few cold tolerant rice germplasm lines at seedling stage, Int. J. Developmental Research., 3(8):010-012

Shrivastava, A. K., Jaiswal, H. K. and Agrawal, R. K. 2012. Combining ability analysis for yield and quality traits in indigenous aromatic rice. *Oryza.*, 49(4): 251-257

Singh, M. and Maurya, D.M. 1999. Heterosis and inbreeding depression in rice for yield and yield components using CMS system. Oryza., 36(1):24-27.

Singh, M., Maurya, D.M. and Singh, M. 1999. Heterosis and inbreeding depression in rice for yield components using CMS line in rice (*Oryza sativa L.*) Crop Research, Hisar., 11(1):131-132.

Singh, N.B. and Singh, H.G. 1985. Heterosis and combining ability for kernel size in rice. Indian J. of Genet., 45(2):181-185.

Singh, N.K., Singh, N.B., Jha P.B. and Sharma V.K. 1993 Combining ability and heterosis for some quality traits in rice. Oryza.,30:159-161

Singh, N.K., Singh, S.. Singh, A.K., Sharma, C.L., Singh, P.K. and Singh, O.N. 2007. Study of heterosis in rice (*Oryza sativa L.*) using line x tester mating system. *Oryza.*, 44(3):260-263

Singh, R. and Singh, A. 1991. Combining ability for harvest index and other related characters in rice. Oryza., 28(1):19-22.

Singh, R.K. and Chaudhary, B.D. 1985. Biometrical Methods in Quantitative Genetic Analysis, Kalyani Publishers, New Delhi, 308.

Singh, R.K. and Singh, O. 2005. Genetic variation for yield and quality characters in mutants of aromatic rice. Ann. Agric. Res., 26(3):406-410

Singh, R.P. 1982. Combining ability for grain weight and its components in rice. Crop Improvement., 9(2):156-159.

Singh, R.P., Singh, R.R., Singh, S.P. and Singh, R.V. 1980. Estimation of genetic components of variation in rice Oryza., 17(1):24-27.

Singh, S. K., Sahu, V., Sharma, A. and Bhati, P.K. 2013. Heterosis for yield components in rice (*Oryza sativa L.*).Bioinfolet., 10(2B):752-761.

Singh, S. K., Singh, C. M., & Lal, G. M. 2011. Assessment of genetic variability for yield and its component characters in rice (*Oryza sativa L.*). Research in Plant Biology., *1*(4):23-26

Singh, S.P. and Haque, M.F. 1999. Heterosis for yield and yield components in rice. Indian J. Genet., 59(2):237-238

Singh, S.P. and Shrivastava, M.N. 1982. Combining ability and heterosis in components of grain yield and panicle geometry in rice. Indian J. Agric. Science., 52(5):271-277.

Singh, S.P., Singh, H.G. and Singh, A.K. 1984. Hybrid vigour for yield and its components in rice. Genetica Iberica., 36(1/2):53-59.

Singh, S.P., Singh, R.R., Singh, R.P. and Singh, R.V. 1980. Combining ability in rice. Oryza., 17(2): 104-108.

Sinha, T.S and Bhattacharya, R.K (1980). Note on genetic variability in sundarban rice varieties under saline soils. J. Agric. Sci., 50(9) : 719-721.

Sivasubramanian, S. and Madhavamenon, P. 1973. Heritability in rice. Madras Agric. J.,60 :1777-1778.

Snedecor, G.J.W. and Cochran, W.G. 1967. Statistical Methods. Iowa St. Uni., 6:135-317

Soni, S. and Sharma, D. 2011. Studies on heterosis for grain yield and its component traits for developing new plant type hybrids in rice (*Oryza sativa L.*) Electronic J. Plant Breeding., 2(4):543-548

Sprague, G.F. and Tatum, L.A. 1942. General verses specific combining ability in single crosses of corn. J. Am. Soc. Agron., 34:923-932.

Sreedhar, S., Reddy, T. D. and Ramesha, M. S. 2012. Expression of heterosis in rice hybrids over three environments. Oryza., 49(1): 10-17.

Srijan, A., Kumar, S. S. and Raju, Ch. D. 2016. Studies on gene action and combining ability in rice (*Oryza sativa L.*). Env. Ecol., 34 (4B): 1749-1755

Srikrishna, L., Sharma, D. and Sanghera, G. S. 2013. Combining ability and heterosis for grain yield and its component traits in rice (*Oryza sativa L.*). Not. Sci. Biol., 5(1): 90-97.

Swain, B., Acharya B. and Pandey K. 2003. Combining ability analysis for yield and its contributing traits in low land Rice. Oryza., 40(3/4):70-72

Tang, Li, Xiao, G.Y., Yuan, L.P. and Deng, X.X. 2002. Study on heterosis of Pei zi 64 X/ javanica rice. Human Agricultural Science and Technology News letter., 3(3):4-10.

Thalapati, S., Guttikonda, H., Nannapaneni, N. D., Adari, P. B., Surendhar Reddy, B. P., Swamy, M., Batchu, A. K., Basava, R. K., Viraktamath, B. C. and Neelamraju, S. 2015. Heterosis and combining ability in rice as influenced by introgressions from wild species *Oryza rufipogon* including qyld2.1 sub-QTL into the restorer line KMR3. Euphytica., 202:81-95.

Thorat, B. S., Kunkerkar, R. L., Thaware B. L., Burondkar M. M. and Bhave S. G. 2017. Heterosis and combining ability in hybrid rice (*Oryza sativa L.*). Contem. Res.India.,7(3): 135-139.

Tiwari, D.N., Tripathi, Santosh Raj and Tripathi, M.P. 2019 Genetic variability and correlation coefficients of major traits in early maturing rice under rainfed lowland environments of Nepal.Hindawi. Adv. in Agric..,19:7-9

Tiwari, D. K., Pandey, P., Giri, S. P. and Dwivedi, J. L. 2011a. Heterosis studies for yield and its components in rice hybrids using CMS system. Asian J. Plant Sci., 10: 29-42.

Tiwari, D. K., Pandey, P., Giri, S. P. and Dwivedi, J. L. 2011b. Nature of gene action and combining ability for yield and its related traits in hybrid rice. Oryza, 48(4): 288-296.

Utharasu, S. and Anandakumar, C. R. 2013. Heterosis and combining ability analysis for grain yield and its component traits in aerobic rice (*Oryza sativa L.*) cultivars. Elect. J. Plant Breed., 4(4): 1271-1279.

Vaithiyalingan, M. and Nadarajan, N. 2010. Heterosis for yield and yield contributing characters in inter sub-specific crosses of rice. Elect. J. Plant Breed., 1(3): 305-310.

Vanisree, S., Anjali, K., Damodar, R.C., Surender, R.C. and Sreedhar, M. 2013.Variability, heritability and association analysis in scented rice. J. Bio. and Sci. Opinion., 1(4): 347-352.

Veeresha, B. A., Hanamaratti, N. G., Salimath, P. M. and Chetti, M. B. 2013. Identification of Restorers and Maintainers for Development of Rice Hybrids. Bioinfolet., 10(2 B): 602-606.

Veni, B.K. and Rani, N.S. 2006. Association of grain yield with quality characteristics and other yield components in rice. Oryza., 43: 320322.

Virmani, S.S.1994. Heterosis and hybrid rice breeding. Springer Verlag, Berlin

Virmani S. S., Aquino R. O. and Khush G. S. 1982. Heterosis breeding in rice (*Oryza sativa L.*). TAG., 63:373-380.

Virmani, S. S., Chaudhary, R. C. and Khus, G. S. 1981. Current outlook on hybrid rice. Oryza., 18: 67-84.

Vivekanandan, P. and Giridharan, S. 1995. Genetic analysis of kernel characters in rice. Madras Agric. J., 82(3):214-215.

Vivekanandan, P., Ranganathan, T.B. and Kaolambananundaram, M.1992. Heterosis for yield and its components in rice (*Oryza sativa L.*). Madras Agric. J.., 79(1):5-8.

Waghmode, B.D and Ingale, B.V. 2011 Evaluation of promising cytoplasmic male sterile lines of rice for agronomical and floral traits. Oryza., 47(2):106-109

Zhu, X. D., Zhao, J. Yan, Q. Q., Zhou, Q. M., Peng, L. J., Xiao, M., Zen, X. D. and Peng, G. D. 2009. Study on combining ability of yield and related traits of hybrid rice with different types of cytoplasm. J.Hunan Agricultural University., 35(4): 352-356

Appendix A: Weekly meteorological data during crop growth period of Rice

(Kharif 2018--19)

Wk No.	Date		Max. Temp. (°C)	Min. Temp. (°C)	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Vapour Pressure (mm of Hg)		Wind Velocity (Kmph)	Evapo-ration (mm)	Sun Shine (hours)
							I	II	I	II			
26		25-01	36.8	27.5	2.0	0	78	53	22.7	22.1	6.6	39.0	5.0
27	Jul	02-08	29.5	24.7	69.6	4	91	84	22.1	23.4	11.0	16.6	0.4
28		09-15	33.5	26.1	13.2	1	82	59	22.1	22.5	8.9	39.1	3.6
29		16-22	35.5	26.4	26.1	3	84	55	23.5	22.0	3.2	36.3	7.5
30		23-29	32.3	25.5	8.4	1	88	77	23.2	24.4	6.3	21.3	2.7
31		30-05	28.0	24.4	99.0	3	90	82	21.2	22.9	10.9	14.5	0.5
32	Aug	06-12	30.2	25.3	185.6	3	89	83	22.8	23.6	9.6	24.3	2.9
33		13-19	30.8	25.4	49.2	2	90	74	22.9	23.6	7.0	18.1	3.8
34		20-26	31.7	25.2	27.8	3	92	75	23.0	24.1	5.3	21.9	3.2
35		27-02	30.9	25.1	53.8	3	92	73	23.1	23.7	4.6	18.2	1.3
36	Sep	03-09	29.5	24.9	239.0	6	94	87	23.2	25.1	5.9	11.6	0.5
37		10-16	30.7	25.0	9.2	1	92	74	22.8	23.4	7.7	21.6	4.3
38		17-23	33.0	25.5	2.4	0	88	63	23.5	22.4	3.6	29.6	8.2
39		24-30	30.2	24.2	178.1	5	91	74	22.1	22.2	4.5	17.7	3.8
40	Oct	01-07	32.0	24.3	1.8	0	90	64	22.0	21.7	3.8	25.3	7.5
41		08-14	31.3	23.6	1.2	0	91	64	21.2	20.5	2.4	23.4	5.4
42		15-21	30.9	21.8	51.0	3	92	65	20.2	18.9	2.6	21.9	5.7
43		22-28	28.1	22.2	27.6	1	92	71	19.6	19.8	3.7	12.5	2.8
44		29-04	31.4	22.2	0.0	0	92	51	19.6	17.2	1.2	19.2	6.0
45	Nov	05-11	30.6	23.0	81.6	4	91	65	20.7	20.1	3.0	92.0	5.5
46		12-18	29.6	15.5	0.0	0	90	38	13.2	11.5	1.8	20.0	8.7
47		19-25	30.2	15.2	0.0	0	89	38	12.8	11.8	1.4	20.2	8.2
48		26-02	29.7	16.3	0.0	0	90	43	13.3	12.8	2.0	20.4	6.3
49	Dec	03-09	28.0	13.3	0.0	0	84	34	10.5	9.4	2.4	21.4	7.6

50	**10-16**	29.5	15.3	0.0	0	91	48	12.5	12.9	1.7	17.3	5.2
51	**17-23**	26.7	14.1	0.8	0	88	42	11.3	11.0	1.9	16.6	4.9
52	**24-31**	26.1	11.9	0.0	0	81	35	9.5	8.2	2.5	21.6	5.7

Appendix B: Mean performance of different parents and checks

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
Parents Lines/Female													
I.Barani	89.00	109.56	25.63	7.30	2.55	167.70	11.60	9.26	2.37	3.91	83.37	30.80	36.94
C.G. ZINC	79.00	94.06	23.69	6.60	2.30	154.30	20.20	8.66	2.44	3.55	78.10	30.22	38.69
SAMLESHWARI	87.00	101.19	25.69	6.40	2.30	139.70	21.70	8.73	2.47	3.53	82.61	30.10	36.43
I.Aerobic	94.50	112.13	26.21	4.50	2.15	163.90	14.40	9.16	2.34	3.91	75.80	27.06	35.69
DURGESHWARI	88.00	103.37	24.83	5.50	2.85	147.60	41.70	7.30	2.92	2.50	67.45	23.62	35.01
Rajeshwari	89.00	106.41	25.49	6.80	2.60	156.00	15.50	9.13	2.25	4.06	82.83	31.12	37.56
IR-64	95.00	110.58	23.86	6.30	3.05	156.20	19.50	9.12	2.68	3.40	76.35	26.66	34.83
Average	88.79	105.33	25.06	6.20	2.54	155.06	20.66	8.77	2.50	3.55	78.07	28.51	36.45
Testers /Male													
K.Jeera	93.00	148.66	27.71	6.20	1.95	78.20	46.60	8.47	2.01	4.22	88.80	32.94	37.10
UPR3565	95.00	113.73	25.70	4.90	2.20	85.20	47.10	12.06	2.20	6.15	84.10	30.64	36.45
J.Sannalu	98.50	100.56	25.23	6.30	1.65	179.60	45.00	7.56	2.14	3.53	83.02	32.40	39.02
Hung	83.50	144.74	24.33	7.40	2.45	122.50	9.60	8.38	2.72	3.08	84.70	32.69	38.60
Muskan	88.00	148.23	30.61	7.00	2.60	99.50	32.20	9.91	2.07	4.63	86.68	32.64	37.66
Average	91.13	126.87	26.44	6.33	2.23	120.01	33.53	9.19	2.27	4.19	84.23	31.64	37.55
Checks													
RAJESHWARI©	89.00	110.58	23.86	6.30	3.07	156.20	19.50	9.12	2.68	3.40	83.68	30.12	35.98
Average	89.00	110.58	23.86	6.30	3.07	156.20	19.50	9.12	2.68	3.40	83.68	30.12	35.98
Overall parental average	**89.88**	**115.67**	**25.60**	**6.26**	**2.44**	**138.96**	**26.50**	**8.98**	**2.40**	**3.83**	**81.34**	**30.07**	**36.91**
Lowest Range	79.0000	94.0600	23.6900	4.5000	1.6500	78.2000	9.6000	7.3000	2.0100	2.4950	67.4500	23.6200	34,83
Highest Range	98.50	148.66	30.61	7.40	3.07	179.60	47.10	12.06	2.92	6.15	88.80	32.94	39.02
SEm +	1.0727	0.9591	0.5229	0.6597	0.0697	1.6566	1.4385	0.0364	0.0253	0.0552	1.3948	1.1581	1.0591
CV	1.6877	1.1725	2.8881	14.8824	4.0423	1.6858	7.6747	0.5728	1.4842	2.0356	2.4249	5.4452	4.057

1 = Days to 50% flowering , 2= Plant height, 3 = Panicle length, 4 = number of effective tillers ,5 = Test Weight of 100 seeds ,6 = Filled grain/panicle , 7 = Unfilled grain/panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, 11 = Biological yield, 12=Economiical Yield, 13 = Harvest index

Appendix C: Mean performance of hybrids for different characters

Characters	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
INDIRA BARANI													
I.Barani*K.Jeera	93.50	167.91	28.57	8.20	3.05	137.60	38.40	8.74	2.45	3.56	84.30	31.54	37.42
I.Barani*UPR3565	92.00	139.22	28.97	6.60	2.60	194.70	38.60	10.74	2.27	4.73	84.20	32.80	38.97
I.Barani*J.Sannalu	95.50	140.78	29.02	5.40	2.95	152.30	19.80	8.78	2.45	3.58	80.60	29.53	36.48
I.Barani*Hung	87.00	133.58	29.17	7.60	2.85	112.80	18.80	8.85	2.74	3.23	75.50	28.70	38.01
I.Barani*Muskan	90.00	143.45	30.30	6.50	2.65	146.30	54.70	9.52	2.50	3.80	77.80	29.78	38.41
Average	91.60	144.99	29.21	6.86	2.82	148.74	34.06	9.33	2.48	3.78	80.48	30.47	37.86
CG ZINC RICE													
CGZ*K.Jeera	80.00	149.94	30.26	8.60	1.05	100.10	192.00	8.47	2.52	3.36	91.90	33.00	35.88
CGZ*UPR3565	86.50	148.60	30.94	5.60	2.70	119.50	72.80	9.16	2.54	3.60	80.60	25.20	31.33
CGZ*J.Sannalu	86.00	152.25	30.48	7.00	2.75	195.90	33.30	8.62	2.55	3.38	101.70	35.17	34.60
CGZ*Hung	97.00	131.40	26.58	6.10	2.65	139.30	40.20	9.72	2.27	4.28	78.07	31.54	40.40
CGZ*Muskan	96.50	168.32	33.19	8.10	1.95	181.00	106.90	8.47	2.46	3.44	85.00	30.94	36.37
Average	89.60	149.25	30.11	7.04	2.32	147.42	79.88	8.96	2.47	3.64	86.29	31.05	36.07
SAMLESHWARI													
SMR*K.Jeera	95.00	134.05	28.06	7.50	2.20	192.00	32.80	8.56	2.55	3.35	84.20	30.43	36.20
SMR*UPR3565	92.00	166.68	33.38	8.30	2.20	183.00	25.70	8.90	2.38	3.74	101.70	33.00	32.47
SMR*J.Sannalu	96.50	126.84	28.36	7.30	2.70	167.80	25.40	9.24	2.42	3.81	93.30	34.17	36.61
SMR*Hung	98.50	118.02	25.84	5.40	2.05	289.30	19.00	8.38	2.40	3.49	87.56	33.72	38.51
SMR*Muskan	97.00	108.57	28.44	6.50	2.40	199.20	23.70	8.53	2.41	3.54	77.34	29.83	38.57
AVERAGE	94.77	133.90	29.03	7.01	2.31	196.45	34.41	8.76	2.44	3.59	88.40	32.03	36.40

INDIRA AEROBIC													
I.Aerobi*K.Jeera	87.00	127.70	27.59	6.00	3.10	99.30	16.60	9.20	2.66	3.46	80.03	31.60	39.50
I.Aerobi*UPR3565	87.50	128.12	27.93	6.20	2.55	133.30	27.90	9.82	2.47	3.98	86.56	33.76	39.00
I.Aerobi*J.Sannalu	86.00	147.66	28.74	9.40	3.05	133.80	24.00	9.21	2.79	3.30	84.10	32.34	38.50
I.Aerobi*Hung	87.00	147.98	28.42	9.10	3.05	145.00	42.40	9.48	2.50	3.79	99.40	36.26	36.50
I.Aerobi*Muskan	93.00	108.98	27.54	6.20	3.20	184.70	25.70	10.78	2.37	4.54	86.92	34.78	40.01
AVERAGE	89.21	132.39	28.21	7.32	2.88	148.76	28.50	9.54	2.54	3.77	87.57	33.46	38.32
DURGESHWARI													
DGR*K.Jeera	95.00	114.25	26.95	8.00	2.70	162.80	66.50	8.44	2.46	3.43	101.07	33.48	33.12
DGR*UPR3565	87.00	149.23	25.60	6.50	2.75	164.00	12.40	8.85	2.52	3.51	83.90	31.36	37.40
DGR*J.Sannalu	91.00	153.00	30.73	6.70	2.60	147.80	35.20	9.60	2.46	3.90	86.60	32.23	37.27
DGR*Hung	93.50	162.08	33.75	6.90	2.85	163.20	83.70	8.87	2.70	3.28	86.48	32.15	37.18
DGR*Muskan	90.00	125.15	30.55	6.80	2.95	121.00	44.20	8.86	2.47	3.59	89.17	33.74	37.83
AVERAGE	90.95	139.35	29.30	7.04	2.79	151.26	45.08	9.03	2.52	3.58	89.13	32.73	36.85
RAJESHWARI													
RJR*K.Jeera	82.00	153.48	30.45	6.70	2.70	157.00	27.80	8.69	2.55	3.41	86.54	35.60	41.15
RJR*UPR3565	87.50	121.19	31.90	4.90	2.65	117.60	78.90	8.95	2.37	3.77	76.10	29.42	38.65
RJR*J.Sannalu	96.00	170.63	31.13	7.60	2.70	155.60	82.60	9.08	2.47	3.67	86.13	31.10	36.10
RJR*Hung	97.00	132.51	28.63	6.30	3.10	169.40	16.70	9.72	2.48	3.92	84.10	27.72	33.00
RJR*Muskan	97.00	117.09	23.08	7.40	2.40	149.90	27.80	10.82	2.32	4.66	81.40	31.12	38.23
AVERAGE	91.74	139.04	29.08	6.66	2.72	150.13	46.48	9.38	2.45	3.83	83.90	31.28	37.33
IR 64													
IR-64*K.Jeera	86.00	139.63	31.44	8.50	3.00	101.40	19.40	8.94	2.55	4.66	83.90	33.56	40.01
IR-64*UPR3565	97.00	161.72	31.36	7.10	3.10	183.80	16.50	9.37	2.73	3.43	85.20	29.20	34.27
IR-64*J.Sannalu	92.50	113.85	25.80	7.10	3.30	144.50	24.30	9.31	2.46	3.78	87.20	32.40	37.17
IR-64*Hung	97.00	109.42	30.61	7.70	2.70	178.20	44.00	9.07	2.39	3.79	87.28	33.91	38.86

IR-64*Muskan	91.00	139.85	30.30	11.30	2.10	79.30	86.80	8.80	2.64	3.33	83.30	31.89	38.25
AVERAGE	92.54	133.92	29.76	8.06	2.82	139.55	39.58	9.15	2.54	3.80	85.13	32.04	37.65
Overall average	91.51	138.6	29.25	7.17	2.66	154.35	44.15	9.15	2.49	3.71	85.97	31.91	37.20
Lowest range	80	108.57	23.07	4.9	1.05	79.30	12.40	8.38	2.27	3.22	75.49	25.2	31.32
Highest range	98.5	170.6	33.75	11.3	3.3	289.3	192	10.82	2.79	4.73	101.7	36.26	41.15
SEm +	0.69	1.16	0.744	0.51	0.058	2.98	1.68	0.03	0.04	0.04	1.89	1.37	1.54
CV	1.06	1.18	3.59	10.16	3.09	2.73	5.38	0.60	2.51	1.56	3.11	6.07	5.87

1= Days to 50% flowering , 2 = Plant height, 3= Panicle length, 4 = number of effective tillers ,5= Test Weight of 100 seeds ,6 = Filled grain/panicle , 7 = Unfilled grain/panicle, 8 = Paddy Length, 9 =Paddy Breadth, 10 = Paddy L/B ratio, , 11=Biological Yield,12 = Economical yield, 13 = Harvest index

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