

**“Estimation of combining ability and heterosis
for drought tolerance in upland rice
(*Oryza sativa* L.)”**

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

**In partial fulfillment of the requirement for
the Degree of**

MASTER OF SCIENCE

In

**AGRICULTURE
(PLANT BREEDING & GENETICS)**

By

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2014

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Lastly, I wish to express my gratitude to the researches whose works have been freely used in the preparation of this manuscript.

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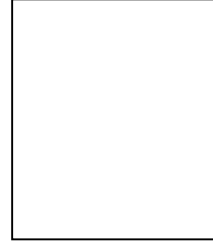
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For the partial fulfillment of the master's degree programme he was allotted a research problem on, “**Estimation of combining ability and heterosis for drought tolerance in upland rice (*Oryza sativa* L.)**” which was successfully conducted by him and being submitted in the form of this thesis.

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LIST OF ABBREVIATIONS

DTH	Days to 50% heading
PH	Plant height (cm)
TPP	No. of tillers per plant
PPP	Panicle per plant
NGPP	No. of grain per panicle
TW	Test weight/ 1000 grain weight (g)
PL	Panicle Length (cm)
GYPP	Grain yield per plant (g)
BY	Biological yield (g)
HI	Harvest index (%)
	Summation
⁰ C	Celsius
⁻¹	Degree
CD	Critical Difference
<i>et al.</i>	And others
g	Gram
Df	Degree of freedom
<i>i.e.</i>	That is
e.g.	Example
M.P.	Madhya Pradesh
G X E	Genotype and environment interaction
Max.	Maximum
Min.	Minimum
Mm	Millimetre
Cm	Centimetre
MI	Millilitre
No.	Number
SD	Standard Deviation
SE	Standard Error
<i>Viz.,</i>	Namely
h^2_b	Broad sense heritability
PCV	Phenotypic coefficient of variation
GCV	Genotypic coefficient of variation

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S.N.	Particulars
3.1	Meteorological data during the period of investigation season (2011)

INTRODUCTION

Rice is the world's most important food crop and a primary source of food for more than half the world population. More than 90 per cent of the world's rice is grown and consumed in Asia where 60 per cent of the people on earth live. Rice accounts for 35 to 75 per cent of the calories consumed by more than 3 billion Asians. It is planted to about 154 million ha. annually or on about 11 per cent of the world's cultivated land. (Khush, 2004). World rice production in 2007 was approximately 645 million tonnes. Asian farmers produce about 90 per cent of the total, with two countries, China and India, growing more than half the total crop.

Rice contributes around 45 percent of India's cereal production and is the main staple food for over 60 percent of the population of the country (Singh *et al.* 2001). It occupies 44.0 million hectares, the largest rice area in the world. Its production in 2007 was 69.35 million tonnes. Even then rice self-sufficiency in India is precarious. The country's population of more than a billion is growing at 1.8% per year, outpacing the 1.4% annual growth rate of rice production. To maintain self-sufficiency, annual production needs to increase by 2 million tonnes every year (IRRI, 2007).

Rice is staple food for many Asian countries. In many Asian countries, rice production would be decreased due to drought stress. Plant breeding and introducing drought resistant varieties as well as improve of drought resistance mechanisms will be useful to solve this problem. Grain yield is a complex polygenic quantitative trait, greatly affected by environment. Hence, selection of superior genotypes based on yield alone as such is not effective. Selection has to be made for the components of grain yield. The systematic breeding program involves the steps like creating genetic variability, practicing selection and utilisation of selected genotypes to evolve promising lines. Estimates of heritability and genetic advance will help in knowing the nature of gene action affecting the concerned trait.

Combining ability analysis helps in the identification of parents with high general combining ability (gca) effects and cross combinations with high specific combining effects (sca) for commercial exploitation of heterosis and isolation of pure lines among the progenies of the heterotic hybrids.

Heterosis in rice was first indicated by Jones (1926) and Ramaiah (1933). Several other workers have reported the heterosis for various economically important characters. The development of F1 hybrids on a commercial scale was a

difficult proposition owing to its strict self pollination. However, concerted efforts by several workers in this direction has made production of F₁ rice hybrids a reality. In order to exploit maximum heterosis, identification of best parents for hybridization is a pre requisite (Rao *et al.* 1996).

Breeding for high yielding varieties of any crop largely depends on the choice of parents. Knowledge of combining ability and heterosis helps in the selection of appropriate parents for a hybridization programme for evolving elite segregants with high grain yield in the segregating generations. (Narasimman *et al.* 2007).

The success of a plant breeding programme greatly depends on correct choice of parents for hybridization and the gene action involving different economic and drought tolerant traits. Combining ability analysis provides such information so as to frame the breeding programme effectively (Dwivedi and Pandey,2012). Among the different methods adopted, the Line x Tester analysis has been recommended for early evaluation of parents, because of its simplicity in both experimentation and analysis (Dhillon, 1975). Knowledge on association of grain yield with its component characters and other morpho-physiological traits governing drought tolerance would be of immense use to breeders in improving efficiency of selection for high yield coupled with drought tolerance (Michael Gomez and Rangasamy, (2002).

Objectives:

1. To estimate the combining ability and gene action for various characters.
2. To study the genetic variability.
3. To study the inter relationship among yield components.

REVIEW OF LITERATURE

The literature relevant to the present study has been reviewed briefly in this chapter under the following heads:

1. Combining ability and gene action for various characters.
2. Genetic variability.
3. Inter relationship among yield components.

1. Combining ability and gene action for various characters.

Combining Ability :

The combining ability is the ability of an inbred or a parent to transmit desirable performance of its hybrid progenies. The average performance of a parents or inbred in a series of cross combinations is known as its „general combining ability and the performance of two specific inbreds in a particular cross combination is known as its „specific combining ability.

Combining ability analysis helps in the identification of parents with high general combining ability (gca) effects and cross combinations with high specific combining ability (sca) effects. Additive and non-additive gene action in the parent estimated through combining ability analysis may be useful in determining the possibility for commercial exploitation of heterosis and isolation of purelines among the progenies of heterotic F₁ (Chakraborty *et al.* 1994).

Days to fifty percent flowering

Kalita and Upadhaya (2000) recorded that Rongadoria was the best combiner for grain yield per plant. They also observed that Maibee/IR 64 was best specific combination for days to 50 per cent flowering.

Bhave *et al.* (2003) studied combining ability analysis for yield and yield components by conducted using 32 F₁ hybrids, 16 restorer lines and 2 maintainer lines of rice. IR-62829A, RTN-73, KJT-1 and KJT-4 were good general combiners for days to 50 per cent flowering and maturity. IR-58025A/RTN 68, IR-58025A x PNL 1 and IR-62829A X PNL 2 which showed high specific combining ability effects were best combination for hybrid breeding.

Allah (2004) observed that, both general and specific combining ability variances were significant for all studied characters except no. of days to heading and grain yield plant-1 indicating the importance of additive and non-additive genetic variance in the inheritance of these characters.

Jagdeesan S. and J. ganesan (2006) study revealed that, results were indicative of predominance of non additive gene actions for all the traits studied . The variances of general combining ability (gca) and specific combining ability (sca) were highly significant . Based on the gca effects of parents, the line IR 58029-99-3-1-3 (L5) and tester BR 4828-2-2-1 (T2) were recorded negative gca effects for days to 50% flowering and plant height , In addition line IR 58108-3-1-1-2 (L6) and tester BR 802-78-2-1-1 (T3) possessed high gca effects , the cross IR 44962-161-2-4-4-2/ AS 37800 and IR 58108-3-1-1-2/AS 37800 showed highly significant results for days to 50 per cent flowering and grain yield per plant respectively.

Singh *et al.* (2007) observed that the magnitude of Specific Combining Ability Variance was higher than General Combining Ability Variance, which reflected that non-additive type of gene action played relatively predominant role in the expression of days to 50 per cent flowering.

Plant height

Reddy (2002) recorded that CN 718-8-21-10 was found to be good combiner plant height.

Number of tiller per plant

Prakash *et al.* (2003) studied combining ability for 10 traits of rice in 13 parental genotypes, consisting of CMS lines as female parents. They identified IR 58025A as a good general combiner for earliness, dwarfness, number of tillers per plant, and number of panicle bearing tillers per plant. Hybrids IR 58025A x Annada, PMS 10A x NDRK-5028, IR 58025A x Sarjo 52 exhibited high specific combining ability effects for grain yield and biological yield were also indicated by them.

Efisue *et al.* (2009) Study revealed that, General combining ability (GCA) effects for females and males were significant for all traits. Female GCA and

specific combining ability (SCA) effects were significant for tiller number, plant height, and specific leaf dry weight. Heritability estimates based on variance ratios ranged from 47% to 67% for plant height, Heritability estimates based on regression were significant and ranged from 22% to 72% for drought-tolerance scores and leaf rolling scores.

Number of panicles per plant

Seyoum *et al.* (2012) reported that highly significant variation was obtained for panicles per plant at three rainfed upland location of south west Ethiopia.

Number of grains per panicle

Singh *et al.* (2007) reported that Saket 4 was the best general combiner for number of effective tillers per hill, Kamini for panicle length and Sudha for number for grains per panicle. They observed that Saket 4 x Sudha, Sita x Vaidhei, Saket 4 x Vaidhei, Prabhat x Sita and Rajshree x Kamini were promising for grain yield.

Test weight

Seyoum *et al.*(2012) reported that test weight showed high GCV and PCV estimates.

Panicle length

El-Rewainy *et al.* (2011) reported that combining ability analysis was carried out in rice through A 8 x 8 diallel set analysis excluding reciprocals involving 8 diverse parents for grain yield and some yield related traits at the Experimental Farm of Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt during 2009 and 2010 summer seasons. Among the parents, IET 1444, Wab 878 were good general combiners for plant height, panicle length.

Grain yield per plant

Babu *et al.* (2000) evaluated thirty-two rice hybrids obtained in line (4 CMS line) x tester (eight testers) fashion. They found CMS lines, IR 58025A and IET10021 to be good general combiners for yield and other yield attributes. They also found some good heterotic hybrids combining for grain yield.

Munhot *et al.* (2000) observed that cross combinations namely RP 2151-

33-2/Pusa Basmati-1 for yield per plant had significant and positive sca effects.

Reddy (2002) reported that Utkalprabha/CN 718-8-21-10, OR 1334-8/CN 1035-59, OR 1334-8/CN 718-8-21-10 and CN 1035-59/CN 718-8-21-10 showed significant positive sca effects for grain yield per plant.

Sharma *et al.* (2002) studied heterosis and combining ability in rice involving a cyto sterile lines using four CMS lines IR 58025A, IR 62829A, IR 68888A, IR 6886A and 18 locally adapted diverse testers in to line x tester fashion. Among 72 crosses attempted only one hybrid IR 68888A/ IR 42253 showed high pollen sterility (99.2%). They observed that lines IR 6886A and IR 58025A were the best general combiners for grain yield and other related traits based on the high spikelet fertility. The F₁ hybrids namely IR 6886A/R 714-3-101, IR 68888A/ IR 64 and IR 58025A/Vaidehi restored good spikelet fertility. Among the testers IR 64, IR 72, Shyamala, Abhaya, R-650-1817, IR 42242, R 574-11 and R-741 were identified as good combiners for grain yield and related traits.

Kumar *et al.* (2004) found that PSRM-1-16-48-1 and RAU 1411-4 were best combiner for yield and its most of the related characters, and reported that the crosses, IR 68886 A x Pusa 1040, IR 68886 A x PSRM-1-16-48-1, IR 58025 x Gautam, IR 68886 A x RAU 1411-10 and IR 68897 A x Dhanalaxmi exhibited high and significant sca effects for grain yield.

Verma and Srivastava (2004) revealed that *per se* performance of the parents is a reflection of their "GCA" effects on most of the crosses. They recorded the genotypes NDR 359 ranked as the top for yield and its associated traits and identified that higher yield was found to be greatly associated with harvest index, biological yield and productive tiller number per plant. They showed most desirable specific combination for hybridity involved high x low general combiners along with high x high with certain limitation of low x low general combiners.

Panwar (2005) observed lines IET 13846 and the testers Kasturi, Basmati 370, Pusa Basmati-1, Taraori Basmati and IR 64 were good general combiners for grain yield per plant and reported that IET 13846 X Pusa Basmati-1, IET 13846 X IR 64, IET 13846 X Kasturi and IET 13846 X Taraori Basmati had high

per se performance with significant sca effects for grain yield.

Sharma *et al.* (2005) found that Punshi, KD-6-7-1 among lines and Neela and Satary among testers were good combiners for grain yield per plant and also reported that two cross combinations CAU-R-1 X Neela and KD-2-7-6-2 X WR-2-3-2 exhibited significant high sca effects for grain yield per plant.

Murugan and Ganesan (2006) studied three cytoplasmic male sterile lines and 6 testers in line x tester fashion. They found L3 and testers T1, T2, and T6 as good general combiners for most of the traits, including grain yield per plant. They also found hybrids, L2 x L3 good specific combiners for grain yield.

Muthuramu *et al.* (2010) observed that, the parents Nootripathu, Mattaikar, Vellaichithiraikar, PMK 3 and NPT 107 were identified as the best genotypes for improvement of yield combined with drought tolerance. The hybrids viz., NPT 107/MDU 5 for rainfed and dry condition and NPT 107/Nootripathu for managed stress condition were observed to have parallelism between desirable mean, sca effects and standard heterosis for most of the drought tolerant traits besides grain yield and hence these hybrids were recommended for commercial exploitation of heterosis. The hybrids obtained by crossing the good general combiners viz., For the crosses of good general combiners viz., PMK 3/Vellaichithiraikar, PMK 3/Nootripathu and Vellaichithiraikar/Nootripathu, can be recommended for the development of high yielding drought tolerant varieties.

Ghosh *et al.*(2014) reported that using line x tester mating design with three CMS lines and seven elite testers, the general combining ability (GCA) of parents and specific combining ability (SCA) of crosses were carried out for grain yield and its attributes. The SCA variance was greater than the GCA variance for grain yield and yield components, suggesting the preponderance of dominance and epistatic gene action in expression of these traits.

Biological yield

Saleem *et al.* (2010) Combining ability analysis was conducted on 12 parental genotypes and their 27 F1 hybrids to identify superior genotypes based on morpho-physiological traits in Basmati rice following line x tester mating design. Highly significant genetic variability was present among treatments,

parents, parents vs. crosses, crosses, testers and line × tester interaction for harvest index, biological yield per plant and yield per plant.

Harvest index

Singh *et al.* (2011) analysis of variance revealed that among the all traits number of spikelets per panicle exhibited high estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) followed by harvest index, grain yield per hill.

Gene action:

Fisher (1918) was the first to partition the genetic variance into three components i.e., additive, dominance and epistatic variance. Additive variance refers to that portion of genetic variance, which is produced by the deviations due to average effects of the alleles of gene at all segregating loci. Dominance variance arises due to the deviation from additive scheme of gene action resulting from intra allelic interaction that is dominance. Epistatic variance arises due to the deviations at a consequence of inter-allelic interactions. Hayman and Mather (1955) further divided the epistatic variance into 3 components (1) additive x additive, (2) additive x dominance, (3) dominance x dominance interactions. Line x Tester analysis (Kempthorne, 1957) has been found to be the best in estimation of unbiased additive and dominance components in the absence of epistasis.

Days to fifty percent flowering

Rao and Kulkarni (2004) estimated gene effects in five intersubspecific (indica x japonica) crosses of which additive and dominance effects were significant for flowering in four crosses and dominance and epistatic components were important for grain yield, plant height, panicle length, filled grains per panicle and harvest index.

Manickavelu *et al* (2006), reported that, plant height were governed by additive gene action; Non-additive gene action was observed for the following traits: drought recovery rate, days to flowering, number of productive tillers/plant, grains/panicle, spikelet fertility, hundred grain weight, biomass yield, root length, dry root weight, root:shoot ratio, harvest index and grain yield.

Plant height

Acharya *et al.* (2000) reported that predominance of non-additive gene action has been reported for plant height, panicle length, harvest index, straw yield per plant and grain yield per plant.

Raju *et al.* (2006) reported that days to 50 per cent flowering, productive tillers per plant, filled grains per panicle and grain yield per plant were predominantly governed by non additive gene action whereas, plant height and panicle length were chiefly governed by additive genetic variations.

Number of tiller per plant

Sharma *et al.* (2005) reported that preponderance of additive gene action for ear bearing tillers per plant, grain length, grain length and breadth ratio, spikelets per panicle and non-additive gene action for plant height, days to 50 per cent flowering, panicle length, grain breadth, filled grains per panicle, grain yield per plant, biological yield per plant and harvest index.

Number of panicle per plant

Veerasha *et al.* (2013) analysis revealed the predominance of non-additive gene action for most of the characters under study. CGMS line IR 68888A was a good general combiner for the number of panicles per plant. These crosses were found to involve at least one parent with high GCA effect and other parents having either high or low GCA effect indicating the involvement of additive as well as non-additive gene action operating in these crosses.

Number of grain per panicles

Patel *et al.* (2013) combining ability analysis in rice carried out during kharif, 2011-12 under coastal salt affected soil at Coastal Soil Salinity Research Station, Danti, Navsari Agricultural University, Navsari, Gujarat. The experiment including 4x12 (line x tester) crossing programme was conducted for investigate the general combining ability (GCA) and specific combining ability analysis (SCA) for the various traits. The general combining ability effect enables to the identification of desirable male and female parents. Parent, IET-18710 as found to be good general combiner for most of the traits viz., grain per panicle. Crosses

were found to involve at least one parent with high GCA effect and other parents having either high or low GCA effect indicating the involvement of additive as well as non-additive gene action operating in these crosses. The preponderance of non additive gene action, presence of substantial degree of sca effects for grain yield and other component characters favoured a hybrid breeding programme in rice.

Test weight

El-Namaky et al. (2010) Egypt has the world's highest rice (*Oryza sativa* L.) productivity, yet yield is constrained by biotic stresses, which are being targeted by breeders. Five parents and their 10 hybrids were used to study gene action, combining ability and heterosis for certain agronomic traits and biotic stresses. The cross Giza177 × M201 gave highly significant and positive estimate of SCA effects for 1000-grain. Significant positive heterosis relative to better parent values would be of interest for flagleaf area, chlorophyll content, panicle length, number of panicles/plant, number of filled grains/panicle, 1000-grain weight and grain yield/plant.

Panicle length

Parimala et al. (2012) Combining ability analysis was carried out for yield and its components in indica and japonica genotypes of rice through diallel analysis. The preponderance of dominant gene action for all the characters studied indicated the scope for exploitation of heterosis in rice. Kavya, BPT-5204 and MLT-278 were found to be good general combiners for productive tillers per hill, filled grains per panicle, panicle length and yield per plant. The hybrid MLT-278 × Kavya with good sca effect for yield involved high × high combining parents, indicating additive × additive type of interactions.

Grain yield per plant

Munhot et al. (2000) reported that dominance gene action is more important for expression of physico-chemical traits like milling percentage, head rice recovery percentage, kernel breadth, elongation ratio and alkali value. They also found that the ratio of additive : dominance variance was closer to unity for grain yield and biological yield suggesting the equal importance of both additive

and dominance gene action in the expression of the traits.

Sreedhar *et al.* (2005) observed that the inheritance of traits like kernel length and breadth was influenced by both additive and non-additive type gene actions. Importance of all types of epistatic interaction were found to be governing the inheritance of grain yield.

Patil *et al.* (2012) observed that the magnitude of mean square due to SCA were smaller than the GCA for the most of the traits indicating the preponderance of additive gene effects for all the character under study, whereas the ratio of the estimates of variances due to GCA to that of SCA indicated the preponderance of non-additive type of gene effects for most of the characters except for kernel length/breadth ratio and protein content. The best general combiners for grain yield per plant were GR-12, IET-20548 and IET-20536, whereas for other yield attributing characters the best general combiners were NVSR-20 and IET-20528. The best specific cross combinations GR-12 x Safed kada, NVSR-20 x IET-20528, Safed kada x Lal kada, IET-20528 x IET-20533 and IET-20548 x IET-20536 showed the highest SCA effect for grain yield per plant.

Biological yield

Kumar *et al.* (2007) reported the preponderance of additive gene action for days to 50 per cent flowering, plant height and preponderance of non additive gene action for length of panicle, biological yield and grain length.

Harvest Index

Sharma *et al.* (2005) reported that non-additive gene action for harvest index. Similar reporting was found by Manickavelu *et al* (2006).

2. Genetic variability

Genetic variability:-

The basic requirement of plant breeding is the presence of genetic variability. Importance of genetic variability in any breeding material is a prerequisite as it provides not only a basis for selection but also some valuable information regarding selection of diverse parents for use in hybridization

programme. Variability in rice, before it became a subject of study by plant breeder was the concern of taxonomists such as Linnaeus (who gave the generic name „Oryza“), Mastura (1933), Porters (1956) and Ghosh *et al.* (1981).

Days to fifty percent flowering

Patra *et al.* (2006) investigated to evaluate the genetic variability of 13 yield attributing characters in 20 long-awned rice genotypes. They indicated that the analysis of variance for all the 13 traits exhibited high genetic variability among 20 long-awned rice genotypes.

Plant height

Kuldeep *et al.* (2004) evaluated seventy rice genotypes for genetic variability and association among various plant characters viz., plant height, number of productive tillers per plant, panicle length, number of days to 50% flowering, flag leaf area, number of days to maturity and grain yield. They observed significant genotypic variation for most of the characters.

Bose *et al.* (2005) studied genetic variability and association of yield attributing characters of grain yield using 35 deepwater rice genotypes. High genotypic co-efficient of variation (GCV) was observed for plant height and days to 50% flowering (DFF). Estimates of the PCV were higher than GCV for all the traits, indicating presence of environmental influence.

Number of tiller per plant

Verma *et al.* (2000) observed that higher GCV and PCV were found. Similar results were found by Patil *et al.* (2003).

Tuwar *et al.* (2013) reported that plant height exhibited high estimates of GCV and PCV preceded by number of tillers.

Number of panicle per plant

Akinwale *et al.* (2011) reported moderate to high differences between genotypic and phenotypic coefficients of variation.

Number of grain per panicles

Sadhukhan and Chattopadhyay (2000) studied 26 aromatic genotypes and observed high Genotypic Correlation Variation for grain per panicle, plant height and kernel length.

Test weight

Karim *et al.* (2007) recorded moderate to high phenotypic and genotypic coefficients of variation.

Akinwale *et al.* (2011) reported moderate to high differences between genotypic and phenotypic coefficients of variation.

Panicle length

Veni *et al.* (2006) reported that kernel length, kernel breadth and length/breadth ratio registered higher variability estimates in hybrids than in parents both at genotypic and phenotypic level. While, kernel length after cooking, elongation ratio, alkali spreading value and amylose content manifested higher values in parents when compared to hybrids.

Sarkar *et al.* (2007) observed that Genotypic and Phenotypic Coefficient of Variation were maximum for cooked kernel length and breadth ratio of cooked rice followed by brown kernel length and breadth ratio. Protein content was positively associated with brown kernel length and breadth ratio while starch content was found to be independent of quality traits.

Grain yield per plant

Verma *et al.* (2000) reported that the higher magnitude of Genotypic Coefficient of Variation and Phenotypic Coefficient of Variation were observed for number of sterile and total spikelets per panicle, grain yield, biological yield, number of productive and total tillers per plant.

Patil *et al.* (2003) carried out the analysis of variance and genotypic coefficients of variation revealed genetic variability for the characters. A high grain yield per plant (18.28 g) was recorded in Badshahbhog; while a low grain yield per plant (4.32 g) was recorded in Aama Gohi. They also observed wide range of variation for ear-bearing tillers (3.50-13.90) and panicle length (18.70-36.60 cm).

Kumar *et al.* (2006) studied to evaluate the genetic parameters for rice cultivars. They recorded high variability for grain yield per plant and concluded that additive gene action was important for grain yield per plant.

Biological yield

Verma *et al.* (2004) reported moderate genotypic and phenotypic coefficients of variation.

Chaudhary *et al.* (2004) reported high genotypic and phenotypic coefficients of variation.

Harvest Index

Nayak *et al.* (2004) observed high genotypic and phenotypic coefficients of variation for harvest index.

3. Interrelationship among yield components

Days to fifty percent flowering

Lakshmi *et al.*(2014) the results revealed that grain yield per plant to be positively and significantly associated with days to maturity, number of productive tillers per plant, plant height and kernel length indicating importance of these traits as selection criteria in yield improvement programmes.

Sarker *et al.*(2014) the results indicated that days to 50% flowering (0.42*), days to maturity (0.35*), total tillers hill-1(0.71**), effective tillers hill-1 (0.82**) had positive and significant association with yield plant-1 for phenotypic correlation coefficient; whereas, unfilled grains panicle-1 (-0.19*) had significantly negative correlation with yield. For phenotypic correlation coefficient, the days to 50% flowering (0.50*), days to maturity (0.39*), total tillers hill-1(0.80**), effective tillers hill-1 (0.88**) showed positive and significant association with yield plant-1, on the other hand unfilled grains panicle-1 (-0.19*) had significantly negative correlation with yield.

Plant height

Lakshmi *et al.*(2014) the results revealed that grain yield per plant to be positively and significantly associated with plant height.

Number of tiller per plant

Sarker *et al.*(2014) observed that total tillers hill-1(0.71**) had positive and significant association with yield plant per plant for phenotypic correlation coefficient.

Number of panicle per plant

El-Rewainy *et al.* (2011) observed that significant and negative estimates of phenotypic correlation coefficients were recorded between number of panicles/plant and each of panicle length (-0.445) and 100-grain weight (-0.295), as well as between the last ones with panicle length (-0.312).

Number of grain per panicles

Yogameenakshi *et al.* (2004) reported that number of grains per panicle and harvest index exhibited highly positive correlation with grain yield and also a positive intercorrelation among themselves.

Seyoum *et al.* (2012) revealed that grains per panicles had maximum positive direct effect and highly significant ($r=0.906^{**}$) genotype correlation coefficient with grain yield. The present study revealed that for increasing rice yield in upland ecology, a genotype should possess more number of grains per panicles, tillers per plant.

Test weight

Ifftikhar *et al.* (2009), Hairmansis *et al.* (2010) reported 1000-grain weight showed very weak correlation with grain yield.

Panicle length

Sadhukhan and Chattopadhyay (2000) reported that yield per plant was positively correlated with kernel length but was negatively correlated with kernel breadth. He also found negative correlation between kernel length and width.

Veni and Rani (2006) reported that panicle length is positively and significantly associated with total spikelets per panicle.

Grain yield per plant

Tomar *et al.* (2000) reported that grain yield per plant was positively associated with plant height, number of effective tillers, panicle length, number of grains per panicle, harvest index, biological yield and days to 50 per cent flowering.

Chakraborty (2001) reported positive correlations of grain yield per plant with plant height, panicles per plant, grains per panicle. He also observed that the harvest index and panicle length showed high heritability and genotypic correlation coefficient with the yield.

Nayak *et al.* (2001) reported that grain yield showed significant positive correlation with plant height, panicle number per plant, panicle length, total number of spikelets per panicle and total number of grains per panicle at both genotypic and phenotypic levels.

Shashidhar *et al.* (2005) reported that grain yield showed significant positive association with plant height, productive tillers per plant and harvest index at both phenotypic and genotypic levels.

Sravan *et al.* (2010) studied that grain yield per plant had significant positive correlation with biological yield per plant, harvest index, panicles per plant, plant height, spikelets per panicle, panicle length, test weight, spikelet fertility and flag leaf length.

El-Rewainy *et al.* (2011) analysed that grain yield was positively and strongly correlated with each of number of panicles/plant (0.563), 100 grain weight (0.659) and panicle length (0.330). However, a highly significant and positive estimate of phenotypic correlation coefficient (0.574) was recorded between plant height and panicle length.

Biological yield

Vikram *et al.* (2011) observed positive significant correlation of biological yield with grain yield. Similar finding was reported by Mohankumar *et al.* (2011).

Harvest Index

Sravan *et al.* (2010) studied that genetic variation and interrelationship of grain yield and its component traits in upland direct seeded rice was carried out using thirty six exotic breeding lines. High genotypic coefficient of variation was exhibited for grain yield followed by harvest index and flag leaf length.

Path analysis

Sravan *et al.* (2010) Path analysis revealed that the biological yield was the major contributor of grain yield per plant followed by harvest index and spikelets per panicle. For maximizing the grain yield per plant emphasis should be given in selection of characters such as higher biological yield, harvest index and more number of spikelets per panicle for further crop improvement programmes.

Sarker et al.(2014) Path analysis revealed that days to maturity (0.87**), total number of tillers hill-1(0.25**), effective number of tillers hill-1(0.48**), panicle length (0.68**) and number of filled grain panicle-1 (1.29**) had positive direct effects on yield plant-1. Results suggest days to maturity, total number of tillers hill-1, and effective number of tillers hill-1 may be used as reliable criteria for improving yield of early maturing rice.

MATERIAL AND METHODS

Experimental site:-

The present study entitled “**Estimation of combining ability and heterosis for drought tolerance in upland rice (*Oryza sativa* L.)**” was conducted at Experimental Farm, College of Agriculture, Rewa, Department of Plant Breeding and Genetics, Jawarharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during *Kharif* 2011-2012.

Climate and weather:-

Rewa is situated at 24.31⁰ N latitude and 81.15⁰ E longitude and at 365.7 meters above mean sea level. climate is typically semi-arid having subtropical climate. Rewa traditionally comes under rice - wheat crop zone of Madhya Pradesh and classified as "Kymore plateau and Satpura hills agro-climatic zone". The maximum temperature during the month of June and July reaches up to 41.16⁰C, whereas minimum temperature goes below 14.25⁰C in the month of November or December. The average rainfall in this region is 1131.80 mm which is mostly received during monsoon season between June to end of September with little occasional showers in other seasons.

This area as per National Bureau of Soil Science and Land Use Planning of ICAR comes under agro-ecological sub region number 10.1 as sub-humid dry eco-region. The soil of experimental areas was silty clay loam with uniform topography.

Experimental material:-

The biological material used in the present study comprises of seven parents *viz.*, REWA-1103-IR, IET-22107, IR-79971-Rewa51, IR82635-47-1, OM7938, IR-82639-115-1, IR-826310-67-2 as lines and three parents IR84898-B-168-39, CRR451-193-3-B, DANTESWARI, as tester.

Table- 3.1 Average weekly metrological data of year (June to October 2011)

Stan- dard week No.	Period	Rainfall (mm)	No. of rainy days	Temperature °C		Relative humidity (%)		Bright sun shine
				Max	Min	N 0705 h	X 1405 h	
23	June 4-10	10.6	1	41.16	25.96	81.85	29.57	7.64
24	June 11-17	70.1	4	40.38	25.85	83.71	32.00	5.94
25	June18-24	210.6	6	35.95	24.47	90.28	50.85	2.34
26	June25-1 July	46.2	3	30.18	23.80	88.00	66.28	4.47
27	July 2-8	35.0	3	31.12	24.00	85.85	60.85	5.10
28	July 9-15	29.8	1	34.24	24.85	86.00	53.57	5.20
29	July 16-22	61.6	3	33.50	25.62	86.28	52.71	3.44
30	July 23-29	114.2	4	29.30	23.45	90.00	67.71	2.06
31	July 30-5 Aug	4.0	2	33.54	24.88	87.57	58.00	6.17
32	Aug 6-12	152.8	5	31.91	24.38	90.85	71.28	2.09
33	Aug 13-19	164.4	6	28.64	29.08	90.00	78.28	1.51
34	Aug 20-27	11.8	2	36.17	23.41	84.42	54.42	5.14
35	Aug27-2 Sept	00.0	0	33.02	24.14	86.00	56.85	6.74
36	Sept 3-9	39.6	3	31.70	24.28	86.00	58.28	6.09
37	Sept 10-16	61.2	3	31.37	23.48	87.71	62.57	2.80
38	Sept 17-23	17.0	3	31.68	23.48	86.85	65.85	5.07
39	Sept 24-30	78.2	3	31.28	22.54	88.28	62.71	3.07
40	Oct 1- 7	24.8	0	32.21	20.17	84.42	58.50	6.24
41	Oct 8-14	00.0	0	33.31	20.17	87.00	56.75	6.91
42	Oct 15-21	00.0	0	34.21	19.24	85.00	60.40	7.20
43	Oct 22-28	00.0	0	32.65	15.71	84.14	58.55	7.88
44	Oct29-Nov 04	00.0	0	32.08	14.25	88.33	63.60	7.37
Total		1131.80	56					

Source: Meteorological observatory, Kuthulia Farm, College of Agriculture, Rewa (M.P.)

Methods:-

For the development of F₁ seeds, ten parents consisting of seven as lines and three as testers were sown in the nursery bed. Crosses were attempted in such a way that each seed parent i.e., each lines was pollinated by all pollen parents presented in Table . The F₁ seeds from each of twenty one cross made was collected separately.

Crossing programme:-

The production of F₁ hybrids involved the following steps

Selection / Preparation of female plants for hybridization:-

Parents plants of Lines REWA-1103-IR, IET-22107, IR-79971-Rewa51, IR82635-47-1, OM7938, IR-82639-115-1, IR-826310-67-2 were selected from the plots. The main criteria of selection was that plants should be healthy and vigorous. The selected plants were uprooted, labelled and transferred into earthen pots before 8.00 AM. A day before the pollination, clipping was done in the evening hours. The spikelets of the plant were clipped one third at the top, without damaging the stigma. Emasculation was done by suction method. The emasculated panicles were completely covered with butter paper bags to avoid outside pollen grains to fertilize the plants.

Pollination of lines parents by tester parents:-

The panicles of desired male parents, which were in flowering were collected, labelled and then panicles were placed in a glass containing water. These glasses were placed in the pollination chamber with an airtight room and temperature was maintained at 40 ° C to facilitate release of pollen dust. After 15 minutes, if the panicles was disturbed the pollen can be seen in the form of fine dust. The female parent planted in pots and whose spikelets were clipped was brought and dusted with the pollen by just tapping the panicle of the pollinators. Entire spikelets on a plant were pollinated by just shaking the panicle. Soon after the pollination, the ear head was covered by butter paper bag to avoid any cross pollination. The ear heads were bagged and labelled with the name of the parents.

Details of parents used in the study:- Table- 3.2

Genotype / Parentage
Lines
REWA-1103-IR
IET-22107
IR-79971-Rewa51
IR82635-47-1
OM7938
IR-82639-115-1
IR-826310-67-2
Tester
IR84898-B-168-39
CRR451-193-3-B
DANTESWARI

Harvesting of F1 seeds:-

The setting and maturity of seeds was completed approximately in thirty days from the date of pollination. These panicles were harvested, threshed separately and stored in labelled envelope after sun drying.

The seeds were also treated with fungicide as a precautionary measure against fungal attack before storing in paper bags.

Raising of F1's and parents:-

During *kharif* 2011, the treated seeds of twenty hybrids generated during the previous season were carefully germinated in petriplates with moist filter paper. These petriplates were kept in germinator. Seven lines along with three testers were also sown in nursery bed on the same day. Germinated seeds were transferred to wooden trays after three days.

Planting of F1's and parents:-

Twenty one crosses along with ten parents were planted in a Randomized Block Design with three replications during the *kharif* season 2011 and twenty five day old seedlings were transplanted with a spacing of 20 X 15 cm. All standard agronomic packages and practices were followed.

List of Crosses: Table- 3.3

S. No	Name of Crosses
1	REWA-1103-IR x IR84898-B-168-39
2	REWA-1103-IR x CRR451-193-3-B
3	REWA-1103-IR x DANTESWARI
4	IET-22107 x IR84898-B-168-39
5	IET-22107 x CRR451-193-3-B
6	IET-22107 x DANTESWARI
7	IR-79971-Rewa51 x IR84898-B-168-39
8	IR-79971-Rewa51 x CRR451-193-3-B
9	IR-79971-Rewa51 x DANTESWARI
10	IR82635-47-1 x IR84898-B-168-39
11	IR82635-47-1 x CRR451-193-3-B
12	IR82635-47-1 x DANTESWARI

13	OM7938 x IR84898-B-168-39
14	OM7938 x CRR451-193-3-B
15	OM7938 x DANTESWARI
16	IR-82639-115-1 x IR84898-B-168-39
17	IR-82639-115-1 x CRR451-193-3-B
18	IR-82639-115-1 x DANTESWARI
19	IR-826310-67-2 x IR84898-B-168-39
20	IR-826310-67-2 x CRR451-193-3-B
21	IR-826310-67-2 x DANTESWARI

Observations recorded

Observations were recorded on five randomly selected plants of each crosses and parents in each replications for following traits.

(A) Agronomic Characters

Days to 50 per cent flowering

The number of days from sowing to the date when primary panicles in 50 per cent plants were in heading were recorded.

Plant height (cm)

The height of plant was measured in centimeters from the ground level to the tip of primary panicles at the time of harvest.

No of tillers per plant

The total numbers of tillers in each plant were recorded at the time of harvest.

No of panicles per plant

The total numbers of panicles in each plant were recorded at the time of harvest.

No of grains per panicle

The total numbers of grains per panicle in each plant were recorded at the time of harvest.

Test weight (gm)

One thousand filled grains were taken and weighed in gram.

Panicle length (cm)

The length of five panicles of each plant was measured from base to the tip of the panicle excluding awns at the time of harvest.

Grain yield per plant (g)

The weight of grains (filled) of each plant in grams was recorded.

Biological yield per plant (g)

Weight of each plant excluding root was recorded and expressed in grams

Harvest index

The ratio of grain yield to the biological yield of each plant was calculated and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Statistical Analysis

The data recorded on 21 crosses and 10 parents for agronomic characters were subjected to the following analysis.

Analysis of variance

The average of all genotypes was subjected to variance analysis and test of significance as per the method of **Fisher (1935)**.

Source of Variation	Degree of Freedom	Mean sum of squares	Expected mean sum of squares
Replications	r-1	Mr	
Treatments	t-1	Mt	Error! Reference source not found. ² e + r Error! Reference source not found. ² g
Error	(r-1) (t-1)	Me	Error! Reference source not found. ² e

r = Number of replication; t = Number of treatment

Parameters of variation:

Mean

Mean is calculated by the following formula:

$$X = \sum X_i / n$$

Where,

$\sum X_i$ = Summation of all the observation

n = Total number of observation

Range

Range is the difference between the least and the greatest terms of a series of observation and thus provides the information about the variability present in the genotypes.

Genetic Variability

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated by the method suggested by **Burton (1952)**.

Phenotypic coefficient of variation (PCV)

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

$$PCV = (\sigma_p / \bar{X}) \times 100$$

$$\text{where, } \sigma_p = \sqrt{\sigma^2_p}$$

Genotypic coefficient of variation (GCV)

$$GCV = (\sigma_g / \bar{X}) \times 100$$

$$\text{Where, } \sigma_g = \sqrt{\sigma^2_g}$$

Where,

σ^2_p = Phenotypic variance

σ_p = Phenotypic standard deviation

σ^2_g = Genotypic variance

σ_g = Genotypic standard deviation

σ^2_e = Environmental variance

\bar{X} = General mean

The estimates of PCV and GCV were classified as low, moderate and high according to **Sivasubramanian and Madhavamenon (1973)**.

< 10 per cent = low

10-20 per cent = moderate

> 20 per cent = high

Heritability (broad sense)

It is the ratio of genotypic variance to the phenotypic variance. Heritability

for the present study was calculated in broad sense by adopting the formula suggested by **Hanson *et al.* (1950)**.

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

Where,

h^2 (bs) = Heritability in broad sense,

σ^2_g = Genotypic variance,

σ^2_p = Phenotypic variance

h^2 (bs) is categorized as

< 30 = low

30-60 = moderate

> 60 = high

Genetic advance

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. Expected genetic advance (GA) was calculated by the method suggested by **Johnson *et al.* (1955)**.

$$GA = K \cdot \sigma_p \cdot h^2(bs)$$

Where,

GA = Genetic advance

K = Constant (Standardized selection differential) having the value of 2.06 at 5 per cent selection intensity

h^2 = Heritability of the character

σ_p = Phenotypic standard deviation

Genetic advance as percentage of mean

It was calculated by the following formula

$$GA \text{ as percentage of mean} = \frac{\text{Genetic advance}}{\text{General mean}} \times 100$$

GA was categorized as

> 20 per cent = high

10-20 per cent = moderate

< 10 per cent = low

Combining ability analysis

Combining ability analysis was carried out by the method suggested by Kempthorne (1957). Mean sum of squares that arises due to different sources of variation were estimated and their expected genetic values were calculated. A model analysis of variance (ANOVA) table for Line x tester analysis is given below:

ANOVA table for line x tester Analysis

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

Where,

r = number of replications

l = number of lines

t = number of testers

Estimation of full sibs and half sibs covariance were calculated from mean squares using following formula:

$$\text{Cov. (HS)} = \frac{ML + Mt - 2M (L \times t)}{r (L \times t)}$$

$$\text{Cov. (FS)} = \frac{\text{Me} + \text{ML} + \text{M (L x t)} - 3 \text{ Me} + 6\text{r Cov. (HS)} - \text{r (L x t) Cov (HS)}}{3\text{r}}$$

Cov.(HS) and Cov.(FS) were utilized to estimate variance due to general combining ability (GCA) and variance due to specific combining ability (SCA) as under:

$$\text{Variance of GCA} = \text{Cov. (HS)}$$

$$\text{Variance of SCA} = \text{Cov. (FS)} - 2 \text{ Cov (HS)}.$$

Estimation of GCA and SCA effects

The GCA and SCA effects of ijk^{th} observation were estimated by adopting the following model.

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

Where,

- i = 1,2,..... i^{th} line
- j = 1,2,..... j^{th} tester
- k = Number of replications
- μ = Mean
- g_i = GCA effect of i^{th} line
- g_j = GCA effect of j^{th} tester
- s_{ij} = SCA effect of hybrid of i^{th} line with j^{th} tester
- e_{ijk} = Error effect associated with ijk^{th} observation

Significance of GCA effects of lines is tested as :

$$t = \frac{g_i}{\text{SE}(g_i)}$$

Significance of GCA effects of testers is tested as :

$$t = \frac{g_j}{SE(g_i)}$$

Significance of SCA effects of hybrids is tested as :

$$t = \frac{S_{ij}}{SE(S_{ij})}$$

The standard errors pertaining to GCA and SCA effects were worked out from the square root of error variance effects as given below:

(i) Standard error for testing the GCA effects of lines :

$$SE(g_i) = \frac{\sqrt{Me}}{rt}$$

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

$$SE(g_i - g_j) = \frac{2 Me \sqrt{\quad}}{rt}$$

(iii) Standard error for testing the GCA effects of testers

$$SE(g_j) = \frac{\sqrt{Me}}{R \ell}$$

Heterosis

Heterosis for each trait was worked out by utilizing the over all mean of each hybrid over replication for each traits. Relative heterosis was estimated as per cent deviation of hybrid value from its mid parental value. The formula used for estimating relative heterosis is under:

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

where,

d_i = Heterosis over mid parental value (relative heterosis),

$\overline{F_1}$ = Mean hybrid performance, and

\overline{MP} = Mid parental value i.e., the arithmetic mean of two parents involved in the respective cross combination.

Heterobeltiosis was, calculated as the deviation of hybrid from the better-parent as under:

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

Where,

d_{ii} = Heterobeltiosis i.e. heterosis over better-parent,

\overline{BP} = Average performance of better-parent in the respected cross combination.

The significance of different types of heterosis was carried out by adopting „t“ test as suggested by Wynne *et al.* (1970) and heterobeltiosis by Sarawgi and Shrivastava (1988)

$$t \text{ (relative heterosis)} = \frac{\overline{F_{ij}} - \overline{MP_{ij}}}{\sqrt{(3/8) Me}} \times 100$$

$$t \text{ (heterobeltiosis)} = \frac{\overline{F_{ij}} - \overline{BP_{ij}}}{\sqrt{S^2 (1/2)}} \times 100$$

where, $\overline{F_{ij}}$ = Mean of i, j^{th} cross,

$\overline{MP_{ij}}$ = Mid parental value for i, j^{th} cross

S^2 = Error mean of squares

$\overline{BP_{ij}}$ = Better parental value of i, j^{th} cross

Me = Estimate of error variance

Correlation coefficient analysis

Correlation coefficients were calculated for all the character combinations at genotypic and phenotypic levels as per the formula given by **Miller et al. (1958)**.

$$r(X_i X_j) = \frac{\text{Cov.}(X_i X_j)}{\sqrt{\text{Var}(X_i) \text{Var}(X_j)}}$$

Where,

$X_i X_j$ = Coefficient of correlation between characters X_i and X_j

$\text{Cov}(X_i X_j)$ = Covariance between characters X_i and X_j

$\text{Var}(X_i)$ = Variance of character X_i

$\text{Var}(X_j)$ = Variance of character X_j

Path coefficient analysis

The Path analysis was originally developed by Wright (1921) and elaborated by Dewey and Lu (1959). Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable.

EXPERIMENTAL RESULTS

The experimental findings are being presented under the following heads:

1. Variability parameters and Gene action for yield and its related characters
2. Combining Ability analysis for yield and its related characters.
3. Heterosis
4. Association Analysis
 - a. Correlation
 - b. Path Coefficient Analysis

4.1 Variability parameters for different characters

4.1.1 Mean performance of genotypes for different characters

The different genotypes i.e., seven lines, three testers and their twenty one F₁s were first judged based on their mean performance for different character (Table 4.a, 4.b). The observation recorded on five randomly selected plants i.e., 10 parents and 21 hybrids into three replication for different characters have been presented below:

4.1.1 (a) Mean performance of parents

1. Days to 50 per cent flowering

The range for Days to 50 per cent flowering varied from 65.67 days (IR-826310-67-2/DANTESWARI) to 95.25 days (IR-82639-115-1/DANTESWARI) with an overall average of 70.33 days. The female parent (IR-82639-115-1) flowered in 71.00 days followed by IR-826310-67-2 (69.33 days) and OM-7938 flowered in 68.67 days. Whereas, male parents DANTESWARI showed the maximum days to flowering of 71.00 days followed by CRR451-193-B-3 (70.67 days) and IR84898-B-168-39 flowered in 66.00 days with an average of 70.25 days among testers.

2. Plant height (cm)

The range of Plant height varied from 77.00 cm (IET-22107) to 103.00cm IR-84898-B-168-39 with an overall average of 93.25 cm. The

highest plant height of 103 cm was observed in the genotype IR-84898-B-168-39 followed by 101cm (DANTESWARI) while shorter plant was observed in (CRR-451-193-3-B) (99.67 cm) with an average of 101.22 cm among the testers. IR-826310-67-2 (89.33 cm) was found tallest followed by IR-79971-REWA-51 88.33 cm and the shortest plant height was found for (IET-22107) (77.00 cm) with an average of 84.99 cm among the males.

3. Number of tillers per plant

DANTESWARI had maximum of tillers 18.67 whereas, OM-7938 (9.33), had minimum number of tillers with an overall average of 15.55 among the parents, among the females the value ranged from 9.33 (OM-7938) to 17.67 (IET-22107) number of tiller with an average of 14.42 number of tillers. Amongst male parents, DANTESWARI exhibited maximum tillers (18.67) followed by CRR451-193-3-B (17) with an average of 17 number of tillers per plant. The lowest value for this trait was recorded in IR-8498-B-168-39 (15.33).

4. Number of panicles per plant

Among the parents, panicle per plant ranged from 6.00 (OM7938) to 11.00 DANTESWARI with an overall average of lines 8.66 and over all range of tester is 10.44, while lowest value of line (6.00) (OM7938) and maximum value 10.33 IR-82635-47-1 ,lowest value of tester 10.33(IR-84898-B-168-39) and highest value is 11.00 (DANTESWARI) with an average of 17 in the testers.

5. Number of grains per plant

The overall average of grain per plant for lines was 106.4 while, REWA-1103-IR showed highest (130.67) and the lowest was recorded 94.67 (IR-82639-115-1). In the testers the highest value was recorded for G DANTESWARI (125) followed by 116.67 (IR-84898-b-168-39) with an average of 118.89 among the testers CRR451-193-3-B showed the lowest 115.

6. Test weight (g)

Test weight ranged from 22.67 (REWA-1103-IR) to 26.33 (IR-

84898-B-168-39) among the parents. In the lines (IR-826310-67-2) had maximum test weight (25) and (REWA-1103-IR) showed minimum test weight 22.67 with an average of 24.09 among lines. In testers (IR-84898-B-168-39) showed the highest test weight (26.33) followed by genotype CRR451-193-3-B (25.67) and the lowest was recorded in the 24.67 (DANTESWARI) with an average of (25.55) in the testers.

7. Panicle length (cm)

The panicle length varied from 16.67cm (IR-79971-REWA-51) to 20.67 cm (IET-22107) with an overall mean of 17.76 cm lines. In the testers DANTESWARI showed maximum panicle length of 20.67 cm followed by IR-84898-B-168-39 (20.00 cm) with an average of 20.22 cm and the lowest were recorded for the tester CRR451-193-3-B (20.00 cm).

8. Grain yield per plant (g)

Genotype IR-79971-REWA-51 had the highest (20.33 g) for the grain yield per plant and the lowest was recorded for IR-826310-67-2 (4.67g) with an overall average of 11.47 among the female parents. The average of grain yield per plant of the male parent was 14.22 g with the highest recorded for the genotype IR-84898-168-39 (15.67g) followed by CRR451-193-3-B (14.00g) and the lowest was recorded for DANTESWARI (13.00 g) among the testers.

9. Biological yield (g)

The biological yield in parents ranged from 20.33 g (IR-826310-67-2) to 56.33g (IR-82635-47-1) with an overall average of 35.95 g. in lines, while in the testers it ranged from 30.67 g (DANTESWARI) to 37.67 g (IR-84898-168-39) ,34.00g (CRR451-193-3-B) with an average of 34.11g., Genotype (IR-82635-47-1) showed maximum value of biological yield of 56.33g followed by 51.7 g (IR-79971-REWA-51) and followed by 33.67g(OM-7938) was recorded in the lines.

10. Harvest Index percentage

The overall average of harvest index among the lines was 30.297. The lowest value was observed as 22.85 (IR-826310-67-2) and genotype (IR-84898-B-168-39) showed highest value (42.40) among

parents. In the lines the highest value was recorded in REWA-1103-IR (39.91) followed by IR79971-REWA (39.29) with an average of 42.21. Among the testers (IR-84898-B-168-39) showed the highest value of 42.40 followed by CRR451-193-3-B (42.13) whereas, DANTESWARI (42.12) showed the lowest value among testers.

4.1.1 (b) Mean performance of hybrids

The mean performance of twenty one hybrids for different characters is presented in Table 4 a and 4 b. The mean performance of different characters are described as below:

1. Days to 50 per cent flowering

The variation for this trait ranged from 65.67 days (IR82630-67-2/DANTESWARI) to 75 days (IR82639-115-1/DANTESWARI) with an overall hybrids mean of 71.00 days. The hybrid IR82630-67-2/CRR451-193-3-B showed earliness (66) followed by IET-22107/ IR84898-B-168-39 (68.00), IR82630-67-2//IR84898-B-168-39 (69.00), IR-79971-REWA-51/IR84898-B-168-39 (69.00), REWA-1103-IR/IR84898-B-168-39 (69.33), OM-7938/CRR451-193-3-B (70.67) and IET-22107/DANTESWARI (71.00). While the cross (IR82639-115-1/DANTESWARI) (75.00) had maximum value of days to 50 per cent flowering, all over lowest range of flowering 65.67 days and highest range 75 days of flowering.

2. Plant height (cm)

The range of Plant height varied from 77.33 cm (IR82639-115-1/CRR451-193-3-B) to 105.33 cm (IET-22107/ IR84898-B-168-39) with an overall average of 94.85 cm. Highest mean value for this trait were recorded for (IET-22107/IR84898-B-168-39) (105.33), followed by REWA-1103-IR/IR84898-B-168-39 (104.00 cm), BR IR-82635-47-1/IR84898-B-168-39 (104.00 cm), REWA-1103-IR/DANTESWARI (102.00 cm), IET-22107/CRR451-193-3-B (101.00 cm), IR82635-47-1/ CRR451-193-3-B (101.00 cm). While the cross (IR82639-115-1/ CRR451-193-3-B) (77.00 cm) showed lowest mean value for this character, the range of crosses, tester and lines varied from 77.00 to 105.33.

3. Number of tillers per plant

The mean of tiller number varied from 11.00(IR82635-47-1/ IR-84898-B-168-39) to 17.33 (REWA-1103-IR/DANTESWARI) with overall mean of 14.33 in crosses. The hybrid (REWA-1103-IR/DANTESWARI) (11.00) showed highest value for this trait followed by IR82639-115-1/DANTESWARI (16.67), IET-22107/CRR451-193-3-B (16.00), OM7938/ CRR451-193-3-B (16.00), IR-82630-67-2/ CRR451-193-3-B (15.67), IR-82630-67-2/ IR84898-B-168-39 (15.33) and IR82635-47-1/DANTESWARI (15.33) while the cross (IR82635-47-1/ IR84898-B-168-39)11.00 showed lowest value for this character. the range of crosses, tester and lines varied from 9.33 to 18.67.

4. Number of panicles per plant

Mean of panical per plant ranged from 8.00 (IR82635-47-1/DANTESWARI) to 13.00 (REWA-1103-IR/DANTESWARI) with an overall mean of 7.6210.30 in crosses. The crosses (REWA-1103-IR/DANTESWARI) (13.00) followed by IET-22107/CRR451-193-3-B (12.00), OM7938/CRR451-193-3-B (12.00), IR-826310-67-2/ IR-84898-B-168-39 (11.33), IR-82635-47-1/DANTESWARI(11.33) and ir-826310-67-2/CRR451-193-3-B (11.00), (REWA-1103-IR/DANTESWARI) (13.00) showed highest mean value while the hybrid (IR82635-47-1/DANTESWARI)) (8.00) showed the lowest value for the panical per plant, the range of crosses, tester and lines varied from 6.00 to 13.00 for this trait.

5. Number of grains per panicle

Among the hybrids number of grains per panicle ranged from 117.33 (REWA-1103-IR/DANTESWARI) to 137.67 (IR-79971-REWA-51/CRR451-193-3-B) with an overall average of 129.26 in crosses. Hybrid (IR-79971-REWA-51/CRR451-193-3-B) (137.67) had highest number of grains followed by OM-7938/ CRR451-193-3-B (136.00), IR-79971-REWA-51/IR-84898-B-168-39 (135.33), IR-79971-REWA-51 /DANTESWARI (134.33), IR-82635-47-1/ IR-84898-B-168-39 (134.33) and IR-82635-47-1/CRR451-193-3-B (133.33) while (REWA-1103-

IR/DANTESWARI) 117.33 showed lowest, the range of crosses, tester and lines varied from 94.67 to 137.67 for this trait.

6. Test weight (g)

The overall mean for test weight was recorded as 23.68. This trait ranged from 22.67 (REWA-1103-IR/IR84898-B-168-39) to IR82639-115-1/ IR84898-B-168-39 (27.00). The highest mean value was recorded in IR82639-115-1/ IR84898-B-168-39 (27.00) followed by IR-82635-47-1/DANTESWARI (26.00), OM-7938/CRR451-193-3-B (26.00), OM-7938/DANTESWARI (37.03), IET-22107/CRR451-193-3-B (26.00) and 1103-IR/IR-84898-B-168-39 (25.67), OM-7938/IR-84898-B-168-39 (25.67), IR82639-115-1/DANTESWARI (25.67), The lowest mean value was recorded for hybrid REWA-1103-IR/IR84898-B-168-39 (22.67), the range of crosses, tester and lines varied from 22.67 to 27.00 for this trait.

7. Panicle length (cm)

In hybrids performance of panicle length ranged from 17.67cm (IET-22107/DANTESWARI) to 20.67 cm (IR-826310-67-2/CRR451-193-3-B) with an overall mean of 20.58 cm in crosses. The highest panicle length was recorded in IR-826310-67-2/CRR451-193-3-B (20.67 cm), in IR-826310-67-2/DANTESWARI (22.67) followed by IET-22107/IR84898-B-168-39 (20.33 cm), IR-79971-REWA-51/ CRR451-193-3-B (19.67 cm), OM-7938/DANTESWARI (19.67 cm), REWA-1103-IR/DANTESWARI (19.33 cm), OM-7938/IR84898-B-168-39 (19.33). The lowest mean value for panicle length was observed for IET-22107/DANTESWARI (17.67 cm). the range of crosses, tester and lines varied from 16.67 to 20.67 for this trait.

8. Grain yield per plant (g)

Hybrid IR-79971-REWA-51-IR/IR84898-B-168-39 had the highest mean for the grain yield per plant (28.33g) followed by the IR-826310-67-2/IR84898-B-168-39 (28.00g), IET-22107/CRR451-193-3-B (21.67g), REWA-1103-IR/DANTESWARI (20.33g), IR-82635-47-1/IR84898-B-168-39 (20.33 g), REWA-1103-IR/IR84898-B-168-39 (18.00g) and the

lowest grain yield per plant was recorded in OM-7938/CRR451-193-3-B (7.33g). The average of grain yield per plant of the hybrids was 15.30 g. the range of crosses, tester and lines varied from 4.67 to 28.33 for this trait.

9. Biological yield (g)

The biological yield in hybrids ranged from 20.00g, (om-7938/DANTESWARI) to 54.33g (IR-826310-67-2/IR84898-B-168-39) with an overall average of 37.98 g. The hybrid IR-826310-67-2/IR84898-B-168-39 (54.33g) showed the highest mean value followed by IR-79971-REWA-51/IR84898-B-168-39 (53.67g), REWA-1103-IR/DANTESWARI (52.67g), IET-22107/CRR451-193-3-B (51.67g), REWA-1103-IR/IR84898-B-168-39 (47.33g), IR-82635-47-1/IR84898-B-168-39 (43.00 g) and IR-82635-47-1/DANTESWARI (43.00g), IR-82635-47-1/CRR451-193-3-B (42.00g), Hybrid OM-7938/DANTESWARI recorded the lowest mean value (20.00g). the range of crosses, tester and lines varied from 4.67 to 28.33 for biological yield.

10. Harvest Index percentage

The highest harvest index was recorded in IR-79971-REWA-51/IR84898-B-168-39 (52.83) followed by IR826310-67-2/IR84898-B-168-39 (51.48), IR826310-67-2/DANTESWARI (51.11), IR-82635-47-1/IR84898-B-168-39 (47.46), REWA-1103-IR/CRR451-193-3-B (46.31), OM-7938/IR84898-B-168-39 (44.54) while, it was lowest for hybrid OM-7938/ CRR451-193-3-B (25.53). The overall mean of harvest index was 49.77 for hybrids. the range of crosses, tester and lines varied from 22.85 to 52.83 for harvest index.

4.1.2 Coefficient of variation

The genotypic and phenotypic coefficients of variations for different characters are presented in Table 5.

The coefficient of variation is a useful tool for obtaining comparison of variability in different characters. A wide range of variation was observed for most of the characters in the materials studied, indicating that selection based on these characters is expected

to be effective.

The phenotypic coefficient of variations was higher in magnitude than that of genotypic coefficient of variation for all the characters studied.

High genotypic and phenotypic coefficient of variations were recorded for grain yield per plant (39.917 and 42.36), biological yield (26.60 and 28.42), phenotypic coefficient of variation high in harvest index (24.84). The moderate estimates genotypic and phenotypic coefficient of variations were observed for tiller number per plant (15.11 and 17.58), panicle per plant (13.49 and 16.95), genotypic coefficient of variation of harvest index (19.95), phenotypic coefficient of variation for number of grains per plant (12.09) and plant height (11.37). The low estimates of genotypic and phenotypic coefficient of variations were recorded for days to 50 per cent flowering (3.06 and 4.39), test weight (3.65 and 7.08), genotypic coefficient of variation of plant height (8.02), panicle length (5.63 and 8.31),

The presence of high magnitude of genotypic coefficient of variation indicates the high genetic variability in the materials studied. In present investigation phenotypic coefficient of variation was in general higher than the genotypic coefficient of variation. This is due to the insertion of error variance into the phenotypic variance.

Heritability

Heritability in broad sense was calculated for each character and is presented in Table 5. Highest heritability were recorded for grain yield per plant (88.80), biological yield (87.70) and number of tillers per plant (73.90) number of panicle per plant (63.30) and harvest index (62.20). In general heritability estimates were recorded high for all the characters under study except test weight, panicle length, number of grains per plant, plant height, days to 50% flowering. In the present study high heritability was observed for grain yield per plant.

4.1.4 Genetic advance

Genetic advance expresses as percentage of mean and is presented in Table 5. The highest genetic advance as percentage of mean was observed for grain yield per plant (77.48) followed by biological yield (51.31), harvest index (31.84), number of tillers per plant (26.77) number of panicle per plant (22.12). The moderate genetic advance as percentage of mean was observed for number of grain per plant (12.20), plant height (11.66). The remaining characters showed a low genetic advance as per cent of mean (< 10 %). High magnitude of genetic advance indicate that the characters are governed by additive genes and selection will be rewarded. Moderate genetic advance indicate the existence of additive as well as non additive gene action for these traits. The low genetic advance indicates that the characters are governed by non additive genes and heterosis breeding may be exploited for the traits.

High heritability estimates coupled with high genetic advance were observed in this study for grain yield per plant, biological yield, harvest index, number of tillers per plant and panicle per plant suggesting the presence of additive gene action for these traits. Hence it indicates that most likely the heritability is due to additive gene effects and selection may be effective.

4.2 Combining ability analysis for different characters.

4.2.1 Analysis of variance for lines x testers

Analysis of variance for all the traits under study has been presented in the Table 6a and 6b.

The variance due to line was significant for the characters days to fifty percent flowering plant height and test weight. The variance due to hybrids was significant for all the characters except number of grains per plant. The variance due to line x tester effect was significant for all the characters except plant height, test weight, number of grains per plant, The variance due to replicates was significant for the characters panicle length except for tiller number, plant height, days to fifty percent

flowering, panicle per plant number of grains per plant test weight grain yield per plant biological yield and harvest index.

4.2.2 Combining ability analysis for GCA, SCA effect and gene action

Data was recorded on twenty one hybrids, seven lines and three testers which were used for combining ability analysis by following the Line x tester approach of Kempthorne (1957). The estimate of gca, sca and gene action for all the character under study are presented in (Table 7 and 8).

1. Days to 50 per cent flowering

The lines showed significant GCA effects negative IR82635-47-1, IR-82639-115-1 and IR-826310-67-2 for this trait. among the testers show non significant GCA effects. Among the hybrids they all showed non significant SCA effects.

The sca variance was greater than the gca variance indicating that the predominance of non-additive gene action for this character.

2. Plant height (cm)

All the lines except IR-82639-115-1 for this trait showed none significant GCA effects. Line IR-82639-115-1 showed significant GCA effect. Among the testers IR-84898-B-168-39 and CRR451-193-3-B, DANTESWARI showed none significant GCA effects whereas, Out of twenty one hybrids, all showed none significant SCA effects,

The sca variance of plant height was greater than the gca variance indicating the predominance of non-additive gene action.

3. Tiller Number per plant

Among the lines, IR-82639-115-1 showed positive significant GCA effects and the remaining three lines IR-79971-REWA-51, IET-22107, IR-82635-47-1 showed negative significant GCA effects, the remaining three lines showed none significant effects. The tester DANTESWARI showed positive significant GCA effect whereas, IR-84898-b-168-39 showed negative GCA effects. Among GCA effects

the remaining showed non significant GCA effects. Out of twenty one hybrids, three hybrids showed positive significant SCA effects whereas, seven hybrids showed negative significant SCA effects remaining are none significant. Hybrid REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B, IR-82635-47-1/DANTESWARI, showed positive significant SCA effects.

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character.

4. Number of Panicles per plant

Among the lines, IR-826310-67-2 showed positive significant GCA effects and IR-79971-REWA-51 showed negative significant GCA effect the remaining lines showed negative none significant GCA effects which are IR-82635-47-1 and IR-82639-115-1. Among the testers, all showed none significant GCA effect whereas IR-84898-b-168-39 showed positive none significant GCA effect. Out of twenty one hybrids, two hybrids showed positive significant SCA effects whereas three hybrids showed negative significant SCA effects, Hybrid REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B showed positive significant SCA effects.

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this trait

5. Number of grains per plant

Among the lines all showed none significant GCA effects and The testers showed none significant GCA effect whereas out of twenty one hybrids, all hybrids showed none significant SCA effects whereas ten hybrids showed negative none significant SCA effects.

The sca variance of grain yield per plant was greater than the gca variance indicating the predominance of non-additive gene action.

6. Test weight (g)

Lines OM-7938 and IR-82639-115-1 showed significant positive GCA effects whereas, REWA-1103-IR/IR84898-B-168-39 showed

negative significant effects. The remaining lines showed non significant GCA effects. Among the testers all showed none significant GCA effects whereas, Out of twenty hybrids, all showed none significant SCA effects.

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character.

7. Panicle length (cm)

Among the lines, IR-826310-67-2 showed positive significant GCA effects and the IR-82639-155-1 showed negative significant GCA effects. Among the testers, all showed none significant GCA effect, Out of twenty one hybrids, one hybrid IET-22107/IR-84898-B-168-39 showed positive significant SCA effects whereas twenty hybrids showed none significant SCA effects

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this trait

8. Grain yield per plant (g)

Among the lines REWA-1103-IR, and IR-79971-REWA-51,IR-82635-47-1,IR-826310-67-2 showed positive significant GCA effects whereas, OM-7938 and IR-82639-115-1 showed negative significant GCA effects. Among the testers, IR-84898-B-168-39, showed positive significant GCA effects whereas, CRR-451-193-3-B showed negative significant GCA effects. Among the hybrids REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B and IR-79971-REWA-51/IR-84898-B-168-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/IR-84898-B-168-39 showed positive significant SCA effects, while, REWA-1103-IR/ IR-84898-B-168-39, REWA-1103-IR/ CRR-451-193-3-39,IET-22107/ IR-84898-B-168-39, IET-22107/DANTESWARI, IR-79971-REWA-51-IR/DANTESWARI, IR-82639-115-1 / IR-84898-B-168-39, IR-826310-67-2 / CRR-451-193-3-39, IR-826310-67-2 / DANTESWARI showed negative significant SCA effects. The remaining hybrids showed non significant positive or negative SCA effects.

9. Biological yield (g)

Among the lines, REWA-1103-IR, , IR-82635-47-1, IR-826310—67-2, and IET-22107, showed positive significant GCA effects whereas OM-7938 and IR-82639-115-1 showed negative significant GCA effects. The line IR-79971-REWA-51 showed positive non significant GCA effects. Among the testers, IR-84898-B-168-39, DANTESWARI and CRR-451-193-3-B showed positive significant GCA effects whereas, Out of twenty one hybrids, six hybrids showed positive significant SCA effects whereas four hybrids showed negative significant SCA effects. The hybrids which showed positive significant SCA effects are namely REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-39, IR-79971-REWA-51/IR-84898-B-168, OM-7938/CR-451-193-3-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/ R-84898-B-168-39,

The sca variance of biological yield was greater than the gca variance indicating the predominance of non-additive gene action. The result is similar to the findings of Verma *et al.* (1995), Reddy (2002), Sharma *et al.* (2005) and Kumar *et al.* (2007).

10. Harvest index percentage

Among lines, IR-826310-67-2 showed positive significant GCA effects whereas IR-82639-115-1 showed negative significant GCA effects. Among the testers, IR-84898-B-168, showed positive significant GCA effects whereas, CRR-451-193-3-B showed negative significant GCA effect DANTESWARI showed non significant GCA effects. Out of twenty one hybrids, one showed positive significant SCA effects, while two showed negative significant SCA effects. The remaining showed non significant SCA effects. The hybrids which showed positive significant SCA effects namely REWA-1103-IR/CRR-451-193-3-B .

4.3 Heterosis

The heterosis over mid parent (relative heterosis), over better parents (heterobeltiosis) was estimated for all the characters under study and is given in Table 9 a and 9b. The results of heterosis are described below :

1. Days to 50 per cent flowering

The value of relative heterosis ranged from -6.41 (IR-826310-67-2/DANTESWARI) to 10.72 (IR-82635-47-100/IR-8489-B-168-39). two hybrids showed significant negative relative heterosis of which (IR-826310-67-2/DANTESWARI) recorded the maximum (-6.41) followed by IR-826310-67-2/CRR-451-193-3-B (-5.71), whereas, six hybrids showed significant positive relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -7.51 (IR-826310-67-2/DANTESWARI) to 9.36(IR-82635-47-100/IR-8489-B-168-39). two hybrids showed significant negative heterobeltiosis of which which (IR-826310-67-2/DANTESWARI) recorded the maximum (-7.51), followed by IR-826310-67-2/CRR-451-193-3-B (-6.60), whereas, three hybrids showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

2. Plant height (cm)

The value of relative heterosis ranged from -14.55 (IR-82639-115-1/CRR451-193-3-B) to 17.04 (IET-22107/IR-84898-B-168-39). One hybrids showed significant negative relative heterosis of which (IR-82639-115-1/CRR451-193-3-B recorded the maximum (-14.55) whereas, four showed significant positive relative heterosis. remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from IR-82639-115-1/CRR-451-193-3-B (-22.41) to 2.27 (IET-22107/IR-84898-B-168-39). Four hybrids namely (IR82639-115-1/IR-84898-B-168-39(20.71), IR82639-115-1/DANTESWARI (-19.80), IR-826310-67-2/IR-84898-B-168-39 (2.27) showed significant negative heterobeltiosis whereas, one hybrid showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

3. Number of tillers per plant

The value of relative heterosis ranged from -32.11(IET-22107/DANTESWARI) to 21.52 (OM-7938/CRR-451-193-3-B). Ten

hybrids showed significant negative relative heterosis of which (IET-22107/DANTESWARI) -32.11, IR-82635-47-1/IR-84898-B-168-39 (-31.96), REWA-1103-IR/CRR-451-193-3-B (-28.00), IR-79971-REWA-51/DANTESWARI (-27.84), IR-826310-67-2/DANTESWARI(-23.08), IR-82635-47-1/CRR-451-193-3-B(-21.57), IR-79971-REWA-51/CRR-451-193-3-B (-19.57), IR-IET-22107/ IR-84898-B-168-39 (-19.19), REWA-1103-IR/IR-84898-B-168-39(-17.89) recorded the maximum whereas one hybrid showed significant positive heterosis. remaining showed hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -33.93 (IET-22107/DANTESWARI) to -4.17(IR-826310-67-2/ IR-84898-B-168-39), none of any hybrid showed significant positive heterobeltiosis whereas out of twenty one hybrids thirteen hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant negative heterobeltiosis.

4. Number of panicles per plant

The value of relative heterosis ranged from -17.24 (IR-79971-REWA-51/DANTESWARI) to 50.00 (OM-7938/CRR-451-B-168-39). Seven hybrids showed significant positive relative heterosis of which IR-79971-REWA-51/DANTESWARI recorded the maximum (50.00) followed by REWA-1103-IR/DANTESWARI (44.44), OM-7938/DANTESWARI (29.41), OM-7938/IR-84898-B-168-39 (18.37), IET-22107/CRR-451-193-3-B(18.03), IR-826310-67-2/IR-84898-B-168-39 (17.24), IR-826310-67-2/ CRR-451-B-168-39 (15.79), whereas, two hybrids showed significant positive relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -27.27 (IR-79971-REWA-51/DANTESWARI) to 20.00 (OM-7938/CRR-451-B-168-39). two hybrids showed significant positive heterobeltiosis of which IR-79971-REWA-51/DANTESWARI recorded the maximum (20.00) followed by REWA-1103-IR/DANTESWARI (18.18), three hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

5. Number of grains per panicle

The value of relative heterosis ranged from -8.21 (REWA-1103-IR/DANTESWARI) to 27.86 (IR-79971-REWA-51/CRR-451-193-3-B). fourteen hybrids showed significant positive relative heterosis of which IR-79971-REWA-51/CRR-451-193-3-B recorded the maximum (27.86) followed by OM-7938/CRR-451-193-3-B (24.77), IR-79971-REWA-51/IR-84898-B-168-39 (24.73), IR-82635-47-1/CRR-451-193-3-B (23.27), IR-82635-47-1/ IR-84898-B-168-39 (23.24), IR-82639-115-1/ CRR-451-193-3-B (23.05), IR-826310-67-2/ IR-84898-B-168-39 (22.34), IR-79971-REWA-51/DANTESWARI (19.23), IR-82639-115-1/ IR-84898-B-168-39 (18.30), IR-826310-67-2/DANTESWARI (18.10), IR-826310-67-2/ CRR-451-193-3-B (16.77), OM-7938/IR-84898-B-168-39 (16.24), IR-82635-47-1/DANTESWARI (16.05), IR-82639-115-1/DANTESWARI (15.93) and whereas, one hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -10.20 (REWA-1103-IR/DANTESWARI) to 19.71 (IR-79971-REWA-51/CRR-451-193-3-B). one hybrids namely REWA-1103-IR/DANTESWARI (-10.20) showed significant negative heterobeltiosis whereas, five hybrids showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

6. Test weight :

The value of relative heterosis ranged from -11.69 (IR-826310-67-2/IR-84898-B-168-39) to 7.95 (OM-7938/DANTESWARI). one hybrids showed significant negative relative heterosis of which IR-826310-67-2/IR-84898-B-168-39 recorded the maximum (-11.69) whereas, non of hybrids showed significant positive relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -13.92 (REWA-1103-IR/IR-84898-B-168-39) to 5.41 (OM-7938/DANTESWARI). three hybrids

showed significant negative heterobeltiosis of which REWA-1103-IR/IR-84898-B-168-39 recorded the maximum (-13.92), followed by IR-826310-67-2/IR-84898-B-168-39 (-13.92), REWA-1103-IR/CRR-451-193-3-B (-11.69), whereas The remaining hybrids showed non significant positive or negative heterobeltiosis.

7. Panicle length (cm)

The value of relative heterosis ranged from -14.52 (IET-22107/DANTESWARI) to 8.77 (IR-826310—67-2/CRR-451-193-3-B). one hybrid showed significant positive relative heterosis of which IR-826310—67-2/CRR-451-193-3-B recorded the maximum (8.77) whereas three hybrids showed significant negative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -16.67 (IR-82639-115-1/CRR-451-193-3-B) to 3.33 (IR-826310-67-2/CRR-451-193-3-B). Eight hybrids showed significant negative heterobeltiosis of which (IR-82639-115-1/CRR-451-193-3-B) recorded the maximum (-16.67) followed by IET-22107/DANTESWARI (-14.52), IET-22107/CRR-451-193-3-B (-12.90), IR-79971-REWA-51/DANTESWARI (-12.90), IR-82635-47-1/DANTESWARI (-12.90) and IR-79971-REWA-51/IR-84898-B-168-39 (-10.00) whereas, one hybrid showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

8. Grain yield per plant (g)

The value of relative heterosis ranged from -34.00 (IR-79971-REWA-51/DANTESWARI) to 175.41 (IR-826310-67-2/IR-84898-B-168-39). eight hybrids showed significant positive relative heterosis of which IR-826310-67-2/IR-84898-B-168-39 recorded the maximum (175.41) followed by IR-826310-67-2/DANTESWARI (100.00), IET-22107/CRR-451-193-3-B (100), IR-826310-67-2/CRR-451-193-3-B (71.41), REWA-1103-IR/ DANTESWARI (58.44), IR-79971-REWA-51/IR-84898-B-168-39 (57.41), IET-22107/IR-84898-B-168-39 (28.57), and REWA-1103-

IR/DANTESWARI (27.06) whereas, four hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -45.90 (IR-79971-REWA-51/DANTESWARI) to 78.72 (IR-826310-67-2/IR-84898-B-168-39). five hybrids namely IR-826310-67-2/IR-84898-B-168-39 (78.72), REWA-1103-IR/DANTESWARI (56.41), and IET-22107/CRR-451-193-3-B (54.76), IR-79971-REWA-51/IR-84898-B-168-39 (39.34), IR-826310-67-2 showed significant positive heterobeltiosis whereas, eight hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

9. Biological yield (g)

The value of relative heterosis ranged from -37.82 (OM-7938/DANTESWARI) to 87.36 (IR-826310-67-2/IR-84898-B-168-39). eight hybrids showed significant positive relative heterosis of which IR - 826310-67-2/IR-84898-B-168-39 recorded the maximum (87.36) followed by REWA-1103-IR/DANTESWARI (68.98), IET-22107/CRR-451-193-3-B (60.62 IR -826310-67-2/ CRR-451-193-3-B (55.83), REWA-1103-IR/IR-84898-B-168-39 (36.54), IR -826310-67-2/DANTESWARI (35.95), IR-79971-REWA-51/ IR-84898-B-168-39 (20.15), IET-22107/DANTESWARI (19.13) whereas, six hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -45.81(IR-79971-REWA-5151/DANTESWARI) to 66.32 (REWA-1103-IR/DANTESWARI). Five hybrids showed significant positive heterobeltiosis of which REWA-1103-IR/DANTESWARI recorded the maximum (66.32) followed by IET-22107/CRR-451-193-3-B (51.96), IR-826310-67-2/ IR-84898-B-168-39 (44.25), REWA-1103-IR/ IR-84898-B-168-39 (25.66), IR-826310-67-2/ CRR-451-193-3-B (24.51), whereas eight showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

10. Harvest index percentage

The value of relative heterosis ranged from -25.25 (OM-7938/CRR-451-193-3-B) to 57.80 (IR-826310-67-2/ IR-84898-B-168-39). seven hybrids showed significant positive relative heterosis of which IR-826310-67-2/ IR-84898-B-168-39 recorded the maximum (57.80) followed by IR-826310-67-2/SAHABHGI (50.35), OM-7938/ IR-84898-B-168-39 (29.93), IR-79971-REWA-51/ IR-84898-B-168-39 (29.35), IET-22107/CRR-451-193-3-B (24.56), IR-82635-47-1/IR-84898-B-168-39 (22.69), IR-826310-67-2/CRR-451-193-3-B (16.04), whereas, one hybrid showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -39.39 (OM-7938-/CRR-451-193-3-B) to IR-79971-REWA-51 / IR-84898-B-168-39 (24.62).one hybrid showed significant positive heterobeltiosis of which IR-79971-REWA-51/IR-84898-B-168-39 recorded the maximum (24.62), whereas, two showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

4.4 Association analysis:

4.4.1. Correlation analysis:

The correlation coefficients are the index of association between two variables. These have been dealt in all possible combinations at Phenotypic, Genotypic and Environmental level and are presented in Table 10.

The character days to 50 per cent flowering had a non significant positive association with the character plant height, panicle per plant, number of grains per plant and test weight at both phenotypic and genotypic level, with tiller number per plant, panicle length biological yield harvest index grain yield per plant, biological yield, harvest index showed non significant negative correlation at both phenotypic and genotypic level.

Highly significant positive correlation of plant height was observed with harvest index and grain yield per plant at phenotypic level while

number of grain per plant and panicle length showed significant positive association at phenotypic level and test weight, panicle pr plant showed positive association at phenotypic level. on the contrary negative non association was observed with the characters tiller number, at both genotypic and phenotypic level,

Number of tillers per plant recorded significant positive association with panicle per plant, panicle length at phenotypic level, while positive non significant association with panicle per plant, test weight, panicle length, biological yield, harvest index, grain yield per plant at genotypic level.

Number of panicle per plant recorded significant positive association with panicle length, biological yield, and harvest index at phenotypic level while at genotypic level non significant association with , biological yield, harvest index, grain yield per plant, panicle length, test weight, number of grains per plant.

Number of grains per plant recorded a significant positive association with harvest index and grain yield per plant, while test weight biological yield, panicle length recorded a non significant positive association at phenotypic, genotypic level.

Test weight expressed non significant positive association with panicle length, non significant negative association with harvest index, grain yield per plant, biological yield at all phenotypic, genotypic level and. The results are similar to the findings of Chauhan *et al.*

Panicle length exhibited significant positive association with, harvest index at phenotypic level, non significant positive association with genotypic level, and non significant negative association with biological yield and non significant positive association with grain yield per plant at phenotypic and genotypic level. panicle length showed significant positive association with, index at phenotypic level.

Biological yield recorded a significant positive association with the harvest index and grain yield per plant at phenotypic level, positive non significant association with genotypic level.

Harvest index expressed a significant positive association with grain yield per plant, at phenotypic, level, and non significant positive association with grain yield at genotypic.

Grain yield had a significant positive association with plant height, number of panicle per plant, number of grain per plant, biological yield and harvest index, at phenotypic, level. All the characters showed non significant positive association at genotypic level with grain yield.

4.4.2 Path coefficient analysis

4.4.2.1 Path coefficients showing direct and indirect effects of different Characters on grain yield

The genotypic correlation coefficient of yield with its components traits were partitioned into direct and indirect effects taking yield per plant as dependent variable and are presented in Table 11.

Direct and indirect effect of different characters on grain yield per plant is presented in Table 11), biological yield (0.684), expressed a highest positive direct effect on yield followed by Harvest index (0.520 and other characters) showed negligible direct effect on grain yield per plant, panicle per plant (0.049) number of grains per plant (0.007), remaining characters showed negative direct effect on grain yield per plant, among the negative direct effect panicle length (-0.007) showed highest negative direct effect on yield followed by test weight (-0.0054), plant height (-0.030). days to fifty percent flowering (-0.025), tiller per plant (-0.024).

Days to 50 per cent flowering showed a negative indirect effect on yield per plant through leaf area (0.072) followed by plant height (0.065), tiller number per plant (0.052) and harvest index (0.040)

Plant height had a positive indirect moderate significant effect on grain yield per plant through panicle length (0.003), biological yield, tiller per plant (0.001) followed by harvest index (0.0004).

Tiller number per plant exhibited a positive in direct effect on yield per plant through plant height (0.0017) number of grain per plant(0.001) harvest index (0.001)and days to 50 per cent flowering (0.001).

Number of panicle per plant recorded a positive indirect high significant effect on grain yield per plant through tiller number (0.023) followed by spikelet sterility panicle length (0.015), biological yield (0.014), test weight (0.009), plant height (0.009) harvest index (0.008), number of grain per plant (0.008) and days to 50 per cent flowering (0.005).

Number of grain per plant showed a positive moderate significant indirect effect on yield per plant through harvest index (0.002) followed by panicle length (0.001), plant height (0.001), panicle per plant (0.001), and days to 50 per cent flowering (0.001), biological yield.

Test weight expressed a negative indirect effect on grain yield per plant through harvest index (0.170) followed by biological yield (0.001), and harvest index (0.0001).

Panicle length had a positive indirect effect on yield per plant through days to 50 per cent flowering (0.001), biological yield (0.0009).

Biological yield expressed a positive indirect highly significant effect on grain yield per plant through harvest index (0.206), number of panicle per plant (0.198), number of tillers per plant (0.053) and number of grains per plant (0.039), plant height (0.038).

Harvest index showed a positive highly significant indirect effect on yield per plant through filled plant height (0.203), Number of grains per panicle (0.188), biological yield (0.157), panicle length (0.136) and number of panicle per plant (0.0898).

DISCUSSION

The biometrical techniques applied in the analysis of the data in the present investigation revealed conclusive findings. The merits of findings are discussed under the following heads.

5.1 Mean performance of genotypes of different characters

5.2 Genotypic and phenotypic coefficient of variation

5.3 Heritability

5.4 Genetic advance

5.5 Combining Ability analysis for yield and its related characters

5.6 Heterosis

5.7 Association analysis

5.1 Mean performance of genotypes for different characters

A. Mean performance of parents

The different genotypes i.e., seven lines, three testers and their twenty one F_1 s were first judged based on their mean performance for different characters presented in Table (4 a and 4b).

5.1.1 Days to 50% flowering

The range for Days to 50 per cent flowering varied from 65.67 days (IR-826310-67-2/DANTESWARI) to 95.25 days (IR-82639-115-1/DANTESWARI) with an overall average of 70.33 days.

5.1.2 Plant height (cm)

The range of Plant height varied from 77.00 cm (IET-22107) to 103.00cm IR-84898-B-168-39 with an overall average of 93.25 cm the shortest plant height was found for (IET-22107) (77.00 cm) with an average of 84.99 cm among the males.

5.1.3 Number of tillers per plant

The lowest value for this trait was recorded in IR-8498-B-168-39 (15.33). DANTESWARI had maximum of tillers 18.67 whereas, OM-7938 (9.33) had minimum number of tillers with an overall average of 15.55 among the parents.

5.1.4 Panicle per plant

Lowest value of tester 10.33(IR-84898-B-168-39) and highest value is 11.00 (DANTESWARI) with an average of 17 in the teters, among the parents, panicle per plant ranged from 6.00 (OM7938) to 11.00 DANTESWARI with an overall average of lines 8.66.

5.1.5 Number of grains per plant

The overall average of grain per plant for lines was 106.4 while REWA-1103-IR showed highest (130.67) and the lowest was recorded 94.67 (IR-82639-115-1).

5.1.6 Test weight (g)

Test weight ranged from 22.67 (REWA-1103-IR) to 26.33 (IR-84898-B-168-39) among the parents. In the lines (IR-826310-67-2) had maximum test weight (25) and (REWA-1103-IR) showed minimum test weight 22.67 with an average of 24.09 among the lines.

5.1.7 Panicle length (cm)

The panicle length varied from 16.67cm (IR-79971-REWA-51) to 20.67 cm (IET-22107) with an overall mean of 17.76 cm lines, the lowest were recorded for the tester CRR451-193-3-B (20.00 cm).

5.1.8 Grain yield per plant (g)

Genotype IR-79971-REWA-51 had the highest (20.33 g) for the grain yield per plant and the lowest was recorded for IR-826310-67-2 (4.67g) with an overall average of 11.47 among the female parents. The average of grain yield per plant of the male parent was 14.22 g

5.1.9 Biological yield (g)

The biological yield in parents ranged from 20.33 g (IR-826310-67-2) to 56.33g (IR-82635-47-1) with an overall average of 35.95 g. in lines.

5.1.10 Harvest index (%)

The overall average of harvest index among the lines was 30.297. The lowest value was observed as 22.85 (ir-826310-67-2) and genotype (IR-84898-B-168-39) showed highest value (42.40) among parents.

B. Mean performance of hybrids

5.1.1 Days to 50% flowering

The hybrid IR82630-67-2/CRR451-193-3-B showed earliness (66). The variation for this trait ranged from 65.67 days (IR82630-67-2/DANTESWARI) to 75 days (IR82639-115-1/DANTESWARI) with an overall hybrids mean of 71.00 days.

5.1.2 Plant height (cm)

The range of Plant height varied from 77.33 cm (IR82639-115-1/CRR451-193-3-B) to 105.33 cm (IET-22107/ IR84898-B-168-39) with an overall average of 94.85 cm. lowest mean value for this character, the range of crosses, tester and lines varied from 77.00 to 105.33.

5.1.3 Number of tillers per plant

The mean of tiller number varied from 11.00(IR82635-47-1/ IR-84898-B-168-39) to 17.33 (REWA-1103-IR/DANTESWARI) with overall mean of 14.33 in crosses. the range of crosses, tester and lines varied from 9.33 to 18.67.

5.1.4 Panicle per plant

Mean of panical per plant ranged from 8.00 (IR82635-47-1/DANTESWARI) to 13.00 (REWA-1103-IR/DANTESWARI) with an overall mean of 7.6210.30 in crosses, range of crosses, tester and lines varied from 94.67 to 137.67for this trait.

5.1.5 Number of grains per plant

The overall average of grain per plant for lines was 106.4 while REWA-1103-IR showed highest (130.67) and the lowest was recorded 94.67 (IR-82639-115-1).

5.1.6 Test weight (g)

Overall mean for test weight was recorded as 23.68. This trait ranged from 22.67 (REWA-1103-IR/IR84898-B-168-39) to IR82639-115-1/ IR84898-B-168-39 (27.00). , tester and lines varied from 22.67 to 27.00 for this trait.

5.1.7 Panicle length (cm)

In hybrids performance of panicle length ranged from 17.67cm (IET-

22107/DANTESWARI) to 20.67 cm (IR-826310-67-2/CRR451-193-3-B) with an overall mean of 20.58 cm in crosses.

5.1.8 Grain yield per plant (g)

Hybrid IR-79971-REWA-51-IR/IR84898-B-168-39 had the highest mean for the grain yield per plant (28.33g) followed by the IR-826310-67-2/IR84898-B-168-39 (28.00g).

5.1.9 Biological yield (g)

The biological yield in hybrids ranged from 20.00g, (om-7938/DANTESWARI) to 54.33g (IR-826310-67-2/IR84898-B-168-39) with an overall average of 37.98 g. tester and lines varied from 4.67 to 28.33 for biological yield.

5.1.10 Harvest index (%)

The highest harvest index was recorded in IR-79971-REWA-51/IR84898-B-168-39 (52.83) followed by IR826310-67-2/IR84898-B-168-39 (51.48), IR826310-67-2/DANTESWARI (51.11), The overall mean of harvest index was 49.77 for hybrids.

5.2 Genotypic and phenotypic coefficient of variation

The simple measure of genetic variability is the coefficient of variation which partitions the total variation into phenotypic, genotypic and environmental components. The genotypic coefficient of variation measures the extent of genetic variability present in the crop species for particular trait. The phenotypic coefficient of variation of characters is the manifestation of genotype, environment and interaction between the genotypes and environment. Therefore, the total variance needs to be partitioned into heritable and non-heritable components to assess the true breeding behavior of a particular trait. The results obtained from quantitative characters studied in the present investigation are being discussed in this chapter presented in Table 5.

High genotypic and phenotypic coefficient of variations were recorded for grain yield per plant (39.917 and 42.36), biological yield (26.60 and 28.42), phenotypic coefficient of variation high in harvest index (24.84).

5.2.1 Days to 50% flowering

The low estimates of genotypic and phenotypic coefficient of variations were recorded for days to 50 per cent flowering (3.06 and 4.39), These results were in agreement with the findings of Debchaudhary and Das (1998) and Nayak *et al.* (2004).

5.2.2 Plant height (cm)

Phenotypic coefficient of variation for plant height (11.37), the low estimates of genotypic coefficient of variation recorded for plant height (8.02). These results were in agreement with the findings of Nayak *et al.* (2004) and Iftekharuddaula *et al.* (2001).

5.2.3 Number of tillers per plant

The moderate estimates genotypic and phenotypic coefficient of variations were observed for tiller number per plant (15.11 and 17.58), these results were in agreement with the findings of Akinwale *et al.* (2011) and Iftekharuddaula *et al.* (2001).

5.2.4 Panicle per plant

The moderate estimates genotypic and phenotypic coefficient of variations were observed for panicle per plant (13.49 and 16.95), These results were in agreement with the findings of Nayak *et al.* (2004) and Akinwale *et al.* (2011).

5.2.5 Number of grains per plant

The moderate estimates phenotypic coefficient of variation for number of grains per plant recorded (12.09) and low estimates recorded for genotypic coefficient of variation (8.46).

5.2.6 Test weight (g)

Low estimates genotypic and phenotypic coefficient of variations were observed for test weight (3.65 and 7.08). These results are in agreement with the findings of Choudhury & Das (1997) and Akinwale *et al.* (2011).

5.2.7 Panicle length (cm)

Low estimates genotypic and phenotypic coefficient of variations were observed in panicle length (5.63 and 8.31), These results were in

agreement with the findings of Nayak *et al.* (2004) and Akinwale *et al.* (2011).

5.2.8 Grain yield per plant (g)

High genotypic and phenotypic coefficient of variations were recorded for grain yield per plant (39.917 and 42.36). These results are in agreement with the findings of Nayak *et al.* (2004), Karim *et al.* (2007), Reddy and Kumar (1996), Choudhury and Das (1997), Akinwale *et al.* (2011) Kumar *et al.* (1998) and Shanthakumar *et al.* (1998).

5.2.9 Biological yield (g)

High genotypic and phenotypic coefficient of variations were recorded for biological yield (26.60 and 28.42), These results were in agreement with the findings of Verma *et al.* (2000).

5.2.10 Harvest index (%)

Phenotypic coefficient of variation high in harvest index (24.84), moderate genotypic coefficient of variation of harvest index observed (19.95). These results were in agreement with the findings of Nayak *et al.* (2004) and Karim *et al.* (2007).

The presence of high magnitude of genotypic coefficient of variation indicates the high genetic variability in the materials studied. In present investigation phenotypic coefficient of variation was in general higher than the genotypic coefficient of variation. This is due to the insertion of error variance into the phenotypic variance. Similar findings were also reported by Sarawgi *et al.* (1994), Sharma and Dubey (1997), Debchaudhary and Das (1998) and Sadhukhan and Chattopadhyay (2000) and Verma *et al.* (2000). The relative low magnitude of differences between GCV and PCV were recorded for all the traits except number of grains per plant, and test weight indicating less environmental influence in the expression of these attributes. The highest magnitude of genotypic coefficient of variation was noted for grain yield per plant. Similar findings were also obtain Debchaudhary and Das (1998), Sadhukhan and Chattopadhyay (2000), Tomar *et al.* (2000) and Verma *et al.* (2000); for number of grains per panicle by Sarawgi and Soni (1994) and Debchaudhary and Das (1998) for grain yield per plant by Rather *et al.* (1998) and Verma *et al.* (2000).

5.3 Heritability

Heritability measures the contribution of genetic variability to the phenotypic variability observed for quantitative traits and it is good index of the transmission of characters from parents to their offspring. The estimate of heritability can be utilized for the prediction of genetic gain, which indicates the genetic improvement that would result from the selection of best individuals. Hence, estimate of heritability is an essential pre-requisite for formulation of an effective selection method for genetic improvement.

Heritability estimates along with genetic advance are normally more helpful in predicting the genetic gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance. In the present study high heritability was observed for grain yield per plant and which is in accordance to the findings of Sarawgi *et al.* (1994), Kumar *et al.* (1998), Kavita and Reddi (2002) and Chandra and Pradhan (2003). The high heritability observed for grain yield per plant is in conformity to the findings of Choudhary and motiramani (2003), Shukla *et al.* (2004), Tyagi *et al.*(2004) and Shukla *et al.* (2005). Similar results of high heritability for number of tillers per plant was observed by Nath and Talukdar (1997), Rao *et al.*(1997), Kaw *et al.* (1999) and Verma *et al.* (2000).

5.3.1 Days to 50% flowering

The broad sense heritability estimates were moderate (48.70). These results were consistent with the findings of Durai *et al.* (2001), Sharma and Bhuyan (2004), Nayak *et al.* (2004), Satyanarayana *et al.* (2005) and Verma *et al.* (2004).

5.3.2 Plant height (cm)

Moderate broad sense heritability estimates were found under up land condition. These results are consistent with the findings of Nayak *et al.* (2004), Zahid *et al.* (2005), Babar *et al.* (2007) and Ifftikhar *et al.* (2009) for plant height.

5.3.3 Number of tillers per plant

The broad sense heritability estimates were high for number of tillers these results were consistent with the findings of Lanceras *et al.* (2004) and Akinwale *et al.* (2011).

5.3.4 Number of panicles per plant

Number of panicles per plant exhibited high heritability. These results were consistent with the findings of Nayak *et al.* (2004) and Akinwale *et al.* (2011).

5.3.5 Number of grains per Panicles

The broad sense heritability estimates were high for number of grains per panicles. These results were consistent with the findings of Nandeshwar *et al.* (2010). Under rainfed condition the broad sense heritability estimates were high and under reproductive stress condition the broad sense heritability estimates were also high. These results were consistent with the findings of Akinwale *et al.* (2011).

5.3.6 Test weight (g)

The broad sense heritability estimates were low for test weight, These results are consistent with the findings of Akanda *et al.* (1997), Bhatti *et al.* (1998), Zahid *et al.* (2005), Choudhury & Das (1997) and Karim *et al.* (2007).

5.3.7 Panicle length (cm)

The broad sense heritability estimates were moderate for panicle length. These results were consistent with the findings of Akinwale *et al.* (2011). Broad sense heritability estimates were Imoderate. These results were consistent with the findings of Nayak *et al.* (2004) and Babar *et al.* (2007).

5.3.8 Grain yield per plant

The broad sense heritability estimates Highest heritability were recorded for grain yield per plant (88.80), These results were consistent with the findings of Reddy and Kumar (1996), Choudhury and Das (1997), Kumar *et al.* (1998) and Shanthakumar *et al.* (1998). Under rainfed stress conditions the broad sense heritability estimates were high and under

reproductive stress condition the broad sense heritability estimates were extremely high. These results were consistent with the findings of Akinwale *et al.* (2011), Babar *et al.* (2007) and Sürek and Korkut (1998).

5.3.9 Biological yield (g)

Broad sense heritability estimates were high for biological yield (87.70), These results were consistent with the findings of Chaudhary *et al.* (2004) and Saleem *et al.* (2008).

5.3.10 Harvest index (%)

Broad sense heritability estimates were high in harvest index. These results were consistent with the findings of Iftekharuddaula *et al.* (2001), Elayaraja *et al.* (2004) and Nayak *et al.* (2004).

5.4 Genetic advance

Genetic advance indicates that the heritability is due to additive gene effect and selection may be effective, while high heritability coupled with low genetic advance, indicates predominance of non additive gene action, while, low heritability is exhibited due to influence of environmental interaction rather than genotype. Selection for such characters may not be rewarding presented in Table 5.

In the present study high heritability was observed for grain yield per plant and which is in accordance to the findings of Sarawgi *et al.* (1994), Kumar *et al.* (1998), Kavita and Reddi (2002) and Chandra and Pradhan (2003). The high heritability observed for grain yield per plant is in conformity to the findings of Choudhary and motiramani (2003), Shukla *et al.* (2004), Tyagi *et al.*(2004) and Shukla *et al.* (2005). Similar results of high heritability for number of tillers per plant was observed by Nath and Talukdar (1997), Rao *et al.*(1997), Kaw *et al.* (1999) and Verma *et al.* (2000).

5.4.1 Days to 50% flowering

The genetic advance estimates were low. These results are consistent with the findings of Satyanarayana *et al.* (2005). Under rainfed conditions the genetic advance estimates were moderate. These results are consistent with the findings of Nayak *et al.* (2004).

5.4.2 Plant height (cm)

Under upland condition the genetic advance estimates were moderate. These results were consistent with the findings of Zahid *et al.* (2005), Ifftikhar *et al.* (2009) and Mishra and Verma (2002).

5.4.3 Number of tillers per plant

The genetic advance estimates were high. These results are consistent with the findings of Gomathinayagam *et al.* (1990), Biswas *et al.* (2000) and Akinwale *et al.* (2011). In rainfed stress and reproductive stress condition the genetic advance estimates were high.

5.4.4 Number of panicles per plant

Genetic advance estimates were high. These results are consistent with the findings of Gomathinayagam *et al.* (1990) and Biswas *et al.* (2000). Under reproductive stress condition the genetic advance estimates were high. These results are consistent with the findings of Nayak *et al.* (2004).

5.4.5 Number of grains per plant

Moderate genetic advance estimates were found in number of grains per plant. These results were consistent with the findings of Nayak *et al.* (2004) and Karim *et al.* (2007).

5.4.6 Test weight (cm)

The genetic advance estimates were low. These results were consistent with the findings of Zahid *et al.* (2005), Rao (2000), Mishra and Verma (2002), Chand *et al.* (2004), Karim *et al.* (2007) and Nandeshwar *et al.* (2010). Under controlled condition the genetic advance estimates were low. These results were consistent with the findings of Satyanarayana *et al.* (2005) and Akinwale *et al.* (2011).

5.4.7 Panicle length (cm)

The genetic advance estimates were low for panicle length. These results are consistent with the findings of Agrawal (2003) and Akinwale *et al.* (2011). Under upland condition the genetic advance estimates were moderate. These results are consistent with the findings of Nayak *et al.* (2004).

5.4.8 Grain yield per plant (g)

The genetic advance estimates were high for grain yield per plant. These results were consistent with the findings of Reddy and Kumar (1996), Choudhury and Das (1997), Kumar *et al.* (1998), Karim *et al.* (2007), Chand *et al.* (2004), Nandeshwar *et al.* (2010) and Akinwale *et al.* (2011).

5.4.9 Biological yield (g)

The genetic advance estimates were high in biological yield. These results were consistent with the findings of Nayak *et al.* (2004) and Saleem *et al.* (2008).

5.4.10 Harvest index (%)

The genetic advance estimates were high in harvest index. These results are consistent with the findings of Iftikharuddaula *et al.* (2001), Elayaraja *et al.* (2004) and Nayak *et al.* (2004). Under rainfed condition the genetic advance estimates were high.

The present findings of low magnitude of GCV and PCV for different characters is an agreement with the findings of Sadhukhan and Chattopadhyay (2000) for days to 50 per cent flowering; Pandey and Mani (1995) and Muker *et al.* (1998) for plant height; For panicle length by Verma *et al.* (2000). Moderate PCV and GCV were recorded for number of panicle per plant and tillers per plant, however high genotypic and phenotypic coefficient of variation have been observed by Verma *et al.* (2000).

In the present study high genetic advance as per cent of mean was observed for grain yield per plant by Rao and Shrivastava (1994), Kumar *et al.* (1998) and Thakur *et al.* (1998). Since broad sense heritability includes both additive and epistatic effects. It will be reliable only when accompanied by high genetic advance. Heritability estimates along with genetic advance is more useful than heritability alone in predicting the effectiveness of selection (Johnson *et al.* 1955). In the present study the characters which showed high heritability associated with high genetic advance are grain yield per plant, biological yield, harvest index, number of tillers per plant and number of panicles per plant.

This indicating that selection for these traits is likely to accumulate more additive genes leading to further improvement, Babu (1996), Borbora and Hazarika (1998), Kavitha and Reddi. (2002), Sharma and Bhuyan (2004) and Satyanarayana *et al.*(2005). High heritability estimates coupled with high genetic advance were observed in this study for grain yield per plant, biological yield, harvest index, number of tillers per plant and panicle per plant suggesting the presence of additive gene action for these traits. Hence it indicates that most likely the heritability is due to additive gene effects and selection may be effective.

5.5 Combining ability analysis for different characters.

5.5.1 Analysis of variance for lines x testers

Analysis of variance for all the traits under study has been presented in the Table 6.

The variance due to line was significant for the characters days to fifty percent flowering plant height and test weight. The variance due to hybrids was significant for all the characters except number of grains per plant. The variance due to line x tester effect was significant for all the characters except plant height, test weight, number of grains per plant, The variance due to replicates was significant for the characters panicle length except for tiller number, plant height, days to fifty percent flowering, panicle per plant number of grains per plant test weight grain yield per plant biological yield and harvest index.

5.5.2 Combining ability analysis for GCA, SCA effect and gene action

Data was recorded on twenty one hybrids, seven lines and three testers which were used for combining ability analysis by following the Line x tester approach of Kempthorne (1957). The estimate of gca, sca and gene action for all the character under study are presented in Table 7 and 8.

5.5.2.1 Days to 50 per cent flowering

. Among the hybrids they all showed non significant SCA effects The sca variance was greater than the gca variance indicating that the predominance of non-additive gene action for this character. Similar results were reported by Sharma and Mani (1996), Acharya *et al.* (2000),

Satyanarayana *et al.* (2000), Kalitha and Upadhaya (2000), Bhave *et al.* (2003), Sharma *et al.* (2005), Kshirsagar *et al.* (2005) and Bisne and Motiramani (2005).

5.5.2.2 Plant height (cm)

The sca variance of plant height was greater than the gca variance indicating the predominance of non-additive gene action.

Similar results were reported by Ramalingam *et al.* (1990), Chakraborty *et al.* (1994), Sharma *et al.* (1996), Kalitha and Upadhaya (2000), Acharya *et al.* (2000), Kshirsagar *et al.* (2005) and Sharma *et al.* (2005).

5.5.2.3 Number of tiller per plant

Among the lines, IR-82639-115-1 showed positive significant GCA effects and the remaining three lines IR-79971-REWA-51, IET-22107, IR-82635-47-1 showed negative significant GCA effects

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character. Similar findings have been reported by Lavanya (2000), Sharma *et al.* (2005) and Kumar *et al.* (2006).

5.5.2.4 Number of Panicles per plant

Among the lines, IR-826310-67-2 showed positive significant GCA effects and IR-79971-REWA-51 showed negative significant GCA.

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this trait. This is in support to the findings of Manuel and Palanisamy (1987), Ramalingam *et al.* (1990), Chakraborty *et al.* (1994), Sharma and Mani (1996), Kalitha and Upadhaya (2000), Acharya *et al.* (2000), Satyanarayana *et al.* (2000), Shanthi *et al.*

Sharma *et al.* (1996) and Lavanaya (2000) recorded the predominance of additive gene action for this character.

5.5.2.5 Number of grains per plant

Among the lines all showed non significant GCA effects and The testers showed non significant GCA effect (2004), Sharma *et al.* (2005), Kumar *et al.* (2006) while Sharma *et al.* (1996) and Lavanaya (2000)

recorded the predominance of additive gene action for this character.

5.5.2.6 Test weight (g)

Lines OM-7938 and IR-82639-115-1 showed significant positive GCA effects. The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character. This finding is in accordance with the results reported by Sharma and Mani (1996), Lavanya (2000), Reddy (2002) and Sharma *et al.* (2005).

5.5.2.7 Panicle length (cm)

Among the lines, IR-826310-67-2 showed positive significant GCA effects and the IR-82639-155-1 showed negative significant GCA effects. Among the testers, all showed none significant GCA effect, Out of twenty one hybrids, one hybrid IET-22107/IR-84898-B-168-39 showed positive significant SCA effects whereas twenty hybrids showed none significant SCA effects.

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this trait. This is in support to the findings of Manuel and Palanisamy (1987), Ramalingam *et al.* (1990), Chakraborty *et al.* (1994), Sharma and Mani (1996), Kalitha and Upadhaya (2000), Acharya *et al.* (2000), Satyanarayana *et al.* (2000), Shanthi *et al.* (2004), Sharma *et al.* (2005), Kumar *et al.* (2006) while Sharma *et al.* (1996) and Lavanaya (2000) recorded the predominance of additive gene action for this character.

5.5.2.8 Grain yield per plant (g)

Among the lines REWA-1103-IR, BR 240 and IR-79971-REWA-51, IR-82635-47-1, IR-826310-67-2 showed positive significant GCA effects whereas, OM-7938 and IR-82639-115-1 showed negative significant GCA effects. Among the testers, IR-84898-B-168-39, showed positive significant GCA effects .

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character. Similar findings have been reported by Manuel and Palanisamy (1987), Manuel and Prasad (1992), Chakraborty *et al.* (1994), Sharma *et al.* (1996), Sharma and Mani

(1996), Acharya *et al.* (2000), Lavanya (2000), Kalitha and Upadhaya (2000), Reddy (2002), Savery and Ganesan (2003), Bisne and Motiramani (2005), Panwar (2005), Sharma *et al.* (2005) and Kumar *et al.* (2006).

5.5.2.9 Biological yield (g)

Among the lines, REWA-1103-IR, IR-82635-47-1, IR-826310—67-2, and IET-22107, showed positive significant GCA effects whereas OM-7938 and IR-82639-115-1 showed negative significant GCA effects. The line IR-79971-REWA-51 showed positive non significant GCA effects. Among the testers, IR-84898-B-168-39, DANTESWARI and CRR-451-193-3-B showed positive significant GCA effects whereas, Out of twenty one hybrids, six hybrids showed positive significant SCA effects whereas four hybrids showed negative significant SCA effects. The hybrids which showed positive significant SCA effects are namely REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-39, IR-79971-REWA-51/IR-84898-B-168, OM-7938/CRR-451-193-3-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/R-84898-B-168-39.

The sca variance of biological yield was greater than the gca variance indicating the predominance of non-additive gene action. The result is similar to the findings of Verma *et al.* (1995), Reddy (2002), Sharma *et al.* (2005) and Kumar *et al.*(2007).

5.5.2.10 Harvest index percentage

Among lines, IR-826310-67-2 showed positive significant GCA effects whereas IR-82639-115-1 showed negative significant GCA effects. Among the testers, IR-84898-B-168, showed positive significant GCA effects whereas, CRR-451-193-3-B showed negative significant GCA effect DANTESWARI showed non significant GCA effects. Out of twenty one hybrids, one showed positive significant SCA effects, while two showed negative significant SCA effects. The remaining showed non significant SCA effects. The hybrids which showed positive significant SCA effects namely REWA-1103-IR/CRR-451-193-3-B .

The sca variance was greater than the gca variance indicating the predominance of non-additive gene action for this character. Similar findings were reported by Manueal and Prasad (1992), Acharya *et al.* (2000),

Lavanya (2000), Munhot *et al.* (2000), Sharma *et al.* (2005), Kshirsagar *et al.* (2005), Panwar (2005), and Bisne and Motiramani (2005).

5.6 Heterosis

The heterosis over mid parent (relative heterosis), over better parents (heterobeltiosis) was estimated for all the characters under study and is given in Table 9a and 9b. The results of heterosis are described below :

5.6.1 Days to 50 per cent flowering

The value of relative heterosis ranged from -6.41 (IR-826310-67-2/DANTESWARI) to 10.72 (IR-82635-47-100/IR-8489-B-168-39). two hybrids showed significant negative relative heterosis of which (IR-826310-67-2/DANTESWARI) recorded the maximum (-6.41).

The value of heterobeltiosis ranged from -7.51 (IR-826310-67-2/DANTESWARI) to 9.36(IR-82635-47-100/IR-8489-B-168-39). two hybrids showed significant negative heterobeltiosis of which which (IR-826310-67-2/DANTESWARI) recorded the maximum (-7.51), followed by IR-826310-67-2/CRR-451-193-3-B (-6.60), whereas, three hybrids showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

These results are similar to the findings of Joshi *et al.* (2004), Verma *et al.* (2004), Bhandarkar *et al.* (2005), Pandya and Tripathi (2006) and Raju *et al.* (2006).

5.6.2. Plant height (cm)

The value of relative heterosis ranged from -14.55 (IR-82639-115-1/CRR451-193-3-B) to 17.04 (IET-22107/IR-84898-B-168-39). One hybrids showed significant negative relative heterosis of which (IR-82639-115-1/CRR451-193-3-B) recorded the maximum (-14.55) whereas, four showed significant positive relative heterosis. remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from IR-82639-115-1/CRR-451-193-3-B (-22.41) to 2.27 (IET-22107/IR-84898-B-168-39). Four hybrids namely (IR82639-115-1/IR-84898-B-168-39(20.71), IR82639-115-1/DANTESWARI (-19.80), IR-826310-67-2/IR-84898-B-168-39 (2.27)

showed significant negative heterobeltiosis whereas, one hybrid showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

Similar results have been reported by Verma *et al.* (2004), Veni *et al.* (2005).

5.6.3. Number of tillers per plant

The value of relative heterosis ranged from -32.11(IET-22107/DANTESWARI) to 21.52 (OM-7938/CRR-451-193-3-B). Ten hybrids showed significant negative relative heterosis of which (IET-22107/DANTESWARI) -32.11, IR-82635-47-1/IR-84898-B-168-39 (-31.96), REWA-1103-IR/CRR-451-193-3-B (-28.00), IR-79971-REWA-51/DANTESWARI (-27.84), IR-826310-67-2/DANTESWARI(-23.08), IR-82635-47-1/CRR-451-193-3-B(-21.57), IR-79971-REWA-51/CRR-451-193-3-B (-19.57), IR-IET-22107/ IR-84898-B-168-39 (-19.19), REWA-1103-IR/IR-84898-B-168-39(-17.89) recorded the maximum whereas one hybrid showed significant positive heterosis. remaining showed hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -33.93 (IET-22107/DANTESWARI)) to -4.17(IR-826310-67-2/ IR-84898-B-168-39), none of any hybrid showed significant positive heterobeltiosis whereas out of twenty one hybrids thirteen hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant negative heterobeltiosis.

Similar results were reported by Joshi *et al.* (2004) and Bhandarkar *et al.*(2005).

5.6.4. Number of panicle per plant

The value of relative heterosis ranged from -17.24 (IR-79971-REWA-51/DANTESWARI) to 50.00 (OM-7938/CRR-451-B-168-39). Seven hybrids showed significant positive relative heterosis of which IR-79971-REWA-51/DANTESWARI recorded the maximum (50.00) followed by REWA-1103-IR/DANTESWARI (44.44), OM-7938/DANTESWARI (29.41), OM-7938/IR-84898-B-168-39 (18.37), IET-22107/CRR-451-193-3-B(18.03), IR-826310-67-2/IR-84898-B-168-39 (17.24), IR-826310-67-2/ CRR-451-B-168-

39 (15.79), whereas, two hybrids showed significant positive relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -27.27 (IR-79971-REWA-51/DANTESWARI) to 20.00 (OM-7938/CRR-451-B-168-39). two hybrids showed significant positive heterobeltiosis of which IR-79971-REWA-51/DANTESWARI recorded the maximum (20.00) followed by REWA-1103-IR/DANTESWARI (18.18), three hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

5.6.5. Number of grains per panicle

The value of relative heterosis ranged from -8.21 (REWA-1103-IR/DANTESWARI) to 27.86 (IR-79971-REWA-51/CRR-451-193-3-B). fourteen hybrids showed significant positive relative heterosis of which IR-79971-REWA-51/CRR-451-193-3-B recorded the maximum (27.86) followed by OM-7938/CRR-451-193-3-B (24.77), IR-79971-REWA-51/IR-84898-B-168-39 (24.73), IR-82635-47-1/CRR-451-193-3-B (23.27), IR-82635-47-1/IR-84898-B-168-39 (23.24), IR-82639-115-1/ CRR-451-193-3-B (23.05), IR-826310-67-2/ IR-84898-B-168-39 (22.34), IR-79971-REWA-51/DANTESWARI (19.23), IR-82639-115-1/ IR-84898-B-168-39 (18.30), IR-826310-67-2/DANTESWARI (18.10), IR-826310-67-2/ CRR-451-193-3-B (16.77), OM-7938/IR-84898-B-168-39 (16.24), IR-82635-47-1/DANTESWARI (16.05), IR-82639-115-1/DANTESWARI (15.93) and whereas, one hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -10.20 (REWA-1103-IR/DANTESWARI) to 19.71 (IR-79971-REWA-51/CRR-451-193-3-B). one hybrids namely REWA-1103-IR/DANTESWARI (-10.20) showed significant negative heterobeltiosis whereas, five hybrids showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

The result is similar to the findings of Pandey *et al.* (1995), Rosamma

and Kumar (2005) and Raju *et al.* (2005).

5.6.6 Test weight (g)

The value of relative heterosis ranged from -11.69 (IR-826310-67-2/IR-84898-B-168-39) to 7.95 (OM-7938/DANTESWARI). one hybrids showed significant negative relative heterosis of which IR-826310-67-2/IR-84898-B-168-39 recorded the maximum (-11.69) whereas, non of hybrids showed significant positive relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -13.92 (REWA-1103-IR/IR-84898-B-168-39) to 5.41 (OM-7938/DANTESWARI). three hybrids showed significant negative heterobeltiosis of which REWA-1103-IR/IR-84898-B-168-39 recorded the maximum (-13.92), followed by IR-826310-67-2/IR-84898-B-168-39 (-13.92), REWA-1103-IR/CRR-451-193-3-B (-11.69), whereas The remaining hybrids showed non significant positive or negative heterobeltiosis.

The result is similar to the findings of Veni *et al.* (2005) and Pandya and Tripathi (2006).

5.6.7. Panicle length (cm)

The value of relative heterosis ranged from -14.52 (IET-22107/DANTESWARI) to 8.77 (IR-826310—67-2/CRR-451-193-3-B). one hybrid showed significant positive relative heterosis of which IR-826310—67-2/CRR-451-193-3-B recorded the maximum (8.77) whereas three hybrids showed significant negative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -16.67 (IR-82639-115-1/CRR-451-193-3-B) to 3.33 (IR-826310-67-2/CRR-451-193-3-B). Eight hybrids showed significant negative heterobeltiosis of which (IR-82639-115-1/CRR-451-193-3-B) recorded the maximum (-16.67) followed by IET-22107/DANTESWARI (-14.52), IET-22107/CRR-451-193-3-B (-12.90), IR-79971-REWA-51/DANTESWARI (-12.90), IR-82635-47-1/DANTESWARI (-12.90) and IR-79971-REWA-51/IR-84898-B-168-39 (-10.00) whereas, one hybrid showed significant positive heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

Similar results were reported by Pandey *et al.* (1995), Ghosh (2002), Joshi *et al.* (2004), Veni *et al.* (2005), Bhandarkar *et al.* (2005), Pandya and Tripathi (2006) and Singh *et al.* (2006).

5.6.8. Grain yield per plant (g)

The value of relative heterosis ranged from -34.00 (IR-79971-REWA-51/DANTESWARI) to 175.41 (IR-826310-67-2/IR-84898-B-168-39). eight hybrids showed significant positive relative heterosis of which IR-826310-67-2/IR-84898-B-168-39 recorded the maximum (175.41) followed by IR-826310-67-2/DANTESWARI (100.00), IET-22107/CRR-451-193-3-B (100), IR-826310-67-2/CRR-451-193-3-B (71.41), REWA-1103-IR/ DANTESWARI (58.44), IR-79971-REWA-51/IR-84898-B-168-39 (57.41), IET-22107/IR-84898-B-168-39 (28.57), and REWA-1103-IR/DANTESWARI (27.06) whereas, four hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -45.90 (IR-79971-REWA-51/DANTESWARI) to 78.72 (IR-826310-67-2/IR-84898-B-168-39). Five hybrids namely IR-826310-67-2/IR-84898-B-168-39 (78.72), REWA-1103-IR/DANTESWARI (56.41), and IET-22107/CRR-451-193-3-B (54.76), IR-79971-REWA-51/IR-84898-B-168-39 (39.34), IR-826310-67-2 showed significant positive heterobeltiosis whereas, eight hybrids showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

The result is similar to the findings of Pandey *et al.* (1995), Rosamma and Kumar (2005) and Raju *et al.* (2005).

5.6.9. Biological yield (g)

The value of relative heterosis ranged from -37.82 (OM-7938/DANTESWARI) to 87.36 (IR-826310-67-2/IR-84898-B-168-39). eight hybrids showed significant positive relative heterosis of which IR -826310-67-2/IR-84898-B-168-39 recorded the maximum (87.36) followed by REWA-1103-IR/DANTESWARI (68.98), IET-22107/CRR-451-193-3-B (60.62 IR -826310-67-2/ CRR-451-193-3-B (55.83), REWA-1103-IR/IR-84898-B-168-39 (36.54), IR -826310-67-2/DANTESWARI (35.95), IR-79971-REWA-51/

IR-84898-B-168-39 (20.15), IET-22107/DANTESWARI (19.13) whereas, six hybrids showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -45.81(IR-79971-REWA-5151/DANTESWARI) to 66.32 (REWA-1103-IR/DANTESWARI). Five hybrids showed significant positive heterobeltiosis of which REWA-1103-IR/DANTESWARI recorded the maximum (66.32) followed by IET-22107/CRR-451-193-3-B (51.96), IR-826310-67-2/ IR-84898-B-168-39 (44.25), REWA-1103-IR/ IR-84898-B-168-39 (25.66), IR-826310-67-2/ CRR-451-193-3-B (24.51), whereas eight showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

This finding is in accordance with results reported by Ramesha *et al.*(1998), Verma *et al.* (2004), Pandya and Tripathi (2006), Singh *et al.* (2006).

5.6.10. Harvest index percentage

The value of relative heterosis ranged from -25.25 (OM-7938/CRR-451-193-3-B) to 57.80 (IR-826310-67-2/ IR-84898-B-168-39). seven hybrids showed significant positive relative heterosis of which IR-826310-67-2/ IR-84898-B-168-39 recorded the maximum (57.80) followed by IR-826310-67-2/SAHABHGI (50.35), OM-7938/ IR-84898-B-168-39 (29.93), IR-79971-REWA-51/ IR-84898-B-168-39 (29.35), IET-22107/CRR-451-193-3-B (24.56), IR-82635-47-1/IR-84898-B-168-39 (22.69), IR-826310-67-2/CRR-451-193-3-B (16.04), whereas, one hybrid showed significant negative relative heterosis. The remaining hybrids showed non significant positive or negative relative heterosis.

The value of heterobeltiosis ranged from -39.39 (OM-7938-/ CRR-451-193-3-B) to IR-79971-REWA-51/IR-84898-B-168-39 (24.62).one hybrid showed significant positive heterobeltiosis of which IR-79971-REWA-51/IR-84898-B-168-39 recorded the maximum (24.62), whereas, two showed significant negative heterobeltiosis. The remaining hybrids showed non significant positive or negative heterobeltiosis.

Similar results were also obtained by Joshi *et al.* (2004), Veni

et al. (2005), Pandya and Tripathi (2006), Raju *et al.* (2006) and Singh *et al.* (2006).

5.7. Association analysis:

5.7.1. Correlation analysis:

The correlation coefficients are the index of association between two variables. These have been dealt in all possible combinations at Phenotypic, Genotypic and Environmental level and are presented in Table 10.

The character days to 50 per cent flowering had a non significant positive association with the character plant height, panicle per plant, number of grains per plant and test weight at both phenotypic and genotypic level, with tiller number per plant, panicle length biological yield harvest index grain yield per plant, biological yield, harvest index showed non significant negative correlation at both phenotypic and genotypic level.

Highly significant positive correlation of plant height was observed with harvest index and grain yield per plant at phenotypic level while number of grain per plant and panicle length showed significant positive association at phenotypic level and test weight, panicle pr plant showed positive association at phenotypic level. on the contrary negative non association was observed with the characters tiller number, at both genotypic and phenotypic level,

Number of tillers per plant recorded significant positive association with panicle per plant, panicle length at phenotypic level, while positive non significant association with panicle per plant, test weight, panicle length, biological yield, harvest index, grain yield per plant at genotypic level. Similar results were also reported by Shashidhar *et al.* (2005).

Number of panicles per plant recorded significant positive association with panicle length, biological yield, and harvest index at phenotypic level while at genotypic level non significant association with , biological yield, harvest index, grain yield per plant, panicle length, test weight, number of grains per plant.

Number of grains per plant recorded a significant positive association with harvest index and grain yield per plant, while test weight biological yield,

panicle length recorded a non significant positive association at phenotypic, genotypic level. These results are similar to the findings of Yogameenakshi *et al.* (2004).

Test weight expressed non significant positive association with panicle length, non significant negative association with harvest index, grain yield per plant, biological yield at all phenotypic, genotypic level and. The results are similar to the findings of Chauhan *et al.* (1996) and Padmavathi *et al.* (1996).

Panicle length exhibited significant positive association with, harvest index at phenotypic level, non significant positive association with genotypic level, and non significant negative association with biological yield and non significant positive association with grain yield per plant at phenotypic and genotypic level. panicle length showed significant positive association with, index at phenotypic level. This is similar to the results of Panwar *et al.* (1989), Chakraborty *et al.* (2001) and Yogameenakshi *et al.* (2004).

Biological yield recorded a significant positive association with the harvest index and grain yield per plant at phenotypic level, positive non significant association with genotypic level. Harvest index expressed a significant positive association with grain yield per plant, at phenotypic, level, and non significant positive association with grain yield at genotypic. These results are similar to the findings of Bagali *et al.* (1999), Shashidar *et al.* (2005) and Yogameenakshi *et al.* (2004).

Grain yield had a significant positive association with plant height, number of panicle per plant, number of grain per plant, biological yield and harvest index, at phenotypic, level. All the characters showed non significant positive association at genotypic level with grain yield.

5.7.2 Path coefficient analysis

5.7.2.1 Path coefficients showing direct and indirect effects of different Characters on grain yield

The genotypic correlation coefficient of yield with its components traits were partitioned into direct and indirect effects taking yield per plant as dependent variable and presented in Table 11.

Direct and indirect effect of different characters on grain yield per plant is presented in Table), biological yield (0.684), expressed a highest positive direct effect on yield followed by Harvest index (0.520) and other characters) showed negligible direct effect on grain yield per plant, panicle per plant (0.049) number of grains per plant (0.007), remaining characters showed negative direct effect on grain yield per plant, among the negative direct effect panicle length (-0.007) showed highest negative direct effect on yield followed by test weight (-0.0054), plant height (-0.030). days to fifty percent flowering (-0.025), tiller per plant (-0.024).

Days to 50 per cent flowering showed a negative indirect effect on yield per plant through leaf area (0.072) followed by plant height (0.065), tiller number per plant (0.052) and harvest index (0.040)

Plant height had a positive indirect moderate significant effect on grain yield per plant through panicle length (0.003), biological yield, tiller per plant (0.001) followed by harvest index (0.0004).

Tiller number per plant exhibited a positive in direct effect on yield per plant through plant height (0.0017) number of grain per plant(0.001) harvest index (0.001)and days to 50 per cent flowering (0.001).

Number of panicle per plant recorded a positive indirect high significant effect on grain yield per plant through tiller number (0.023) followed by spikelet sterility panicle length (0.015), biological yield (0.014), test weight (0.009), plant height (0.009) harvest index (0.008),number of grain per plant(0.008) and days to 50 per cent flowering (0.005).

Number of grain per plant showed a positive moderate significant indirect effect on yield per plant through harvest index (0.002) followed by panicle length (0.001), plant height (0.001), panicle per plant (0.001), and days to 50 per cent flowering (0.001), biological yield.

Test weight expressed a negative indirect effect on grain yield per plant through harvest index (0.170) followed by biological yield (0.001), and harvest index (0.0001).

Panicle length had a positive indirect effect on yield per plant through days to 50 per cent flowering (0.001), biological yield (0.0009).

Biological yield expressed a positive indirect highly significant effect on grain yield per plant through harvest index (0.206), number of panicle per plant (0.198), number of tillers per plant (0.053) and number of grains per plant (0.039), plant height (0.038).

Harvest index showed a positive highly significant indirect effect on yield per plant through filled plant height (0.203), Number of grains per panicle (0.188), biological yield (0.157), panicle length (0.136) and number of panicle per plant (0.0898).

The positive direct effect of various characters of grain yield observed in the present study are in accordance with the findings of Anand *et al.* (1998), Bagali (1999), Chakraborty *et al.* (2001) for harvest index, Shashidhar *et al.* (2005) for plant height.

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The present investigation entitled “**Estimation of combining ability and heterosis for drought tolerance and in upland rice (*Oryza sativa* L.)**” was undertaken to determine the extent of variability, to assess the GCA effects of parents and SCA effects of crosses, to ascertain the magnitude of exploitable heterosis, to study type of gene action involved for yield, grain quality and other related characters and to study correlations and path coefficients.

The experimental material consisted of seven lines *viz.*, REWA-1103-IR, IET-22107, IR-79971-REWA-51, IR-82635-47-1, OM-7938, IR-82639-115-1, IR-826310-67-2 and three testers *viz.*, IR-84898-B-168-39, CRR-451-193-3-B, DANTESWARI and twenty one hybrids were generated in line x testers pattern. The parents and hybrids were raised in a randomized block design with three replications during *kharif* 2011 at the Research Farm, College of Agriculture Rewa, JNKVV, Jabalpur, (M.P.) India.

Observations were recorded for days to 50 per cent flowering, plant height, number tillers per plant, number of panicles per plant, number of grains per panicle, test weight, panicle length, grain yield per plant, biological yield per plant, harvest index.

Analysis of variance revealed that variance due to the line x tester was significant for all the characters, this suggested that sufficient variability is available in material used for present study.

The mean data were calculated to analysis of variance as per the Randomized Block Design. Analysis of data revealed highly significant differences among genotypes for all traits.

Highest heritability was recorded for grain yield per plant, biological yield and number of tillers per plant, number of panicle per plant and harvest index.

6.2 Conclusion

Combining ability analysis revealed the preponderance of non-additive gene action for all the characters studied. among the lines, IR-82639-115-1 showed positive significant GCA effects was best general combiner for all the characters except days to 50 per cent flowering, panicle length and among the lines, IR-826310-67-2 was best general combiner for tiller number per plant, number of grains per panicle, biological yield, harvest index, grain yield per plant, Among the lines REWA-1103-IR, BR 240 and IR79971-REWA,IR-82635-47-1,IR-826310-67-2 showed positive significant GCA effects was best general combiner for panicle length, harvest index, grain yield per plant, Among the lines, REWA-1103-IR, , IR-82635-47-1, IR-826310—67-2, and IET-22107, showed positive significant GCA effects was best general combiner number of tillers per plant and biological yield.

Among the testers, the tester IR-84898-B-168-39, showed positive significant GCA effects was best general combiner for all the characters except plant height, IR-84898-B-168-39, DANTESWARI and CRR-451-193-3-B was best general combiner for, number of grains per panicle, biological yield, grain yield per panicle, Tester IR-84898-B-168-39 was best general combiner for panicle length, harvest index, grain yield per plant, test weight, DANTESWARI was best general combiner for plant height, number of grains per panicle, harvest index.

Hybrid REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B IR-82635-47-1/DANTESWARI for number of tillers per plant; REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B for number of panicles per; hybrid IET-22107/IR-84898-B-168-39 for panicle length per plant; hybrids REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B and IR79971-REWA/IR-84898-B-168-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/IR-84898-B-168-39 for grain yield per plant number of tiller per plant; REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-39, IR-79971-REWA/IR-84898-B-168, OM-7938/CRR-451-193-3-39, IR-82639-115-

1/DANTESWARI, IR-826310-67-2/ R-84898-B-168-39 for biological yield; REWA-1103-IR/CRR-451-193-3-B for harvest index; were found as good specific combiners.

The phenotypic coefficient of variation was higher in magnitude than that of genotypic coefficient of variation for all the characters studied. High genotypic and phenotypic coefficients of variation were recorded for grain yield per plant, harvest index, The moderate estimates genotypic and phenotypic coefficient of variations were observed for tiller number per plant, panicle per plant, genotypic coefficient of variation of harvest index, phenotypic coefficient of variation for number of grains per plant and plant height. The low estimates of genotypic and phenotypic coefficient of variations were recorded for days to 50 per cent flowering, test weight, genotypic coefficient of variation of plant height, panicle length.

The highest heritability were recorded for grain yield per plant, biological yield and number of tillers per plant, number of panicle per plant and harvest index.

The estimates of relative heterosis and heterobeltiosis were also obtained for different characters under study. A high degree of relative heterosis and heterobeltiosis was observed for all the traits. The highest relative heterosis was exhibited by IR-826310-67-2/IR-84898-B-168-39 followed by IVTE/DANTESWARI, IET-22107/CRR-451-193-3-B, highest heterobeltiosis was observed for IR-826310-67-2/IR-84898-B-168-39 followed by IET-22107//IR-84898-B-168-39 However, a high degree of heterosis for other traits in desired direction was also observed.

Grain yield was positive significantly correlated with the, panicle length, number of tillers per plant, biological yield, harvest index and number of panicles per plant.

The study of path analysis of positive direct effects on grain yield showed that harvest index, biological yield, number of grains per plant and number of panicles per plant were most important contributing characters towards the yield, Therefor, the direct selection for harvest index, biological yield, number of grains per plant and number of

panicles per plant is likely to be effective in increasing the yield.

6.3 Suggestion for future work

Based on the finding of the present investigations, the following suggestions are being made for future work:

1. Lines, IR-82639-115-1 and IR-826310-67-2 were identified as best general combiners for 50 per cent flowering, panicle length and number tillers per plant, number of grains per panicle and should further be utilized in developing superior hybrids with other source materials also.
2. Testers IR-84898-B-168, DANTESWARI and CRR-451-193-3-B was best general combiner for number of grains per panicle, biological yield, grain yield per panicle were identified as good general combiners for most of the characters and may be utilized in recombination breeding programme to bring in further improvement in respective traits.
- 3 Non-additive gene action was predominant for grain yield and related traits, which offers scope for exploitation of heterosis.
- 4 The present investigation revealed that yield is highly positively correlated with the panicle length, number of tillers per plant, biological yield, harvest index and number of panicles per plant and these characters therefore, should be given importance in further selection.
- 5 The hybrids REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B, IR-82635-47-1/DANTESWARI, IR-826310-67-2/IR-84898-B-168-39 showed superior performances and high heterosis for grain yield per plant and therefore, may be recommended for commercial exploitation of heterosis.

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Appendix I :- ANOVA for DTH

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replication	2	7.11828	3.55914	0.7275	0.4873
Treatments	30	564.645	18.8215**	3.847	0
Error	60	293.548	4.89247		

Appendix II :- ANOVA for PH

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replication	2	141.054	70.5269	1.2469	0.2947
Treatments	30	6738.65	224.622**	3.9714	0
Error	60	3393.61	56.5602		

Appendix III:- ANOVA for TPP

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	0.924731	0.462366	0.2763	0.7596
Treatments	30	477.1398	15.90466**	9.504	0
Error	60	100.4086	1.673477		

Appendix IV:- ANOVA for PPP

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replication	2	4.7957	2.39785	2.3006	0.109
Treatments	30	193.398	6.4466**	6.185	0
Error	60	62.5376	1.04229		

Appendix V:- ANOVA for NGPP

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	363.2473	181.6237	1.607	0.209
Treatments	30	13151.16	438.372**	3.8786	0
Error	60	6781.419	113.0237		

Appendix VI:- ANOVA for TW

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	4.666667	2.333333	1.0396	0.3599
Treatments	30	140.6237	4.687455**	2.0885	0.0077
Error	60	134.6667	2.244444		

Appendix VII:- ANOVA for PL

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	4.924731	2.462366	1.8843	0.1608
Treatments	30	139.3978	4.646595**	3.5557	0
Error	60	78.4086	1.30681		

Appendix VIII:- ANOVA for GYPP

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	2.860215	1.430107	0.3463	0.7087
Treatments	30	3070	102.3333**	24.7774	0
Error	60	247.8065	4.130108		

Appendix IX:- ANOVA for BY

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	1.956989	0.978495	0.0711	0.9315
Treatments	30	9207.892	306.9297**	22.294	0
Error	60	826.043	13.76738		

Appendix X :- ANOVA for HI

Source of Variations	df	Sum of Squares	Mean Squares	F Ratio	Probability
Replicate	2	76.04646	38.02323	1.1414	0.3262
Treatments	30	5937.299	197.91**	5.9408	0
Error	60	1998.832	33.31386		

Appendix XI Mean performance of different characters

S. No	Crosses	DTH	PH	TPP	PPP	NGPP	TW	PL	GYPP	BY	HI
1	REWA-1103-IR x IR84898-B-168-39	69.33	104.00	13.00	10.00	127.67	22.67	19.00	18.00	47.33	38.03
2	REWA-1103-IR x CRR451-193-3-B	71.67	93.00	12.00	8.33	122.67	22.67	18.00	12.33	27.33	46.31
3	REWA-1103-IR x DANTESWARI	72.67	102.00	17.33	13.00	117.33	23.33	19.33	20.33	52.67	38.58
4	IET-22107 x IR84898-B-168-39	68.00	105.33	13.33	10.67	125.67	25.67	20.33	15.00	38.00	39.47
5	IET-22107 x CRR451-193-3-B	72.67	101.00	16.00	12.00	125.67	26.00	18.00	21.67	51.67	41.97
6	IET-22107 x DANTESWARI	71.00	88.33	12.33	9.00	132.33	25.33	17.67	12.33	36.33	33.96
7	IR-79971-Rewa51 x IR84898-B-168-39	69.00	98.67	12.00	10.33	135.33	25.00	18.00	28.33	53.67	52.83
8	IR-79971-Rewa51 x CRR451-193-3-B	70.33	91.33	12.33	9.00	137.67	23.33	19.67	12.00	33.00	37.28
9	IR-79971-Rewa51 x DANTESWARI	71.67	93.67	11.67	8.00	134.33	24.00	18.00	11.00	28.00	39.50
10	IR82635-47-1 x IR84898-B-168-39	74.00	104.00	11.00	10.00	134.33	24.00	18.33	20.33	43.00	47.46
11	IR82635-47-1 x CRR451-193-3-B	72.00	101.00	13.33	9.33	133.33	23.67	18.67	16.33	39.33	41.66
12	IR82635-47-1 x DANTESWARI	72.00	96.00	15.33	11.33	131.33	26.00	18.00	14.67	43.00	33.63
13	OM7938 x IR84898-B-168-39	74.33	99.67	12.67	9.67	127.67	25.67	19.33	11.67	26.67	44.54
14	OM7938 x CRR451-193-3-B	70.67	99.67	16.00	12.00	136.00	26.00	18.67	7.33	28.67	25.53
15	OM7938 x DANTESWARI	71.67	95.67	15.67	11.00	121.67	26.00	19.67	7.67	20.00	38.23
16	IR-82639-115-1 x IR84898-B-168-39	73.00	81.67	14.67	10.67	125.00	27.00	18.67	11.33	32.67	34.78
17	IR-82639-115-1 x CRR451-193-3-B	71.33	77.33	15.00	10.00	129.00	25.00	16.67	8.00	30.33	26.34
18	IR-82639-115-1 x DANTESWARI	75.00	81.00	16.67	9.00	127.33	25.67	18.67	11.33	34.67	32.73
19	IR-826310-67-2 x IR84898-B-168-39	69.00	86.67	15.33	11.33	132.33	22.67	19.33	28.00	54.33	51.48
20	IR-826310-67-2 x CRR451-193-3-B	66.00	93.33	15.67	11.00	125.33	24.00	20.67	16.00	42.33	37.70
21	IR-826310-67-2 x DANTESWARI	65.67	98.67	13.33	10.67	132.67	26.33	20.67	17.67	34.67	51.11
	Crosses Mean	71.00	94.86	14.03	10.30	129.27	24.76	18.83	15.30	37.98	39.67
22	REWA-1103-IR	67.00	88.33	16.33	7.00	130.67	22.67	18.00	12.67	31.67	39.91
23	IET-22107	68.00	77.00	17.67	10.33	113.33	24.33	20.67	7.67	30.33	25.26
24	IR-79971-Rewa51	67.33	88.33	13.67	8.33	100.33	24.00	16.67	20.33	51.67	39.29

25	IR82635-47-1	67.67	77.67	17.00	10.33	101.33	24.00	17.00	19.67	56.33	34.97
26	OM7938	68.67	93.00	9.33	6.00	103.00	23.67	17.33	8.67	33.67	26.16
27	IR-82639-115-1	71.00	81.33	11.00	9.67	94.67	25.00	16.67	6.67	27.67	23.64
28	IR-826310-67-2	69.33	89.33	16.00	9.00	99.67	25.00	18.00	4.67	20.33	22.85
	Line Mean	68.43	85.00	14.43	8.67	106.14	24.10	17.76	11.48	35.95	30.30
29	IR84898-B-168-39	66.00	103.00	15.33	10.33	116.67	26.33	20.00	15.67	37.67	42.40
30	CRR451-193-3-B	70.67	99.67	17.00	10.00	115.00	25.67	20.00	14.00	34.00	42.13
31	DANTESWARI	71.00	101.00	18.67	11.00	125.00	24.67	20.67	13.00	30.67	42.12
	Testers Mean	69.22	101.22	17.00	10.44	118.89	25.56	20.22	14.22	34.11	42.21
	Overall Mean	70.25	93.25	14.41	9.95	123.04	24.69	18.72	14.33	37.15	37.80
	C.V.	3.15	8.07	8.98	10.26	8.64	6.07	6.11	14.18	9.99	15.27
	S.E.	1.28	4.34	0.75	0.59	6.14	0.87	0.66	1.17	2.14	3.33
	C.D. 5%	3.61	12.28	2.11	1.67	17.36	2.45	1.87	3.32	6.06	9.43
	Range Lowest	65.67	77.00	9.33	6.00	94.67	22.67	16.67	4.67	20.00	22.85
	Range Highest	75.00	105.33	18.67	13.00	137.67	27.00	20.67	28.33	56.33	52.83

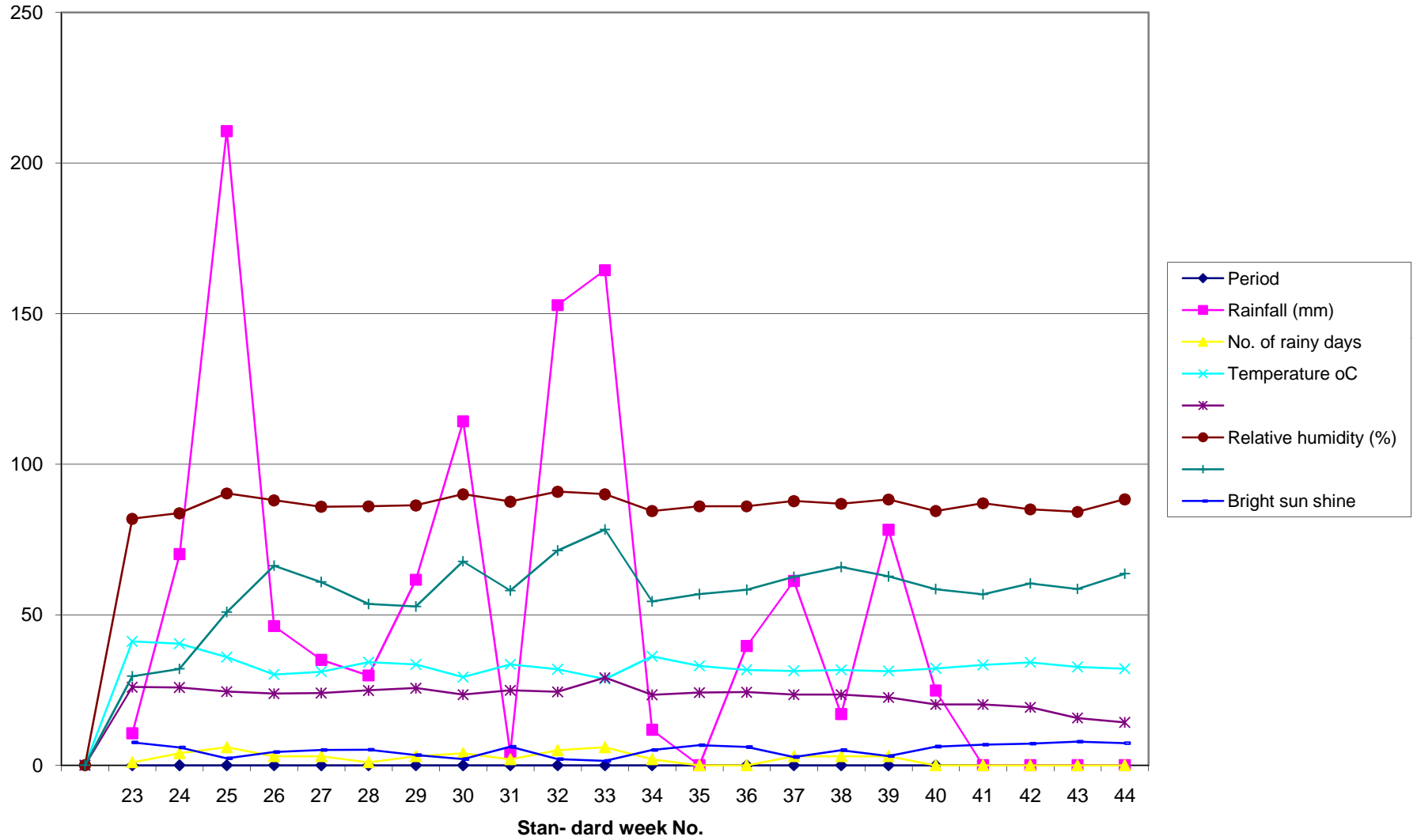
Table 4a Mean performance of different characters

S. No	Crosses	DTH	PH	TPP	PPP	NGPP	TW	PL	GYPP	BY	HI
1	REWA-1103-IR x IR84898-B-168-39	69.33	104.00	13.00	10.00	127.67	22.67	19.00	18.00	47.33	38.03
2	REWA-1103-IR x CRR451-193-3-B	71.67	93.00	12.00	8.33	122.67	22.67	18.00	12.33	27.33	46.31
3	REWA-1103-IR x DANTESWARI	72.67	102.00	17.33	13.00	117.33	23.33	19.33	20.33	52.67	38.58
4	IET-22107 x IR84898-B-168-39	68.00	105.33	13.33	10.67	125.67	25.67	20.33	15.00	38.00	39.47
5	IET-22107 x CRR451-193-3-B	72.67	101.00	16.00	12.00	125.67	26.00	18.00	21.67	51.67	41.97
6	IET-22107 x DANTESWARI	71.00	88.33	12.33	9.00	132.33	25.33	17.67	12.33	36.33	33.96
7	IR-79971-Rewa51 x IR84898-B-168-39	69.00	98.67	12.00	10.33	135.33	25.00	18.00	28.33	53.67	52.83
8	IR-79971-Rewa51 x CRR451-193-3-B	70.33	91.33	12.33	9.00	137.67	23.33	19.67	12.00	33.00	37.28
9	IR-79971-Rewa51 x DANTESWARI	71.67	93.67	11.67	8.00	134.33	24.00	18.00	11.00	28.00	39.50
10	IR82635-47-1 x IR84898-B-168-39	74.00	104.00	11.00	10.00	134.33	24.00	18.33	20.33	43.00	47.46
11	IR82635-47-1 x CRR451-193-3-B	72.00	101.00	13.33	9.33	133.33	23.67	18.67	16.33	39.33	41.66
12	IR82635-47-1 x DANTESWARI	72.00	96.00	15.33	11.33	131.33	26.00	18.00	14.67	43.00	33.63
13	OM7938 x IR84898-B-168-39	74.33	99.67	12.67	9.67	127.67	25.67	19.33	11.67	26.67	44.54
14	OM7938 x CRR451-193-3-B	70.67	99.67	16.00	12.00	136.00	26.00	18.67	7.33	28.67	25.53
15	OM7938 x DANTESWARI	71.67	95.67	15.67	11.00	121.67	26.00	19.67	7.67	20.00	38.23
16	IR-82639-115-1 x IR84898-B-168-39	73.00	81.67	14.67	10.67	125.00	27.00	18.67	11.33	32.67	34.78
17	IR-82639-115-1 x CRR451-193-3-B	71.33	77.33	15.00	10.00	129.00	25.00	16.67	8.00	30.33	26.34
18	IR-82639-115-1 x DANTESWARI	75.00	81.00	16.67	9.00	127.33	25.67	18.67	11.33	34.67	32.73
19	IR-826310-67-2 x IR84898-B-168-39	69.00	86.67	15.33	11.33	132.33	22.67	19.33	28.00	54.33	51.48

20	IR-826310-67-2 x CRR451-193-3-B	66.00	93.33	15.67	11.00	125.33	24.00	20.67	16.00	42.33	37.70
21	IR-826310-67-2 x DANTESWARI	65.67	98.67	13.33	10.67	132.67	26.33	20.67	17.67	34.67	51.11
	Crosses Mean	71.00	94.86	14.03	10.30	129.27	24.76	18.83	15.30	37.98	39.67
22	REWA-1103-IR	67.00	88.33	16.33	7.00	130.67	22.67	18.00	12.67	31.67	39.91
23	IET-22107	68.00	77.00	17.67	10.33	113.33	24.33	20.67	7.67	30.33	25.26
24	IR-79971-Rewa51	67.33	88.33	13.67	8.33	100.33	24.00	16.67	20.33	51.67	39.29
25	IR82635-47-1	67.67	77.67	17.00	10.33	101.33	24.00	17.00	19.67	56.33	34.97
26	OM7938	68.67	93.00	9.33	6.00	103.00	23.67	17.33	8.67	33.67	26.16
27	IR-82639-115-1	71.00	81.33	11.00	9.67	94.67	25.00	16.67	6.67	27.67	23.64
28	IR-826310-67-2	69.33	89.33	16.00	9.00	99.67	25.00	18.00	4.67	20.33	22.85
	Line Mean	68.43	85.00	14.43	8.67	106.14	24.10	17.76	11.48	35.95	30.30
29	IR84898-B-168-39	66.00	103.00	15.33	10.33	116.67	26.33	20.00	15.67	37.67	42.40
30	CRR451-193-3-B	70.67	99.67	17.00	10.00	115.00	25.67	20.00	14.00	34.00	42.13
31	DANESWARI	71.00	101.00	18.67	11.00	125.00	24.67	20.67	13.00	30.67	42.12
	Testers Mean	69.22	101.22	17.00	10.44	118.89	25.56	20.22	14.22	34.11	42.21
	Overall Mean	70.25	93.25	14.41	9.95	123.04	24.69	18.72	14.33	37.15	37.80
	C.V.	3.15	8.07	8.98	10.26	8.64	6.07	6.11	14.18	9.99	15.27
	S.E.	1.28	4.34	0.75	0.59	6.14	0.87	0.66	1.17	2.14	3.33
	C.D. 5%	3.61	12.28	2.11	1.67	17.36	2.45	1.87	3.32	6.06	9.43
	Range Lowest	65.67	77.00	9.33	6.00	94.67	22.67	16.67	4.67	20.00	22.85
	Range Highest	75.00	105.33	18.67	13.00	137.67	27.00	20.67	28.33	56.33	52.83

SSS

Fig. 3.1 Average weekly metrological data of year (June to October 2011)



Standard week No.	Period	Rainfall (mm)	No. of rainy days	Temperature °C		Relative Humidity (%) N 0705 h
				Max	Min	
23	June 4-10	10.6	1	41.16	25.96	81.85
24	June 11-17	70.1	4	40.38	25.85	83.71
25	June 18-24	210.6	6	35.95	24.47	90.28
26	June 25-1 July	46.2	3	30.18	23.8	88
27	July 2-8	35	3	31.12	24	85.85
28	July 9-15	29.8	1	34.24	24.85	86
29	July 16-22	61.6	3	33.5	25.62	86.28
30	July 23-29	114.2	4	29.3	23.45	90
31	July 30-5 Aug	4	2	33.54	24.88	87.57
32	Aug 6-12	152.8	5	31.91	24.38	90.85
33	Aug 13-19	164.4	6	28.64	29.08	90
34	Aug 20-27	11.8	2	36.17	23.41	84.42
35	Aug 27-2 Sept	0	0	33.02	24.14	86
36	Sept 3-9	39.6	3	31.7	24.28	86
37	Sept 10-16	61.2	3	31.37	23.48	87.71
38	Sept 17-23	17	3	31.68	23.48	86.85
39	Sept 24-30	78.2	3	31.28	22.54	88.28
40	Oct 1-7	24.8	0	32.21	20.17	84.42
41	Oct 8-14	0	0	33.31	20.17	87
42	Oct 15-21	0	0	34.21	19.24	85
43	Oct 22-28	0	0	32.65	15.71	84.14
44	Oct 29-Nov 04	0	0	32.08	14.25	88.33

humidity (%)	Bright sun shine
X 1405 h	
29.57	7.64
32	5.94
50.85	2.34
66.28	4.47
60.85	5.1
53.57	5.2
52.71	3.44
67.71	2.06
58	6.17
71.28	2.09
78.28	1.51
54.42	5.14
56.85	6.74
58.28	6.09
62.57	2.8
65.85	5.07
62.71	3.07
58.5	6.24
56.75	6.91
60.4	7.2
58.55	7.88
63.6	7.37

Table : 6.(b) Analysis of variance for 10 characters in rice

Sources of variation	d.f.	Days to 50% flowering	Plant height	No. of tillers per plant	No. of panicles per plant	No. of grain per plant	Test weight	Panicle length per plant	Grain yield per plant	Biological yield	Harvest index
Replications	2	3.56	70.53	0.46	2.40	181.62	2.33	2.46	1.43	0.98	38.02
Treatments	30	18.82**	224.62**	15.90**	6.45**	438.37**	4.69**	4.65**	102.33**	306.93**	197.91**
Error	60	4.89	56.56	1.67	1.04	113.02	2.24	1.31	4.13	13.77	33.31

*, ** Significant at 5% and 1% probability levels, respectively.

Table: 5. Estimates of variability, heritability and genetic advance for 10 characters in rice

Sl. No.	Characters	Coefficient of variation		Heritability in broad sense (h^2_b) %	Gen adv as per cent of mean 5%
		PCV	GCV		
1.	Days to 50% flowering	4.39	3.06	49.00	4.40
2.	Plant height	11.37	8.02	50.00	11.66
3.	No. of tillers per plant	17.58	15.11	74.00	26.77
4.	No. of panicle per plant	16.95	13.49	63.30	22.12
5.	No. of grain per plant	12.09	8.64	49.00	12.20
6.	Test weight	7.08	3.65	27.00	3.88
7.	Panicle length per plant	8.31	5.63	46.00	7.87
8.	Grain yield per plant	42.36	39.91	89.00	77.48
9.	Biological yield	28.42	26.60	88.00	51.31
10.	Harvest index	24.84	19.59	62.22	31.84

Table 6(a) : Analysis of variance for line x testers for 10 characters in rice

Sources of variation	d.f.	Days to 50% flowering	Plant height	No. of tillers per plant	No. of panicles per plant	No.of grain per plant	Test weight	Panicle length per plant	Grain yield per plant	Biological yield	Harvest index
Replication	2	4.00	77.28	2.11	1.25	121.25	3.47	11.15**	4.63	0.96	48.65
Crosses	20	18.43**	192.45**	10.33**	4.86**	85.12	5.50*	3.15**	105.59**	294.34**	167.33**
Lines Effect	6	39.48*	451.84**	11.87	3.76	163.95	11.28*	4.69	156.98	418.83	225.88
Testers Effect	2	2.71	82.47	12.87	0.11	20.30	4.00	0.77	210.11	286.20	319.34
Lines x Testers Effect	12	10.52*	81.08	9.13**	6.20**	56.50	2.87	2.77*	62.48**	233.46**	112.72**
Error	40	4.03	46.60	1.92	1.23	138.58	2.40	1.09	3.65	11.50	29.39
Total	62	8.67	94.64	4.64	2.40	120.78	3.44	2.08	36.56	102.40	74.51

*, **, Significant at 5% and 1% probability levels, respectively.

Table 7 : Estimates of general combining ability (gca) effects of lines x testers for 10 characters in rice

S. No.	Parents	Days to 50% flowering	Plant height	No. of tillers per plant	No. of panicles per plant	No. of grain per plant	Test weight	Panicle length per plant	Grain yield per plant	Biological yield	Harvest index
Females (Lines)											
1.	REWA-1103-IR	0.22	4.81	0.07	0.14	-6.71	-1.87	-0.04	1.58*	4.46	1.30
2.	IET-22107	-0.44	3.36	-0.14	0.25	-1.38	0.90	-0.15	1.03	4.01**	-1.20
3.	IR-79971-Rewa51	-0.66	-0.30	-2.03	-1.19**	6.50	-0.65	-0.27	1.81*	0.23	3.53
4.	IR82635-47-1	1.66*	5.47*	-0.81	-0.07	3.73	-0.20	-0.49	1.81*	3.79**	1.24
5.	OM7938	1.22	3.47	0.74	0.58	-0.82	1.12*	0.39	-6.41	-12.87	-3.57
6.	IR-82639-115-1	2.11**	-14.85	1.41	-0.41	-2.15	1.12*	-0.82*	-5.07	-5.42	-8.39
7.	IR-826310-67-2	-4.11	-1.96	0.74	0.69*	0.84	-0.42	1.39	5.25	5.79	7.09
	SE (gi) Female	0.73	2.50	0.43	0.34	3.54	0.49	0.38	0.67	1.23	1.92
	SE (gi-gj)	1.04	3.54	0.60	0.48	5.01	0.70	0.53	0.95	1.74	2.72
Males (Testers)											
1.	IR84898-B-168-39	-0.04	2.28	-0.88**	0.07	0.44	-0.09	0.17	3.65	4.25	4.41**
2.	CRR451-193-3-B	-0.33	-1.04	0.30	-0.06	0.68	-0.38	-0.20	-1.92	-1.88*	-2.98*
3.	DANTESWARI	0.38	-1.23	0.58*	-0.01	-1.12	0.47	0.03	-1.73	-2.36**	-1.42
	SE (gi) Male	0.48	1.64	0.28	0.22	2.31	0.32	0.24	0.44	0.80	1.25
	SE (gi-gj)	0.68	2.32	0.39	0.31	3.28	0.46	0.35	0.62	1.14	1.78

*, **, Significant at 5% and 1% probability levels, respectively.

Table 8 : Estimates of specific combining ability (sca) effects of line x tester for 10 characters in rice

S. N.	Crosses	Days to 50% flowering	Plant height	No. of tillers per plant	No. of panicle per plant	No. of grain per plant	Test weight	Panicle length per plant	Grain yield per plant	Biological yield	Harvest index
1.	REWA-1103-IR x IR84898-B-168-39	-1.84	2.04	-0.22	-0.52	4.66	-0.12	0.04	-2.54*	0.63	-7.35*
2.	REWA-1103-IR x CRR451-193-3-B	0.77	-5.61	-2.41**	-2.04**	-0.57	0.15	-0.57	-2.63*	-13.22	8.32*
3.	REWA-1103-IR x DANESWARI	1.06	3.57	2.63**	2.57	-4.09	-0.03	0.52	5.17	12.58	-0.97
4.	IET-22107 x IR84898-B-168-39	-2.50	4.82	0.33	0.03	-2.66	0.09	1.49*	-4.98	-8.25	-3.40
5.	IET-22107 x CRR451-193-3-B	2.44	3.82	1.81*	1.50*	-2.90	0.71	-0.46	7.25	11.55	6.49
6.	IET-22107 x DANESWARI	0.06	-8.65	-2.14	-1.54*	5.57	-0.81	-1.03	-2.27	-3.30	-308
7.	IR-79971-Rewa51 x IR84898-B-168-39	-1.28	1.82	0.88	1.14	-0.88	0.98	-0.73	7.57	11.19	5.21
8.	IR-79971-Rewa51 x CRR451-193-3-B	0.33	-2.17	0.03	0.04	1.20	-0.39	1.31	-3.19**	-3.33	-2.93
9.	IR-79971-Rewa51 x DANESWARI	0.95	0.34	-0.92	0.09	0.31	-0.58	-0.58	-4.38	-7.85	-2.28
10.	IR82635-47-1 x IR84898-B-168-39	1.38	1.38	-1.33	-0.30	0.88	-0.46	-0.17	-0.42	-3.03	2.13
11.	IR82635-47-1 x CRR451-193-3-B	-0.33	1.71	-0.19	-0.82	0.34	-0.50	0.54	1.14	-0.55	3.72
12.	IR82635-47-1 x DANESWARI	-1.04	3.09	1.52*	1.12	-0.54	0.96	-0.36	0.71	3.58	-5.86
13.	OM7938 x IR84898-B-168-39	2.15	0.95	-1.22	-1.30*	-1.22	-0.12	-0.06	-0.87	-2.69	4.02
14.	OM7938 x CRR451-193-3-B	-1.22	2.38	0.92	1.17	6.87	0.49	-0.34	0.36	5.44*	-7.57*
15.	OM7938 x DANESWARI	-0.93	-1.42	0.30	0.12	-5.65	-0.36	0.41	0.50	2.74	3.55
16.	IR-82639-115-1 x IR84898-B-168-39	-0.06	-0.61	0.11	0.69	-0.55	1.20	0.49	-2.54*	-4.14	-0.91
17.	IR-82639-115-1 x CRR451-193-3-B	-1.44	-1.61	-0.74	-0.17	1.20	-0.50	-1.12	-0.30	-0.33	-1.55
18.	IR-82639-115-1 x DANESWARI	1.50	2.23	0.63	-0.87	1.34	-0.69	0.36	2.84*	4.47*	2.87
19.	IR-826310-67-2 x IR84898-B-168-39	2.15	-8.50	1.44	0.25	1.77	-1.57	-1.06	3.79**	6.30**	0.30
20.	IR-826310-67-2 x CRR451-193-3-B	-0.55	1.49	0.58	0.06	-5.46	0.04	0.65	-2.63*	0.44	-6.07
21.	IR-826310-67-2 x DANESWARI	-1.60	7.01	-2.03**	-0.31	3.68	1.52	0.41	-1.15	-6.74**	5.77
	SE (ij)	1.80	6.14	1.05	0.83	8.68	1.22	0.93	1.65	3.02	4.71
	SE (ij-ik)	2.94	10.02	1.72	1.36	14.17	1.99	1.52	2.70	4.94	7.69

*, **, Significant at 5% and 1% probability levels, respectively.

Table 9 (a) : Extent of heterosis over better parent and mid parent in 21 hybrids for 10 characters in rice

S.N.	Crosses	Days to 50% flowering		Plant height		No. of tillers per plant		No. of panicles per plant		No. of grain per plant	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1.	REWA-1103-IR x IR84898-B-168-39	4.26	3.48	8.71	0.97	-17.89**	-20.41**	15.38	-3.23	3.23	-2.30
2.	REWA-1103-IR x CRR451-193-3-B	4.12	1.42	-1.06	-6.69	28.00**	-29.41**	1.96	-16.67	-0.14	-6.12
3.	REWA-1103-IR x DANTESWARI	5.31*	2.35	7.75	0.99	-0.95	-7.14	44.44**	18.18*	-8.21	-10.20
4.	IET-22107 x IR84898-B-168-39	1.49	0.00	17.04**	2.27	-19.19**	-24.53**	3.23	3.23	9.28	7.71
5.	IET-22107 x CRR451-193-3-B	4.81	2.83	14.34*	1.34	-7.69	-9.43	18.03*	16.13	10.07	9.28
6.	IET-22107 x DANTESWARI	2.16	0.00	-0.75	-12.54*	-32.11**	-33.93**	-15.63.*	-18.18*	11.05	5.87
7.	IR-79971-Rewa51 x IR84898-B-168-39	3.50	2.48	3.14	-4.21	-17.24**	-21.74**	10.78	0.00	24.73**	16.00*
8.	IR-79971-Rewa51 x CRR451-193-3-B	1.93	-0.47	-2.84	-8.36	-19.57**	-27.45**	-1.82	-10.00	27.86**	19.71*
9.	IR-79971-Rewa51 x DANTESWARI	3.61	0.94	-1.06	-7.26	-27.84**	-37.50**	-17.24*	-27.27**	19.23**	7.47
10.	IR82635-47-1 x IR84898-B-168-39	10.72**	9.36**	15.13*	0.97	-31.96**	-35.29**	-3.23	-3.23	23.24**	15.14*
11.	IR82635-47-1 x CRR451-193-3-B	4.10	1.89	13.91*	1.34	21.97**	-21.57**	-8.20	-.9.68	23.27**	15.94*
12.	IR82635-47-1 x DANTESWARI	3.85	1.41	7.46	-4.95	-14.02**	-17.86**	6.25	3.03	16.04*	5.07
13.	OM7938 x IR84898-B-168-39	10.40**	8.25**	1.70	-3.24	2.70	-17.39*	18.37*	-6.45	16.24*	9.43
14.	OM7938 x CRR451-193-3-B	1.44	0.00	3.46	0.00	21.52**	-5.88	50.00**	20.00*	24.77**	18.26
15.	OM7938 x DANTESWARI	2.63	0.94	-1.37	-5.28	11.90	-16.07**	29.41**	0.00	6.73	-2.67
16.	IR-82639-115-1 x IR84898-B-168-39	6.57**	2.82	-11.39	-20.71**	11.39	-4.35	6.67	3.23	18.30*	7.14
17.	IR-82639-115-1 x CRR451-193-3-B	0.71	0.47	-14.55	-22.41**	7.14	-11.76	1.69	0.00	23.05**	12.17
18.	IR-82639-115-1 x DANTESWARI	5.63*	5.63*	-11.15	-19.80**	12.36	-10.71	12.90	-18.18*	15.93*	1.87
19.	IR-826310-67-2 x IR84898-B-168-39	1.97	-0.48	-9.88	-15.86*	-2.13	-4.17	17.24*	9.68	22.34**	13.43
20.	IR-826310-67-2 x CRR451-193-3-B	-5.71*	-6.60*	-1.23	-6.35	-5.05	-7.84	15.79	10.00	16.77*	8.99
21.	IR-826310-67-2 x DANTESWARI	-6.41**	-7.51**	3.68	-2.31	-23.08**	-28.57**	6.67	-3.03	18.10**	6.13
	No. of crosses with significant positive heterosis	19	17	11	7	8	0	16	11	19	17
	No. of crosses with significant negative heterosis	2	4	10	14	13	21	5	10	2	4
	Range of heterosis	-6.41	-7.51	-14.55	-22.41	-32.11	-37.50	-17.24	-27.27	-8.21	-10.20
		10.72	9.36	17.04	2.27	21.52	-4.17	50.00	20.00	27.86	19.71

Table 9 (b) : Extent of heterosis over better parent and mid parent in 21 hybrids for 10 characters in rice

S.N.	Crosses	Test weight		Panicle length per plant		Grain yield per plant		Biological yield		Harvest index	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1.	REWA-1103-IR x IR84898-B-168-39	-7.49	-13.92**	0.00	-5.00	27.06*	14.89	36.54**	25.66**	-7.58	-10.29
2.	REWA-1103-IR x CRR451-193-3-B	-6.21	-11.69*	-5.26	-10.00*	-7.50	-11.90	-16.75*	-19.61*	12.90	9.92
3.	REWA-1103-IR x DANTESWARI	-1.41	-5.41	0.00	-6.45	58.44**	56.41**	68.98**	66.32**	-5.93	-8.40
4.	IET-22107 x IR84898-B-168-39	1.32	-2.53	0.00	-1.61	28.57*	-4.26	11.76	0.88	16.67	-6.90
5.	IET-22107 x CRR451-193-3-B	4.00	1.30	-11.48**	-12.90*	100.00**	54.76**	60.62**	51.96**	24.56*	-0.37
6.	IET-22107 x DANTESWARI	3.40	2.70	-14.52**	-14.52**	19.35	5.13	19.13*	18.48	0.80	-19.37
7.	IR-79971-Rewa51 x IR84898-B-168-39	-0.66	-5.06	-1.82	-10.00*	57.41**	39.34**	20.15**	3.87	29.35**	24.62*
8.	IR-79971-Rewa51 x CRR451-193-3-B	-6.04	-9.09	7.27	-1.67	-30.10**	-40.98**	-22.96**	-36.13**	-8.43	-11.51*
9.	IR-79971-Rewa51 x DANTESWARI	-1.37	-2.70	-3.57	-12.90**	-34.00**	-45.90**	-31.98**	-45.81**	-2.96	-6.21
10.	IR82635-47-1 x IR84898-B-168-39	-4.64	-8.86	-0.90	-8.33	15.09	3.39	-8.51	-23.67**	22.69*	11.94
11.	IR82635-47-1 x CRR451-193-3-B	-4.70	-7.79	0.90	-6.67	-2.97	-16.95	-12.92*	-30.18**	8.06	-1.12
12.	IR82635-47-1 x DANTESWARI	6.85	5.41	-4.42	-12.90**	-10.20	-25.42**	-1.15	-23.67**	-12.74	-20.15
13.	OM7938 x IR84898-B-168-39	2.67	-2.53	3.57	-3.33	-4.11	-25.53*	-25.23**	-29.20**	29.93*	5.05
14.	OM7938 x CRR451-193-3-B	5.41	1.30	0.00	-6.67	-35.29**	-47.62**	-15.27	-15.69	-25.22*	-39.39**
15.	OM7938 x DANTESWARI	7.59	5.41	3.51	-4.84	-29.23	-41.03**	-37.82**	-40.59**	11.99	-9.23
16.	IR-82639-115-1 x IR84898-B-168-39	5.19	2.53	1.82	-6.67	1.49	-27.66*	0.00	-13.27	5.32	-17.97
17.	IR-82639-115-1 x CRR451-193-3-B	-1.32	-2.60	-9.09	-16.67**	-22.58	-42.86**	-1.62	-10.78	19.91	-37.48**
18.	IR-82639-115-1 x DANTESWARI	3.36	2.67	0.00	-9.68*	15.25	-12.82	18.86*	13.04	-0.46	-22.29
19.	IR-826310-67-2 x IR84898-B-168-39	-11.69**	-13.92**	1.75	-3.33	175.41**	78.71**	87.36**	44.25**	57.80**	21.42
20.	IR-826310-67-2 x CRR451-193-3-B	5.26	-6.49	8.77*	3.33	71.43**	14.29	55.83**	24.51**	16.04	-10.52
21.	IR-826310-67-2 x DANTESWARI	6.04	5.33	6.90	0.00	100.00**	35.90	35.95**	13.04	57.35**	21.35
	No. of crosses with significant positive heterosis	11	8	13	2	12	9	11	10	14	6
	No. of crosses with significant negative heterosis	10	13	8	19	9	12	10	11	7	15
	Range of heterosis	-11.69	-13.92	-14.52	-16.67	-35.29	-47.62	-37.82	-45.81	-25.22	-39.39
		7.59	5.41	8.77	3.33	175.41	78.72	87.36	66.32	57.80	24.62

Table 11. Path coefficients showing direct and indirect effects of different characters on grain yield

		DTH	PH	TPP	PPP	NGPP	TW	PL	BY	HI	GYPP
DTH	p	-0.0255	-0.0002	0.0013	-0.0026	-0.0045	-0.0015	0.0034	0.0027	0.0004	-0.0991
	g	0.0835	0.0066	-0.0074	0.012	0.028	0.0264	-0.0239	-0.0204	-0.0071	-0.2104
PH	p	-0.0003	-0.0307	0.0021	-0.0061	-0.0079	-0.0004	-0.0077	-0.0017	-0.0123	0.2282
	g	-0.0112	-0.1418	0.0298	-0.0465	-0.0643	-0.0201	-0.0828	-0.0272	-0.0866	0.3940
TPP	p	0.0013	0.0017	-0.0244	-0.0118	0.0014	-0.0019	-0.0067	-0.0019	0.0012	0.028
	g	0.0116	0.0274	-0.1305	-0.0712	0.0115	-0.0377	-0.0605	-0.008	0.0219	-0.0418
PPP	p	0.0051	0.0098	0.0239	0.0494	0.008	0.0093	0.0155	0.0143	0.0085	0.3149
	g	-0.0043	-0.0099	-0.0165	-0.0302	-0.0076	-0.0182	-0.0155	-0.0108	-0.0046	0.3312
NGPP	p	0.0012	0.0018	-0.0004	0.0011	0.007	0.0003	0.0013	0.0004	0.0025	0.2299
	g	-0.0162	-0.0219	0.0042	-0.0121	-0.0483	-0.0001	-0.0221	-0.0013	-0.0283	0.2775
TW	p	-0.0003	-0.0001	-0.0004	-0.001	-0.0002	-0.0054	-0.0005	0.001	0.0001	-0.1418
	g	0.0141	0.0063	0.0129	0.0269	0.0001	0.0446	0.0113	-0.0166	-0.0123	-0.376
PL	p	0.001	-0.0019	-0.002	-0.0023	-0.0013	-0.0006	-0.0074	0.0009	-0.0019	0.0526
	g	-0.0542	0.1108	0.088	0.0973	0.0867	0.0482	0.1898	-0.0261	0.0743	0.0527
BY	p	-0.0732	0.0386	0.0533	0.1985	0.039	-0.1304	-0.082	0.6844	0.2069	0.8575
	g	-0.1972	0.1553	0.0496	0.2905	0.0211	-0.3009	-0.1113	0.8091	0.4043	0.9125
HI	p	-0.0083	0.2093	-0.0253	0.0897	0.1884	-0.0111	0.1368	0.1574	0.5206	0.726
	g	-0.0363	0.2612	-0.0719	0.0646	0.2503	-0.1182	0.1676	0.2138	0.4278	0.7895
Partial R _g		0.0025	-0.007	-0.0007	0.0156	0.0016	0.0008	-0.0004	0.5869	0.3779	
Partial R _p		-0.0176	-0.0559	0.0055	-0.01	-0.0134	-0.0168	0.01	0.7382	0.3378	

“Estimation of combining ability and heterosis for drought tolerance in upland rice (*Oryza sativa* L.)”

THESIS ABSTRACT

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ABSTRACT

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Abstract

The present investigation entitled “**Estimation of combining ability and heterosis for drought tolerance and in upland rice (*Oryza sativa* L.)**” was undertaken to determine the extent of variability, to assess the GCA effects of parents and SCA effects of crosses, to ascertain the magnitude of exploitable heterosis, to study type of gene action involved for yield, grain quality and other related characters and to study correlations and path coefficients.

The experimental material consisted of seven lines *viz.*, REWA-1103-IR, IET-22107, IR-79971-REWA-51, IR-82635-47-1, OM-7938, IR-82639-115-1, IR-826310-67-2 and three testers *viz.*, IR-84898-B-168-39, CRR-451-193-3-B, DANTESWARI and twenty one hybrids were generated in line x testers pattern. The parents and hybrids were raised in a randomized block design with three replications during *kharif* 2011 at the Research Farm, College of Agriculture Rewa, JNKVV, Jabalpur, (M.P.) India.

Observations were recorded for days to 50 per cent flowering, plant height, number tillers per plant, number of panicles per plant, number of grains per panicle, test weight, panicle length, grain yield per plant, biological yield per plant, harvest index.

Analysis of variance revealed that variance due to the line x tester was significant for all the characters, this suggested that sufficient variability is available in material used for present study.

The mean data were calculated to analysis of variance as per the Randomized Block Design. Analysis of data revealed highly significant differences among genotypes for all traits.

Highest heritability was recorded for grain yield per plant, biological yield and number of tillers per plant, number of panicle per plant and harvest index.

6.2 Conclusion

Combining ability analysis revealed the preponderance of non-additive gene action for all the characters studied. among the lines, IR-82639-115-1 showed positive significant GCA effects was best general

combiner for all the characters except days to 50 per cent flowering, panicle length and among the lines, IR-826310-67-2 was best general combiner for tiller number per plant, number of grains per panicle, biological yield, harvest index, grain yield per plant, Among the lines REWA-1103-IR, and IR79971-REWA,IR-82635-47-1,IR-826310-67-2 showed positive significant GCA effects was best general combiner for panicle length, harvest index, grain yield per plant, Among the lines, REWA-1103-IR, , IR-82635-47-1, IR-826310—67-2, and IET-22107, showed positive significant GCA effects was best general combiner number of tillers per plant and biological yield.

Among the testers, the testers, IR-84898-B-168-39, showed positive significant GCA effects was best general combiner for all the characters except plant height, IR-84898-B-168-39, DANTESWARI and CRR-451-193-3-B was best general combiner for, number of grains per panicle, biological yield, grain yield per panicle, Tester IR-84898-B-168-39 was best general combiner for panicle length, harvest index, grain yield per plant, test weight, DANTESWARI was best general combiner for plant height, number of grains per panicle, harvest index.

Hybrid REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B IR-82635-47-1/DANTESWARI for number of tillers per plant; REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B for number of panicles per; hybrid IET-22107/IR-84898-B-168-39 for panicle length per plant; hybrids REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B and IR79971-REWA/IR-84898-B-168-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/IR-84898-B-168-39 for grain yield per plant number of tiller per plant; REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-39, IR-79971-REWA/IR-84898-B-168, OM-7938/CR-451-193-3-39, IR-82639-115-1/DANTESWARI, IR-826310-67-2/ R-84898-B-168-39 for biological yield; REWA-1103-IR/CRR-451-193-3-B for harvest index; were found as good specific combiners.

The phenotypic coefficient of variation was higher in magnitude than that of genotypic coefficient of variation for all the characters studied. High genotypic and phenotypic coefficients of variation were recorded for grain yield per plant, harvest index, the moderate estimates genotypic and phenotypic coefficient of variations were observed for tiller number per plant,

panicle per plant, genotypic coefficient of variation of harvest index, phenotypic coefficient of variation for number of grains per plant and plant height. The low estimates of genotypic and phenotypic coefficient of variations were recorded for days to 50 per cent flowering, test weight, genotypic coefficient of variation of plant height, panicle length.

The highest heritability were recorded for grain yield per plant, biological yield and number of tillers per plant, number of panicle per plant and harvest index.

The estimates of relative heterosis and heterobeltiosis were also obtained for different characters under study. A high degree of relative heterosis and heterobeltiosis was observed for all the traits. The highest relative heterosis was exhibited by IR-826310-67-2/IR-84898-B-168-39 followed by IVTE/DANTESWARI, IET-22107/CRR-451-193-3-B, highest heterobeltiosis was observed for IR-826310-67-2/IR-84898-B-168-39 followed by IET-22107//IR-84898-B-168-39 However, a high degree of heterosis for other traits in desired direction was also observed.

Grain yield was positive significantly correlated with the, panicle length, number of tillers per plant, biological yield, harvest index and number of panicles per plant.

The study of path analysis of positive direct effects on grain yield showed that harvest index, biological yield, number of grains per plant and number of panicles per plant were most important contributing characters towards the yield, Therefore, the direct selection for harvest index, biological yield, number of grains per plant and number of panicles per plant is likely to be effective in increasing the yield.

6.3 Suggestion for future work

Based on the finding of the present investigations, the following suggestions are being made for future work:

1. Lines, IR-82639-115-1 and IR-826310-67-2 were identified as best general combiners for 50 per cent flowering, panicle length and number tillers per plant, number of grains per panicle and should further be utilized in developing superior hybrids with other source materials also.

2. Testers IR-84898-B-168, DANTESWARI and CRR-451-193-3-B was best general combiner for number of grains per panicle, biological yield, grain yield per panicle were identified as good general combiners for most of the characters and may be utilized in recombination breeding programme to bring in further improvement in respective traits.
- 3 Non-additive gene action was predominant for grain yield and related traits, which offers scope for exploitation of heterosis.
- 4 The present investigation revealed that yield is highly positively correlated with the panicle length, number of tillers per plant, biological yield, harvest index and number of panicles per plant and these characters therefore, should be given importance in further selection.
- 5 The hybrids REWA-1103-IR/DANTESWARI, IET-22107/CRR-451-193-3-B, IR-82635-47-1/DANTESWARI, IR-826310-67-2/IR-84898-B-168-39 showed superior performances and high heterosis for grain yield per plant and therefore, may be recommended for commercial exploitation of heterosis.