"Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice (*Oryza sativa* L.)"

Thesis

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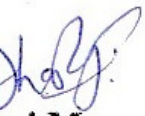

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CERTIFICATE

This is to certify that the thesis entitled **"Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice (*Oryza sativa* L.)"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Genetics and Plant Breeding,** of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Dhanraj Meena, Id. No. 51151**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(M.K. Karnwal)
Chairman
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Pantnagar
June, 2018

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Dhanraj Meena, Id. No. 51151**, a candidate for the degree of **Master of Science in Agriculture** with major in **Genetics and Plant Breeding,** agree that the thesis entitled **"Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice (*Oryza sativa* L.)"** may be submitted in partial fulfillment of the requirements for the degree.

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Introduction

CHAPTER 1 INTRODUCTION

Rice *(Oryza sativa* L.*)* is the most popular cereal grain and, is the staple food of about half of the world's population. More than 90% of rice is consumed in Asia; therefore, rice plays an important role in ensuring food security and reducing poverty and malnutrition. As the world population continues to increase, there will be further demand on rice supply to meet additional consumption requirement. Since the rice lands have been decreased due to expansion of urban areas and industrialization or agricultural diversification in the past decades, thus, the increase of rice production in the future would primarily rely on the increase of productivity**.** Being versatile crop, rice can be cultivated from mean sea level to an altitude of 3100 meters **(Kushwaha, 2016).** Rice also having special aerial root system due to which it can be grown even in water logged conditions. It is assumed that rice needs approximately 3000 liters of water to produce one kg of grains. But now different drought rice varieties have been developed which requires minimum amount of water for its grain production.

Rice belongs to the genus *Oryza* containing 24 species out of which 2 are cultivated and 22 are of wild type, the cultivated species are *Oryza sativa* and *Oryza glaberrima*. The *Oryza sativa* consist of three sub species *Indica* (tropical rice grown in India, long and weak stem, irresponsive to high input condition, low productivity), *Japonica* (grown in temperate and sub-tropical regions of Japan, short stature, sturdy stem, responsive to high input condition, high productivity), *Javanica* (grown in Indonesia, wild form of rice). The South-East Asian region considered as center of origin of *Oryza sativa*, the cultivated rice in India. Rice is the world second most important cereal crop after corn. Five countries in the global scenario namely India, China, Indonesia, Thailand and Bangladesh having more than 10 million hectares rice area and covers more than two- thirds of total area under rice cultivation. In general, Asian countries having largest share in world rice production. According to the most recent official report of the United States Department of Agriculture (USDA) estimates that, the World Rice Production 2017-2018 will be 481.04 million metric tons (milled rice), which is 2.06 million tons lesser than the last year production i.e. 483.1 million metric tons. India is 2nd largest rice producing country in the world after China (210MT). During 2016-17, India produced 104.32 million tons of rice from about 45 million hectares of land as

compared to 105.20 million tons harvested from 43.57 million hectares in 2015-16 (Agriculture statistics at a glance, 2016-17).

Rice is grown under many different conditions and production systems, but submerged in water is the most common method used worldwide. It has many characteristics, making one variety more popular in one region of the world than another. There are three main categories of rice are, (i) long-grain- relatively long and bold types, known as Carolina rice, (ii) medium-grain-long, thin, cylindrical grain, known as Patna, and (iii) short-grain-short, stout grain, known as Spanish-Japan. In addition to that, most of the countries quantify rice into four main categories (i) milling quality (ii) cooking, eating and processing quality, (iii) nutritional quality and specific standards for cleanliness, soundness and purity. However, three more factors has been added by the United States particularly, (i) hull and pericarp (ii) color grain size, shape, weight, uniformity and general appearance and (iii) kernel chalkiness, translucency and color. The nutritional component of rice is one of the most important indicators of quality; rice is predominantly a starchy food though it also contributes useful quantities of proteins and vitamins, mineral, and fiber. The two most important physiochemical properties of cooking quality in rice are amylose content and gelatinization temperature. Starch content (amylose) of rice plays an important role in yield, processing and palatability. Gelatinization temperature is related to many factors such as cooking time, granule size, and molecular size of starch fraction. Some rice varieties are considered aromatic (long slender, translucent grains with aroma), and some are basmati (extra-long slender grains with pleasant aroma). A variety of special quality rice is of great significance with better premium in the domestic as well as export market. Bringing such varieties to the knowledge of consumers abroad would certainly find small but assured market for them**.** However, major attempts have been made for the improvement of such rice genotypes. The anaerobic land races posses immense potential of most valuable genes which can be effectively utilized in the present day breeding programme to evaluate varieties that posses not only high yield potential and quality but also resistant to biotic and abiotic stresses.

The major objectives of rice breeding programme are to improve rice production and productivity to fulfill the growing mouth. Breeding for insect pest resistance, lodging resistance, wider adaptability to different environmental conditions are other breeding objectives ultimately leading to higher production. Heterosis breeding evolved as one of the most reliable way to break the yield plateau and achieve quantum jump in rice production

worldwide. It has been found through several studies that inter sub-specific hybrid (*indica* × *japonica*) show high heterosis for grain yield than inter-varietal hybrids, therefore more emphasis is laid down on exploitation of inter sub-specific heterosis in rice because heterosis breeding become the backbone of modern plant breeding.

Heterosis is quantitatively defined as an upward deviation of the mid parent, based on the average of the value of two parents. Heterosis refers as superiority of F_1 hybrid to its either parent in most of the characters such as hybrid vigour, fitness, adaptability and other morphological characters (**Shull, 1914**). An offspring exhibits heterosis if its traits are enhanced as a result of mixing the genetic contributions of its parents. These effects can be due to Mendelian or non-Mendelian inheritance. Early discovery of heterosis in rice by **Jones, (1926)** followed by reports of male sterility **(Ramanujan, 1935, Sampath and Mohanty, 1954),** the rice scientists in Japan, IRRI, Philippines, USA including India initiated an organized research programme on hybrid rice with serious limitations of strictly self-pollinating nature of rice crop and absence of usable form of male sterility.

Selection of appropriate parents by studying their combining ability and heterosis still remains best option for increasing the breeding efficiency in identifying heterotic hybrids. By analyzing the combining ability and estimating the degree of heterosis, clues on the nature of gene action, desirable parents and important yield traits may be found. Accordingly, the present investigation is undertaken to get an idea of the combining ability for yield and quality traits with a view to identify good combiners which may be used to create a population with favorable genes for yield and quality traits in rice.

Combining ability analysis **(Sprague and Tatum (1942)** is one of the powerful tools available to estimate the combining effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. Line × tester analysis provides information about general combining ability (GCA) and specific combining ability (SCA) effects of parents and is helpful in estimating various types of gene action. GCA and SCA effects are useful for hybrid rice breeding program by identifying traits that are predominantly governed by non-additive genetic variance such as number of panicles per plant, number of spikelet per panicle, test weight, total dry matter accumulation, spikelet fertility and grain yield. Various biometrical techniques have been developed to obtain valid information with regards to genetic architecture and inheritance of different yield

components, among which line × tester analysis technique **(Kempthorne, 1957)** are more systematic approach to assess the general combining ability of parents and specific combining ability of crosses for different quantitative and qualitative characters. Line × tester mating design consists of 'l' lines used as female parents and 't' tester used as male parents. Each male parent is crossed with each of the female parent thus producing 'l×t' full sib progenies. In line × tester analysis, testers should have broad genetic base, commercially well adapted, low yield potential and also should be inferior in performance for other traits than lines. The full sib progenies along with the parent are tested in a replicated trial using a suitable design. This technique enables evaluation of large number of germplasm lines for combining ability variance and effects.

Therefore, in view of the above facts and considering the importance of rice, the present investigation is undertaken with the following objectives:

1. To estimate genetic variability parameters in yield and yield contributing traits.
2. Selection of good combiner parents and specific combiner crosses for better heterotic output based on the GCA and SCA effects.
3. To estimate the combining ability of lines and testers with their crosses.
4. To estimate the magnitude and nature of heterosis in different crosses of rice lines**.**

Review of Literature

CHAPTER 2 REVIEW OF LITERATURE

The present review is an attempt at bringing together some of the findings on rice pertaining to studies on heterosis, combining ability analysis by using line × tester mating design and presented under following sub-heads.

2.1 Genetic variability, heritability and genetic advance

2.2 Combining ability

2.3 Heterosis

2.1 Genetic variability, heritability and genetic advance

The effectiveness of selection irrespective of any crop depends on the magnitude of genetic variability and heritability for the traits being selected. Heritability directly helps to the breeder to predict the genetic gain under selection. Heritability with genetic advance is more helpful in predicting the gain under effective selection. Genetic advance is the measure of genetic gain under selection. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone **(Chaudhary *et al.* 2004).** The success of genetic advance under selection depends on genetic variability, heritability and selection intensity **(Johnson *et al.* 1955).**

Padmaja *et al.* (2008) studied genetic variability, genotypic and phenotypic coefficients of variation, heritability and genetic advance for 11 characters in 150 genotypes including 5 check varieties of rice. The analysis of variance revealed that there were highly significant differences for all the characters among the genotypes. The estimates of PCV and GCV were high for all the characters except days to 50% flowering and panicle length. Heritability and genetic advance were high for all the characters except days to 50% flowering and panicle length, which had moderate genetic advance along with high heritability indicating the involvement of additive type of gene action in controlling these characters.

Bisne *et al.* (2009) estimated genetic parameters for yield and its correspondent characters in rice from a trial with 4 lines, 8 testers and 32 crosses were evaluated for 13 characters related to yield. The result revealed that high genotypic and phenotypic coefficient

of variations was expressed by harvest index, total number of filled spikelets per panicle, 100-grain weight and spikelet fertility percentage. High heritability coupled with high genetic advance was exhibited by harvest index, total number of chaffy spikelets per panicle, grain yield per plant, total number of filled spikelets per panicle and spikelet fertility percentage and selection may be effective for these characters.

Umadevi *et al.* (2009) estimated genetic variability and correlation coefficients from 74 rice genotypes for morphological traits. Highest GCV and PCV were reported for total number of tillers per plant, number of secondary branches in panicle, leaf length and straw yield. High heritability was observed for all the traits estimated. High heritability accompanied by high genetic advance as percent of mean was observed for plant height, total number of tillers per plant, panicle length, and number of secondary branches per panicle, leaf length, leaf width, kernel breadth, 100 grain weight, and length/breadth ratio, grain yield per plant and straw yield.

Tandekar *et al.* (2010) estimated the genetic variability, heritability and genetic advance in 97 rice genotypes with 3 check varieties which was laid to randomized block. The highest magnitudes of Phenotypic and genotypic coefficient of variation were found for number of unfilled spikelets per plant, number of total spikelets per plan respectively. High estimates of heritability coupled with high genetic advance was found for number of total spikelets per plant and number of filled spikelets per plant, indicating that they can be effectively improved through selection.

Akinwale *et al.* (2011) studied the phenotypic and genotypic coefficients of variation, broad sense heritability, genetic gain and correlations in rice (*Oryza sativa* L.). Genotypic coefficients of variation were lower than the corresponding phenotypic coefficients in all the traits studied, indicating considerable influence of the environment on the expression of the traits. High to medium broad sense heritability estimates observed on days to heading, days to maturity, plant height, grain yield and number of grains per panicle, panicle weight, number of panicles per plant and panicle length suggests high component of heritable portion of variation. High to medium heritability and genetic advance were recorded for the number of grains per panicle, grain yield, panicle weight and the number of panicles per plant.

Mirarab *et al.* (2011) studied heritability in yield and yield components in rice using 5 lines, 2 testers were crossed in line × tester manner to produce 10 F_1. Results show that highest general heritability was obtained for tiller number (96.1%), indicating slight effects of

the environment on the trait, while for other traits, a mild general heritability (~70%) was obtained, indicating considerable effect of environment on phenotypic expression of most yield traits. A low specific heritability was obtained for all traits (18.2 to 26.3%), indicating that non-additive effects play an important role in genetic control of yield traits.

Singh *et al.* (2011) evaluated 81 rice genotypes for 13 quantitative traits to examine the genetic variability, heritability (broad sense) and genetic advance and observed among all the 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 and number of panicles per hill. Broad sense heritability was highest for biological yield per plant, which suggested that this trait would respond to selection owing their high genetic variability and transmissibility. Maximum genetic advance as per cent of mean was recorded for number of spikelets per panicle with high value of heritability.

Tiwari *et al.* (2011) crossed 3 testers and 20 lines in line × tester manner to estimate genetic variability and heritability in rice. Result revealed that higher magnitude of PCV and GCV was recorded for 1000 grain weight, grain yield per plant, number of fertile spikelets, pollen fertility percent, tillers per plant, panicle length, and number of spikelets per panicle and harvest index. High heritability coupled with high genetic advance was recorded for number of fertile spikelets, spikelet fertility percent and pollen fertility percent indicated the major role of additive gene action in the inheritance of these characters.

Lal and Devendra (2013) revealed that high GCV and heritability was estimated for plant height, stem length, seeds per panicle, L/B ratio, moderate for 1000 seed weight, flag leaf length, leaf breadth, days to flowering, seed/plant and days to maturity, whereas low was estimated for panicle length. High genetic advance was estimated for plant height number of panicles per plant, stem length, L/B ratio, 1000 seed weight and number of seeds per panicle, however moderate for leaf breadth and days to flowering.

Ismaila *et al.* (2015) crossed 4 lines and 2 testers in a line × tester mating fashion to develop 8 F_1 to obtain information on estimates of genetic variations and heritability. They reported the high broad sense heritability estimates coupled with high genetic advance for yield per plant, 1000 grain weight, panicle weight, number of tillers and plant height, while the lowest genetic advance was observed in panicle length.

Sameera *et al.* (2016) evaluated 25 rice genotypes for their variability and heritability with regard to yield and yield components. The results revealed high variability, heritability and genetic advance as per cent mean for tillers per plant, number of tillers per plant, number of grains per panicle and number of filled grains per panicle, while days to maturity was recorded with high heritability coupled with low genetic advance as per cent of mean.

Sathya (2016) estimated heritability, coefficients of variability and genetic advance in rice for 19 characters including drought and yield contributing traits. Results revealed that traits viz., productive tillers per plant, panicles per plant, filled grains per panicle, harvest index, proline content, biomass yield, dry root weight, dry shoot weight, root/shoot ratio and root length have high heritability coupled with high genetic advance indicating lesser environmental influence and were under the control of additive gene effect.

Abebe *et al.* (2017) evaluated 36 rice genotypes to study genetic variability, heritability and genetic advance for grain yield and yield associated traits. Result revealed that higher PCV and GCV values were exhibited by plant height, culm length, and number of unfilled grain per panicle, biomass yield and grain yield, which suggests the possibility of improving this trait through selection. The highest heritability was recorded for culm length followed by plant height, biomass yield and panicle length. High to medium heritability coupled with high GCV and high genetic advance as percentage of means were exhibited for plant height, biomass yield, grain yield and number of unfilled grain per panicle. High genetic advances as percent of means were recorded by plant height, culm length, biomass yield, grain yield and number of filled grain per panicle.

Ajmera *et al.* (2017) evaluated 37 rice genotypes for their variability, heritability and genetic advance with regards to yield and yield components. All the characters under study except days to 50% flowering exhibited high heritability coupled with high genetic advance as per cent of mean, which indicated that these traits were controlled by additive type of gene action in the inheritance of these characters. The high estimates of heritability coupled with low genetic advance as percent of mean for days to 50% flowering indicated the presence of non-additive gene effects, in addition to influence of environment to some extent, hence its response to selection would be poor.

Bhatt *et al*. (2017) evaluated 48 rice genotypes representing diversity for yield and yield attributing characters to irrigated condition. Wide range of variation was observed for

all the quantitative traits under study indicating enough scope for bringing about improvement in desirable direction for hybridization. Phenotypic coefficient of variation was highest for grains yield per plant followed by number of fertile grain per panicle, flag leaf length, length breadth ratio and text weight exhibited moderate high phenotypic coefficient. High heritability values were also recorded for test weight, plant height at maturity and vegetative plant height. Estimate of genetic advance was highest for number of grains per panicle, followed by plant height.

Edukondalu *et al.* (2017) studied the heritability, variability, correlation and path analysis for 15 characters in 40 genotypes of rice during Kharif, 2016. Analysis of variance revealed that mean sum of squares due to genotypes showed significant differences for all 15 characters studied. The magnitude of PCV and GCV was high for number of grains per panicle. High heritability coupled with high genetic advance as per cent of mean was observed for number of grains per panicle, number of tillers per plant, 1000-grain weight, L/B ratio, plant height, and kernel length, grain yield per plant, kernel breadth and days to flowering.

Prasad *et al.* (2017) evaluated 50 rice genotypes to estimate variability, heritability and genetic advance in yield and yield contributing characters. Analysis of variance indicated the existence of significant genotypic differences among the genotypes for the yield, its components for all the characters. High GCV and PCV values were observed for number of filled grains per panicle, number of unfilled grains per panicle, grain yield per plant. High heritability coupled with high genetic advance as per cent of mean was observed for plant height, number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, number of unfilled grains per panicle, 1000 grain weight and grain yield per plant which indicated that these traits were controlled by additive type of gene action.

Rajpoot *et al.* (2017) conducted an experiment with 83 genotypes (20 lines, 3 testers and 60 F_1) to study the genetic variability, heritability and genetic advance in rice. The estimates of PCV were higher than GCV for all the traits indicating that they all interacted with the environment to some extent. Besides, high estimates of phenotypic and genotypic coefficient of variation were estimated for grains yield per plant. High estimates of broad sense heritability was recorded for the characters viz., days to 50% flowering, plant height, grains per panicle, spikelet fertility (%), 1000 grain weight, biological yield per plant, L/B ratio, grains yield per plant. High heritability coupled with high genetic advance in per cent

of mean were observed for the characters like grain yield per plant, biological yield per plant, grains per panicle, L/B ratio and flag leaf area indicating the involvement additive gene action.

Thorat *et al.* (2017) studied heritability and genetic variability in 12 F_1 crosses along with rice genotypes (3 lines and 4 testers) and three checks to know the pattern of inheritance of some morphological traits for selecting superior genotypes. The experiment was carried out according to line × tester mating design, during 2015-16. Analysis of variance revealed significant differences among genotypes, crosses, lines, testers and line × tester interactions for most of the traits. Ratio of SCA variances was higher than the GCA variances for traits which indicated predominance of non-additive gene action in the inheritance of the traits. The highest broad sense heritability (ns) was observed for grain yield (74.46%) and straw yield (74.13%).

Tripathi *et al.* (2018) estimated genetic variability and heritability for yield and yield contributing components in rice involving 20 lines and 3 testers crossed in line × tester manner to generate 60 F_1. The analysis of variance revealed that all the treatments, parents, parent vs crosses, crosses, lines and lines x testers were highly significant for majority of the yield and its contributing traits indicated sufficient variation among the treatments under study. In general, PCV were higher than the GCV for all traits studied under salt affected environment. High heritability coupled with high genetic advance were observed for panicle bearing tillers per plant, spikelets per panicle, grains per panicle, biological yield per plant, L/B ratio and grain yield per plant, showed presence of additive gene action.

2.2 Combining Ability Analysis

Sprague and Tatum (1942) combining ability is the capacity of a genotype to transmit superior performance to its crosses. They categorize as General combining ability (GCA) and specific combining ability (SCA). General combining ability is the relative ability of a genotype to transmit desirable performance to its crosses. GCA is the average performance of a genotype in a series of crosses. It is a measure of additive gene action. Whereas, SCA is used to designate those crosses in which certain combinations do relatively better than what is expected on the basis of average performance of lines involved. It is the performance of a genotype in a specific cross. It is a measure of non-additive gene action.

Haripasanna *et al.* (2006) estimated combining ability of parents and F_1 hybrids by using line × tester design and observed that significant SCA effects for grain yield had significant SCA effects for one or more yield components, also they found that significant positive effect for particular trait were obtained in average × average, average × low and low × low parental combinations.

Malini *et al.* (2006) studied combining ability analysis of 50 F_1 in rice along with their parents reveals the preponderance of non-additive gene action. The specific combining ability variance was higher than general combining ability variance for all the characters studied viz., days to flowering, plant height, and panicles per plant, panicle length, and spikelet per panicle, grains per panicle, straw yield and grain yield.

Tiwari *et al.* (2011) studied the inheritance pattern of some morphological traits and 60 F_1 crosses along with their parents were evaluated to identify best heterotic combinations. The higher magnitude of SCA than GCA variance, greater values of average degree of dominance was observed in all characters studied suggested significant role of non-additive gene action. Out of 60 crosses, about 30% crosses showed significant and desirable SCA effects for grain yield. More than 50% heterosis in order of merit grain yield and other yield components as well as significant SCA effects for major components were most promising combinations and need to be tested on large scale for commercial exploitation of heterosis.

Dwivedi *et al.* (2012) evaluated 45 F_1s along with 6 semi-dwarf and high yielding indica rice cultivars (Govind, Manhar, Pant Dhan 4, Sarjoo 52, Pant Dhan 12 and Narendra 359) along with 4 tropical japonicas cultivars (BSI10, BSI16, B4116 and B4122) having wide compatibility gene, in relation to estimate combining ability effects for grain yield and associated traits in rice. The crosses B4116 × Sarjoo 52, BSI10 × Pant Dhan 12 and BSI10 × Narendra 359 were identified as the best cross combinations on the basis of *per se* performance and combining ability effects.

Sanghera and Hussein (2013) analyzed 36 F_1 developed through 2 lines and 18 male parents and reported that significant and positive GCA as well as SCA effects for the traits days to 50% flowering, number of grains per panicle, panicle length, number of productive tillers per plant and L/B ratio. However the magnitude of SCA variance was higher than GCA variance for all the traits indicating preponderance of non-additive gene action for all the traits. The same has been confirmed also from GCA/SCA ratio and degree of dominance.

Sathya and Jebaraj (2013) studied combining ability and heterosis in 21 parents (15 lines and 6 testers) and 90 F_1 for yield and physiological traits under aerobic condition. Analysis of variance was highly significant for all the characters and predominantly controlled by non-additive gene action. The hybrids IR70369 × IR7925-428-2-1-1, IR79128 × BR-2655, IR70369 × KMP-105 and IR79128 × KMP-149 were found to have specific combiners for most of the yield contributing and drought tolerant traits including single plant yield.

Thakare *et al.* (2013) crossed 3 lines with 15 testers in a line × tester mating design to obtain 45 F_1's to estimate combining ability effects in rice. The estimates of GCA effects indicated that, among females, IR68886 and IR68897 and among males IR-44, IR-60, IR-9761, IR-4266-29-4-2-2-2, IR-5638-139-2-2, IR-69701-9-3-1 and IR-71138-49-2-2 were found as good general combiners for grain yield per plant. High SCA effects were observed in the crosses, IR68886 × IR44, IR68897 × IET15554, IR68897 × IR56455-206-2, IR68902 × IR4266-29-4-2-2-2and IR68897 × IR62161-184-3-1-3-2. They were found to be the best combinations for grain yield per plant and quality traits. The preponderance of non-additive type of gene actions clearly indicated that selection of superior plants should be use for further improvement.

Utharasu and Kumar (2013) carried out an investigation on l × t analysis were with six popular and ten improved cultures to estimate gene action, combining ability and heterosis for yield and yield components. Both additive and non-additive gene action were found to control the expression of the traits under study. The magnitude of combining ability revealed non-additive genetic variance was higher than the additive variance for all the studied traits. The crosses RMD1 × ARB7, PMK3 × ARB8, PMK3 × ARB7, ADT43 × IR77080-B-34-3 and MDU5 × Anjali recorded high SCA effects and high standard heterosis for grain yield.

Dorosti and Monajjem (2014) conducted line (five) × tester (two) analysis to determine good combiner parents and the nature of gene action governing yield and its component traits in rice. The line × testers showed significant differences for all traits except for number of spikelets per panicle and hundred grain weight. The study showed GCA to only identify better parental lots and it will be unwise to discard the low GCA types.

Jayasudha and Sharma (2014) generated 33 crosses from crossing 3 lines with 11 testers and studied along with their parents for combining ability and gene action involved in

the expression of characters in rice. The magnitude of SCA variance was higher than the GCA variance for all the characters revealed the presence of predominance of non-additive gene action for all the characters under study. Promising hybrids based on *per se* performance, GCA and SCA effects are IR 58025A × OR 1898-18, IR 58025A × R 304-34, CRMS 31A × RPHR 203-3 and IR 58025A × Chinikapoor.

Bhatti *et al.* (2015) estimated combining ability effects for yield and its component traits in rice. The material consisted of 30 F_1 crosses developed by crossing 10 lines with 3 testers. Result revealed that cross combination HPR 2639 × HPR 2143 is good specific combination for grain yield per plant, panicle length, spikelets per panicle, grains per panicle, biological yield per plant, days to 50% flowering and plant height.

Prasad *et al.* (2015) assessed the gene action, general combining ability and specific combining ability for yield and its contributing traits in rice involving a line × tester set of 36 F_1's and their 15 parents along with 2 checks for 9 traits. The dominance variance was more than additive variance. In general, maximum contribution to the total variance was due to females higher than due to males for all the traits except days to 50% flowering and L/B ratio. Among the parents, best genotype was IR 55179-3B-11-3 which exhibited significant GCA effect for grain yield per plant, indicating the involvement of additive gene action for yield and component traits. Among the crosses the best hybrids was Narendra Usar Dhan 2009 × NDRK 50026 which exhibited significant SCA effect for grain yield per plant, indicating the preponderance of non-additive gene action for yield and its contributing traits.

Veeresha *et al.* (2015) accessed the extent of heterosis, general and specific combining ability for yield and productivity traits in rice. In majority of the experiments, high SCA variances than GCA variances for most of the traits were reported which indicate the predominance of non-additive gene action in the inheritance of these traits. They also found some correspondence between good general combiners and *per se* performance for some of the traits.

Kumar *et al.* (2016) studied combining ability effects for grain yield and yield attributing traits in 82 genotypes including 22 parents (15 testers, 4 lines and 3 checks) and 60 F_1's. The results revealed that, most of the crosses showed positive and significant SCA effects for grain yield per plant, 1000 grain weight and number of grains per panicle.

Satheeshkumar *et al.* (2016) studied combining ability effect in a line x tester

analysis of rice (*Oryza sativa* L.). The analysis revealed that the variance due to GCA and SCA were highly significant for all the characters studied, indicating the presence of non-additive gene action. The promising line AURC 14 and testers IR 64, ADT 43 having high GCA effects in desirable direction for yield and quality attributes. These lines can be use in future crossing programme. The crosses AURC 14 × TRY 1 and AURC 22 × IR 64 exhibited good SCA effects for major yield and more than seven yield contributing characters.

Sran *et al.* (2016) studied the combining ability and heterosis for grain quality traits in rice using line × tester mating design. GCA and SCA results revealed the predominance of SCA variance in relation to GCA variance for all the traits. Among lines, investigation of highest GCA effects illustrated that HPR 2858, HPR 2761, HPR 2754, HPR 2668 and HPR 2748 (P) were good general combiners for different quality traits.

Devi *et al.* (2017) evaluated the performance of 54 F_1 developed by crossing of 18 lines with 3 testers in rice. Result revealed that parents NDRK 5014 and NDRK 50001 with highest GCA effects for grain yield per plant also showed significant and desirable GCA effects for days to 50% flowering and plant height. Fifteen crosses were exhibited significant and positive SCA effects for grain yield per plant, as well as for some morphological traits. The estimates of variance of specific combining ability effects, ratio of variance of general combining ability to specific combining ability and degree of dominance indicated preponderance of non-additive gene effects for each trait.

Gahtyari *et al.* (2017) generated 40 F_1's using 4 lines (female) and 10 testers (male) after using Line × tester mating design. They observed significant GCA variances for females at 1% level of significance for plant height (40.8), No. of grains per panicle (505.9), grain yield per plant (29.1), test weight(17.9), straw yield per plant (61.3) and kernel L/B ratio (0.2) whereas specific combining ability (SCA) variances for l × t interactions were highly significant for all the characters studied.

Maurya *et al.* (2017) evaluated 36 crosses and 15 parents along with 2 checks for various characters under line × tester statistical analysis. The analysis of variance for combining ability revealed high significant mean squares due to lines × tester interactions expressing the preponderance of non-additive gene effects for all the characters. The estimates of sca variance were higher than the corresponding estimates of GCA variance for all the characters. On the basis of general combining ability effects, IR 127193, NDRK 50051, NDRK 50060, and IRRI 123 were identified as good general combiners. Five crosses

namely, NDRK 50037 × CSR 28, IR 79156 × IRRI 123, NDRK 50051 × FL 478, NDRK 50058 × FL 478 and NDRK 50060 × IRRI 123 showed significant and positive sca effects for grain yield per plant and its contributing attributes.

Saravanan *et al.* (2018) estimated combining ability effects for yield and grain quality traits in rice through line × tester analysis. General combining ability effects indicated that line KR 09009 and ASD 19 were emerged as good general combiners for 1000 grain weight, high kernel length, high kernel L/B ratio, moderate panicle exertion and kernel breadth.

2.3 Heterosis

Heterosis is one of the most successful approaches for the improvement productivity in crop plants. The term Heterosis was given by **Shull (1914)** and is defined as superiority of F_1 over its parent for one or more characters. An offspring exhibits heterosis if its traits are enhanced as a result of mixing the genetic contributions of its parents. These effects can be due to Mendelian or non-Mendelian inheritance. Heterosis is confined to F_1 and it declines or disappears in F_2 and subsequent segregating generations of a cross. It has positive correlation with SCA variance as SCA variance is a measure of dominance variance which is essential for undertaking heterosis breeding programme. Dominance and overdominance have different consequences for the gene expression profile of the individuals. If over-dominance is the main cause for the fitness advantages of heterosis, then there should be an over-expression of certain genes in the heterozygous offspring compared to the homozygous parents. On the other hand, if dominance is the cause, fewer genes should be under-expressed in the heterozygous offspring compared to the parents. Furthermore, for any given gene, the expression should be comparable to the one observed in the fitter of the two parents. Occurrence of heterosis is more frequent in cross pollinated crops as compared to self pollinated crops.

Virmani *et al.* (1982) conducted an experiment at the International Rice Research Institute (IRRI) during 1980 and 1981 and it has been reported up to 73% heterosis, 59% heterobelteiosis and 34% standard heterosis for yield in rice. Selection of parents among elite breeding lines on the basis of their per se yield performance, diverse origin and resistance to insects and diseases should give better heterotic combination.

Raj *et al.* (2007) evaluated eighteen parents and forty-five crosses for relative heterosis, heterobeltiosis and standard heterosis for yield. They found crosses viz., BR-9 × Cauvery, BR-10 × IR-8, Janki × Archana, Birsa Dhan-202 × Cauvery and IR-36 × IR-8 were best for heterosis pertaining to grain yield per plant.

Rashid *et al.* (2007) experimented on line × tester mating design along with 5 rice genotypes and 6 F_1's. They reported the highest significant heterosis (61.9%) for yield per plant was reported in the cross DM-25 × DM-107-4 and also observed to be good general combiners for most of the characters.

Bagheri and Jelodar (2010) studied magnitude of heterosis on 12 F_1 along with 7 rice genotypes including 4 lines and 3 testers to know the pattern of inheritance of some morphological traits for selecting superior genotypes. The experiment was carried out according to line × tester mating design. Analysis of variance revealed significant differences among genotypes, crosses, lines, testers and line × tester interactions for tiller number, plant height, days to 50% flowering, panicle length, number of spikelet per panicle, spikelet fertility and grain yield traits. The highest heterosis (106.60%) was observed in cross IR 68899A × Poya followed by other eight crosses for yield and most of its related traits.

Mirarab *et al.* (2011) studied heterosis, combining ability and genetic parameters of yield and yield components in rice, to achieving these 4 lines were crossed with 3 testers in line × tester manner to produce 12 F_1. Results show that some cross exhibited significant and high level of heterosis for tiller number and grain yield in combinations of IR 42 × IR 68897 and IR 42 × Usen. It seems that hybridization must be a choice for utilizing the putative heterosis in special crosses.

Singh *et al.* (2011) generated 15 crosses by crossing 5 lines and 3 testers in l × t mating design to study the heterosis for 12 quantitative characters in rice. Results revealed that maximum relative heterosis and heterobeltiosis for grain yield per plant recorded for IR 74371-54-1-1 × IR 67017-124-2-4. The maximum standard heterosis for grain yield was exhibited by IR 81413-B-B-75-4 × IR 81429-B-31 (179.95%). On the basis of SCA effects, seven crosses were identified for high grain yield per plant. These crosses may be gives the better segregates from the early segregating generation or can be utilized for heterosis breeding for yield improvement under rainfed condition.

Dwivedi *et al.* (2012) evaluated 45 F_1s along with six semi-dwarf and high yielding indica rice cultivars (Govind, Manhar, Pant Dhan 4, Sarjoo 52, Pant Dhan 12 and Narendra 359) along with four tropical japonicas cultivars (BSI10, BSI16, B4116 and B4122) having wide compatibility gene, in relation to analyze heterosis for grain yield and associated traits. Heterosis over mid-parent, better parent and standard variety ranged between -54.17 to 169.70, -58.31 to 150.32 and -64.55 to 146.15%, respectively. The crosses B4116 × Sarjoo 52, BSI10 × Pant Dhan 12 and BSI10 × Narendra 359 were identified as the best cross combinations on the basis of per se performance and high heterosis. Inter-specific hybrids exhibited high heterobeltiosis and economic heterosis.

Patil *et al.* (2012) carried out line × tester analysis using a set of 4 females and 10 males to estimate the heterobeltiosis for yield and its components in rice. Sufficiently high magnitude of heterobeltiosis in desirable direction was observed for grain yield per plant, grains per panicle, panicles per plant, panicle length, days to 50% flowering, 1000 grain weight and L/B ratio. As many as sixteen crosses showed significant positive heterosis over their respective better parental value for grain yield per plant. Crosses viz., Sathi 34-36 × Lalkada, Sathi 34-36 × GR 6, and GR 5 × GR 6 were found to be most heterotic hybrids for grain yield per plant. Simultaneous increase in panicles per plant, grains per panicle and 1000 grain weight had positive SCA effects towards higher grain yield.

Latha *et al.* (2013) studied the nature and magnitude of heterosis and combining ability in 18 F_1 crosses developed through crossing 3 lines and 6 testers using line × tester mating design in rice. Result revealed that magnitude of relative heterosis, heterobeltiosis and standard heterosis were also estimated for different characters. A high degree of relative heterosis and heterobeltiosis were observed for grain yield (20.45- 82.37%) and (13.60-68.37%), respectively.

Sharma *et al.* (2013) studied the magnitude of heterosis of 48 crosses made by involving 16 lines and 3 testers in line × tester mating design. The result indicated that the magnitude of heterobeltiosis for grain yield was significantly superior. These crosses also exhibited significant heterosis for days to maturity, number of spikelet per panicle, number of grains per panicle. Some crosses expressed more than 40% heterobelteiosis for grain yield along with other desirable traits may be considered for commercial exploitation.

Devi *et al.* (2014) crossed 4 lines with 5 testers in line × tester mating design in rice to develop 20 F_1s were evaluated along with their parents and check variety (BPT 5204) to

estimate mid parental heterosis, heterobeltiosis and standard heterosis for yield and quality traits. The highest values of heterosis for grain yield per plant was recorded 245.83% over mid parent, 197.6 % over better parent and 224.85 % over standard check and number of grains per panicle was recorded 91.74% over mid parent, 82.25% and 93.3% over better parent and standard check. Highly significant positive average heterosis, heterobeltiosis and standard heterosis for grain yield per plant was expressed due to manifestation of additive heterotic effect of one or more yield contributing traits. On the basis of high mean, high heterosis for yield and quality traits with earliness, the crosses DR 714-IR × 1005, EPLT 109 × IR 55838-B2-2 and SN 415R × 1005 were found superior.

Kumari *et al.* (2014) experimented to estimate the combining ability and heterosis for yield, yield contributing traits and grain quality parameters in rice. The superior hybrid combinations were identified on the basis of combining ability effect and relative heterosis. The higher magnitudes of heterosis for all the yield and quality traits were not expressed in a single hybrid combination. Two crosses IR 68897A × Jaya and IR 68897A × BPT 5204 were found to be heterotic for yield and yield traits as well as the grain quality characters.

Rukmini *et al.* (2014) crossed four lines with five testers in line × tester mating design in rice. The resultant 20 F_1 was evaluated along with their parents and check variety (BPT 5204) to estimate mid parental heterosis, heterobeltiosis and standard heterosis for yield and quality traits. Number of grains per panicle recorded 91.74% over mid parent, 82.25% and 93.3 % over better parent and standard check. The highest values of heterosis 245.83% over mid parent, 197.6% over better parent and 224.85% over standard check were recorded for grain yield per plant. Highly significant positive average heterosis, heterobeltiosis and standard heterosis for grain yield per plant was expressed due to manifestation of additive heterotic effect of most of yield contributing traits.

Bhatti *et al.* (2015) estimated heterosis for yield and its component traits in rice. The material consisted of 30 F_1 crosses developed by crossing 10 lines with 3 testers. Result revealed that cross HPR 2529 × HPR 1156 show high heterosis over standard check for grain yield per plant biological yield/plant, grain fertility and plant height.

Khute *et al.* (2015) estimated the average heterosis, heterobeltiosis and standard-heterosis in rice Heterosis in rice was studied for yield and component traits in 18 F_1 involving 9 parents comprises of 3 lines and 6 testers. Result revealed that maximum heterotic effect was obtained by two cross combinations viz., IR 58025 × HR 703, IR 79156

× IIRON-1-114 over the mid parent, better parent and check variety for grain yield per plant and almost all the characters. Eight crosses had positive average heterosis for grain yield per plant and ranged from -54.82% and 7 crosses having heterobeltiosis and 6 crosses showing positive standard heterosis for grain yield were also significant for days to 50% flowering, plant height, number of spikelet per panicle, panicle and almost all the characters.

Chouhan *et al.* (2016) evaluated 13 parents and their 30 F_1's to study heterotic expression in rice for yield and its contributing components. Among the heterotic crosses Jaya × Pant 12 (for days to 50% flowering), NDR 359 × Pant 12 (for number of effective tillers per panicle), Sarjoo 52 × Pant 12 (for panicle length), NDR 359 × NDR 97 (for number of grains per panicle), NDR 359 × NDR 97 (for seed index), NDR 359 × HUR 3022 (for grain yield per plant) over better parent and NDR 359 × Pant Dhan 12 (for days to 50% flowering), Jaya × NDR 97 (for number of effective tillers per panicle), NDR 359 × Sahabhagi dhan (for panicle length), Sarjoo 52 × Krishna hamsha (for number of grains per panicle), Sarjoo 52 × Krishna hamsha (for seed index) and NDR 359 × Pusa Basmati 1 (for grain yield per plant) over standard check were found superior crosses in expression of heterobeltiosis and standard heterosis.

Showkat *et al.* (2016) evaluated 24 F_1 from 3 lines and 8 male parents to study the heterosis for various yield and quality traits in rice. The findings suggested that the magnitude of heterosis differed from character to character and cross to cross. Majority of the hybrids recorded desirable heterosis for grain yield, days to 50% flowering, days to maturity and number of effective tillers per plant. Among the crosses, IR 58025 × Pusa Sugandh 5 was found relatively better performing cross for majority of the quality traits and considered as the best cross combination if both yield and quality traits are taken into consideration.

Borah *et al.* (2017) evaluated 60 F_1 generated through l × t mating design along with 15 parental lines, 4 testers and 2 standard varieties. Standard heterosis for grain yield ranging from 91.3 to 56.5% over the late maturing check Ranjit and -86.2 to 148.3% over medium duration check TTB 404.

Premkumar *et al.* (2017) studied nature and magnitude of heterosis for yield and yield component traits involving 10 high yielding lines and 3 superior grain quality testers and 30 hybrids which were developed through line × tester mating design. Significant heterosis for grain yield and yield component traits were observed in most of the hybrids. Standard heterosis and heterobeltiosis for grain yield ranged from -15.64 to 20.04% and

-23.75 to 15.50%, respectively. A total of 4 hybrids viz., ADT 39 × IW Ponni, ADT 43 × IW Ponni, ADT 49 × IW Ponni and CO 50 × IW Ponni were recorded higher grain yield over both better parent and standard check and were identified as best hybrids for exploiting hybrid vigor.

Santoshkumar *et al.* (2017) studied heterosis for different morphological traits under drought conditions. They reported that, the maximum standard heterosis (119.05%) was recorded in tillers per plant followed by 109.86% for grain yield per plant, 73.53% for grains per panicle, 27.72% for harvest index, 27.08% for 1000 grain weight and 24.40% for panicle length. The hybrids expressed high heterosis for specific traits such as tillers per plant, 1000 grain weight and yield per plant that can be used for the development of improved rice varieties.

Materials and Methods

CHAPTER 3 MATERIALS AND METHODS

3.1 Location

The present study entitled **"Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice *(Oryza sativa* L.)"** was conducted at Norman E. Borlaug Crop Research Centre, Pantnagar, Uttarakhand, India. In the present investigation 51 F_1's were developed by using 17 lines and 3 testers and crossed in a line × tester fashion during *kharif* 2016. These F_1's were subjected to evaluation along with their parents in a replicated trial using Randomized Block Design (RBD) at NEB Crop Research Centre, Pantnagar during *kharif* 2017. Geographically Pantnagar is situated at 29.0°N latitude and 79.3°E longitude and at an altitude of 243.84 m above the mean sea level. It falls under humid subtropical climate zone and is located at the foothills of the Shivalik range of the Himalayas in a narrow belt called *Tarai*. The soil texture is of miscellaneous type and it is generally 1.0 to 1.5 m deep. High water table, Shallow depth and calcareous nature are the characteristic feature of the soil.

3.2 Weather Condition

The weather data during the crop growing season i.e. June, 20th to November, 5th 2017 at Norman E. Borlaug Crop Research Centre, Pantnagar has been represented in Table 3.1.

3.3 Experimental material

The basic experimental material comprised of 51 F_1 crosses and 20 parents (17 lines and 3 testers) along with 2 checks i.e. Govind and Pant Dhan 4. Line × tester mating system was used to cross 17 lines with 3 testers to generate 51 F_1's for quantitative and qualitative traits evaluation in rice. The detailed information of the planting material is as follows (Table 3.2):

Table 3.1: Weekly weather data during experimental period (June, 20th 2017 to Nov. 5th 2017)

Date & Month	Temperature ^{0}C		R. Humidity %		Rainfall (mm)	Sun-shine hrs.	Wind Velocity (Km/hr)	Evapo-transpiration (mm)
	Max.	Min.	Max.	Min.				
20-26 June	35.9	25.6	74	53	0.00	6	6.7	6.3
27 June-3 July	34.8	25.5	91	72	14.57	5.8	7.2	7.2
4-10 July	30.8	25.7	92	83	23.82	2.0	5.6	4.0
11-17 July	31.9	26.2	88	80	9.68	4.8	5.5	4.0
18-24 July	33.6	25.9	87	72	11.05	7.2	7.0	4.8
25-31 July	31.8	24.6	90	76	20.77	3.6	7.2	3.6
1-7 Aug.	31.9	26.0	90	77	20.68	3.1	5.5	4.3
8-14 Aug.	31.1	25.6	92	78	26.91	1.6	6.8	4.6
15-21 Aug.	33.1	25.9	89	70	5.76	5.4	5.9	4.2
22-28 Aug.	31.9	25.0	89	76	9.54	4.7	4.0	3.7
29 Aug.- 4 September	30.6	24.9	91	76	21.30	4.4	4.8	3.6
5-11 Sept.	33.1	24.2	87	65	3.94	8.7	3.5	4.4
12-18 Sept.	34.3	25.5	89	65	0.00	7.9	2.5	3.7
19-25 Sept.	31.3	23.8	92	77	25.02	4.4	5.5	2.9
26 Sept.-2 October	33.0	23.6	86	62	0.00	5.9	2.2	3.1
3-10 Oct.	33.4	23.3	84	57	0.00	6.6	2.5	2.6
11-17 Oct.	33.2	18.4	85	46	0.00	8.3	2.2	3.5
18-25 Oct.	33.0	16.8	84	46	0.00	8.8	2.5	3.1
26 Oct.-1 November	29.2	14.6	88	52	0.00	7.1	2.1	2.4
2-5 Nov.	28.1	14.2	92.7	52	0.00	2.3	1.3	1.9

Table 3.2 Rice Genotypes used for the experimental material during *kharif* 2016.

SI No.	Designation	Genotypes	Characteristics
1.	L1	UPRI 2011-21	Medium tall, medium duration, long slender grain, high yielding & blast resist.
2.	L2	UPRI 2008-6	Medium tall, medium duration, long slender grain, high yielding & blast resist.
3.	L3	BBL 180-5-1-4-1	BLB resistant, medium duration
4.	L4	UPRI 2012-10	Medium tall, medium duration, LS grain type
5.	L5	UPRI 2008-8	Medium tall, medium duration, long slender grain, high yielding, blast resist.
6.	L6	UPRI 2012-19	Medium tall, medium duration, long slender grain, high yielding, blast resist.
7.	L7	Pant Dhan 22	Mid duration, dwarf, long grain, resistant to blight, leaf roller
8.	L8	Pant Dhan 10	Mid duration, dwarf, high yielding, long grain, resistant to blight, stem borer
9.	L9	Pant Dhan 18	Mid-late, medium, high yielding, long grain, medium resistant to brown spot, leaf roller
10.	L10	Pant Dhan 24	Mid-late, medium, high yielding, long grain, medium resistant to brown spot, stem borer
11.	L11	UPR 3871-8-1-2-2	Long slender grain type, mid-late duration
12.	L12	UPR 3199-464-1-2	Medium tall, medium duration, long slender grain, blast resistant
13.	L13	UPRI 2014-8	Medium tall, medium duration, long slender grain, high yielding, blast resist.
14.	L14	CR 2644-2-6-4-3-2	Long slender grain type, mid-late duration
15.	L15	NDR 3012	Medium tall, medium duration, red color grain
16.	L16	JGL 1172-7	Medium duration, LS grain type
17.	L17	Pant Dhan 19	Mid duration, medium, long slender grain, high yielding, medium resistant to blight
18.	T1	Pant Dhan 4	Mid-late, dwarf plant, long grain, high yielding, resistant to blight
19.	T2	Pant Dhan 23	Mid-late, dwarf, long grain, resistant to brown spot, leaf roller, high yielding
20.	T2	Pant Dhan 26	Mid-early, medium long grain, resistant to brown spot, leaf blight, high yielding
21.	C1	Govind	Early, dwarf, LS grain type, resistant to brown spot, blight, average yielding
22.	C2	Pant Dhan 4	Mid-late, dwarf plant, long grain, high yielding, resistant to blight

3.4 Generation of material.

Selected plants from each parental lines are uprooted from the rice breeding nursery at appropriate stage (when 3/4 of panicle is still inside the flag leaf) and transplanted in the pots in glass house during September 2016. The female parent is emasculated. Emasculation is done by cutoff the tip of floret and removing the anthers with forceps carefully. Emasculated panicle is covered with butter paper bag to prevent any foreign pollen contamination. Pollination of emasculated flower was done in the next morning by shaking panicle with matured pollen over the emasculated panicle these results in pollen shedding. Pollinated panicles were again covered with butter paper bag to protect it from natural crossing. Pollinated panicles in the female plant were harvested 25-30 days after pollination (November 2016). Harvested panicles from each cross were sun dried for 3-4 days and hand threshed and was kept in separate seed packets. A total of 51 F_1's seed packets were made and were assigned number 1 to 51 (Table 3.3).

3.5 Layout and evaluation of material

The experimental material consisted of 73 genotypes i.e., 17 lines, 3 testers, 51 F_1's and 2 checks. The experimental material was laid out in a Randomized Block Design (RBD) with 3 replications during *kharif* 2017. The seeds of all 73 genotypes were sown in nursery at Norman E. Borlaug Crop Research Centre. Twenty one days old seedling were transplanted in the main field in a single row of 2 m length and spacing of 30 cm was kept between two entries with plant to plant spacing of 15 cm.

3.6 Observation recorded

Observations were recorded on the whole plot basis in respect of days to 50% flowering and days to maturity, however, plant height (cm), number of tillers per plant, panicle length (cm), number of filled grains per panicle, spikelet fertility (%), grain length (mm), grain width (mm), 1000 grain weight (g), kernel length (mm), kernel breadth (mm), kernel length/breadth ratio, hulling recovery (%), milling recovery (%), harvest index (%), alkali digestion value and grain yield per plant were recorded on the basis of five randomly selected plants from the F_1 crosses, lines and the testers separately. The mean value for these plants were calculated and used for statistical analysis. The techniques employed to record data on individual character are discussed here under:

Table 3.3 F_1's generated during 2016 and evaluated during *kharif* season 2017.

SI No.	Designation	Genotypes
1.	L1 X T1	UPRI 2011-21 X Pant Dhan 4
2.	L1 X T2	UPRI 2011-21 X Pant Dhan 23
3.	L1 X T3	UPRI 2011-21 X Pant Dhan 26
4.	L2 X T1	UPRI 2008-6 X Pant Dhan 4
5.	L2 X T2	UPRI 2008-6 X Pant Dhan 23
6.	L2 X T3	UPRI 2008-6 X Pant Dhan 26
7.	L3 X T1	BBL 180-5-1-4-1 X Pant Dhan 4
8.	L3 X T2	BBL 180-5-1-4-1 X Pant Dhan 23
9.	L3 X T3	BBL 180-5-1-4-1 X Pant Dhan 26
10.	L4 X T1	UPRI 20112-10 X Pant Dhan 4
11.	L4 X T2	UPRI 20112-10 X Pant Dhan 23
12.	L4 X T3	UPRI 20112-10 X Pant Dhan 26
13.	L5 X T1	UPRI 2008-8 X Pant Dhan 4
14.	L5 X T2	UPRI 2008-8 X Pant Dhan 23
15.	L5 X T3	UPRI 2008-8 X Pant Dhan 26
16.	L6 X T1	UPRI 2012-19 X Pant Dhan 4
17.	L6 X T2	UPRI 2012-19 X Pant Dhan 23
18.	L6 X T3	UPRI 2012-19 X Pant Dhan 26
19.	L7 X T1	Pant Dhan 22 X Pant Dhan 4
20.	L7 X T2	Pant Dhan 22 X Pant Dhan 23
21.	L7 X T3	Pant Dhan 22 X Pant Dhan 26
22.	L8 X T1	Pant Dhan 10 X Pant Dhan 4
23.	L8 X T2	Pant Dhan 10 X Pant Dhan 23
24.	L8 X T3	Pant Dhan 10 X Pant Dhan 26
25.	L9 X T1	Pant Dhan 18 X Pant Dhan 4
26.	L9 X T2	Pant Dhan 18 X Pant Dhan 23
27.	L9 X T3	Pant Dhan 18 X Pant Dhan 26
28.	L10 X T1	Pant Dhan 24 X Pant Dhan 4
29.	L10 X T2	Pant Dhan 24 X Pant Dhan 23
30.	L10 X T3	Pant Dhan 24 X Pant Dhan 26
31.	L11 X T1	UPR 3871-8-1-2-2 X Pant Dhan 4

32.	L11 X T2	UPR 3871-8-1-2-2 X Pant Dhan 23
33.	L11 X T3	UPR 3871-8-1-2-2 X Pant Dhan 26
34.	L12 X T1	UPR 3199-464-1-2 X Pant Dhan 4
35.	L12 X T2	UPR 3199-464-1-2 X Pant Dhan 23
36.	L12 X T3	UPR 3199-464-1-2 X Pant Dhan 26
37.	L13 X T1	UPRI 2014-8 X Pant Dhan 4
38.	L13 X T2	UPRI 2014-8 X Pant Dhan 23
39.	L13 X T3	UPRI 2014-8 X Pant Dhan 26
40.	L14 X T1	CR 2644-2-6-4-3-2 X Pant Dhan 4
41.	L14 X T2	CR 2644-2-6-4-3-2 X Pant Dhan 23
42.	L14 X T3	CR 2644-2-6-4-3-2 X Pant Dhan 26
43.	L15 X T1	NDR 3012 X Pant Dhan 4
44.	L15 X T2	NDR 3012 X Pant Dhan 23
45.	L15 X T3	NDR 3012 X Pant Dhan 26
46.	L16 X T1	JGL 1172-7 X Pant Dhan 4
47.	L16 X T2	JGL 1172-7 X Pant Dhan 23
48.	L16 X T3	JGL 1172-7 X Pant Dhan 26
49.	L17 X T1	Pant Dhan 19 X Pant Dhan 4
50.	L17 X T2	Pant Dhan 19 X Pant Dhan 23
51.	L17 X T3	Pant Dhan 19 X Pant Dhan26

3.6.1 Days to 50% flowering

The numbers of days were calculated from the date of sowing to the date when panicle appeared in 50% of the plants in a particular plot.

3.6.2 Days to maturity

It was recorded as the number of days taken from date of sowing to physiological maturity.

3.6.3 Pant height at maturity (cm)

The height of main tiller from the base of the plant to the tip of the panicle (excluding awns) was measured at physiological maturity in centimeters.

3.6.4 Number of tillers per plant

Number of tillers was counted at physiological maturity on plant basis.

3.6.5 Panicle length (cm)

The length of the panicle of main tiller was measured in centimeters from the base of the panicle to its tip (excluding awns and flag leaf).

3.6.6 Number of grains per panicle

The number of grains per panicle was counted after threshing the panicle from each of the randomly selected plant separately.

3.6.7 Spikelet fertility (%)

Spikelet fertility was estimated as the ratio of number of filled grains to total number of grains per panicle and expressed as percentage (%).

3.6.8 1000 grain weight (g)

1000 grains from selected plants were counted and weighed.

3.6.9 Grain length (mm)

Grain length was measured by keeping ten grain with their tips touching each other along the markings of centimeter scale. Grain length of individual kernel is obtained by dividing this value by ten in millimeters.

3.6.10 Grain width (mm)

Grain width was measured by keeping ten grain side by side and their tips towards the markings of centimeter scale. Grain width of individual grain is obtained by dividing this value by ten in millimeters.

3.6.11 Kernel length (mm)

Kernel length was measured by keeping ten kernels with their tips touching each other along the markings of centimeter scale. Kernel length of individual kernel is obtained by dividing this value by ten in millimeters.

3.6.12 Kernel breadth (mm)

Kernel breadth was measured by keeping ten kernels side by side and their tips towards the markings of centimeter scale. Kernel breadth of individual kernel is obtained by dividing this value by ten in millimeters.

3.6.13 Length/Breadth ratio

It is ratio between kernel length and kernel breadth. L/B ratio can be calculated simply by dividing kernel length to the kernel breadth.

3.6.14 Harvest index (HI)

It will be computed using the following formula-

$$\text{Harvest index} = \frac{\textit{Economic yield}}{\textit{Biological yield}} \times 100$$

3.6.15 Hulling recovery (%)

Removal of hull (lemma & palea) is called as hulling. Hulling recovery can be calculated as hulled rice/brown rice to the total/whole rice. It expressed as percentage (%).

3.6.16 Milling recovery (%)

Removal of bran from brown/hulled rice is called as milling. Milling recovery can be calculated as milled rice/white rice to whole rice. It expressed as percentage (%).

3.6.17 Alkali digestion value

Alkali digestion value (ADV) is calculated by scaling genotypes 1 to 7.

3.6.18 Grain yield per plant

The randomly selected plants from each F_1 cross were threshed and yield obtained was weighed and calculated for per plant.

3.7 Statistical analysis

In the present study Randomized Block Design (RBD) was followed for line × tester analysis and the replication wise mean value of the various data were subjected to

the following statistical and genetic analysis using statistical software STPR 17 and OPSTAT for drawing conclusion from the present investigation.

1. **Analysis of variance**
2. **Heritability and genetic advance**
3. **Combining ability analysis**
4. **Estimation of heterosis**

3.7.1 Analysis of variance

Eighteen characters were analyzed using analysis of variance in Randomized Block Design (RBD) to test whether treatments were differing significantly among themselves. Analysis was carried out as per **Panse and Sukhatme (1985).** The model used for analysis of variance was as follows (Table 3.4):

$$Y_{ij} = \mu + g_i + b_j + e_{ij}$$

Where,

i = 1, 2, 3, ..., g (genotypes)

j = 1, 2, 3, ..., r (replications)

Y_{ij} = Performance of i^{th} genotype in the j^{th} replication

μ = General mean of the population

g_i = True effect of i^{th} genotype

b_j = True effect of j^{th} block

e_{ij} = Random effect associated with the i^{th} genotype and j^{th} block

Table 3.4: Skeleton of ANOVA for RBD is given below

Source of Variation	Degree of Freedom (d.f.)	Mean square	Variance ratio (F)
Replication	(r-1)	Mr	Mr/Me
Genotypes	(g-1)	Mg	Mg/Me
Error	(r-1)(g-1)	Me	
Total	r(g-1)		

Where,

r = number of replication

g = number of genotypes

Mr = Mean square due to replication

M_g = Mean square due to treatment

M_e = Mean square due to error

The data for different characters were analyzed and tested for the significance of difference among genotypes by 'F' test and whenever the 'F' test was found to be significant critical difference was calculated to test significance of difference between any two treatments means.

C.D. (at 5%) = $SE_d \times t$ (5%) at error d.f.

C.D. (at 1%) = $SE_d \times t$ (1%) at error d.f.

Where,

SE_d = Standard error of difference between two treatment means

$$SE_d = \sqrt{\frac{2EMS}{r}}$$

Where,

EMS = Error mean sum of square

r = number of replication

Table 3.5: Detailed ANOVA with parents and crosses

Source of variation	d.f.	SS	MS	F-ratio
Replications	r-1	SS_R	MS_R	MS_R/MS_E
Treatments	t-1	SS_T	MS_T	MS_T/MS_E
Parents	p-1	SS_P	$MS_{;P}$	MS_P/MS_E
Crosses	c-1	SS_{F1}	MS_{F1}	MS_{F1}/MS_E
Parents Vs Crosses	1	SS_P Vs SS_{F1}	MS_P Vs MS_{F1}	
Error	(r-1)(t-1)	SS_E	MS_E	

Standard Error Mean

$$S.E.M = \sqrt{\frac{EMS}{r}}$$

Where,

EMS = Error mean sum of square r = number of replication

Table 3.6: Analysis of variance for line × tester analysis including parents

Source of variation	d.f.	Mean Square	'F' value
Replications	(r-1)	M_r	M_r/M_e
Parents	(l+t-1)	M_p	M_p/M_e
Crosses	(lt-1)	M_c	M_c/M_e
Parents *vs*. crosses	1	M_{pvsc}	M_{pvsc}/M_e
Lines	(l-1)	M_l	M_1/ M_{lvst}
Testers	(t-1)	M_t	M_t/ M_{lvst}
Line × Tester	(l-1) (t-1)	M_{lvst}	M_{lvst}/M_e
Error	(r-1) (lt+l+t-1)	M_e	
Total	[r(lt+l+t-1)]-1	M_T	

Where,

r = Number of replications

l = Number of lines

t = Number of testers

Selection Parameters:

i) Coefficient of variance (CV)

Estimation of Phenotypic, genotypic and environmental coefficient of variation according to **Burton (1952)**

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{Phenotypic variance}}{\bar{X}}$$

Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{Genotypic\ variance}}{\bar{X}}$$

Environmental coefficient of variation (ECV)

$$ECV = \frac{\sqrt{Environmental\ variance}}{\bar{X}}$$

Where,

$\bar{X}$ = general mean of the character

3.7.2: Estimation of heritability and Genetic Advance (Table 3.7)

Heritability in broad sense was calculated according to **Allard (1960)**

$$h^2x = (\sigma^2G_{xx}/\sigma^2P_{xx}) \times 100$$

Where,

h^2x =heritability in broad sense of character X

σ^2G_{xx} = genotypic variance of the character X

σ^2P_{xx}= phenotypic variance of the character X

Genetic Advance:

$$G.A. = K \times \sigma_p \times H_b$$

Where,

K= selection differential expressed in standard unit

σp= phenotypic standard deviation calculated as square root of phenotypic variance

H_b= heritability in broad sense (σ^2g/σ^2p)

Table 3.7 Ranges of genetic variability parameters

Range / Parameters	Low	Medium	High
PCV	**<10**	**10-20**	**>20**
GCV	**<10**	**10-20**	**>20**
Heritability (H_b)	**<30**	**30-60**	**>60**
Genetic advance	**<10**	**10-20**	**>20**

3.7.3: Combining ability analysis

Combining ability analysis in line × tester was done as per the method given by **Kempthorne (1957)** which was later on modified by **Arunachalam (1974)**. The model used for estimation of GCA and SCA effect in combining ability analysis is as follows (Table 3.8):

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

Where,

μ = general mean

g_i = GCA effect of i^{th} line; i=1, 2, 3,.....1

g_j = GCA effect of j^{th} tester; j=1, 2, 3,.....t

Sij = SCA effect of ij^{th} combination

e_{ijk} = error associated with the observation X_{ijk}

i = number of male parent 1, 2 .....t

j = number of female parent 1, 2 l

k = number of replications 1, 2 .....r

Table 3.8: Analysis of Variance for combining ability

Source	**d.f.**	**M.S.**	**F Value**
Replication	r-1	MS_r	MS_r/ MS_e
Genotype	g-1	MS_g	MS_g /MS_e
Lines	l-1	MS_l	MS_l /MS_e
Testers	t-1	MS_t	MS_t /MS_e
Lines × Testers	(l-1)(t-1)	MS_{lt}	MS_{lt} /MS_e
Error	(lt-1)(r-1)	MS_e	
Total	(rg-1)		

Estimation of general combining ability effect

a) For lines:

$$g_i = \frac{Xi...}{tr} - \frac{X...}{ltr}$$

b) For testers:

$$g_j = \frac{X_{.j.}}{lr} - \frac{X_{...}}{ltr}$$

Estimation of specific combining ability effect

$$S_{ij} = (X_{ij.}/r) - (X_{l..}/tr) - (X_{.j.}/lr) - (X_{...}/ltr)$$

Where,

g_i = General combining ability effect of i^{th} line

$X_{...}$ = Grand total (Sum of all the crosses over all the replication)

$X_{i..}$ = Performance of i^{th} line crossed with the testers over all the replications

g_j = General combining ability effects of j^{th} tester

$X_{.j.}$ = Performance of j^{th} tester crossed with the lines over all the replications

S_{ij} = Specific combining ability of the cross between i^{th} line and j^{th} tester

X_{ij} = Total of $(ij)^{th}$ combination over all replications

r = Number of replications

l = Number of lines

t = Number of testers

Standard error for combining ability effects and their differences

S.Em. (g_i) for lines $= \sqrt{\frac{Me}{rt}}$

S.Em. (g_i) for testers $= \sqrt{\frac{Me}{rl}}$

S.Em. (S_{ij}) for crosses $= \sqrt{\frac{Me}{r}}$

S.Ed. ($g_i - g_j$) for lines $= \sqrt{\frac{2Me}{rt}}$

S.Ed. ($g_i - g_j$) for testers $= \sqrt{\frac{2Me}{rl}}$

S.Ed. ($S_{ij} - S_{kl}$) for crosses $= \sqrt{\frac{2Me}{r}}$

Where,

S.Em. = Standard error of mean

S.Ed. = Standard error of difference between two mean values

M_e = Error mean square

Critical difference (C.D.) = S.Ed.×'t' at error d.f.

Testing of significance of GCA and SCA effects

Significance of GCA and SCA effects was tested by 't' test as follows:

t value for GCA effect in lines = g_i/S.Em. g_i

t value for GCA effect in testers = g_j/S.Em. g_j and

t value for SCA effect in crosses = s_{ij}/S.Em. s_{ij}

Where,

g_i = *gca* of i^{th} line

g_j = *gca* of j^{th} tester

S.Em. g_i = Standard error of mean for lines

S.Em. g_j = Standard error of mean for testers

s_{ij} = *sca* of the cross between i^{th} line and j^{th} tester

S.Em. s_{ij} = Standard error of mean for crosses

Calculated values of 't' were tested against table value of 't' at error degree of freedom at 5% and 1% levels of significance.

Estimation of genetic components of variance

To estimate GCA and SCA variance, the covariance of half sib and covariance of full sib was calculated from expectations of mean square as follows:

Cov. H.S. (line) = $(M_l - M_{lt})/rt$

Cov. H.S. (tester) = $(M_t - M_{lt})/rl$

Cov. H.S. (average) = $[1/\{r(2lt - l - t)\}] [\{\{(l - 1)(M_l) + (t-1)(M_t)\}/l+t-2\} - M_{lt}]$

Cov. F.S. = $[\{(M_l - M_e) + (M_t - M_e) + (M_{lt} - M_e)\}/3r] + [\{6r$Cov H.S. $- r(l + t)$ Cov H.S.$\}/3r]$

Where,

M_l = Mean square due to lines

M_t = Mean square due to testers

M_{lt} = mean square due to line x tester interaction

M_e = error mean sum of square

Variance components

Kempthorne (1957) expressed the covariance of half sib (average) [Cov (HS)] and covariance of full sibs [Cov (FS)] in terms of variance due to *gca* and variance due to *sca*, respectively as follows.

Variance due to *gca* (σ^2gca) = Cov HS (average)

Variance due to s*ca* (σ^2sca) = Cov FS - 2Cov HS

The variance due to *gca* (σ^2gca) and variance due to *sca* (σ^2sca) can be used to estimate the additive variance (σ^2_A) and dominance variance (σ^2_D) as follows:

σ^2 *gca*	=	Cov HS = $[(1+F)/4]^2 \sigma^2A$
If, F	=	0, (for cross pollinated crops)
σ^2A	=	4 σ^2 *gca*
If, F	=	1 (for self pollinated crops)
σ^2A	=	σ^2 *gca*
σ^2 *sca*	=	$(M_{lt} - M_e)/r = 1/2(1+F)^2 \sigma^2D$
If, F	=	0, (for cross pollinated crops)
σ^2D	=	2 σ^2 *sca*
If, F	=	1, (for cross pollinated crops)
σ^2D	=	σ^2 *sca*

3.7.4: Estimation of heterosis

Heterosis was expressed as percentage increases or decreases in the performance of F_1's over mid parent (average or relative heterosis), better parent (heterobelteiosis) and check parent (standard heterosis). Heterosis for each character in each cross was computed by the following formulae as given below:

a) Relative heterosis = $\frac{F1-MP}{MP} \times 100$

b) Heterobeltiosis (%) – $\frac{\bar{F}_{1i}-\overline{BP}_i}{\overline{BP}_i} \times 100$

c) Standard heterosis (%) = $\frac{\bar{F}_{1i}-\overline{SP}_i}{\overline{SP}_i} \times 100$

Where,

$\bar{F}_{1i}$= Mean value of F_1 for i^{th} character

$\overline{BP}_i$= Mean value of better parent of the cross for i^{th} character

$\overline{SP}_i$= Mean value of standard parent (SP)/check variety/hybrid for i^{th} trait

The significance of heterosis was worked out with 't' test (Fisher and Yates, 1963) at error degree of freedom of ANOVA table for RBD.

(a) For heterobelteiosis

$$t = \frac{\bar{F}_{1ij} - \overline{BP}_{i\,or\,j}}{\left(\frac{2Me}{r}\right)^{\frac{1}{2}}}$$

(b) For standard heterosis

$$t = \frac{\bar{F}_{1ij} - \overline{SP}}{\left(\frac{2Me}{r}\right)^{\frac{1}{2}}}$$

Where,

$\overline{F_{1ij}}$ = Mean of F_1 hybrid between i^{th} and j^{th} parent

$\overline{BP_{i\,or\,j}}$ = Mean of superior (better) parent out of i^{th} and j^{th} parent

$\overline{SP}$ = Mean of standard parent (check variety/line)

M_e = Error mean square for ANOVA table and

r = Number of replications

The significance was tested against 't' value from 't' table of Fisher and Yates (1963) at error degree of freedom of ANOVA table at 5% and 1% levels of probability.

Results and Discussion

CHAPTER 4 RESULTS AND DISCUSSION

The results obtained from the present investigation have been presented under the following sub-heads.

4.1 Analysis of variance

4.2 Heritability and genetic advance

4.3 Combining ability analysis

4.4 Estimation of heterosis

4.1 Analysis of Variance

Analysis of variance for eighteen characters viz., days to 50% flowering, days to maturity, number of tillers per plant, plant height (cm), panicle length (cm), number of grains per panicle, spikelet fertility (%), grain length (mm), grain width (mm), 1000 grain weight (g), kernel length (mm), kernel breadth (mm), L/B ratio, alkali digestion value, hulling recovery (%), milling recovery (%), harvest index and grain yield per plant (g) are given in Table 4.1. Significant differences among the genotypes were observed for all the characters under study.

The analysis of variance for all the characters was carried out following randomized block design (RBD) analysis.

4.1.1 Days to 50% flowering

Days to 50% flowering among all 73 genotypes ranged from 83.00 days (Pant Dhan 10) to 114.00 days (NDR 3012) with a general mean of 97.32 days. Coefficient of variation for this character was 5.75. The earliest flowering female parent (line) was reported as Pant Dhan 10 (83.00 days) and the earliest flowering male parent (tester) was reported as Pant Dhan 4 (87.33 days).

4.1.2 Days to maturity

Days to maturity among all 73 genotypes ranged from 106.66 days (Govind) to 139.00 days (UPRI 2012-19 × Pant Dhan 26) with a general mean of 126.18 days.

Coefficient of variation for this character was 6.02. The earliest maturing female parent was Pant Dhan 10 (114.66 days) and male parent was Pant Dhan 4 (120 days).

4.1.3 Plant height (cm)

Plant height among all 73 genotypes ranged from 84.67 cm (Pant Dhan 10 × Pant Dhan 26) to 139.33 cm (Pant Dhan 22 × Pant Dhan 26) with a general mean of 108.73 cm. Coefficient of variation for this character was 8.77. The shortest female parent was reported as NDR 3012 (91.00 cm) and the shortest male parent was reported as Pant Dhan 4 (96.60 cm).

4.1.4 Number of tillers per plant

Number of tillers per plant among all 73 genotypes ranged from 9.00 (Pant Dhan 10 × Pant Dhan 26) to 38.67 (UPRI 2008-8 × Pant Dhan 26) with a general mean of 22.17. Coefficient of variation for this character was 13.25. Among the male parents maximum number of tillers per plant was observed in Pant Dhan 4 (22.67) and the maximum number of tillers among female parents was reported in UPRI 2012-19 (29.34).

4.1.5 Panicle length (cm)

Panicle length among all 73 genotypes ranged from 20.16 cm (UPRI 2008-6 × Pant Dhan 4) to 34.00 cm (Pant Dhan 22 × Pant Dhan 23) with a general mean of 28.72 cm. Coefficient of variation for this character was 8.73. Female parent Pant Dhan 24 (31.33 cm) and male parent Pant Dhan 26 (29.67 cm) were found to have highest panicle length.

4.1.6 Number of grains per panicle

Number of grains per panicle among all 73 genotypes ranged from 109.03 (Pant Dhan 18) to 334.83 (UPRI 2011-21 × Pant Dhan 26) with a general mean of 201.93. Coefficient of variation for this character was 10.56. Maximum number of grains per panicle was observed in UPR 3199-464-1-2 (240.33) among the lines and Pant Dhan 26 (198.80) among the testers.

4.1.7 Spikelet fertility (%)

Spikelet fertility among all 73 genotypes ranged from 16.53% (JGL 1172-7) to 90.22% (Pant Dhan 10 × Pant Dhan 23) with a general mean of 57.61%. Coefficient of

variation for this character was 6.52. Maximum fertile spikelets were observed in Pant Dhan 10 (77.31%) among the lines and Pant Dhan 26 (73.85%) among the testers.

4.1.8 1000 grain weight (g)

1000 grain weight among all 73 genotypes ranged from 7.08 g (JGL 1172-7) to 48.71 g (Pant Dhan 19 × Pant Dhan 23) with a general mean of 21.69 g. Coefficient of variation for this character was 12.63. Highest weight of 1000 grain was observed in Pant Dhan 24 (27.70 g) among the female parents and Pant Dhan 26 (28.80 g) among the male parents.

4.1.9 Grain length (mm)

Grain length among all 73 genotypes ranged from 7.30 mm (UPR 3199-464-1-2) to 9.80 mm (Pant Dhan 26) with a general mean of 9.04 mm. Coefficient of variation for this character was 2.52. Among the lines, UPRI 2011-21 (9.73 mm) and among the testers, Pant Dhan 4 (9.67 mm) was observed to have highest mean value for grain length.

4.1.10 Grain width (mm)

Grain width among all 73 genotypes ranged from 2.16 mm (JGL 1172-7) to 3.13 mm (NDR 3012 × Pant Dhan 26) with a general mean of 2.68 mm. Coefficient of variation for this character was 2.12. Highest mean value for Grain width was observed in female parent CR 2644-2-6-4-3-2 (2.96 mm) and in male parent Pant Dhan 23 (2.93 mm).

4.1.11 Kernel length (mm)

Kernel length among all 73 genotypes ranged from 5.26 mm (Pant Dhan 24) to 7.50 mm (Pant Dhan 18) with a general mean of 6.10 mm. Coefficient of variation for this character was 3.68. The highest mean value for kernel length was observed for Pant Dhan 18 (7.50 mm) among the female parents and Pant Dhan 26 (6.46 mm) among the male parents.

4.1.12 Kernel breadth (mm)

Kernel breadth among all 73 genotypes ranged from 1.86 mm (UPR 3871-8-1-2-2 × Pant Dhan 23) to 2.46 mm (NDR 3012 × Pant Dhan 26) with a general mean of 2.10 mm. Coefficient of variation for this character was 5.36. The highest mean value for kernel breadth was observed for CR 2644-2-6-4-3-2 (2.33 mm) among the female parents and Pant Dhan 23 (2.16 mm) among the male parents.

Table 4.1 Analysis of variance for various yield and quality character in rice genotypes

Source of variation	d.f	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of tiller per plant	Panicle length(cm)	No. of grain per panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain length (mm)
		Mean sum of squares								
Replication	**2**	4.22	0.43	128.74	48.73	6.24	38.34	51.91	5.91	0.92
Treatment	**70**	125.20**	98.61**	342.84**	74.61**	18.36**	7617.18**	804.45**	139.48**	0.68**
Error	**140**	5.57	6.61	16.62	15.67	5.48	8.24	2.96	18.21	0.30

(Contd...) Table 4.1

Source of variation	d.f	Grain width (mm)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Harvest index	Hulling recovery (%)	Milling recovery (%)	Alkali digestion value	Grain yield per plant (g)
		Mean sum of squares								
Replication	**2**	0.65	0.48	0.27	0.90	0.33	2.22	3.70	9.72	7.94
Treatment	**70**	0.98**	0.60**	0.44**	0.84**	0.24**	143.4**	139.0**	2.08**	610.08**
Error	**140**	0.42	0.12	0.12	0.20	0.20	1.91	2.05	0.73	4.53

* Significant at 5% level, ** significant at 1% level

4.1.13 L/B ratio

L/B ratio among all 73 genotypes ranged from 2.61 (BBL 180-5-1-4-1) to 3.68 (Pant Dhan 18) with a general mean of 2.93. Coefficient of variation for this character was 4.90. The highest mean value for L/B ratio was observed for Pant Dhan 18 (3.68) among the female parents and Pant Dhan 26 (3.08) among the male parents.

4.1.14 Harvest index

Harvest index among all 73 genotypes ranged from 0.29 (CR 2644-2-6-4-3-2) to 0.68 (Pant Dhan 19 × Pant Dhan 4) with a general mean of 0.52. Coefficient of variation for this character was 8.33. The highest mean value for harvest index was observed for UPR 3871-8-1-2-2 (0.67) among the female parents and Pant Dhan 26 (0.59) among the male parents.

4.1.15 Hulling recovery (%)

Hulling recovery among all 73 genotypes ranged from 52.00% (JGL 1172-7) to 81.00% (CR 2644-2-6-4-3-2 × Pant Dhan 4) with a general mean of 69.09%. Coefficient of variation for this character was 3.25. The highest mean value for hulling recovery was observed for Pant Dhan 19 (77.33%) among the female parents and Pant Dhan 4 & 23 (75.67%) among the male parents.

4.1.16 Milling recovery (%)

Milling recovery among all 73 genotypes ranged from 46.33% (CR 2644-2-6-4-3-2) to 74.00% (Pant Dhan 10 × Pant Dhan 4) with a general mean of 61.43%. Coefficient of variation for this character was 2.93. The highest mean value for milling recovery was observed for UPRI 2012-10 (66.67%) among the female parents and Pant Dhan 23 (66.33%) among the male parents.

4.1.17 Alkali digestion value

Alkali digestion value among all 73 genotypes ranged from 1.00 (JGL 1172-7) to 5.00 (UPRI 2012-19) with a general mean of 2.64. Coefficient of variation for this character was 9.72. The highest mean value for alkali digestion value was observed for UPRI 2012-19 (5.00) among the female parents and Pant Dhan 23 (2.67) among the male parents.

4.1.18 Grain yield per plant (g)

Grain yield per plant among all 73 genotypes ranged from 16.43 g (Govind) to 77.76 g (Pant Dhan 22 × Pant Dhan 26) with a general mean of 39.44 g. Coefficient of variation for this character was 8.63. Highest grain yield per plant was observed for female parent BBL180-5-1-4-1 (30.41 g) male parent Pant Dhan 26 (35.26 g).

Genetic variability parameters

The general mean, coefficient of variation, critical difference at 1% and at 5% level of significance, range of variation, standard error mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and environmental coefficient of variation (ECV) for the eighteen characters under study are presented in Table 4.2. The magnitude of phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters under study. Highest phenotypic coefficient of variation was observed for alkali value (40.94%) and lowest PCV for days to maturity (5.16%) and other were grain yield per plant (37.09%) followed by 1000 grain weight (34.95%), spikelet fertility (28.26%), number of tillers per plant (27.13%), number of grains per panicle (25.51%), harvest index (17.62%), milling recovery (11.37%), panicle length (10.92%), plant height (10.50%), hulling recovery (10.15%), kernel length (7.79%), days to 50% flowering (7.44%), kernel breadth (7.32%), L/B ratio (7.04%), grain width (6.94%) and grain length (5.52%). Highest genotypic coefficient of variation was observed for grain yield per plant (36.69%) followed by 1000 grain weight (29.01%), spikelet fertility (28.10%), number of grains per panicle (25.46%), alkali value (25.41%), number of tillers per plant (20.57%), harvest index (17.41%), milling recovery (11.12%), hulling recovery (9.95%), plant height (9.81%), kernel length (7.58%), panicle length (7.34%), days to maturity (7.02%), grain width (6.51%), grain length (5.18%) and L/B ratio (5.08%). The lowest genotypic coefficient of variation was observed for days to maturity (4.74%). The results were in support with the earlier findings of **Singh *et al.* (2011), Tiwari *et al.* (2011), Ismaila *et al.* (2015), Saleem *et al.* (2005), Bhatt *et al.* (2017) and Kumar *et al.,* (2013).**

The highest environmental coefficient of variation (ECV) was observed for alkali digestion value (15.52%) and lowest for number of grains per plant (0.04%).

Table 4.2 summery table depicting variability among rice genotypes with respect to different characters

Sr. No.	Characters	General mean	CV	CD at 1%	CD at 5%	SE±	Range of variation	PCV	GCV	ECV
1.	Days to 50% flowering	97.32	5.75	5.03	3.81	1.36	83-114	7.44	7.02	0.41
2.	Days to maturity	126.08	6.02	5.48	4.15	1.48	114-139	5.16	4.74	0.42
3.	Plant height (cm)	108.73	8.77	8.69	6.58	2.35	86.66-139.33	10.50	9.81	0.68
4.	Number of tillers/plant	22.17	13.22	8.44	6.39	2.28	9.0-38.66	27.13	20.57	6.56
5.	Panicle length (cm)	28.72	8.73	4.99	3.78	1.35	20.16-34.0	10.92	7.34	3.58
6.	Number of grains/panicle	201.93	10.56	6.12	4.63	1.65	109.03-334.83	25.51	25.46	0.04
7.	Spikelet fertility (%)	57.61	6.52	3.67	2.79	0.99	16.53-90.22	28.26	28.10	0.16
8.	1000 grain weight (g)	21.69	12.63	9.10	6.88	2.46	7.08-48.71	34.95	29.01	5.93
9.	Grain length (mm)	9.04	2.52	0.36	0.27	0.10	8.09-9.80	5.52	5.18	0.34
10.	Grain width (mm)	2.68	2.12	0.13	0.10	0.37	2.16-3.13	6.94	6.51	0.43
11.	Kernel length (mm)	6.15	3.68	0.23	0.17	0.63	5.26-7.50	7.79	7.58	0.20
12.	Kernel breadth (mm)	2.10	5.36	0.24	0 .18	0 .65	1.86-2.46	7.32	5.02	2.30
13.	Length/Breadth ratio	2.93	4.90	0 .30	0 .23	0 .83	2.62-3.68	7.04	5.08	1.96
14.	Harvest index	0.52	8.33	0 .30	0 .23	0 .82	0.29-0.67	17.62	17.41	0.20
15.	Hulling recovery (%)	69.09	3.25	2.95	2.23	0 .79	52.0-81.0	10.15	9.95	0.19
16.	Milling recovery (%)	61.43	2.93	3.05	2.31	0 .82	46.33-74.0	11.37	11.12	0.24
17.	Alkali digestion value	2.64	9.72	1.83	1.38	0 .49	1.0-5.0	40.94	25.41	15.52
18.	Grain yield per plant (g)	39.44	8.63	4.53	3.43	1.22	17.28-77.76	37.09	36.69	0.39

4.2 Estimation of heritability and genetic advance.

The estimation of broad sense heritability and genetic advance under selection for all the eighteen characters under study is presented in the Table 4.3. High heritability was observed for number of grains per panicle (99.68%) followed by spikelet fertility (98.86%), grain yield per plant (97.87%), alkali value (97.64%), harvest index (96.13%), hulling recovery (95.78%), kernel length (94.72%), days to 50% flowering (89.05%), grain width (87.84%), kernel length (87.93%), plant height (87.33%), days to maturity (84.37%) and 1000 grain weight (68.91%). Medium heritability was observed for number of tillers per plant (57.42%) followed by L/B ratio (51.94%), kernel width (47.04%), panicle length (45.18%) and milling recovery (38.53%). As same way, high genetic advance was observed for number of grains per panicle (104.79) followed by spikelet fertility (33.24), grain yield per plant (29.16) and plant height (20.47). Medium genetic advance was observed for harvest index (13.85) followed by hulling recovery (13.73), days to 50% flowering (13.23), days to maturity (11.28) and 1000 grain weight (10.74). Low genetic advance was observed for number of tillers per plant (7.11) followed by panicle length (2.91), kernel length (0.93) and grain length (0.90).

High heritability was coupled with high genetic advance for important characters such as, number of grains per panicle, spikelet fertility, grain yield per plant and plant height. High heritability was coupled with medium genetic advance for harvest index, hulling recovery, days to 50% flowering, days to maturity and 1000 grain weight. High heritability was coupled with low genetic advance for grain length, grain width, kernel length, alkali value and number of tillers per plant.

Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone **(Chaudhary *et al.* 2004).** These results showed that the characters having high heritability with high genetic advance have greater scope for improvement through direct phenotypic selection by fixing additive genetic effects. The results were found similarity with findings of **Padmaja *et al.* (2008), Bisne *et al.* (2009), Umadevi *et al.* (2009)**, **Akinwale *et al.* (2011), Tiwari *et al.* (2011), Sran *et al.,* (2016), Edukondalu *et al.* (2017), Ajmera *et al.* (2017), Bhatt *et al*. (2017), Prasad *et al.* (2017) and Tripathi *et al.* (2018)**.

Table 4.3: Estimated heritability (broad sense) and genetic advance for different characters in rice genotypes

Sl. No.	Characters	Heritability in broad sense (%)	Genetic advance
1.	Days to 50% flowering	89.05	13.23
2.	Days to maturity	84.37	11.28
3.	Plant height (cm)	87.33	20.47
4.	Number of tillers per plant	57.46	7.11
5.	Panicle length (cm)	45.18	2.91
6.	Number of grains per panicle	99.68	104.79
7.	Spikelet fertility (%)	98.86	33.24
8.	1000 grain weight (g)	68.91	10.74
9.	Grain length (mm)	87.84	0.90
10.	Grain width (mm)	87.93	0.33
11.	Kernel length (mm)	94.72	0.93
12.	Kernel width (mm)	47.04	0.14
13.	L/B ratio	51.94	0.22
14.	Harvest index	96.13	13.85
15.	Hulling recovery (%)	95.78	13.73
16.	Milling recovery (%)	38.53	0.86
17.	Alkali digestion value	97.64	0.18
18.	Grain yield per plant (g)	97.87	29.16

4.3 Combining ability analysis

4.3.1 Estimates of components of genetic variance

Analysis of variance for combining ability (GCA and SCA) for eighteen characters under study is represented in Table 4.4(a). Results indicated significance differences among crosses for most of the character under study. Significant differences were observed among the lines and testers for days to 50% flowering, days to maturity, number of tillers per plant, plant height (cm), panicle length (cm), number of grains per panicle, spikelet fertility (%), 1000 grain weight (g), hulling and milling recovery and grain yield per plant (g). Line × tester showed significant difference for all the character under study except grain length, grain width, kernel length and breadth, L/B ratio and harvest index. Similarity in results found with the reports of **Malini *et al.* (2006)**, **Tiwari *et al.* (2011)**, **Patil *et al*. (2012), Thakare *et al*. (2013), and Latha *et al.* (2013).**

The estimates of variance due to GCA (σ^2gca) and variance due to SCA (σ^2sca) for eighteen characters are given in Table 4.4(b). Results revealed that sca variance is higher than GCA variance for all the characters except L/B ratio and alkali digestion value under study indicating predominance of non-additive gene action in the inheritance for all these characters. The estimate of variance component for various characters indicated that SCA variances were higher than GCA variances for all the characters under study. Therefore, the ratios of variances of GCA and sca were less than unity (<1) for most of the characters except L/B ratio and alkali digestion value under study. Similarity in results found with the reports of **Roy and Mandal (2001), Panwar (2005), Saidaiah *et al.* (2010), Tiwari *et al.* (2011) and Thakare *et al*. (2013).**

Table 4.4(a) Analysis of variance for combining ability for various characters in rice genotypes

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain length (mm)
Replication	2	1.96	6.41	110.86	4.72	8.05	32.45	65.16	12.76	0.07
Treatment	70	125.20**	98.61**	342.84**	74.61**	18.36**	7617.18**	804.45**	139.48**	0.68**
Crosses	50	93.99**	93.39**	373.25**	88.63**	20.75**	7622.53**	554.21**	116.47**	0.47
Lines	16	131.29**	107.75**	766.80**	123.63**	24.98**	16416.73**	877.92**	167.92**	0.94
Tester	2	180.81**	98.84**	195.93**	181.43**	10.26**	22757.37**	116.40**	4.34*	0.46
Line × Tester	32	69.91**	85.87**	187.56**	65.33**	19.30**	2279.50**	419.72**	97.75**	0.23
Error	100	5.66	6.80	20.00	15.56	6.92	9.01	2.56	24.51	0.03

(Contd.) Table 4.4(a) Analysis of variance for combining ability for various characters in rice genotypes

Source of variation	d.f.	Grain width (mm)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Harvest index	Hulling recovery (%)	Milling recovery (%)	Alkali digestion value	Grain yield per plant (g)
Replication	2	0.05	0.02	0.04	0.11	0.01	0.86	5.90	6.51	13.53
Treatment	70	0.98**	0.60**	0.44**	0.84**	0.24**	143.40**	139.05**	2.08**	610.08**
Crosses	50	0.07	0.56	0.04	0.05	0.02	112.91**	117.41**	1.79**	551.58**
Lines	16	0.08	0.89	0.07	0.11	0.03	206.55**	232.50**	3.42**	720.46**
Tester	2	0.01	0.36	0.00	0.02	0.01	100.49**	40.00**	2.69**	2,239.89**
Line × tester	32	0.08	0.41	0.03	0.02	0.01	66.86**	64.70**	0.92**	361.62**
Error	100	0.00	0.01	0.01	0.02	0.00	1.66	1.96	0.87	4.33

** Significant at 1% level, * significant at 5%level

Table 4.4(b) General and specific combining ability variances for various characters in rice genotypes

Sl. No.	Characters	σ^2gca	σ^2sca	σ^2gca/ σ^2sca	Mean degree of dominance (F=1)
1.	Days to 50% flowering	2.87	21.41	0.13	21.41
2.	Days to maturity	0.58	26.35	0.02	26.35
3.	Plant height (cm)	9.79	55.85	0.17	55.85
4.	Number of tillers/plant	2.90	16.59	0.17	16.59
5.	Panicle length (cm)	-0.05	4.12	-0.01	4.12
6.	Number of grains/panicle	576.91	756.83	0.76	756.83
7.	Spikelet fertility (%)	2.58	139.05	0.01	139.05
8.	1000 grain weight (g)	-0.38	24.41	-0.01	24.41
9.	Grain length (mm)	0.01	0.06	0.23	0.06
10.	Grain width (mm)	-0.01	0.02	-0.03	0.02
11.	Kernel length (mm)	0.07	0.13	0.05	0.13
12.	Kernel breadth (mm)	0.01	0.05	0.20	0.05
13.	Length/Breadth ratio	0.02	-0.01	-2.0	-0.01
14.	Harvest index	0.01	0.05	0.20	0.05
15.	Hulling recovery (%)	2.88	21.73	0.13	21.73
16.	Milling recovery (%)	2.38	20.91	0.11	20.91
17.	Alkali digestion value	0.07	0.01	3.94	0.01
18.	Grain yield per plant (g)	37.28	119.09	0.31	119.09

4.3.2 Estimates of combining ability effects

The results of combining ability analysis i.e. the GCA effect of 17 lines and 3 testers and the SCA effect for 51 cross combination are given in Table 4.5 and 4.6, respectively. The results are described as follows:

4.3.2.1 Days to 50% flowering

The range of GCA effects of lines for days to 50% flowering varies from -6.94 to 7.39 and for testers it ranges from -1.62 to 2.06. Among the lines, Pant Dhan 10 (-6.94), Pant Dhan 24 (-3.60), Pant Dhan 22 (-3.38), Pant Dhan 19 (-3.16) and NDR 3012 (-2.38) showed significant negative GCA effects and found as good general combiner for this character. Among the testers, Pant Dhan 4 (-1.62) showed significant negative GCA effects and found to be as good general combiner for this character.

The SCA effects of crosses for days to 50% flowering ranges from -7.55 to 9.93. Out of 51 crosses, 10 crosses showed significant negative SCA effects which are BBL 180-5-1-4-1 × Pant Dhan 23 (-7.55), UPRI 2008-6 × Pant Dhan 23 (-7.33), UPRI 2008-8 × Pant Dhan 4 (-6.15), UPRI 2012-19 × Pant Dhan 4 (-4.82), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-4.73), UPR 3871-8-1-2-2 × Pant Dhan 24 (-4.39), UPRI 2014-8 × Pant Dhan 26 (-3.62), UPRI 2012-10 × Pant Dhan 4 (-3.26) and Pant Dhan 10 × Pant Dhan 23 (-3.00). Twelve cross combinations exhibited significantly positive SCA effects for this character.

4.3.2.2 Days to maturity

The GCA effect of lines for days to maturity varies from -6.09 to 7.90 and for testers it varies from -1.39 to 1.39**.** Among the lines, Pant Dhan 24 (-6.09), Pant Dhan 10 (-5.31) and Pant Dhan 22 (-3.31), exhibited significantly negative GCA effects and found as good combiners for days to maturity. Among the testers Pant Dhan 4 (-1.39) exhibited significant negative GCA effects and found to be as good general combiner for this character.

The SCA effects of crosses ranged from -9.33 to 11.72. Among the 51 cross studied, 9 cross combinations namely UPRI 2008-6 × Pant Dhan 23 (-9.33), UPRI 2012-10 × Pant Dhan 26 (-7.94), UPRI 2008-8 × Pant Dhan 4 (-7.38), Pant Dhan18 × Pant Dhan 26 (-7.28), BBL 180-5-1-4-1 × Pant Dhan 23 (-7.00), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-4.83), UPRI 2012-19 × Pant Dhan 4 (-3.49), BBL 180-5-1-4-1 × Pant Dhan 4 (-3.27) and UPR 3871-8-1-2-2 × Pant Dhan 4 (-3.05) exhibited significantly negative SCA effects for this character.

4.3.2.3 Plant height (cm)

The GCA effects for plant height ranged from -17.62 to 17.70 and -1.44 to 2.23 in lines and testers, respectively. Among the 17 lines, 6 lines namely Pant Dhan 10 (-17.62), UPR 3871-8-1-2-2 (-10.51), UPR 3199-464-1-2 (-8.06), Pant Dhan 24 (-7.40), BBL 180-5-1-4-1 (-7.29), UPRI 2012-19 (-3.23), UPRI 2012-10 (-2.48) and UPRI 2008-8 (-2.18) and among the testers Pant Dhan 23 (-1.44) showed significant negative GCA effects and found as good general combiner for this character.

The SCA effects of crosses for this character were ranged from -12.89 to 13.34. Among the 51 crosses under study, 12 cross combinations namely UPR 3871-8-1-2-2 × Pant Dhan 26 (-12.89), UPR 3199-464-1-2 × Pant Dhan 23 (-10.22), Pant Dhan 10 × Pant Dhan 26 (-9.45), NDR 3012 × Pant Dhan 26 (-8.01), JGL 1172-7 × Pant Dhan 26 (-7.78), BBL 180-5-1-4-1 × Pant Dhan 4 (-7.09), UPRI 2012-10 × Pant Dhan 4 (-6.14), UPRI 2012-19 × Pant Dhan 4 (-5.98), UPRI 2008-8 × Pant Dhan 26 (-5.56) and Pant Dhan 22 × Pant Dhan 4 (-5.43) exhibited significant negative SCA effect values for this character.

4.3.2.4 Number of tillers per plant

For number of tillers per plant, the GCA effects for lines ranged from -7.26 to 6.07 and for testers it ranged from -2.13 to 1.43. Among the lines, UPRI 2008-8 (6.07) and UPRI 2012-19 (4.40), BBL 180-5-1-4-1 (3.62), Pant Dhan 24 (3.51) exhibited significant positive GCA effects and found as good general combiner for this character. Among the testers, Pant Dhan 26 showed significant positive GCA effect and also found to be as good general combiner.

The SCA effect of crosses for number of tillers per plant ranged from -8.09 to 8.79. Among the 51 crosses studied, 7 cross combinations namely UPRI 2008-8 × Pant Dhan 26 (8.79), Pant Dhan 10 × Pant Dhan 23 (7.35), UPR 3871-8-1-2-2 × Pant Dhan 4 (5.40), Pant Dhan 18 × Pant Dhan 23 (5.13), UPRI 2014-8 × Pant Dhan 26, JGL 1172-7 × Pant Dhan 26, BBL 180-5-1-4-1 × Pant Dhan 26 (4.61) exhibited significant positive sca effects and 5 crosses showed significant and negative sca effects.

4.3.2.5 Panicle length (cm)

The range of GCA effects of lines for panicle length varied from -2.91 to 3.80 and for testers -0.45 to 0.43. Among the 17 lines, 3 lines namely Pant Dhan 22 (3.80), JGL 1172-7 (2.47) and NDR 3012 (2.08) exhibited significant positive GCA effect and found as good general combiner for panicle length.

Table 4.5 GCA effects of parents for different character in rice genotypes

Particulars	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain length (mm)
Lines (female)									
UPRI 2011-21	1.39	0.13	5.93**	0.18	-1.53	65.73**	0.92	-5.39**	-0.38**
UPRI 2008-6	4.05**	-0.31	1.59	-0.59	-1.35	-27.86**	-1.81**	-5.88**	0.01
BBL 180-5-1-4-1	1.61*	-0.98	-7.29**	3.62**	-0.47	-32.81**	1.57**	7.29**	0.55**
UPRI 2012-10	0.17	-0.75	-2.48	-0.92	-1.46	-16.19**	0.24	2.08	-0.08
UPRI 2008-8	6.39**	5.13**	-2.18	6.07**	0.36	11.17**	-2.57**	-4.56**	-0.06
UPRI 2012-19	7.39**	7.90**	-3.23*	4.40**	-0.36	-34.09**	-17.68**	-0.62	0.13**
Pant Dhan 22	-3.38**	-3.31**	17.70**	0.85	3.80**	46.82**	2.58**	-0.95	0.47**
Pant Dhan 10	-6.94**	-5.31**	-17.62**	-7.26**	-2.91**	-82.24**	24.48**	3.72*	0.00
Pant Dhan 18	2.50**	-0.75	-0.62	-6.03**	-0.58	-39.77**	7.24**	0.74	0.20**
Pant Dhan 24	-3.60**	-6.09**	-7.40**	3.51**	-0.02	-25.15**	11.62**	-0.99	-0.11*
UPR 3871-8-1-2-2	0.94	1.13	-10.51**	-1.15	-1.58	27.12**	-6.26**	-2.87	-0.37**
UPR 3199-464-1-2	-2.38**	0.02	-8.06**	2.29	-0.24	-0.54	-11.79**	-4.62**	-0.56**
UPRI 2014-8	-3.83**	-1.53	2.48	1.29	0.41	-15.32**	9.10**	0.11	0.12**
CR 2644-2-6-4-3-2	0.94	3.46**	-1.10	-0.48	0.52	25.79**	-12.33**	0.32	-0.55**
NDR 3012	-2.38**	-0.31	8.26**	-5.37**	2.08*	-2.82**	-2.10**	4.17*	0.21**
JGL 1172-7	0.28	2.68**	15.37**	-2.37*	2.47**	92.67**	-4.60**	-1.93	0.23**
Pant Dhan 19	-3.16**	-1.09	9.15**	1.96	0.87	7.50**	1.39*	9.41**	0.18**
$SE(g_i)\pm$	0.77	0.84	1.44	1.27	0.85	0.97	0.51	1.61	0.05
$SE(g_i - g_j)\pm$	0.47	0.51	0.88	0.78	0.52	0.59	0.31	0.98	0.03
Testers (male)									
Pant Dhan 4	-1.62**	-1.39**	-0.79	0.70	-0.45	-23.08**	-1.01**	0.13	0.04
Pant Dhan 23	-0.44	0.00	-1.44**	-2.13**	0.02	4.71**	1.73**	0.19	0.06**
Pant Dhan 26	2.06**	1.39**	2.23**	1.43*	0.43	18.36**	-0.71**	-0.33	-0.10**
$SE(g_j)\pm$	0.27	0.29	0.45	0.65	0.30	0.34	0.18	0.56	0.02
$SE(g_i - g_j)\pm$	1.12	1.23	2.10	1.86	1.24	1.41	0.75	2.33	0.08

** Significant at 1% level, * significant at 5%level

The SCA effects for panicle length ranged from -6.98 to 5.70. Out of 51 crosses, 3 cross combinations namely UPRI 2008-6 × Pant Dhan 23 (5.70), UPRI 2014-8 × Pant Dhan 4 (3.07), UPRI 2012-10 × Pant Dhan 26 (3.05) exhibited significant positive sca effects and 4 crosses showed significantly negative sca effects for this character.

4.3.2.6 Number of grains per panicle

For number of grains per panicle, the range of GCA effects among the parents varies from -82.24 to 92.67 in the lines and -23.08 to 18.36 in the testers, respectively. Among the lines except UPR3199-464-1-2 showed significant GCA effects. Seven lines namely, JGL 1172-7 (92.67), UPRI 2011-21 (65.73), Pant Dhan 22 (46.82), UPR 3871-8-1-2-2 (27.12) and CR 2644-2-6-4-3-2 (25.79) and two testers viz., Pant Dhan 26 (18.36) and Pant Dhan 23 (4.71) exhibited significantly positive gca effects and found as good general combiners for this character.

The SCA effects of crosses for this character ranged from -36.71 to 49.83. Among the 51 crosses studied, 9 cross combinations namely, Pant Dhan 24 × Pant Dhan 23 (49.83), Pant Dhan 22 × Pant Dhan 26 (42.37), UPRI 2011-21 × Pant Dhan 26 (38.16), UPRI 2012-19 × Pant Dhan 23 (37.62), UPRI 2012-10 × Pant Dhan 26 (36.26), UPR 3871-8-1-2-2 × Pant Dhan 26 (35.28), Pant Dhan 10 × Pant Dhan 4 (27.68), UPRI 2008-8 × Pant Dhan 4 (26.27) and UPRI 2008-6 × Pant Dhan 23 (26.08) exhibited highly significant positive sca effects and 24 crosses showed highly significant and negative sca effects for this character.

4.3.2.7 Spikelet fertility (%)

The GCA effect for spikelet fertility ranged from -17.68 to 24.48 in lines and -1.01 to 1.73 in testers, respectively. Among the lines, Pant Dhan 10 (24.48), Pant Dhan 24 (11.62), UPRI 2014-8 (9.10), Pant Dhan 18 (7.24) and Pant Dhan 22 (2.58) and among the testers Pant Dhan 23 (1.73) exhibited highly significant and positive GCA effects and appeared as good general combiners for spikelet fertility.

The SCA effects of crosses for this character ranged from -21.89 to 18.29. Out of 51 crosses, 12 cross combination showed significant and positive sca effects viz., UPRI 2012-19 × Pant Dhan 4 (18.29), UPR 3871-8-1-2-2 × Pant Dhan 26 (15.73), UPRI 2008-8 × Pant Dhan 4 (15.56), Pant Dhan 22 × Pant Dhan 26 (15.19), NDR 3012 × Pant Dhan 23 (13.12), UPRI 2008-6 × Pant Dhan 23 (12.90), CR 2644-2-6-4-3-2 × Pant Dhan 23 (11.82), Pant Dhan 24 × Pant Dhan 26 (8.51), UPRI 2011-21 × Pant Dhan 4 (8.00), BBL 180-5-1-4-1 × Pant Dhan 4 (7.26), Pant Dhan 18 × Pant Dhan 26 (7.18), Pant Dhan 19 × Pant Dhan 26 (7.14) and UPRI 2008-8 × Pant Dhan 23 (6.33) and 19 crosses exhibited highly significant and negative sca effects for spikelet fertility.

(Contd.) Table 4.5: GCA effects of parents for different character in rice genotypes

Particulars	Grain width (mm)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Harvest index	Hulling recovery (%)	Milling recovery (%)	Alkali digestion value	Grain yield per plant (g)
Lines (female)									
UPRI 2011-21	0.01	-0.60**	-0.05	-0.22**	-0.03**	-4.25**	-5.94**	0.12	-0.95
UPRI 2008-6	0.06**	-0.18**	-0.04	-0.00	0.04**	-5.14**	-3.83**	-0.43	-2.32**
BBL 180-5-1-4-1	0.06**	-0.29**	-0.07	-0.03	-0.02**	-5.03**	-6.06**	1.23**	-5.07**
UPRI 2012-10	-0.07**	0.08*	-0.00	0.03	-0.02*	0.96*	-0.94*	-0.54	-11.80**
UPRI 2008-8	-0.04*	-0.13**	-0.05	0.04	-0.05**	-11.47**	-10.28**	0.12	-1.61*
UPRI 2012-19	-0.05**	0.55**	0.06	0.15**	-0.02**	-1.03*	-2.61**	0.90**	-5.91**
Pant Dhan 22	0.09**	0.07	0.00	0.02	0.06**	-2.14**	-1.72**	-0.09	16.02**
Pant Dhan 10	-0.07**	0.57**	0.06	0.16**	0.01	8.30**	8.94**	-0.76*	-15.76**
Pant Dhan 18	-0.05**	0.42**	0.08*	0.08	-0.06**	1.63**	3.38**	0.68*	1.28
Pant Dhan 24	-0.04*	-0.21**	-0.09*	0.02	-0.03**	3.41**	5.16**	0.01	-0.67
UPR 3871-8-1-2-2	-0.15**	-0.26**	-0.13**	0.05	0.01	4.19**	0.27	-0.65*	14.74**
UPR 3199-464-1-2	-0.02	-0.10**	-0.05	0.01	0.11**	-2.92**	-1.72**	1.01**	13.73**
UPRI 2014-8	0.05*	0.12**	0.03	0.00	-0.01	4.63**	6.60**	-0.32	-1.10
CR 2644-2-6-4-3-2	0.13**	-0.22**	0.08*	-0.18**	-0.09**	1.96**	-0.17	-0.32	2.82**
NDR 3012	0.22**	0.20**	0.23**	-0.20**	-0.02*	1.52**	2.38**	-0.65*	-7.42**
JGL 1172-7	-0.02	-0.10**	-0.08*	0.06	0.02*	0.74	0.27	-0.32	-4.53**
Pant Dhan 19	-0.07**	0.10**	0.02	0.01	0.12**	4.63**	6.28**	0.01	8.58**
SE(gi) ±	0.02	0.03	0.03	0.04	0.00	0.41	0.45	0.30	0.67
SE(gi − gj) ±	0.01	0.02	0.02	0.03	0.00	0.25	0.27	0.18	0.41
Testers (male)									
Pant Dhan 4	-0.01	-0.09**	-0.01	-0.02	0.01**	0.81**	0.10	0.17	-3.79**
Pant Dhan 23	0.01*	0.06**	0.01	0.00	-0.00	0.81**	0.82**	-0.26*	-3.86**
Pant Dhan 26	-0.00	0.03*	0.00	0.01	-0.01*	-1.62**	-0.93**	0.09	7.65**
SE(gj) ±	0.00	0.01	0.01	0.01	0.00	0.14	0.16	0.10	0.23
SE(gi − gj) ±	0.03	0.05	0.05	0.07	0.00	0.60	0.66	0.44	0.98

** Significant at 1% level, * significant at 5%level

4.3.2.8 1000 Grain weight (g)

For 1000 grain weight, the GCA effects among lines ranged from -5.88 to 9.41 and among testers ranged from -0.33 to 0.19. Among the lines, Pant Dhan 19 (9.41), BBL180-5-1-4-1 (7.29), NDR 3012 (4.17) and Pant Dhan 10 (3.72) exhibited significantly positive GCA effects and found as good general combiner for this character.

The SCA effect for 1000 grain weight was ranged from -8.73 to 16.09. Among the 51 crosses, 4 cross combinations namely Pant Dhan 19 × Pant Dhan 23 (16.09), UPRI 2014-8 × Pant Dhan 26 (7.44), UPRI 2008-8 × Pant Dhan 4 (7.16) and UPRI 2012-19 × Pant Dhan 26 (6.91) showed significantly positive sca effects and 7 crosses showed significant and negative sca effects for this character.

4.3.2.9 Grain length (mm)

The GCA effects for grain length in lines ranged from -0.56 to 0.55 and -0.10 to 0.06 in the testers, respectively. Among the lines, BBL 180-5-1-4-1 (0.55), Pant Dhan 22 (0.47), JGL 1172-7 (0.23), NDR 3012 (0.21), Pant Dhan 18 (0.20) and Pant Dhan 19 (0.18) exhibited significant positive gca effect values and found as good combiners for grain length. Among the testers, Pant Dhan 26 (-0.10) and Pant Dhan 23 (0.06) exhibited significantly negative and positive GCA effects values and found as good general combiners for grain length.

The SCA effects of crosses for grain length ranged from -0.58 to 0.50. Among the 51 crosses studied, 8 cross combinations namely UPRI 2008-8 × Pant Dhan 23 (0.50), UPR 3871-8-1-2-2 × Pant Dhan 26 (0.46), UPRI 2012-19 × Pant Dhan 4 (0.40), Pant Dhan 18 × Pant Dhan 4 (0.33), JGL 1172-7 × Pant Dhan 4 (0.30), NDR 3012 × Pant Dhan 26 (0.27), Pant Dhan 18 × Pant Dhan 23 (0.24) and CR 2644-2-6-4-3-2 × Pant Dhan 23 (0.22) exhibited significant and positive sca effects and nine crosses showed significantly negative SCA effects for this character.

4.3.2.10 Grain width (mm)

The GCA effects for grain width ranged from -0.15 to 0.22 in lines and -0.01 to 0.01 in testers, respectively. Among the lines, 6 lines exhibited significant positive GCA effects viz., NDR 3012 (0.22), CR 2644-2-6-4-3-2 (0.13), Pant Dhan 22 (0.09), UPRI 2008-6 (0.06), BBL 180-5-1-4-1 (0.06) and UPRI 2014-8 (0.05) and among the testers, Pant Dhan 23 (0.01) exhibited significant positive GCA effects and emerged as good general combiner for grain width.

Table 4.6: SCA Effects of crosses for different characters in rice genotypes

Sl. No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain length (mm)
1.	UPRI 2011-21 X Pant Dhan 4	-2.15	-2.38	-2.98	-1.26	2.55	-1.49	8.00**	0.62	-0.00
2.	UPRI 2011-21 X Pant Dhan 23	-2.66	-2.77	-3.00	2.24	-3.42*	-36.71**	-12.04**	-0.84	-0.16
3.	UPRI 2011-21 X Pant Dhan 26	4.82**	5.16**	5.99*	-0.98	0.86	38.16**	4.03**	0.21	0.17
4.	UPRI 2008-6 X Pant Dhan 4	9.84**	11.72**	-0.65	0.18	-6.98**	-1.18	-8.59**	-2.47	0.12
5.	UPRI 2008-6 X Pant Dhan 23	-7.33**	-9.33**	-3.33	2.02	5.70**	26.08**	12.90**	4.26	-0.20
6.	UPRI 2008-6 X Pant Dhan 26	-2.51	-2.39	3.99	-2.20	1.28	-24.90**	-4.31**	-1.78	0.07
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-2.37	-3.27*	-7.09**	-6.37**	-3.04*	21.46**	7.26**	3.97	-0.15
8.	BBL 180-5-1-4-1 X Pant Dhan 23	-7.55**	-7.00**	-4.44	1.80	1.31	-18.40**	3.01**	-4.85	0.12
9.	BBL 180-5-1-4-1 X Pant Dhan 26	9.93**	10.27**	11.54**	4.56*	1.72	-3.05	-10.28**	0.87	0.03
10.	UPRI 2012-10 X Pant Dhan 4	-3.26*	-0.16	-6.14*	2.85	0.30	-25.28**	5.54**	-0.37	0.09
11.	UPRI 2012-10 X Pant Dhan 23	7.22**	8.11**	-3.59	-2.30	-3.36*	-10.98**	-7.08**	-2.78	-0.23*
12.	UPRI 2012-10 X Pant Dhan 26	-3.95**	-7.94**	9.73**	-0.54	3.05*	36.26**	1.53	3.16	0.14
13.	UPRI 2008-8 X Pant Dhan 4	-6.15**	-7.38**	2.12	-3.48	1.12	26.27**	15.56**	7.16*	-0.29**
14.	UPRI 2008-8 X Pant Dhan 23	1.00	1.22	3.44	-5.30*	-0.52	-9.22**	6.33**	-1.43	0.50**
15.	UPRI 2008-8 X Pant Dhan 26	5.15**	6.16**	-5.56*	8.79**	-0.60	-17.04**	-21.89**	-5.73*	-0.21*
16.	UPRI 2012-19 X Pant Dhan 4	-4.82**	-3.49*	-5.98*	-0.15	-0.39	-12.25**	18.29**	-1.41	0.40**
17.	UPRI 2012-19 X Pant Dhan 23	0.66	-0.55	-3.17	-2.64	0.10	37.62**	-3.55**	-5.50*	-0.22*
18.	UPRI 2012-19 X Pant Dhan 26	4.15**	4.05**	9.15**	2.79	0.29	-25.37**	-14.74**	6.91*	-0.18
19.	Pant Dhan 22 X Pant Dhan 4	3.62**	-0.27	-5.43*	0.40	-0.31	-27.57**	-18.29**	-7.80**	-0.22*
20.	Pant Dhan 22 X Pant Dhan 23	-1.55	2.66	-4.44	-0.08	1.20	-14.80**	3.09	4.99	0.14
21.	Pant Dhan 22 X Pant Dhan 26	-2.06	-2.39	9.87**	-0.32	-0.88	42.37**	15.19**	2.81	0.08
22.	Pant Dhan 10 X Pant Dhan 4	-0.82	-2.27	3.23	0.18	1.40	27.68**	-6.37**	2.23	-0.06
23.	Pant Dhan 10 X Pant Dhan 23	-3.00*	0.33	6.21*	7.35**	0.92	-3.86*	3.05**	-1.47	-0.02
24.	Pant Dhan 10 X Pant Dhan 26	3.82**	1.94	-9.45**	-7.54**	-2.32	-23.81**	3.31**	-0.76	0.08
25.	Pant Dhan 18 X Pant Dhan 4	-2.60	4.83**	-4.43	2.96	0.90	-16.50**	1.29	1.69	0.33**
26.	Pant Dhan 18 X Pant Dhan 23	1.55	2.44	3.88	5.13*	0.59	11.59**	-8.48**	4.59	0.24*

27.	Pant Dhan 18 X Pant Dhan 26	1.04	-7.28**	0.54	-8.09**	-1.49	4.91**	7.18**	-6.29*	-0.58**
28.	Pant Dhan 24 X Pant Dhan 4	2.84*	1.17	-0.65	3.73	-0.15	-15.52**	-5.84**	0.42	0.12
29.	Pant Dhan 24 X Pant Dhan 23	-0.33	-1.88	2.66	-0.08	2.03	49.83**	-2.67**	-1.22	-0.00
30.	Pant Dhan 24 X Pant Dhan 26	-2.51	0.71	-2.00	-3.65	-1.88	-34.31**	8.51**	0.80	-0.12
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	-0.71	-3.05*	1.12	5.40*	-1.09	-14.20**	4.98**	4.24	-0.18
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	5.11* *	5.55**	11.77**	-8.08**	-0.91	-21.07**	-20.71**	-7.91**	-0.28**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-4.39**	-2.50	-12.89**	2.68	2.00	35.28**	15.73**	3.67	0.46**
34.	UPR 3199-464-1-2 X Pant Dhan 4	0.62	-0.94	7.79**	-3.37	-0.36	9.79**	-0.24	0.49	0.03
35.	UPR 3199-464-1-2 X Pant Dhan 23	1.44	-0.33	-10.22**	3.80	-0.31	-0.13	-1.41	-1.02	-0.19
36.	UPR 3199-464-1-2 X Pant Dhan 26	-2.06	1.27	2.43	-0.43	0.67	-9.65**	1.65	0.52	0.15
37.	UPRI 2014-8 X Pant Dhan 4	3.73**	2.94	2.01	-2.70	3.07*	9.77**	0.15	-6.59*	0.04
38.	UPRI 2014-8 X Pant Dhan 23	-0.11	-1.11	-0.33	-1.86	-0.07	-2.26	5.12**	-0.85	-0.11
39.	UPRI 2014-8 X Pant Dhan 26	-3.62**	-1.83	-1.67	4.56*	-2.99	-7.51**	-5.28**	7.44*	0.06
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-0.37	-0.05	-2.62	0.73	2.29	17.02**	-0.30	4.53	-0.16
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	5.11**	4.88**	3.26	-2.41	-2.03	-34.86**	11.82**	-1.34	0.22*
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-4.73**	-4.83**	-0.64	1.68	-0.26	17.83**	-11.52**	-3.18	-0.05
43.	NDR 3012 X Pant Dhan 4	1.62	1.05	13.34**	0.96	-1.59	16.54**	-13.43**	0.82	-0.37**
44.	NDR 3012 X Pant Dhan 23	0.44	-0.33	-5.33*	2.13	-0.24	3.80*	13.12**	0.37	0.09
45.	NDR 3012 X Pant Dhan 26	-2.06	-0.72	-8.01**	-3.09	1.84	-20.34**	0.31	-1.19	0.27**
46.	JGL 1172-7 X Pant Dhan 4	0.04	-0.27	-2.43	-2.70	1.68	4.30*	0.52	1.18	0.30**
47.	JGL 1172-7 X Pant Dhan 23	0.77	0.00	10.21**	-1.86	-0.79	4.80**	-3.93**	-1.07	0.10
48.	JGL 1172-7 X Pant Dhan 26	-0.73	0.27	-7.78**	4.56*	-0.88	-9.11**	3.40**	-0.10	-0.41**
49.	Pant Dhan 19 X Pant Dhan 4	1.06	1.83	8.79**	2.62	0.61	-18.88**	-8.55**	-8.73**	-0.00
50.	Pant Dhan 19 X Pant Dhan 23	-0.77	-1.88	-3.55	0.13	-0.19	18.58**	1.40	16.09**	-0.00
51.	Pant Dhan 19 X Pant Dhan26	-0.28	0.05	-5.23*	-2.76	-0.41	0.29	7.14**	-7.36*	0.00
(i)	$SE(S_{ij})$	1.08	1.19	2.04	1.80	1.20	1.37	0.73	2.26	0.08
(ii)	$SE(S_{ij}-S_{kl})$ (Having a common line)	2.24	2.45	4.21	3.72	2.48	2.83	1.51	4.66	0.17
(iii)	$SE(S_{ij}-S_{kl})$ (Having a common tester)	2.00	2.19	3.75	3.31	2.21	2.52	1.34	4.16	0.15

** Significant at 1% level, * significant at 5% level

The SCA effects of crosses for grain width ranged from -0.23 to 0.29. Among the 51 cross studied, 16 cross combinations viz., JGL 1172-7 × Pant Dhan 4 (0.29), Pant Dhan 19 × Pant Dhan 26 (0.23), UPR 3871-8-1-2-2 × Pant Dhan 4 (0.22), NDR 3012 × Pant Dhan 26 (0.20), UPRI 2012-19 × Pant Dhan 23 (0.19), Pant Dhan 24 × Pant Dhan 4 (0.18), BBL 180-5-1-4-1 × Pant Dhan 23 (0.13), UPRI 2012-10 × Pant Dhan 26 (0.13), Pant Dhan 22 × Pant Dhan 4 (0.13), CR 2644-2-6-4-3-2 × Pant Dhan 23 (0.10), UPRI 2014-8 × Pant Dhan 26 (0.10), Pant Dhan 10 × Pant Dhan 26 (0.10) and UPRI 2011-21 × Pant Dhan 23 (0.09) exhibited significant positive SCA effects and 16 crosses showed significantly negative SCA effects for this character.

4.3.2.11 Kernel length (mm)

For kernel length, the GCA effects among the lines ranged from -0.60 to 0.57 and among the testers it varies from -0.09 to 0.06. All of the lines except Pant Dhan 22 showed significant GCA effects for this character. Out of 17 lines, 7 lines namely Pant Dhan 10 (0.57), Pant Dhan 19 (0.55), Pant Dhan 18 (0.42), NDR 3012 (0.20), UPRI 2014-8 (0.12), Pant Dhan 19 (0.10) and UPRI 2012-10 (0.08) and among the testers Pant Dhan 23 (0.06) and Pant Dhan 26 (0.03) exhibited significant and positive GCA effect and found as good general combiners for this character.

The SCA effects of crosses for kernel length were ranged from -0.90 to 0.73. Among the 51 crosses studied, 15 cross combinations namely Pant Dhan 18 × Pant Dhan 23 (0.73), UPRI 2012-10 × Pant Dhan 23 (0.48), Pant Dhan 10 × Pant Dhan 4 (0.45), UPRI 2012-19 × Pant Dhan 23 (0.44), UPR 3871-8-1-2-2 × Pant Dhan 4 (0.31), UPRI 2012-19 × Pant Dhan 26 (0.31), JGL 1172-7 × Pant Dhan 26 (0.30), UPRI 2014-8 × Pant Dhan 4 (0.26), Pant Dhan 10 × Pant Dhan 26 (0.25), Pant Dhan 24 × Pant Dhan 4 (0.24), Pant Dhan 19 × Pant Dhan 26 (0.22), CR 2644-2-6-4-3-2 × Pant Dhan 4 (0.21) and UPRI 2008-6 × Pant Dhan 26 (0.21) exhibited significantly positive sca effects and 13 crosses showed significant negative SCA effects for this character.

4.3.2.12 Kernel breadth (mm)

For kernel breadth, the GCA effect values among the parents ranged from -0.13 to 0.23 and -0.01 to 0.01 in the lines and in the testers, respectively. Among the lines, NDR 3012 (0.23), CR 2644-2-6-4-3-2 (0.08) and Pant Dhan 18 (0.08) showed significant positive GCA effects and UPR 3871-8-1-2-2 (-0.13), Pant Dhan 24 (-0.09) and JGL 1172-7 (-0.08)

exhibited significant negative GCA effects and appeared as good general combiners for this character. None of the testers were exhibited significant GCA effects for this character.

The SCA effects of crosses for kernel breadth ranged from -0.16 to 0.19. Out of 51 crosses studied, only 2 cross combination namely Pant Dhan 18 × Pant Dhan 26 (0.19) and CR 2644-2-6-4-3-2 × Pant Dhan 4 (0.15) found positively significant and crosses namely UPRI 2012-19 × Pant Dhan 4 (-0.16) and CR 2644-2-6-4-3-2 × Pant Dhan 26 (-0.15) found negatively significant for SCA effects for this character.

4.3.2.13 Length/Breadth ratio

The GCA values for L/B ratio in lines ranged from -0.22 to 0.16 and in testers it ranged from -0.02 to 0.01. Among the lines, Pant Dhan 10 (0.16) and UPRI 2008-8 (0.15) exhibited significant positive GCA effects and NDR 3012 (-0.20) and CR 2644-2-6-4-3-2 (-0.18) showed significant negative GCA effects and appeared as good general combiners for this character. None of the testers were exhibited significant GCA values for L/B ratio.

The SCA effects for L/B ratio among the crosses ranged from -0.16 to 0.16. Out of 51 crosses studied, eight cross combinations exhibited significant sca effects from which crosses viz., Pant Dhan 10 × Pant Dhan 4 (0.16), Pant Dhan 18 × Pant Dhan 23 (0.15), UPRI 2012-10 × Pant Dhan 23 (0.11) and NDR 3012 × Pant Dhan 4 (0.09) showed significant positive sca effects and Pant Dhan 18 × Pant Dhan 26 (-0.16), Pant Dhan 10 × Pant Dhan 23 (-0.15) and UPRI 2012-19 × Pant Dhan 4 (-0.12) showed significant and negative SCA effects for this character.

4.3.2.14 Harvest index

For harvest index, the GCA effects of lines ranged from -0.09 to 0.12 and in testers -0.01 to 0.01. Among the lines, Pant Dhan 19 (0.12), UPR 3199-464-1-2 (0.11), Pant Dhan 22 (0.06), UPRI 2008-6 (0.04) and JGL 1172-7 (0.02) and among the testers, Pant Dhan 4 (0.01) exhibited significant positive GCA effects and found as good general combiners for this character.

(Contd.) Table 4.6: SCA Effects for different characters in rice genotypes

Sl. No.	Crosses	Grain width (mm)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Harvest index	Hulling recovery (%)	Milling recovery (%)	Alkali digestion value	Grain yield per plant (g)
1.	UPRI 2011-21 X Pant Dhan 4	-0.04	0.02	-0.01	0.02	-0.0	6.41**	4.00**	-0.61*	0.76
2.	UPRI 2011-21 X Pant Dhan 23	0.09*	-0.02	0.00	-0.00	0.06**	-5.25**	-1.71*	0.48	0.69
3.	UPRI 2011-21 X Pant Dhan 26	-0.05	-0.00	0.01	-0.01	-0.06**	-1.15	-2.28**	0.13	-1.46
4.	UPRI 2008-6 X Pant Dhan 4	-0.03	-0.19**	-0.02	-0.09*	-0.00	-5.36**	-4.10**	0.27	1.25
5.	UPRI 2008-6 X Pant Dhan 23	0.03	-0.01	-0.04	0.02	-0.03*	4.30**	1.17	0.03	4.07**
6.	UPRI 2008-6 X Pant Dhan 26	-0.00	0.21**	0.06	0.07	0.04*	1.06	2.93**	-0.31	-5.32**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-0.19**	-0.18**	-0.02	-0.06	0.02	0.52	-1.21	-0.39	-3.91**
8.	BBL 180-5-1-4-1 X Pant Dhan 23	0.13**	0.15*	0.05	0.00	0.10**	4.19**	6.39**	0.37	0.78
9.	BBL 180-5-1-4-1 X Pant Dhan 26	0.05	0.02	-0.03	0.05	-0.12**	-4.71**	-5.17**	0.02	3.12*
10.	UPRI 2012-10 X Pant Dhan 4	0.04	-0.29**	-0.05	-0.07	0.03	2.52**	4.34**	0.38	-1.54
11.	UPRI 2012-10 X Pant Dhan 23	-0.18**	0.48**	0.08	0.11*	-0.08**	2.85**	1.94*	-0.51	-11.66**
12.	UPRI 2012-10 X Pant Dhan 26	0.13**	-0.18**	-0.03	-0.03	0.05**	-5.37**	-6.28**	0.13	13.21**
13.	UPRI 2008-8 X Pant Dhan 4	0.08*	-0.00	-0.04	0.05	0.07**	-1.03	-1.99*	0.05	5.82**
14.	UPRI 2008-8 X Pant Dhan 23	-0.05	-0.02	0.00	-0.01	-0.02	-2.03**	-2.38**	0.48	4.29**
15.	UPRI 2008-8 X Pant Dhan 26	-0.03	0.03	0.03	-0.04	-0.04**	3.06**	4.37**	-0.53	-10.12**
16.	UPRI 2012-19 X Pant Dhan 4	-0.07*	-0.75**	-0.16*	-0.12**	0.00	3.52**	3.00**	0.27	-7.10**
17.	UPRI 2012-19 X Pant Dhan 23	0.19**	0.44**	0.07	0.10*	0.02	7.52**	4.94**	-0.96**	6.22**
18.	UPRI 2012-19 X Pant Dhan 26	-0.12**	0.31**	0.08	0.02	-0.02	-11.04**	-7.95**	0.68*	0.88
19.	Pant Dhan 22 X Pant Dhan 4	0.13**	-0.04	-0.06	0.07	-0.07**	-7.36**	-6.54**	-0.05	-11.24**
20.	Pant Dhan 22 X Pant Dhan 23	0.00	-0.04	0.04	-0.07	0.09**	1.96**	2.06*	0.70*	1.76
21.	Pant Dhan 22 X Pant Dhan 26	-0.14**	0.08	0.02	0.00	-0.02	5.39**	4.48**	-0.64*	9.48**
22.	Pant Dhan 10 X Pant Dhan 4	-0.08*	0.45**	0.03	0.16**	-0.05**	0.85	2.11*	-0.72*	11.48**
23.	Pant Dhan 10 X Pant Dhan 23	-0.01	-0.70**	-0.12*	-0.15**	0.12**	-2.47**	-1.60*	0.03	5.17**
24.	Pant Dhan 10 X Pant Dhan 26	0.10**	0.25**	0.08	-0.01	-0.07**	1.62*	-0.51	0.68*	-16.65**

25.	Pant Dhan 18 X Pant Dhan 4	0.05	0.16*	0.05	0.01	-0.06**	-2.81**	-5.32**	0.83**	-17.56**
26.	Pant Dhan 18 X Pant Dhan 23	0.06	0.73**	0.13*	0.15**	0.02	-0.81	4.94**	-0.73*	14.61**
27.	Pant Dhan 18 X Pant Dhan 26	-0.12**	-0.90**	0.19**	-0.16**	0.04*	3.62**	0.37	-0.09	2.95*
28.	Pant Dhan 24 X Pant Dhan 4	0.18**	0.24**	0.06	0.00	-0.01	-2.58**	-1.10	0.16	0.32
29.	Pant Dhan 24 X Pant Dhan 23	0.05	0.04	0.04	-0.03	-0.00	-0.25	0.17	-0.07	15.37**
30.	Pant Dhan 24 X Pant Dhan 26	-0.23**	-0.28**	-0.11	0.02	0.02	2.84**	0.93	-0.09	-15.70**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	0.22**	0.31**	0.13*	-0.04	0.06**	2.96**	7.11**	-0.50	16.60**
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-0.13**	-0.27**	-0.12*	0.05	-0.07**	-2.03**	-9.27**	-0.07	-19.08**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-0.08*	-0.04	-0.01	-0.08	0.00	-0.93	2.15**	0.57*	2.47*
34.	UPR 3199-464-1-2 X Pant Dhan 4	0.05	0.06	-0.01	0.04	0.00	0.74	0.11	0.16	-0.35
35.	UPR 3199-464-1-2 X Pant Dhan 23	-0.13**	-0.09	0.00	-0.04	-0.01	-0.58	-0.27	-0.45	-2.07
36.	UPR 3199-464-1-2 X Pant Dhan 26	0.08*	0.03	0.01	-0.00	0.01	-0.15	0.15	0.24	2.42*
37.	UPRI 2014-8 X Pant Dhan 4	-0.05	0.26**	0.10	-0.01	0.06**	-0.81	2.11*	-0.17	1.10
38.	UPRI 2014-8 X Pant Dhan 23	-0.05	-0.26**	-0.08	0.00	-0.06**	0.52	-1.27	0.26	-8.38**
39.	UPRI 2014-8 X Pant Dhan 26	0.10**	-0.00	-0.01	0.01	-0.00	0.28	-0.84	-0.09	7.28**
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-0.19**	0.21**	0.15*	-0.05	-0.00	7.85**	1.23	-0.50	3.62**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.10**	0.02	0.00	-0.02	0.00	-8.47**	-6.16**	0.59*	-16.97**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	0.09*	-0.24**	-0.15*	0.07	-0.00	0.62	4.93**	-0.09	13.34**
43.	NDR 3012 X Pant Dhan 4	-0.18**	-0.18**	-0.13*	0.09*	-0.07**	-1.69**	-4.32**	0.83*	-0.94
44.	NDR 3012 X Pant Dhan 23	-0.01	-0.00	0.01	-0.02	-0.04*	0.96	2.61**	-0.07	11.12**
45.	NDR 3012 X Pant Dhan 26	0.20**	0.18**	0.12*	-0.07	0.12**	0.73	1.71*	-0.75*	-10.17**
46.	JGL 1172-7 X Pant Dhan 4	0.29**	0.02	0.02	-0.02	0.00	-0.92	-1.21	-0.17	4.11**
47.	JGL 1172-7 X Pant Dhan 23	-0.07	-0.32**	-0.10	-0.00	-0.07**	-0.58	-0.90	0.26	-5.80**
48.	JGL 1172-7 X Pant Dhan 26	-0.22**	0.30**	0.07	0.03	0.07**	1.51*	2.15**	-0.09	1.69
49.	Pant Dhan 19 X Pant Dhan 4	-0.21**	-0.11	-0.05	0.01	0.01	-2.81**	1.77*	0.16	-2.43*
50.	Pant Dhan 19 X Pant Dhan 23	-0.01	-0.10	0.02	-0.07	-0.01	0.19	-0.62	-0.40	-0.13
51.	Pant Dhan 19 X Pant Dhan26	0.23**	0.22**	0.03	0.05	-0.00	2.62**	-1.14	0.24	2.57*
(i)	$SE(S_{ij})$	0.02	0.05	0.05	0.07	0.00	0.60	0.64	0.42	0.95
(ii)	$SE(S_{ij}-S_{kl})$ (Having a common line)	0.06	0.10	0.11	0.14	0.01	1.21	1.32	0.88	1.96
(iii)	$SE(S_{ij}-S_{kl})$ (3Having a common tester)	0.05	0.09	0.10	0.12	0.01	1.08	1.17	0.78	1.75

The SCA effects of crosses for harvest index ranged from -0.12 to 0.12. Among the 51 crosses studied, twelve cross combinations namely NDR 3012 × Pant Dhan 26 (0.12), Pant Dhan 10 × Pant Dhan 23 (0.12), BBL 180-5-1-4-1 × Pant Dhan 23 (0.10), Pant Dhan 22 × Pant Dhan 23 (0.09), JGL 1172-7 × Pant Dhan 26 (0.07), UPRI 2011-21 × Pant Dhan 23 (0.06), UPR 3871-8-1-2-2 × Pant Dhan 4 (0.06), UPRI 2012-10 × Pant Dhan 26 (0.05), UPRI 2008-6× Pant Dhan 26 (0.04) and Pant Dhan 18 × Pant Dhan 26 (0.04) exhibited significant positive SCA effects and fourteen cross combinations showed significant and negative SCA effects for this character.

4.3.2.15 Hulling recovery (%)

For hulling recovery, the GCA effects among the parents ranged from -11.47 to 8.30 and -1.62 to 0.81 in the lines and in the testers, respectively. Among the lines, Pant Dhan 10 (8.30), Pant Dhan 19 (4.63), UPRI 2014-8 (4.63), UPR 3871-8-1-2-2 (4.19), Pant Dhan 24 (3.41), CR 2644-2-6-4-3-2 (1.96) and Pant Dhan 18 (1.63) and among the testers, Pant Dhan 4 (0.81), Pant Dhan 23 (0.81) exhibited significant positive GCA effects and found as good general combiners for this character.

The SCA effects of crosses for hulling recovery ranged from -11.04 to 7.85. Out of 51 crosses studied, 17 cross combinations namely CR 2644-2-6-4-3-2 × Pant Dhan 4 (7.85), UPRI 2012-19 × Pant Dhan 23 (7.52), UPRI 2011-21 × Pant Dhan 4 (6.41), Pant Dhan 22 × Pant Dhan 26 (5.39), UPRI 2008-6 × Pant Dhan 23 (4.30), Pant Dhan 18 × Pant Dhan 26 (3.62), UPRI 2008-8 × Pant Dhan 26 (3.06), UPR 3871-8-1-2-2 × Pant Dhan 4 (2.96), UPRI 2012-10 × Pant Dhan 23 (2.85), Pant Dhan 24 × Pant Dhan 26 (2.84), Pant Dhan 19 × Pant Dhan 26 (2.62) and UPRI 2012-10 × Pant Dhan 4 (2.52) exhibited significant and positive SCA effects and 14 crosses showed significantly negative SCA effects for this character.

4.3.2.16 Milling recovery (%)

For milling recovery, the GCA effects among the parents ranged from -10.28 to 8.94 and -0.93 to 0.82 in the lines and testers, respectively. Among the 17 lines, 14 lines showed significant GCA effects and emerged as good general combiners. Out of which Pant Dhan 10 (8.94), UPRI 2014-8 (6.60), Pant Dhan 19 (6.28), Pant Dhan 24 (5.16) and Pant Dhan 18 (3.38) and among the testers, Pant Dhan 23 (0.82) exhibited significant positive GCA effects for this character.

The SCA effects of crosses for milling recovery ranged from -9.27 to 7.11. Out of 51 cross studied, 19 cross combinations viz., UPR 3871-8-1-2-2 × Pant Dhan 4 (7.11), BBL 180-5-1-4-1 × Pant Dhan 23 (6.39), UPRI 2012-19 × Pant Dhan 23 (4.94), Pant Dhan 18 × Pant

Dhan 23 (4.94), CR 2644-2-6-4-3-2 × Pant Dhan 26 (4.93), Pant Dhan 22 × Pant Dhan 26 (4.48), UPRI 2008-8 × Pant Dhan 26 (4.37), UPRI 2011-21 × Pant Dhan 4 (4.00), UPRI 2012-19 × Pant Dhan 4 (3.00), UPRI 2008-6 × Pant Dhan 26 (2.93), NDR 3012 × Pant Dhan 23 (2.61) and JGL 1172-7 × Pant Dhan 26 (2.15) exhibited significantly positive SCA effects and 14 crosses showed significantly negative SCA effects for this character.

4.3.2.17 Alkali digestion value

For alkali digestion value, the GCA effects among the parents ranged from -0.76 to 1.23 in lines and -0.26 to 0.17 in the testers, respectively. Among the lines, BBL 180-5-1-4-1 (1.23), UPR 3199-464-1-2 (1.01), UPRI 2012-19 (0.90) and Pant Dhan 18 (0.68) exhibited significant positive GCA effects and found as good general combiners for this character. None of the testers were exhibited significant GCA effects for L/B ratio.

The SCA effects of crosses for alkali digestion value ranged from -0.96 to 0.83. Out of 51 cross studied, 7 cross combinations viz., Pant Dhan 18 × Pant Dhan 4 (0.83), NDR 3012 × Pant Dhan 4 (0.83), Pant Dhan 22 × Pant Dhan 23 (0.70), Pant Dhan 10 × Pant Dhan 26 (0.68), CR 2644-2-6-4-3-2 × Pant Dhan 23 (0.59) and UPR 3871-8-1-2-2 × Pant Dhan 26 (0.57) exhibited significant positive SCA effects for this character.

4.3.2.18 Grain yield per plant (g)

For grain yield per plant, the GCA effects in lines ranged from -15.76 to 16.02 and in testers it ranged from -3.86 to 7.65. Among the lines, Pant Dhan 22 (16.02), UPR 3871-8-1-2-2 (14.74), UPR 3199-464-1-2 (13.73), Pant Dhan 19 (8.58) and CR 2644-2-6-4-3-2 (2.82) and among the testers, Pant Dhan 26 (7.65) showed significant positive GCA effects and found as good general combiners for this character.

The SCA effects of crosses for grain yield per plant ranged from -19.08 to 16.60. Out of 51 cross studied, 21 cross combinations namely UPR 3871-8-1-2-2 × Pant Dhan 4 (16.60), Pant Dhan 24 × Pant Dhan 23 (15.37), Pant Dhan 18 × Pant Dhan 23 (14.61), CR 2644-2-6-4-3-2 × Pant Dhan 26 (13.34), Pant Dhan 10 × Pant Dhan 4 (11.48), NDR 3012 × Pant Dhan 23 (11.12), Pant Dhan 22 × Pant Dhan 26 (9.48), UPRI 2014-8 × Pant Dhan 26 (7.28), UPRI2012-19 × Pant Dhan 23 (6.22), Pant Dhan 10 × Pant Dhan 23 (5.17), UPRI 2008-8 × Pant Dhan 23 (4.29), JGL 1172-7 × Pant Dhan 4 (4.11), UPRI 2008-6 × Pant Dhan 23 (4.07), CR 2644-2-6-4-3-2 × Pant Dhan 4 (3.62), BBL 180-5-1-4-1 × Pant Dhan 26 (3.12), Pant Dhan 18 × Pant Dhan 26 (2.95) and Pant Dhan 19 × Pant Dhan 26 (2.57) exhibited significant and positive SCA effects for this character.

On the basis of above results and findings in respect to heterosis (mid parent heterosis, heterobeltiosis and standard heterosis) and combining ability (GCA & SCA effects and variances) conclusion of present study such as that most of the crosses found superior in their performances in respect to the characters studied.

Considering combining ability estimates as major objective of line × tester analysis, the GCA effects of parents characterized as G = good, A= average and P = poor general combiner represented in the Table 4.7. On the basis of GCA effects of the parents, lines Pant Dhan 22, Pant Dhan 24, Pant Dhan 10, CR 2644-2-6-4-3-2, UPR 3871-8-1-2-2, Pant Dhan 19, UPRI 2014-8 and testers Pant Dhan 23 & Pant Dhan 26 were found good general combiner for grain yield and quality traits under studied. On the basis of SCA effects, crosses UPRI 2008-6 × Pant Dhan 23, UPRI 2012-10 × Pant Dhan 26, CR 2644-2-6-4-3-2 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 4, Pant Dhan 18 × Pant Dhan 23, Pant Dhan 22 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 23, BBL 180-5-1-4-1 × Pant Dhan 23 were found best specific combiner for grain yield and quality traits under studied.

The parental line Pant Dhan 10 was found good general combiner for days to 50% flowering (-6.94), days to maturity (-5.31), plant height (-17.62), spikelet fertility (24.48), 1000 grain weight (3.72), grain width (-0.07), kernel length (0.57), hulling recovery (8.30), milling recovery (8.94) and L/B ratio (0.16) and average combiner for grain length (0.04), kernel breadth (0.06) and harvest index (0.01).

The parental line Pant Dhan 24 was found good general combiner for days to 50% flowering (-3.60), days to maturity (-6.09), plant height (-7.40), number of tillers per plant (3.51) spikelet fertility (11.62), grain length (-0.11), grain width (-0.04), kernel length (-0.21), hulling recovery (3.41), milling recovery (5.16).

The parental line UPR 3871-8-1-2-2 was found good general combiner for plant height (-10.51), number of grains per panicle (27.12), grain length (-0.37), grain width (-0.15), kernel length (-026), kernel breadth (-0.13), hulling recovery (3.41) and grain yield per plant (14.74) while the parental line CR 2644-2-6-4-3-2 was found good general combiner for number of grains per panicle (25.79), grain length (-0.55), grain width (0.13), kernel length (-0.22), kernel breadth (0.08), L/B ratio (-0.18), hulling recovery (1.96) and grain yield per plant (2.82).

Table 4.7: Summary table depicting general combining ability of parental genotypes for various traits in rice

Characters / Parents	Days to 50% flowering	Days to maturity	Plant height	Number of tillers per plant	Panicle length	Number of grains per plant	Spikelet fertility	1000 grain weight	Grain length	Grain width	Kernel length	Kernel breadth	L/B ratio	Harvest index	Hulling recovery	Milling recovery	Alkali digestion value	Grain yield per plant
Lines																		
UPRI 2011-21	A	P	G	P	P	G	A	P	G	P	G	A	G	P	P	P	A	P
UPRI 2008-6	G	P	A	P	P	P	P	P	P	A	G	A	P	G	P	P	P	P
BBL 180-5-1-4-1	A	A	G	G	P	P	G	G	G	A	G	A	P	P	P	P	G	P
UPRI 2012-10	P	A	A	P	P	A	A	A	P	G	A	P	P	P	A	A	P	P
UPRI 2008-8	G	G	A	G	A	G	P	P	P	G	G	A	P	P	P	P	A	P
UPRI 2012-19	G	G	G	G	P	P	P	P	G	G	G	A	G	P	P	P	G	P
Pant Dhan 22	G	G	G	A	G	G	G	G	G	G	G	P	P	G	P	P	P	G
Pant Dhan 10	G	G	G	P	P	P	G	G	A	G	G	A	G	A	G	G	P	P
Pant Dhan 18	A	A	P	P	P	P	G	P	G	G	G	G	A	G	G	G	G	A
Pant Dhan 24	G	G	G	G	P	P	G	P	G	G	G	G	P	P	G	G	P	P
UPR 3871-8-1-2-2	A	P	G	A	P	G	P	P	G	G	G	G	A	P	G	A	P	G
UPR 3199-464-1-2	A	P	G	A	A	A	P	P	G	A	G	A	P	A	P	P	G	G
UPRI 2014-8	G	A	A	A	A	A	G	A	A	A	A	P	P	G	G	G	P	P
CR 2644-2-6-4-3-2	P	G	A	P	A	G	P	A	G	G	G	G	G	P	G	P	P	G
NDR 3012	A	P	G	P	G	A	P	G	G	G	G	G	G	P	G	G	P	P
JGL 1172-7	P	A	G	P	G	G	P	P	G	A	G	G	A	P	A	A	P	P
Pant Dhan 19	G	A	A	A	A	G	A	A	A	G	G	P	P	G	G	G	P	G
Testers																		
Pant Dhan 4	G	A	P	A	P	P	P	A	P	A	G	A	A	G	G	A	A	P
Pant Dhan 23	P	P	G	P	P	A	A	A	A	G	G	P	P	P	G	G	P	P
Pant Dhan 26	G	A	G	G	A	G	P	P	G	P	A	A	P	P	P	P	A	G

A=Average general combiner, G=Good general combiner, P=Poor general combiner

The tester Pant Dhan 4 was found good general combiner for days to 50% flowering (-1.62), days to maturity (-1.39), kernel length (-0.09), harvest index (0.01) and hulling recovery (0.81) whereas Pant Dhan 23 was found good combiner for plant height (-1.44), number of grains per panicle (4.71), spikelet fertility (1.73), grain length (0.06), grain width (0.01), kernel length (0.06), hulling recovery (0.81) and milling recovery (0.82) while Pant Dhan 26 was found good combiner for grain yield (7.65), number of grains per panicle (18.36), number of tillers per plant (1.43) and grain length (-0.10).

For days to 50% flowering, among the lines Pant Dhan 10 (-6.94), Pant Dhan 22 (-3.38), Pant Dhan 24 (-3.60), UPRI 2014-8 (-3.83), Pant Dhan 19 (-3.16) and NDR 3012 (-2.38) and among the tester Pant Dhan 4 (-1.62) were found good general combiner with significant negative GCA effect while, for days to maturity, Pant Dhan 24 (-6.09), Pant Dhan 10 (-5.31) and Pant Dhan 22 (-3.31) among the parental lines and Pant Dhan 4 (-1.39) among the testers were exhibited significant negative GCA effects and emerged to be as good general combiners.

In respect to plant height, lines Pant Dhan 10 (-17.62), UPR 3871-8-1-2-2 (-10.51), UPR 3199-464-1-2 (-8.06), Pant Dhan 24 (-7.40), BBL 180-5-1-4-1 (-7.29) and tester Pant Dhan 23 (-1.44) exhibited significant negative GCA effects and found as good general combiners while for number of tiller per plant, UPRI 2008-8 (6.07), UPRI 2012-19 (4.40), BBL180-5-1-4-1 (3.62) and Pant Dhan 24 (3.51) among the lines and Pant Dhan 26 (2.23) among the tester exhibited significant positive gca effects and emerged as good general combiners.

For panicle length, parental lines Pant Dhan 22 (3.80), JGL 1172-7 (2.47) and NDR 3012 (2.08), for 1000 grain wt Pant Dhan 19 (9.41), BBL 180-5-1-4-1 (7.29) and NDR 3012 (4.17) and for spikelet fertility, Pant Dhan 10 (24.48), Pant Dhan 24 (11.62), UPRI 2014-8 (9.10) and Pant Dhan 18 (7.24) exhibited significant positive GCA effects and found as good general combiners for these traits.

For number of grain per panicle, lines namely JGL 1172-7 (92.67), UPRI 2011-21 (65.73), Pant Dhan 22 (46.82), UPR 3871-8-1-2-2 (27.12) and CR 2644-2-6-4-3-2 (25.76) and for harvest index, Pant Dhan 19 (0.12), UPR 3199-464-1-2 (0.11), Pant Dhan 22 (0.06) and UPRI 2008-6 (0.04) and for alkali digestion value, BBL 180-5-1-4-1 (1.23), UPRI 2014-8 (1.01), UPRI 2012-19 (0.90) and Pant Dhan 18 (0.68) exhibited significant positive GCA effects and emerged as good general combiners for these traits.

Table 4.8: Top ranking desirable crosses for SCA effects with their mean performance, GCA effects of parents and standard heterosis for each of eighteen characters in rice

SI. No.	Characters and crosses	F_1 mean value	GCA effects of parents	SCA effect value	Mid parent heterosis	Standard heterosis	
						Over Govind	Over Pant Dhan 4
1.	**Days to 50% flowering**						
	BBL 180-5-1-4-1 × Pant Dhan 23	90.00	Average × Poor	-7.56**	-7.85**	18.42**	3.84
	UPRI 2008-6 × Pant Dhan 23	92.66	Good × Poor	-7.33**	-5.76**	21.93**	6.92**
	UPRI 2008-8 × Pant Dhan 4	95.00	Good × Good	-6.15**	-2.39	25.00**	9.61**
	UPRI 2012-19 × Pant Dhan 4	97.33	Good × Good	-4.82**	0.17	28.06**	12.30**
	CR 2644-2-6-4-3-2 × Pant Dhan 26	94.66	Poor × Good	-4.73**	-7.34**	24.56**	9.23**
2.	**Days to maturity**						
	UPRI 2008-6 × Pant Dhan 23	116.00	Poor × Poor	-9.33**	-10.76**	8.75**	-2.52
	UPRI 2012-10 × Pant Dhan 26	118.33	Average × Good	-7.94**	-2.87	10.97**	-0.56
	UPRI 2008-8 × Pant Dhan 4	122.00	Good × Average	-7.38**	-2.53	14.37**	2.52
	Pant Dhan18 × Pant Dhan 26	119.00	Average × Average	-7.28**	-6.42**	11.56**	0.00
	BBL 180-5-1-4-1 × Pant Dhan 23	117.66	Average × Poor	-7.00**	-8.19**	10.31**	-1.12
3.	**Plant height (cm)**						
	UPR 3871-8-1-2-2 × Pant Dhan 26	88.33	Good × Good	-12.89**	-20.55**	2.31	-13.39**
	UPR 3199-464-1-2 × Pant Dhan 23	100.33	Good × Good	-10.22**	-3.68	16.21**	-1.63
	Pant Dhan 10 × Pant Dhan 26	84.66	Good × Good	-9.45**	-23.50**	-1.93	-16.99**
	NDR 3012 × Pant Dhan 26	112.00	Good × Good	-8.01**	4.98	29.73**	9.80**
	JGL 1172-7 × Pant Dhan 26	119.33	Good × Good	-7.78**	-1.66	38.22**	16.93**
4.	**Number of tillers per plant**						
	UPRI 2008-8 × Pant Dhan 26	38.66	Good × Good	8.79**	90.16 **	182.92**	31.82**
	Pant Dhan 10 × Pant Dhan 23	20.33	Poor × Poor	7.35**	9.91	48.77*	-30.68**
	UPR 3871-8-1-2-2 × Pant Dhan 4	27.33	Average × Average	5.40*	40.17**	99.99**	-6.81*
	Pant Dhan 18 × Pant Dhan 23	19.33	Poor × Poor	5.13*	2.65	41.46	-34.09**
	BBL 180-5-1-4-1 × Pant Dhan 26	32.00	Good × Good	4.56*	68.42**	134.14**	9.09**

5.	**Panicle length (cm)**						
	UPRI 2008-6 × Pant Dhan 23	33.33	Poor × Poor	5.70**	19.26**	37.36**	15.47*
	UPRI 2014-8 × Pant Dhan 4	32.00	Average × Poor	3.07*	14.90**	31.86**	10.85*
	UPRI 2012-10 × Pant Dhan 26	31.00	Poor × Average	3.05*	10.51*	27.74**	7.38
6.	**Number of grains per panicle**						
	Pant Dhan 24 × Pant Dhan 23	241.96	Poor × Average	49.83**	29.75**	96.88**	68.42**
	Pant Dhan 22 × Pant Dhan 26	320.13	Good × Good	42.37**	75.73**	160.48**	122.83**
	UPRI 2011-21 × Pant Dhan 26	334.83	Good × Good	38.16**	70.41**	172.44**	133.06**
	UPRI 2012-19 × Pant Dhan 23	220.81	Poor × Average	37.62**	37.06**	79.66**	53.69**
	UPRI 2012-10 × Pant Dhan 26	251.00	Average × Good	36.26**	48.93**	104.21**	74.71**
7.	**Spikelet fertility (%)**						
	UPRI 2012-19 × Pant Dhan 4	60.54	Poor × Poor	18.29**	-0.00	-16.91**	17.15**
	UPR 3871-8-1-2-2 × Pant Dhan 26	69.69	Poor × Poor	15.73**	34.62**	-4.35	34.86**
	UPRI 2008-8 × Pant Dhan 4	72.91	Poor × Poor	15.56**	30.81**	0.06	41.09**
	Pant Dhan 22 × Pant Dhan 26	78.01	Good × Poor	15.19**	20.45**	7.06*	50.96**
	NDR 3012 × Pant Dhan 23	73.69	Poor × Average	13.12**	62.54**	1.14	42.61**
8.	**1000 grain weight (g)**						
	Pant Dhan 19 × Pant Dhan 23	48.71	Average × Average	16.09**	137.35**	171.92**	108.26**
	UPRI 2014-8 × Pant Dhan 26	30.22	Average × Poor	7.44**	52.93**	68.72**	32.33**
	UPRI 2008-8 × Pant Dhan 4	25.73	Poor × Average	7.16**	28.45**	43.66**	13.90
	UPRI 2012-19 × Pant Dhan 26	28.96	Poor × Poor	6.91**	32.95**	61.70**	27.17
9.	**Grain length (mm)**						
	UPRI 2008-8 × Pant Dhan 23	9.53	Poor × Average	0.50**	3.81**	-1.38*	1.41*
	UPRI 2012-19 × Pant Dhan 4	9.60	Good × Poor	0.40**	0.00	-0.69	2.12*
	Pant Dhan 18 × Pant Dhan 4	9.60	Good × Poor	0.33**	0.00	-0.69	2.12*
	JGL 1172-7 × Pant Dhan 4	9.60	Good × Poor	0.30**	1.23	-0.69	2.12*
	NDR 3012 × Pant Dhan 26	9.40	Good × Good	0.27**	-3.42**	-2.76*	0.00

10.	**Grain width (mm)**						
	JGL 1172-7 × Pant Dhan 4	2.96	Average × Average	0.29**	22.75**	12.53**	7.21*
	Pant Dhan 19 × Pant Dhan 26	2.86	Good × Poor	0.23**	0.00	8.77**	3.60*
	UPR 3871-8-1-2-2 × Pant Dhan 4	2.76	Good × Average	0.22**	12.16**	5.01*	-0.01
	NDR 3012 × Pant Dhan 26	3.13	Good × Poor	0.20**	11.24**	18.78**	13.23**
	UPRI 2012-19 × Pant Dhan 23	2.86	Good × Good	0.19**	6.17**	8.77**	3.60*
11.	**Kernel length (mm)**						
	Pant Dhan 18 × Pant Dhan 23	7.40	Good × Good	0.73**	9.63**	29.82**	17.00**
	UPRI 2012-10 × Pant Dhan 23	6.80	Average × Good	0.48**	16.57**	19.29**	38.76**
	Pant Dhan 10 × Pant Dhan 4	7.10	Good × Good	0.45**	17.03**	24.56**	44.89**
	UPRI 2012-19 × Pant Dhan 23	7.23	Good × Good	0.44**	23.64**	26.90**	47.61**
	UPR 3871-8-1-2-2 × Pant Dhan 4	6.13	Good × Good	0.31**	1.93	7.60**	25.17**
12.	**Kernel breadth (mm)**						
	Pant Dhan 18 × Pant Dhan 26	2.00	Good × Average	0.19**	-3.22	3.46	5.26
	CR 2644-2-6-4-3-2 × Pant Dhan 4	2.33	Good × Average	0.15**	6.87*	20.71**	22.80**
	UPRI 2012-19 × Pant Dhan 4	2.00	Average × Average	-0.16**	0.84	3.46	5.26
	CR 2644-2-6-4-3-2 × Pant Dhan 26	2.03	Good × Average	-0.15**	-8.21*	5.19	7.01
13.	**Length/Breadth ratio**						
	Pant Dhan 10 × Pant Dhan 4	3.24	Good × Average	0.16**	9.52**	9.94**	25.43**
	Pant Dhan 18 × Pant Dhan 23	3.17	Average × Poor	0.15**	-1.65	7.68*	22.85**
	UPRI 2012-10 × Pant Dhan 23	3.09	Poor × Poor	0.11*	11.28**	4.85*	19.62**
	NDR 3012 × Pant Dhan 4	2.79	Good × Average	0.09*	-2.78	-5.10*	8.27
14.	**Harvest index**						
	NDR 3012 × Pant Dhan 26	0.61	Poor × Poor	0.12**	24.10**	-7.84*	62.96*
	Pant Dhan 10 × Pant Dhan 23	0.65	Average × Poor	0.12**	15.31**	-1.51*	74.18**
	BBL 180-5-1-4-1 × Pant Dhan 23	0.59	Poor × Poor	0.10**	2.35	-10.69**	57.94**
	Pant Dhan 22 × Pant Dhan 23	0.67	Good × Poor	0.09**	18.07**	1.70*	79.87**
	JGL 1172-7 × Pant Dhan 26	0.61	Average × Poor	0.07**	30.74**	-7.59*	63.43*

15.	**Hulling recovery (%)**						
	CR 2644-2-6-4-3-2 × Pant Dhan 4	81.00	Good × Good	7.85**	25.58**	32.78**	33.51**
	UPRI 2012-19 × Pant Dhan 23	77.67	Poor × Good	7.52**	6.39*	27.32**	28.02**
	UPRI 2011-21 × Pant Dhan 4	73.33	Poor × Good	6.41**	-1.34	20.21**	20.87**
	Pant Dhan 22 × Pant Dhan 26	72.00	Poor × Poor	5.39**	9.09**	18.03**	18.68**
	UPRI 2008-6 × Pant Dhan 23	70.33	Poor × Good	4.30**	1.68	15.30**	15.93**
16.	**Milling recovery (%)**						
	UPR 3871-8-1-2-2 × Pant Dhan 4	70.33	Average × Average	7.11**	20.91**	28.65**	37.01**
	BBL 180-5-1-4-1 × Pant Dhan 23	64.00	Poor × Good	6.39**	0.00	17.07**	24.67**
	UPRI 2012-19 Pant Dhan 23	66.00	Poor × Good	4.94**	3.39**	20.73**	28.57**
	Pant Dhan 18 × Pant Dhan 23	72.00	Good × Good	4.94**	18.68**	31.70**	27.92**
	CR 2644-2-6-4-3-2 × Pant Dhan 26	66.67	Poor × Poor	4.93**	20.48**	21.95**	29.87**
17	**Alkali digestion value**						
	Pant Dhan 18 × Pant Dhan 4	4.33	Good × Average	0.83**	85.71**	44.44**	8.33**
	NDR 3012 × Pant Dhan 4	3.00	Poor × Average	0.83**	38.46**	0.00	-25.00**
	Pant Dhan 22 × Pant Dhan 23	3.00	Poor × Poor	0.70*	12.50*	0.00	-25.00**
	Pant Dhan 10 × Pant Dhan 26	2.67	Poor × Average	0.68*	23.07**	-11.11	-16.66
	UPRI 2012-19 × Pant Dhan 26	4.33	Good × Average	0.68*	23.81**	44.44**	8.33**
18	**Grain yield per plant (g)**						
	UPR 3871-8-1-2-2 × Pant Dhan 4	72.17	Good × Poor	16.60**	193.51**	339.17**	145.22**
	Pant Dhan 24 × Pant Dhan 23	55.45	Poor × Poor	15.37**	113.54**	237.44**	88.41**
	Pant Dhan 18 × Pant Dhan 23	56.63	Average × Poor	14.61**	127.90**	244.67**	92.45**
	CR 2644-2-6-4-3-2 × Pant Dhan 26	68.43	Good × Good	13.34**	128.96**	316.46**	132.54**
	UPRI 2012-10 × Pant Dhan 26	53.66	Poor × Good	13.21**	67.92**	226.59**	82.36**

In respect to grain yield per plant, among the parental lines namely Pant Dhan 22 (16.02), UPR 3871-8-1-2-2 (14.74), UPR 3199-464-1-2 (13.73), Pant Dhan 19 (8.58) and CR 2644-2-6-4-3-2 (2.82) and among the testers Pant Dhan 26 (7.65) exhibited significant positive GCA effects and emerged as good general combiners. Similar trends of result also obtained by **Haripasanna *et al.* (2006)**, **Tiwari *et al.* (2011)**, **Dwivedi *et al.* (2012)**, **Sanghera and Hussein (2013)**, **Utharasu and Kumar (2013)**, **Dorosti and Monajjem (2014), Veeresha *et al.* (2015)**, **Devi *et al.* (2017)**, **Maurya *et al.* (2017) and Saravanan *et al.* (2018).**

Superior crosses were identified on the basis of SCA effects values and heterosis over standard parents and also characterized in respect to each character in present study in Table 4.8. The major findings described as follow:

For days to 50% flowering, crosses BBL 180-5-1-4-1 × Pant Dhan 23 (-7.55) with high F_1 mean value (90.00) and significant positive standard heterosis over standard parent Govind (18.42) with Average × Poor interaction of GCA effects of parent and UPRI 2008-8 × Pant Dhan 4 (-6.15) with mean value (95.00) and significant positive standard heterosis over Govind (28.06) and Pant Dhan 4 (12.30) with Good × Good GCA effects of parents. UPRI 2008-8 × Pant Dhan 4 also found superior heterotic cross with high F_1 mean (122.00) and significant standard heterosis over both the standard parents for days to maturity.

For plant height, UPR 3871-8-1-2-2 × Pant Dhan 26 (-12.89) identified as best specific combiner with Good × Good GCA effects of parents, F_1 mean (88.33) and significant negative standard heterosis over Pant Dhan 4 (-13.39) also found superior heterotic cross for spikelet fertility in respect to SCA effects (15.73) and standard heterosis over Pant Dhan 4 (34.86) with Poor × Poor interaction of GCA effects of parents.

For the character number of tillers per plant, UPRI 2008-8 × Pant Dhan 26 was identified as best specific combiner with highest SCA effects (8.79), high F_1 mean (38.66), Good × Good GCA effects of parent and significant positive standard heterosis over Govind (182.90) and Pant Dhan 4 (31.82). For panicle length, UPRI 2008-6 × Pant Dhan 23 identified as best specific combiner with significant SCA effects (5.70), high F_1 mean value (33.33), significant positive standard heterosis over Govind (37.36) and Pant Dhan 4 (15.47) with Poor × Poor interaction of GCA of parents. Pant Dhan 22 × Pant Dhan 26 identified as

best specific combiner for number of grain per panicle (42.37), spikelet fertility (15.19) and hulling recovery (5.39) with Good × Good, Good × Poor and Poor × Poor GCA effects of parents, respectively.

For 1000 grain weight, Pant Dhan 19 × Pant Dhan 23 exhibited significant positive SCA effects (16.09), high F_1 mean (48.71), significant positive standard heterosis over Govind (171.92) and Pant Dhan 4 (108.26) with Average × Average interaction of GCA of parents while, Pant Dhan 19 × Pant Dhan 26 found superior cross for grain width with significant SCA effects (0.23) and standard heterosis over Govind (8.77), Pant Dhan 4 (3.60), having Good × Poor interaction of GCA effects of parents. For grain length, UPRI 2008-8 × Pant Dhan 23 (0.50), UPRI 2012-19 × Pant Dhan 4 (0.40) and for grain width, JGL 1172-7 × Pant Dhan 4 (0.29) and NDR 3012 × Pant Dhan 26 (0.20) with Poor × Average, Good × Poor, Average × Average and Good × Poor interaction of GCA of parents, respectively and these superior crosses showed significant positive standard heterosis over Pant Dhan 4 for these traits.

For kernel length, Pant Dhan 18 × Pant Dhan 23, for kernel breadth CR 2644-2-6-4-3-2 × Pant Dhan 4 and Pant Dhan 10 × Pant Dhan 4 for L/B ratio were identified as best specific combiners with Good × Good, Good × Average and Good × Average GCA effects of parent, respectively and also showed significant standard heterosis over both the standard parents for these traits. Crosses namely NDR 3012 × Pant Dhan 26 (0.12), CR 2644-2-6-4-3-2 × Pant Dhan 4 (7.85), UPR 3871-8-1-2-2 × Pant Dhan 4 (7.119), Pant Dhan 18 × Pant Dhan 4 (0.83) and UPRI 2012-19 × Pant Dhan 26 (0.68) exhibited significant SCA effects with Poor × Poor, Good × Good, Average × Average and Good × Average GCA effects of parents for harvest index, hulling recovery, milling recovery and alkali value, respectively.

For grain yield per plant, UPR 3871-8-1-2-2 × Pant Dhan 4 (16.60) exhibited significant positive SCA effects and emerged as best specific combiner with highly significant positive standard heterosis over Govind (339.17) and Pant Dhan 4 (145.22) having Good × Poor GCA effect of parents followed by CR 2644-2-6-4-3-2 × Pant Dhan 26 (13.34) with significant standard heterosis over Govind (316.46) and P ant Dhan 4 (132.54) having Good × Good GCA effects of parents. Both the crosses exhibited high F_1 mean (72.17) and (68.43), respectively. Similar trends of result also obtained by **Sathya and Jebaraj (2013), Utharasu and Kumar (2013), Dorosti and Monajjem (2014), Jayasudha and Sharma**

(2014), Prasad *et al.* (2015), Satheeshkumar *et al.* (2016), Sran *et al.,* (2016), Gahtyari *et al.* (2017) and Maurya *et al.* (2017).

The crosses exhibited high and significant SCA effects also showed high, significant standard heterosis with high F_1 mean for grain yield per plant, number of tiller per plant, panicle length, and number of grains per panicle, spikelet fertility, 1000 grain weight, grain width, kernel length, L/B ratio and hulling recovery. This is not necessary that those crosses exhibited high, significant SCA effects values would also showed high and significant standard heterosis. However, those crosses exhibited significant SCA effects with lesser value would be showed high and significant standard heterosis.

In present study, most of the crosses found heterotic having Good × Good, Good × Poor, Good × Average, Average × Average and Poor × Good types of GCA effects of parents. It is not necessary that crosses having Good × Good, Good × Poor and Poor × Good showed high, significant SCA effects and standard heterosis. The results revealed that crosses having Poor × Poor type of GCA effects of parent would also showed high significant standard heterosis. For days to maturity, panicle length, spikelet fertility, L/B ratio and harvest index, high heterotic crosses having Poor × Poor type of GCA effects of parent would also found superior performing hybrids. This type of findings also reported by **Haripasanna *et al.* (2006)**, **Dorosti and Monajjem (2014), Jayasudha and Sharma (2014), Prasad *et al.* (2015) and Devi *et al.* (2017)**.

4.4 Manifestation of heterosis

Manifestation of heterosis was estimated by comparing the mean value for all the genotypes under study for eighteen characters of crosses with mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent (standard heterosis) expressed as percentage increase or decrease is represented in the Table 4.9. Standard heterosis is desirable for the breeder point of view. The results of heterotic expression of crosses are described under as follows:

4.4.1 Days to 50% flowering

4.4.1.1 Mid parent heterosis

The mid parent heterosis for days to 50% flowering ranged from -10.47 to 14.99. Out of 51 crosses evaluated, twenty one cross combinations showed significant mid parent heterosis (average heterosis) over their mid parental values. Out of these, eleven cross combinations exhibited significant negative heterosis viz., NDR 3012 × Pant Dhan 26 (-10.47), NDR 3012 × Pant Dhan 23 (-10.04), UPRI 2014-8 × Pant Dhan 26 (-9.00), BBL 180-5-1-4-1 × Pant Dhan 23 (-7.85), UPRI 2014-8 × Pant Dhan 23 (-7.53), CR 2644-2-6-4-3-2 × Pant Dhan 2 (-7.34), UPR 3871-8-1-2-2 × Pant Dhan 26 (-6.71), NDR 3012 × Pant Dhan 4 (-6.62), UPRI 2008-6 × Pant Dhan 23 (-5.76), UPR 3199-464-4-2 × Pant Dhan 26 (-5.21), JGL 1172-7 × Pant Dhan 23 (-4.90), JGL 1172-7 × Pant Dhan 26 (-4.39) and ten crosses namely, UPRI 2008-6 × Pant Dhan 4 (14.99), BBL 180-5-1-4-1 × Pant Dhan 26 (12.05), UPRI 2011-21 × Pant Dhan 26 (10.95), UPRI 2012-10 × Pant Dhan 23 (8.58), UPRI 2012-19 × Pant Dhan 26 (8.37), UPRI 2008-8 × Pant Dhan 26 (8.19) and Pant Dhan 10 × Pant Dhan 26 (6.51) exhibited significant and positive average heterosis for this character.

4.4.1.2 Heterobeltiosis

Heterobeltiosis for days to 50% flowering ranged from -17.54 to 9.63. Out of 51 crosses studied, thirty crosses exhibited significant heterosis, out of which twenty six cross combinations namely, NDR 3012 × Pant Dhan 4, 23 & 26 (-17.54), JGL 1172-7 × Pant Dhan 4 (-12.84), UPRI 2014-8 × Pant Dhan 26 (-12.50), UPRI 2014-8 × Pant Dhan 23 (-11.53), JGL 1172-7 × Pant Dhan 26 (-10.09), Pant Dhan 10 × Pant Dhan 23 (-9.47), UPR 3199-464-4-2 × Pant Dhan 4 (-9.12), UPRI 2012-19 × Pant Dhan 4 (-9.03), UPRI 2014-8 × Pant Dhan 4 (-8.97), UPRI 2008-6 × Pant Dhan 23 (-8.85), UPR 3199-464-4-2 × Pant Dhan 26 (-8.14), BBL 180-5-1-4-1 × Pant Dhan 4 (-6.31), Pant Dhan 18 × Pant Dhan 4 (-5.96), CR 2644-2-6-4-3-2 × Pant Dhan 23 (-5.84), UPR 3871-8-1-2-2 × Pant Dhan 23 (-5.26), Pant Dhan 22 × Pant Dhan 23 (-4.21) exhibited significant and negative heterosis over their respective better parent.

Table 4.9: Estimates of heterosis for days to 50% flowering and days to maturity in rice

Sl. No.	Crosses	Days to 50% flowering				Days to maturity			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	4.44*	1.43	23.68**	8.46**	0.27	-1.08	6.25*	-4.76
2.	UPRI 2011-21 X Pant Dhan 23	0.88	-0.35	24.56**	9.23**	-1.99	-3.65	15.31**	3.36
3.	UPRI 2011-21 X Pant Dhan 26	10.95**	9.02**	37.71**	20.76**	7.00**	6.72**	24.06**	11.24**
4.	UPRI 2008-6 X Pant Dhan 4	14.99**	6.88**	42.98**	25.38**	7.53**	2.51	27.18**	14.00**
5.	UPRI 2008-6 X Pant Dhan 23	-5.76**	-8.85**	21.93**	6.92**	-10.76 **	-12.34**	8.75*	-2.52
6.	UPRI 2008-6 X Pant Dhan 26	1.18	-1.63	31.57**	15.38**	-2.99	-6.04**	16.56**	4.48*
7.	BBL 180-5-1-4-1 X Pant Dhan 4	0.17	-6.31**	23.68**	8.46**	-3.48	-6.73**	12.50**	0.84
8.	BBL 180-5-1-4-1 X Pant Dhan 23	-7.85**	-10.29**	18.42	3.84	-8.19**	-8.54**	10.31**	-1.12
9.	BBL 180-5-1-4-1 X Pant Dhan 26	12.05**	9.63**	44.73**	26.92**	7.91**	5.95**	27.81**	14.56**
10.	UPRI 2012-10 X Pant Dhan 4	0.36	-3.84	20.61	5.76*	2.92	2.77	15.62**	3.64*
11.	UPRI 2012-10 X Pant Dhan 23	8.58**	8.39**	35.96**	19.22**	7.54**	4.17	24.68**	11.76**
12.	UPRI 2012-10 X Pant Dhan 26	-1.04	-1.38	24.56**	9.23**	-2.83	-4.57	10.93**	-0.56
13.	UPRI 2008-8 X Pant Dhan 4	-2.39	-11.49**	25.00**	9.61**	-2.53	-6.39**	14.37**	2.52
14.	UPRI 2008-8 X Pant Dhan 23	2.14	-3.72	35.96**	19.22**	2.32	1.27	23.75**	10.92**
15.	UPRI 2008-8 X Pant Dhan 26	8.19**	2.48	44.73**	26.92**	8.78**	6.13**	29.68**	16.24**
16.	UPRI 2012-19 X Pant Dhan 4	0.17	-9.03**	28.06**	12.30**	2.52	-1.78	20.62**	8.12**
17.	UPRI 2012-19 X Pant Dhan 23	2.97	-2.80	36.84**	19.99**	2.83	1.52	24.68**	11.75**

18.	UPRI 2012-19 X Pant Dhan 26	8.37**	2.80	44.73**	26.92**	9.02**	6.10**	30.31**	16.80**
19.	Pant Dhan 22 X Pant Dhan 4	4.39*	0.35	25.00**	9.61**	-0.54	-1.63	13.12**	1.40
20.	Pant Dhan 22 X Pant Dhan 23	-4.04	-4.21*	19.73	4.99*	-0.13	-2.08	17.18**	5.04**
21.	Pant Dhan 22 X Pant Dhan 26	-2.44	-3.12	22.36**	7.30**	-1.62	-2.15	13.75**	1.96
22.	Pant Dhan 10 X Pant Dhan 4	2.15	-0.38	14.47	0.38	-0.56	-2.77	9.37*	-1.96
23.	Pant Dhan 10 X Pant Dhan 23	-3.37	-9.47**	13.15	-0.76	-0.41	-5.48*	13.12**	1.40
24.	Pant Dhan 10 X Pant Dhan 26	6.51*	-0.69	25.43**	9.99**	3.63	-0.26	15.93**	3.92*
25.	Pant Dhan 18 X Pant Dhan 4	0.70	-5.96*	24.56**	9.23**	2.53	-1.53	20.31**	7.84**
26.	Pant Dhan 18 X Pant Dhan 23	2.21	-0.66	31.57**	15.38**	-1.29	-2.30	19.37**	7.00**
27.	Pant Dhan 18 X Pant Dhan 26	3.72	1.32	34.21**	17.69**	-6.42*	-8.69**	11.56**	0.00
28.	Pant Dhan 24 X Pant Dhan 4	3.48	-0.35	23.68**	8.46**	-0.83	-1.10	11.87**	0.28
29.	Pant Dhan 24 X Pant Dhan 23	-2.87	-3.15	21.05*	6.15**	-5.23*	-7.83**	10.31**	-1.12
30.	Pant Dhan 24 X Pant Dhan 26	-2.97	-3.81	21.49*	6.53**	-0.54	-1.88	14.06**	2.24
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	-2.56	-11.76**	25.00**	9.61**	-3.03	-7.55**	14.68**	2.80
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	0.65	-5.26*	34.21**	17.69**	1.79	0.00	24.06**	11.20**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-6.71**	-11.76**	25.00**	9.61**	-1.95	-5.03*	17.81**	5.60**
34.	UPR 3199-464-1-2 X Pant Dhan 4	-1.93	-9.12**	22.36**	7.30**	-0.53	-3.64	15.62**	3.64*
35.	UPR 3199-464-1-2 X Pant Dhan 23	-3.71	-7.16**	25.00**	9.61**	-1.95	-2.03	17.50**	5.32**
36.	UPR 3199-464-1-2 X Pant Dhan 26	-5.21*	-8.14**	23.68**	8.46**	1.85	0.26	20.31**	7.84**
37.	UPRI 2014-8 X Pant Dhan 4	-1.04	-8.97**	24.56**	9.23**	-0.26	-4.79	17.81**	5.60**

38.	UPRI 2014-8 X Pant Dhan 23	-7.53**	-11.53**	21.05*	6.15**	-5.26*	-6.81**	15.31**	3.36
39.	UPRI 2014-8 X Pant Dhan 26	-9.00**	-12.50**	19.73	4.99*	-3.38	-6.31**	15.93**	3.92*
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-2.55	-12.00**	25.43**	9.99**	-0.26	-6.12**	19.68**	7.28**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.32	-5.84*	34.21**	17.69**	1.64	-1.47	25.62**	12.60**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-7.34**	-12.61**	24.56**	9.23**	-3.33	-7.59**	17.81**	5.60**
43.	NDR 3012 X Pant Dhan 4	-6.62**	-17.54**	23.68**	8.46**	-2.08	-7.63**	17.18**	5.04**
44.	NDR 3012 X Pant Dhan 23	-10.04**	-17.54**	23.68**	8.46**	-4.94	-7.63**	17.18*	5.04**
45.	NDR 3012 X Pant Dhan 26	-10.47**	-17.54**	23.68**	8.46**	-2.82	-6.89**	18.12**	5.88**
46.	JGL 1172-7 X Pant Dhan 4	-3.22	-12.84**	25.00**	9.61**	-0.52	-5.94*	18.75**	6.44**
47.	JGL 1172-7 X Pant Dhan 23	-4.90*	-11.00**	27.63**	11.92**	-2.16	-4.70	20.31**	7.84**
48.	JGL 1172-7 X Pant Dhan 26	-4.39*	-10.09**	28.94**	13.07**	0.51	-3.46	21.87**	9.24**
49.	Pant Dhan 19 X Pant Dhan 4	2.20	-1.41	21.93**	6.92**	3.87*	3.59	17.18**	5.04**
50.	Pant Dhan 19 X Pant Dhan 23	-2.64	-3.15	21.05*	6.15**	-1.20	-3.91	15.00**	3.08
51.	Pant Dhan 19 X Pant Dhan26	0.00	-1.04	25.00**	9.61**	2.99	1.61	18.12**	5.88**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

Four cross combinations namely, UPRI 2011-21 × Pant Dhan 26 (9.02), UPRI 2012-10 × Pant Dhan 23 (8.39), BBL 180-5-1-4-1 × Pant Dhan 23 (8.39) and UPRI 2008-6 × Pant Dhan 4 (6.88) exhibited significant and positive heterobeltiosis for this character.

4.4.1.3 Standard heterosis

The standard heterosis for days to 50% flowering over the check cultivar Govind ranged from 13.15 to 44.73. Almost all cross combinations showed positive standard heterosis over Govind which are BBL 180-5-1-4-1 × Pant Dhan 26, UPRI 2008-8 × Pant Dhan 26 & UPRI 2012-19 × Pant Dhan 26 (44.73), UPRI 2008-6 × Pant Dhan 4 (42.98), UPRI 2011-21 × Pant Dhan 26 (37.71), UPRI 2012-19 × Pant Dhan 23 (36.84), UPRI 2008-8 × Pant Dhan 23 & UPRI 2012-10 × Pant Dhan 23 (35.96), Pant Dhan 18 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 4 & CR 2644-2-6-4-3-2 × Pant Dhan 23 (34.21), Pant Dhan 18 × Pant Dhan 26 & UPRI 2008-6 × Pant Dhan 26 (31.57) and none of the crosses showed significant negative standard heterosis over check parent Govind for this character.

The standard heterosis for days to 50% flowering over the standard parent Pant Dhan 4 ranged from -0.76 to 26.92. Most of the crosses showed significant and positive standard heterosis over Pant Dhan 4 which are BBL 180-5-1-4-1 × Pant Dhan 26, UPRI 2008-8 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 26 (26.92), UPRI 2008-6 × Pant Dhan 4 (25.38), UPRI 2011-21 × Pant Dhan 26 (20.76), UPRI 2008-8 × Pant Dhan 23 (19.99), UPRI 2012-10 × Pant Dhan 23 (19.29), Pant Dhan 18 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 23 (17.69), Pant Dhan 18 × Pant Dhan 26 & UPRI 2008-6 × Pant Dhan 23 (15.38), JGL 1172-7 × Pant Dhan 4 (13.07), UPRI 2012-19 × Pant Dhan 4 (12.30), JGL 1172-7 × Pant Dhan 23 (11.92) and Pant Dhan 10 × Pant Dhan 26 (9.99) showed significant and positive standard heterosis over standard parent Pant Dhan 4 for this character.

For days to 50% flowering negative heterosis is desirable for shortening the duration of flowering. For the same, cross NDR 3012 × Pant Dhan 26, NDR 3012 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 26 showed highest significant negative mid parent heterosis and heterobeltiosis. None of the crosses showed significant negative standard heterosis over standard parents. The results were support by earlier reports of **Dwivedi *et al.* (2012), Abdel *et al.* (2016), Mirarab *et al.* (2017), Tiwari *et al.* (2011), and Priyanka *et al.* (2017).** However, positive standard heterosis was reported by **Bisne *et al.* (2009).**

4.4.2 Days to maturity

4.4.2.2 Mid parent heterosis

Average heterosis (mid parent heterosis) for days to maturity ranged from -10.76 to 9.02. Among the 51 crosses evaluated, five cross combinations exhibited significant and negative heterosis which are UPRI 2008-6 × Pant Dhan 23 (-10.76), BBL 180-5-1-4-1 × Pant Dhan 23 (-8.19), Pant Dhan 10 × Pant Dhan 26 (-6.42), UPRI 2014-8 × Pant Dhan 23 (-5.26), Pant Dhan 24 × Pant Dhan 23 (-5.235) and eight crosses namely, UPRI 2012-19 × Pant Dhan 26 (9.02), UPRI 2008-8 × Pant Dhan 26 (8.781), BBL 180-5-1-4-1 × Pant Dhan 26 (7.91), UPRI 2012-10 × Pant Dhan 23 (7.54), UPRI 2008-6 × Pant Dhan 4 (7.53), UPRI 2011-21 × Pant Dhan 26 (7.00), Pant Dhan 19 × Pant Dhan 4 (3.87) and Pant Dhan 10 × Pant Dhan 26 (3.63) exhibited significant average heterosis over their mid parental values for this character.

4.4.2.2 Heterobeltiosis

The heterobeltiosis for days to maturity ranged from -12.34 to 6.72. Out of 51 crosses evaluated, eighteen crosses namely UPRI 2008-6 × Pant Dhan 23 (-12.34), Pant Dhan 10 × Pant Dhan 26 (-8.69), BBL 180-5-1-4-1 × Pant Dhan 23 (-8.54), Pant Dhan 24 × Pant Dhan 23 (-7.88), NDR 3012 × Pant Dhan 4 & 23 (-7.63), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-7.59), UPR 3871-8-1-2-2 × Pant Dhan 4 (-7.557), NDR 3012 × Pant Dhan 26 (-6.89), UPRI 2014-8 × Pant Dhan 23 (-6.81), BBL 180-5-1-4-1 × Pant Dhan 4 (-6.73), UPRI 2008-8 × Pant Dhan 4 (-6.39), UPRI 2014-8 × Pant Dhan 26 (-6.31), CR 2644-2-6-4-3-2 × Pant Dhan 4 (-6.12), UPRI 2008-6 × Pant Dhan 26 (-6.04), JGL 1172-7 × Pant Dhan 4 (-5.94), Pant Dhan 10 × Pant Dhan 23 (-5.48) showed significant and negative heterobeltiosis for this character. Four cross combinations exhibited significant and positive heterobeltiosis over their respective better parent value for this character.

4.4.2.3 Standard heterosis

The standard heterosis for days to maturity over the standard parent Govind ranged from 6.25 to 30.12. Almost all cross combinations showed significant and positive standard heterosis over standard parent Govind which are UPRI 2012-19 × Pant Dhan 26 (30.31), UPRI 2008-8 × Pant Dhan 26 (29.68), UPRI 2008-6 × Pant Dhan 4 (27.18), CR 2644-2-6-4-3-2 × Pant Dhan 23 (25.62), UPRI 2012-19 × Pant Dhan 23 & UPRI 2012-10 × Pant Dhan 23 (24.68), Kharif 2015-SNo-1414 × Pant Dhan 23 & UPRI 2011-21 × Pant Dhan 26 (24.06),

UPRI 2008-8 × Pant Dhan 23 (23.75), JGL 1172-7 × Pant Dhan 23 (21.87), UPRI 2012-19 × Pant Dhan 4 (20.62), Pant Dhan 18 × Pant Dhan 4 (20.31), CR 2644-2-6-4-3-2 × Pant Dhan 4 (19.68), Pant Dhan 18 × Pant Dhan 23 (19.37), JGL 1172-7 × Pant Dhan 4 (18.75) and NDR 3012 × Pant Dhan 26 (18.12).

The standard heterosis for days to maturity over the standard parent Pant Dhan 4 ranged from -4.76 to 16.80. Thirty three crosses showed significant and positive standard heterosis were UPRI 2012-19 × Pant Dhan 26 (16.80), UPRI 2008-8 × Pant Dhan 26 (16.24), BBL 180-5-1-4-1 × Pant Dhan 26 (14.56), UPRI 2008-6 × Pant Dhan 4 (14.00), CR 2644-2-6-4-3-2 × Pant Dhan 23 (12.60), UPRI 2012-19 × Pant Dhan 23, UPRI 2012-10 × Pant Dhan 23 (11.75), UPRI 2011-21 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 23 (11.20), UPRI 2008-8 × Pant Dhan 23 (10.92), JGL 1172-7 × Pant Dhan 26 (9.24), UPRI 2012-19 × Pant Dhan 4 (8.13), Pant Dhan 18 × Pant Dhan 4, UPR 3199-464-1-2 × Pant Dhan 26 & JGL 1172-7 × Pant Dhan 23 (7.84), CR 2644-2-6-4-3-2 × Pant Dhan 4 (7.28), Pant Dhan 18 × Pant Dhan 23 (7.00), JGL 1172-7 × Pant Dhan 4 (6.44) and NDR 3012 × Pant Dhan 26 (5.82).

For days to maturity, there are also negative heterosis is desirable. The results indicated that crosses UPRI 2008-6 × Pant Dhan 23 and BBL 180-5-1-4-1 × Pant Dhan 23 showed highest significant negative average heterosis and heterobeltiosis. The findings were similar with **Perera *et al.* (2001), Nuruzzaman *et al.* (2002), Mirarab *et al.* (2017), Tiwari *et al.* (2011), Kumar *et al.* (2011), Showkat *et al.* (2016)**, **Patil *et al.* (2011) and Priyanka *et al.* (2017).** None of the crosses showed significant negative standard heterosis over standard check supported by **Waza *et al.* (2016)** and **Bisne *et al.* (2009).**

4.4.3 Plant height (cm)

4.4.3.1 Mid parent heterosis

The mid parent heterosis for plant height ranged from -23.50 to 38.94. Out of 51 crosses evaluated, six crosses namely, Pant Dhan 10 × Pant Dhan 26 (-23.505), UPR 3871-8-1-2-2 × Pant Dhan 26 (-20.552), Pant Dhan 24 × Pant Dhan 26 (-14.615), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-10.216), UPRI 2014-8 × Pant Dhan 26 (-9.481) and UPRI 2008-8 × Pant Dhan 26 (-8.127) exhibited significant and negative average heterosis for this character.

4.4.3.2 Heterobeltiosis

The heterobeltiosis for plant height ranged from -30.80 to 34.92. Out of 51 cross evaluated, sixteen cross combinations namely, Pant Dhan 10 × Pant Dhan 26 (-30.80), UPR 3871-8-1-2-2 × Pant Dhan 26 (-27.81), UPRI 2014-8 × Pant Dhan 26 (-16.64), Pant Dhan 24 × Pant Dhan 26 (-16.37), UPRI 2008-8 × Pant Dhan 26 (-15.01), CR 2644-2-6-4-3-2 × Pant Dhan 4 (-14.40), Pant Dhan 24 × Pant Dhan 4 (-14.20), Pant Dhan 24 × Pant Dhan 23 (-11.93), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-10.32), CR 2644-2-6-4-3-2 × Pant Dhan 23 (-10.13), UPR 3199-464-1-2 × Pant Dhan 23 (-9.06), Pant Dhan 18 × Pant Dhan 26 (-8.74), Pant Dhan 18 × Pant Dhan 4 (-8.52), NDR 3012 × Pant Dhan 26 (-8.47), Pant Dhan 19 × Pant Dhan 26 (-5.47) and BBL 180-5-1-4-1 × Pant Dhan 26 (-5.20) showed significant negative heterobeltiosis for this character.

4.4.3.3 Standard heterosis

The standard heterosis over the check parent Govind for plant height ranged from -1.93 to 61.39. Most of the cross combination exhibited significant and positive standard heterosis over check parent Govind, which are Pant Dhan 22 × Pant Dhan 26 (61.39), JGL 1172-7 × Pant Dhan 23 (54.82), NDR 3012 × Pant Dhan 4 (50.96), Pant Dhan 19 × Pant Dhan 4 (46.71), UPRI 2011-21 × Pant Dhan 26 (43.22), JGL 1172-7 × Pant Dhan 4 (40.92), Pant Dhan 22 × Pant Dhan 23 (40.54), JGL 1172-7 × Pant Dhan 26 (38.22), UPR 3199-464-1-2 × Pant Dhan 26, UPRI 2012-10 × Pant Dhan 26 (37.83), UPRI 2012-19 × Pant Dhan 26 (36.29), UPRI 2008-6 × Pant Dhan 26 (35.90), BBL 180-5-1-4-1 × Pant Dhan 26 (34.36), Pant Dhan 19 × Pant Dhan 26 (33.97), Pant Dhan 19 × Pant Dhan 23 (31.66), Pant Dhan 18 × Pant Dhan 26, UPRI 2011-21 × Pant Dhan 4 (29.34), Pant Dhan 18 × Pant Dhan 26 (28.95), UPRI 2011-21 × Pant Dhan 23 (28.57), CR 2644-2-6-4-3-2 × Pant Dhan 23 (27.68), UPR 3871-8-1-2-2 × Pant Dhan 23 (26.64), UPRI 2008-8 × Pant Dhan 4 (25.86), UPRI 2008-6 × Pant Dhan 23 (23.16), CR 2644-2-6-4-3-2 × Pant Dhan 4 (21.62), Pant Dhan 18 × Pant Dhan 4 (20.07), Pant Dhan 24 × Pant Dhan 23 (19.69), UPRI 2014-8 × Pant Dhan 4 (18.91), UPRI 2012-19 × Pant Dhan 23 (17.76), UPRI 2012-10 × Pant Dhan 4 (15.94) and BBL 180-5-1-4-1 × Pant Dhan 23 (11.58).

The standard heterosis over the check parent Pant Dhan 4 for plant height ranged from -16.99 to 36.61. Twenty nine crosses namely, Pant Dhan 22 × Pant Dhan 26 (36.60), JGL 1172-7 × Pant Dhan 23 (31.04), NDR 3012 × Pant Dhan 4 (27.77), Pant Dhan 19 × Pant

Dhan 4 (24.18), UPRI 2011-21 × Pant Dhan 26 (21.24), Pant Dhan 22 × Pant Dhan 23 (18.95), Pant Dhan 22 × Pant Dhan 4 (18.62), JGL 1172-7 × Pant Dhan 23 (16.99), UPR 3199-464-1-2 × Pant Dhan 4, UPRI 2012-10 × Pant Dhan 26 (16.66), UPRI 2008-6 × Pant Dhan 26 (15.03), UPR 3199-464-1-2 × Pant Dhan 26 (14.37), BBL 180-5-1-4-1 × Pant Dhan 26 (13.72) and Pant Dhan 19 × Pant Dhan 23 (11.43) exhibited significant positive and six cross combinations namely Pant Dhan 10 × Pant Dhan 26 (-16.99), UPR 3871-8-1-2-2 × Pant Dhan 26 (-13.39), Pant Dhan 10 × Pant Dhan 4, BBL 180-5-1-4-1 × Pant Dhan 4 (-7.51), BBL 180-5-1-4-1 × Pant Dhan 23 (-5.55) and Pant Dhan 10 × Pant Dhan 23 (-5.29) showed standard heterosis over the check parent Pant Dhan 4 for this character.

For plant height, there are also negative heterosis is desirable, short to medium plant height is desirable characteristics of semi-dwarf varieties in rice. The results indicated that crosses Pant Dhan 10 × Pant Dhan 26 (-23.50) and UPR 3871-8-1-2-2 × Pant Dhan 26 (-20.55) having highest mid parent heterosis, heterobeltiosis and Pant Dhan 10 × Pant Dhan 26 (-16.99) having highest standard heterosis over standard parent Pant Dhan 4. Similarity in results were found with **Rao *et al.* (1996), Vishwakarma *et al.* (1999), Saleem *et al.* (2005), Kumar *et al.* (2010), (Sen and Singh, 2011), Rahimi *et al.* (2010) Waza *et al.* (2016)**, **Priyanka *et al.* (2017).**

(Contd.) Table 4.9: Estimates of heterosis for or Plant height (cm) and Number of tillers per plant in rice genotypes

Sl. No.	Crosses	Plant height (cm)				Number of tillers per plant			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	6.51*	-1.23	29.34**	9.47**	-1.49	-2.94	60.97*	-24.99**
2.	UPRI 2011-21 X Pant Dhan 23	5.18	-1.82	28.57**	8.82**	25.92	3.03	65.85**	-22.72**
3.	UPRI 2011-21 X Pant Dhan 26	5.05	1.06	43.24**	21.24**	17.94	4.54	68.28**	-21.59**
4.	UPRI 2008-6 X Pant Dhan 4	10.81**	8.22**	27.02**	7.51*	-2.85	-5.55	65.85**	-22.72**
5.	UPRI 2008-6 X Pant Dhan 23	6.68*	4.93	23.16**	4.28	14.03	-9.72	58.53*	-26.13**
6.	UPRI 2008-6 X Pant Dhan 26	4.90	-4.11	35.90**	15.03**	2.43	-12.50	53.65*	-28.40**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-2.55	-2.68	9.26*	-7.56	-6.87	-10.29	48.77**	-30.68**
8.	BBL 180-5-1-4-1 X Pant Dhan 23	-1.16	-1.70	11.58**	-5.55	46.66**	22.22*	87.80**	-12.49**
9.	BBL 180-5-1-4-1 X Pant Dhan 26	5.79	-5.20*	34.36**	13.72**	68.42**	52.3**	134.14**	9.09**
10.	UPRI 2012-10 X Pant Dhan 4	0.00	-3.37	15.94**	-1.86	1.35	-6.25	82.92**	-14.77**
11.	UPRI 2012-10 X Pant Dhan 23	1.19	-1.54	18.14**	0.00	-16.39	-36.25**	24.37	-42.04**
12.	UPRI 2012-10 X Pant Dhan 26	5.32	-2.75	37.83**	16.66**	2.29	-16.25	63.41**	-23.86**
13.	UPRI 2008-8 X Pant Dhan 4	8.32**	4.45	25.86**	6.53*	10.79	8.45	87.80**	-12.49**
14.	UPRI 2008-8 X Pant Dhan 23	8.23**	5.09*	26.64**	7.19*	11.50	-11.26	53.65*	-28.40**
15.	UPRI 2008-8 X Pant Dhan 26	-8.12**	-15.01**	20.46**	1.96	90.00**	63.38**	182.92**	31.82**
16.	UPRI 2012-19 X Pant Dhan 4	0.00	-2.83	15.25**	-2.45	5.12	-6.88	99.99**	-6.81*
17.	UPRI 2012-19 X Pant Dhan 23	1.46	-0.71	17.76**	-0.32	1.53	-25.00*	60.97**	-24.99**

18.	UPRI 2012-19 X Pant Dhan 26	4.70	-3.84	36.29**	15.35**	33.81*	5.68	126.82**	5.68*
19.	Pant Dhan 22 X Pant Dhan 4	14.36**	5.21*	40.15**	18.62**	4.28	1.38	78.04**	-17.04**
20.	Pant Dhan 22 X Pant Dhan 23	13.92**	5.50*	40.54**	18.95**	10.52	-12.50	53.65*	-28.40**
21.	Pant Dhan 22 X Pant Dhan 26	17.39**	13.86**	61.39**	36.60**	18.69	1.38	78.04**	-17.04**
22.	Pant Dhan 10 X Pant Dhan 4	-3.54	-4.71	9.26*	-7.51	-29.92	-30.43*	17.07	-45.45**
23.	Pant Dhan 10 X Pant Dhan 23	-1.86	-2.35	11.97**	-5.22	9.91	-11.59	48.77	-30.68**
24.	Pant Dhan 10 X Pant Dhan 26	-23.50**	-30.80**	-1.93	-16.99	-55.00**	-60.87**	-34.14	-69.31**
25.	Pant Dhan 18 X Pant Dhan 4	-1.23	-8.529**	20.07**	1.64	-13.66	-15.49	46.33	-31.81**
26.	Pant Dhan 18 X Pant Dhan 23	5.36	-1.76	28.95**	9.15**	2.65	-18.31	41.46	-34.09**
27.	Pant Dhan 18 X Pant Dhan 26	-5.24	-8.74**	29.34**	9.47**	-52.45**	-59.15**	-29.27	-67.04**
28.	Pant Dhan 24 X Pant Dhan 4	-5.89	-14.20**	16.60**	-1.30	49.18**	33.82*	121.94**	3.41*
29.	Pant Dhan 24 X Pant Dhan 23	-4.02	-11.93**	19.69**	1.30	47.91**	31.48*	73.16**	-19.31**
30.	Pant Dhan 24 X Pant Dhan 26	-14.61**	-16.37**	18.53**	0.32	35.23*	31.48*	73.16**	-19.31**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	1.05	-0.67	15.05**	-2.61	40.17*	20.58	99.99**	-6.81*
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	10.43**	9.33**	26.64**	7.190*	-27.43	-32.65*	-19.54	-62.50**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-20.52**	-27.81**	2.31	-13.39	52.00**	49.02**	85.36**	-13.63**
34.	UPR 3199-464-1-2 X Pant Dhan 4	15.01**	7.85**	37.83**	16.66**	-0.75	-2.94	60.97**	-24.99**
35.	UPR 3199-464-1-2 X Pant Dhan 23	-3.68	-9.06**	16.21**	-1.63	47.66**	21.53*	92.67**	-10.22**
36.	UPR 3199-464-1-2 X Pant Dhan 26	0.27	-4.65	35.13**	14.37**	32.75*	18.46	87.80**	-12.49**
37.	UPRI 2014-8 X Pant Dhan 4	2.87	-0.32	18.91**	0.65	-7.14	-9.72	58.53*	-26.13**

38.	UPRI 2014-8 X Pant Dhan 23	-0.82	-3.23	15.44**	-2.28	3.50	-18.05	43.89	-32.9**
39.	UPRI 2014-8 X Pant Dhan 26	-9.48*	-16.64**	18.14**	0.00	44.7**	23.61*	117.06**	1.13*
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-4.22	-14.40**	21.62**	2.94	8.52	2.94	70.72**	-20.45**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	-0.09	-10.13**	27.68**	8.07*	0.97	-14.75	26.82	-40.90**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-10.21**	-10.32**	27.41**	7.84*	33.92*	22.9*	82.92**	-14.77**
43.	NDR 3012 X Pant Dhan 4	38.94**	34.92**	50.96**	27.77**	-7.43	-17.64	36.58	-36.36**
44.	NDR 3012 X Pant Dhan 23	17.46**	13.26**	28.57**	8.82**	7.36	-3.77	24.38	-42.04**
45.	NDR 3012 X Pant Dhan 26	4.98	-8.47**	29.73**	9.80**	-11.53	-13.2	12.19	-47.72**
46.	JGL 1172-7 X Pant Dhan 4	12.17**	1.10	40.92**	19.28**	-16.92	-20.58	31.70	-38.63**
47.	JGL 1172-7 X Pant Dhan 23	22.44**	11.08**	54.82**	31.04**	-7.69	-22.5*	17.07	-45.45**
48.	JGL 1172-7 X Pant Dhan 26	-1.66	-2.49	38.22**	16.99**	38.05**	25.80*	90.23**	-11.36**
49.	Pant Dhan 19 X Pant Dhan 4	25.66**	20.65**	46.71**	24.18**	19.42	16.91	102.43**	-5.68*
50.	Pant Dhan 19 X Pant Dhan 23	11.98**	8.25**	31.66**	11.43**	18.58	-5.63	63.41**	-23.86**
51.	Pant Dhan 19 X Pant Dhan26	1.74	-5.47	33.97**	13.39**	13.11	-2.81	68.28**	-21.59**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

4.4.4 Number of tillers per plant

4.4.4.1 Mid parent heterosis

The mid parent heterosis for number of tillers per plant ranged from -55.00 to 90.16. Out of 51 crosses evaluated, fourteen cross combinations namely UPRI 2008-8 × Pant Dhan 26 (90.16), BBL 180-5-1-4-1 × Pant Dhan 26 (68.42), UPR 3871-8-1-2-2 × Pant Dhan 26 (52.00), Pant Dhan 24 × Pant Dhan 4 (49.18), Pant Dhan 24 × Pant Dhan 23 (47.91), UPR 3199-464-1-2 × Pant Dhan 23 (47.66), BBL 180-5-1-4-1 × Pant Dhan 23 (46.66), UPRI 2014-8 × Pant Dhan 26 (44.71), UPR 3871-8-1-2-2 × Pant Dhan 4 (40.17), JGL 1172-7 × Pant Dhan 26 (38.05), Pant Dhan 24 × Pant Dhan 26 (35.23), CR 2644-2-6-4-3-2 × Pant Dhan 26 (33.92), UPRI 2012-19 × Pant Dhan 26 (33.813) and UPR 3199-464-1-2 × Pant Dhan 26 (32.75) exhibited significant and positive heterosis over the mid parental values for this character.

4.4.4.2 Heterobeltiosis

The heterobeltiosis for number of tillers per plant ranged from -60.87 to 63.38. out of 51 cross evaluated, eleven cross combinations namely UPRI 2008-8 × Pant Dhan 26 (63.38), BBL 180-5-1-4-1 × Pant Dhan 26 (52.38), UPR 3871-8-1-2-2 × Pant Dhan 26 (49.02), Pant Dhan 24 × Pant Dhan 4 (33.82), Pant Dhan 24 × Pant Dhan 4 & 23 (31.48), JGL 1172-7 × Pant Dhan 26 (25.80), UPR 3199-464-1-2 × Pant Dhan 26 (23.611), CR 2644-2-6-4-3-2 × Pant Dhan 26 (22.95), BBL 180-5-1-4-1 × Pant Dhan 23 (22.22) and UPR 3199-464-1-2 × Pant Dhan 23 (21.53) exhibited significant and positive heterosis over the better parent. Nine cross combinations showed significant and negative heterobeltiosis for this character.

4.4.4.3 Standard heterosis

The standard heterosis over the standard parent Govind ranged from -19.51 to 182.92. Out of 51 crosses evaluated, thirty six cross combinations viz., UPRI 2008-8 × Pant Dhan 26 (182.92), BBL 180-5-1-4-1 × Pant Dhan 26 (134.14), UPRI 2012-19 × Pant Dhan 26 (126.82), Pant Dhan 19 × Pant Dhan 4 (121.94), UPRI 2014-8 × Pant Dhan 26 (117.06), Pant Dhan 19 × Pant Dhan 4 (102.43), UPR 3871-8-1-2-2 × Pant Dhan 4 (99.99), UPR 3199-464-1-2 × Pant Dhan 23 (92.67), JGL 1172-7 × Pant Dhan 26 (90.23), BBL 180-5-1-4-1 × Pant Dhan 23 (87.80), UPR 3871-8-1-2-2 × Pant Dhan 26 (85.36), UPRI 2012-10 × Pant Dhan 23 (82.92), Pant Dhan 22 × Pant Dhan 4, Pant Dhan 22 × Pant Dhan 26 (78.04), Pant Dhan 24 × Pant Dhan 26 (73.17), CR 2644-2-6-4-3-2 × Pant Dhan 4 (70.72), UPRI 2011-21 × Pant

Dhan 26, Pant Dhan 19 × Pant Dhan 26 (68.28), UPRI 2008-6 × Pant Dhan 4 (65.85) and UPRI 2012-10 × Pant Dhan 26 (63.41) showed significant and positive standard heterosis over check parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 ranged from -69.31 to 31.82. Out of 51 crosses evaluated, five cross combinations viz., UPRI 2008-8 × Pant Dhan 26 (31.82), BBL 180-5-1-4-1 × Pant Dhan 26 (9.09), UPRI 2012-19 × Pant Dhan 26 (5.68), Pant Dhan 24 × Pant Dhan 4 (3.41) and UPRI 2014-8 × Pant Dhan 26 (1.13) showed significant positive and forty crosses showed significant and negative standard heterosis over check parent Pant Dhan 4 for this character.

Maximum number of tillers and grains per panicle both are essential for being a genotype to emerge as high yielding variety that's why for the trait number of tillers per plant positive heterosis is desirable. The result revealed that crosses UPRI 2008-8 × Pant Dhan 26, BBL 180-5-1-4-1 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 26 and Pant Dhan 19 × Pant Dhan 4 exhibited high value of standard heterosis over standard check Govind and Pant Dhan 4. Positive heterosis for tillers per plant was also reported by **Anand and Singh (2002), Veeresha *et al.* (2013), Parihar and Pathak (2008), Tiwari *et al.* (2011), Rukmini *et al.* (2014) and Khute *et al.* (2015).**

4.4.5 Panicle length (cm)

4.4.5.1 Mid parent heterosis

The average heterosis for panicle length ranged from -14.26 to 24.22. Out of 51 crosses evaluated, twelve cross combinations namely, NDR 3012 × Pant Dhan 26 (24.22), UPRI 2008-6 × Pant Dhan 23 (19.26), NDR 3012 × Pant Dhan 23 (18.81), UPRI 2014-8 × Pant Dhan 4 (14.90), Pant Dhan 22 × Pant Dhan 23 (14.80), CR 2644-2-6-4-3-2 × Pant Dhan 4 (13.25), NDR 3012 × Pant Dhan 4 (10.96), UPRI 2012-10 × Pant Dhan 26 (10.51), JGL 1172-7 × Pant Dhan 4 (10.23), UPRI 2008-8 × Pant Dhan 4 (10.09) and UPR 3871-8-1-2-2 × Pant Dhan 26 (8.48) showed significant positive mid parent heterosis and eight crosses showed significant negative mid parent heterosis for this character.

(Contd.) Table (contd.) 4.9: Estimates of heterosis for Panicle length (cm) and Number of grains per panicle in rice

Sl. No.	Crosses	Panicle length (cm)				Number of grains per panicle			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	4.66	4.48	21.70**	2.30	44.22**	30.69**	106.48**	76.63**
2.	UPRI 2011-21 X Pant Dhan 23	-14.26	-14.67**	-0.96	-16.74	27.01**	26.85**	100.40**	71.43**
3.	UPRI 2011-21 X Pant Dhan 26	-0.63	-3.14	18.40*	-0.46	70.41**	68.42**	172.44**	133.06**
4.	UPRI 2008-6 X Pant Dhan 4	-28.31**	-28.65**	-16.89	-30.13	1.12	0.54	30.54**	11.67**
5.	UPRI 2008-6 X Pant Dhan 23	19.26**	19.04**	37.36**	15.47*	22.01**	11.27**	75.34**	50.00**
6.	UPRI 2008-6 X Pant Dhan 26	1.73	-1.12	20.87**	1.61	-0.56	-10.37	44.96**	24.01**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-12.94*	-14.28**	3.02	-13.39	0.00	-10.27	44.94**	23.99**
8.	BBL 180-5-1-4-1 X Pant Dhan 23	4.55	2.28	22.93**	3.34	-15.31	-16.35	35.12**	15.59**
9.	BBL 180-5-1-4-1 X Pant Dhan 26	4.24	3.37	26.37**	6.23	-1.81	-1.87	58.72**	35.77**
10.	UPRI 2012-10 X Pant Dhan 4	0.00	-3.24	12.70	-5.25	0.00	-6.11	20.42**	3.01
11.	UPRI 2012-10 X Pant Dhan 23	- 11.04*	-13.38**	-0.41	-16.28	14.54**	-1.84	54.67**	32.32**
12.	UPRI 2012-10 X Pant Dhan 26	10.51*	4.49	27.74**	7.38	48.93**	26.25**	104.23**	74.70**
13.	UPRI 2008-8 X Pant Dhan 4	10.09*	6.13	23.62**	3.92	36.44**	29.75**	84.64**	57.95**
14.	UPRI 2008-8 X Pant Dhan 23	6.52	3.34	18.81**	-0.11	18.96**	13.20**	78.38**	52.59**
15.	UPRI 2008-8 X Pant Dhan 26	4.35	-1.68	20.19**	1.03	20.45**	13.21**	83.13**	56.65**
16.	UPRI 2012-19 X Pant Dhan 4	0.00	-1.82	14.33	-3.86	0.00	-9.25	16.46**	-0.37
17.	UPRI 2012-19 X Pant Dhan 23	4.23	2.98	18.40*	-0.46	37.06**	14.01**	79.66**	53.69**

18.	UPRI 2012-19 X Pant Dhan 26	3.10	-1.12	20.87**	1.61	4.76	-13.74	39.51**	19.35**
19.	Pant Dhan 22 X Pant Dhan 4	7.38*	2.12	31.86**	10.85	29.14**	26.09**	69.84**	45.29**
20.	Pant Dhan 22 X Pant Dhan 23	14.80**	8.51*	40.10**	17.78**	38.80**	28.72**	102.84**	73.52**
21.	Pant Dhan 22 X Pant Dhan 26	6.01	3.19	33.24**	12.00	75.73**	61.03**	160.48**	122.83**
22.	Pant Dhan 10 X Pant Dhan 4	-1.52	-4.48	11.22	-6.46	-2.80	-14.46	9.77**	-6.09
23.	Pant Dhan 10 X Pant Dhan 23	-0.85	-3.22	11.26	-6.46	-16.33	-32.27	6.72**	-8.70
24.	Pant Dhan 10 X Pant Dhan 26	-14.04**	-18.53**	-0.41	-16.28	-21.64	-37.19	1.60	-13.08
25.	Pant Dhan 18 X Pant Dhan 4	1.58	1.17	18.81*	-0.11	-0.13	-15.55	8.38**	-7.28
26.	Pant Dhan 18 X Pant Dhan 23	2.83	1.75	19.50*	0.46	24.94**	-2.35	53.86**	31.62**
27.	Pant Dhan 18 X Pant Dhan 26	-6.01	-7.86	12.63	-5.33	27.38 **	-1.37	59.53**	36.47**
28.	Pant Dhan 24 X Pant Dhan 4	-4.92	-9.57*	16.75	-1.84	-11.70	-17.01	21.07**	3.57*
29.	Pant Dhan 24 X Pant Dhan 23	4.67	-1.06	27.74**	7.38	29.75**	24.94**	96.88**	68.42**
30.	Pant Dhan 24 X Pant Dhan 26	-9.83*	-12.23*	13.33	-4.73	-9.30	-13.74	39.51**	19.35**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	-3.60	-8.60*	6.45	-10.50	4.05	-12.45	64.68**	40.88**
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-0.43	-5.01	9.20	-8.20	5.10*	-3.44	81.71**	55.44**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	8.48*	0.56	22.93**	3.34	36.40**	26.81**	138.67**	104.17**
34.	UPR 3199-464-1-2 X Pant Dhan 4	-3.95	-6.48	14.97	-3.35	-0.15	-17.30	61.70**	38.32**
35.	UPR 3199-464-1-2 X Pant Dhan 23	-1.50	-4.69	17.16*	-1.50	-0.18	-9.87	76.24**	50.76**
36.	UPR 3199-464-1-2 X Pant Dhan 26	0.28	0.00	22.93**	3.34	0.53	-8.15	79.60**	53.64**
37.	UPRI 2014-8 X Pant Dhan 4	14.90**	13.20**	31.86**	10.85	13.14**	9.87**	49.66**	28.02**

38.	UPRI 2014-8 X Pant Dhan 23	6.02	5.13	20.87**	1.61	10.61**	3.11	62.49**	39.00**
39.	UPRI 2014-8 X Pant Dhan 26	-6.01	-9.55*	10.55	-7.04	13.65**	4.67*	69.32**	44.84**
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	13.25**	10.84*	29.11**	8.54	22.10 **	4.28*	89.01**	61.69**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.00	-1.49	13.25	-4.79	-0.00	-6.53	69.42**	44.93**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	4.58	0.00	22.25**	2.77	30.26**	23.25**	123.40**	91.11**
43.	NDR 3012 X Pant Dhan 4	10.96*	2.59	19.50*	0.46	42.26**	28.82**	65.33**	41.43**
44.	NDR 3012 X Pant Dhan 23	18.81**	10.51*	27.05**	6.81	35.73**	12.70**	77.59**	51.92**
45.	NDR 3012 X Pant Dhan 26	24.22**	12.36*	37.36**	15.47*	27.17**	4.51*	69.05**	44.61**
46.	JGL 1172-7 X Pant Dhan 4	10.23	5.37	34.61**	13.16*	44.08**	19.41**	133.08**	99.39**
47.	JGL 1172-7 X Pant Dhan 23	4.13	-1.07	26.37**	6.23	45.19**	31.20**	156.11**	119.09**
48.	JGL 1172-7 X Pant Dhan 26	2.19	0.00	27.74**	7.38	43.37**	31.09**	155.89**	118.90**
49.	Pant Dhan 19 X Pant Dhan 4	5.32	4.53	23.62**	3.92	16.05**	12.91**	44.91**	23.96**
50.	Pant Dhan 19 X Pant Dhan 23	4.82	3.36	22.25**	2.70	41.96**	25.66**	98.02**	69.39**
51.	Pant Dhan 19 X Pant Dhan26	2.34	0.67	23.07**	3.46	37.20**	20.08**	94.25**	66.17**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

4.4.5.2 Heterobeltiosis

The heterobeltiosis for panicle length ranged from -28.65 to 19.04. Out of 51 crosses evaluated, six cross combinations viz., UPRI 2008-6 × Pant Dhan 23 (19.04), UPRI 2014-8 × Pant Dhan 4 (13.20), NDR 3012 × Pant Dhan 26 (12.36), CR 2644-2-6-4-3-2 × Pant Dhan 4 (10.84), NDR 3012 × Pant Dhan 23 (10.51) and Pant Dhan 22 × Pant Dhan 23 (8.51) showed significant and positive heterobeltiosis heterobeltiosis for this character.

4.4.5.3 Standard heterosis

The standard heterosis over the check parent Govind for panicle length ranged from -16.89 to 40.10. Out of 51 crosses evaluated, thirty five cross combination namely, Pant Dhan 22 × Pant Dhan 23 (40.10), NDR 3012 × Pant Dhan 26, UPRI 2008-6 × Pant Dhan 23 (37.36), UPRI 2014-8 × Pant Dhan 4, Pant Dhan 22 × Pant Dhan 4 (31.86), CR 2644-2-6-4-3-2 × Pant Dhan 4 (29.11), UPRI 2012-10 × Pant Dhan 26, Pant Dhan 24 × Pant Dhan 23 & JGL 1172-7 × Pant Dhan 4 (27.74), Pant Dhan 19 × Pant Dhan 23 (23.62), UPR 3199-464-1-2 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 26, BBL 180-5-1-4-1 × Pant Dhan 23 (22.938), UPRI 2011-21 × Pant Dhan 4 (21.70), UPRI 2008-6 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 26 (20.87), UPR 3199-464-1-2 × Pant Dhan 23 (17.16) and Pant Dhan 24 × Pant Dhan 26 (13.32) showed significant positive standard heterosis over standard parent Govind.

The standard heterosis over the check parent Pant Dhan 4 for panicle length ranged from -16.74 to 17.78. Out of 51 crosses evaluated, only four cross combinations namely, Pant Dhan 22 × Pant Dhan 23 (17.78), UPRI 2008-6 × Pant Dhan 23, NDR 3012 × Pant Dhan 26 (15.47), JGL 1172-7 × Pant Dhan 4 (13.16) showed significant positive standard heterosis over standard parent Pant Dhan 4 for this character. The similar result was also obtained by **Patil *et al.* (2003), Verma *et al.* (2005), Kumar *et al.* (2010), Bagheri and Jelodar (2010), Tiwari *et al.* (2011), Mirarab *et al.* (2011), Latha *et al.* (2013), Hussain and Sanghera (2012) and Hefena *et al.* (2016)**

4.4.6 Number of grains per panicle

4.4.6.1 Mid parent heterosis

The average heterosis for number of grains per panicle ranged from -21.64 to 75.73. Out of 51 crosses evaluated, thirty two cross combinations namely Pant Dhan 22 × Pant Dhan 26 (75.73), UPRI 2011-21 × Pant Dhan 26 (70.41), UPRI 2012-10 × Pant Dhan 26 (48.93),

JGL 1172-7 × Pant Dhan 23 (45.19), UPRI 2011-21 × Pant Dhan 4 (44.22), JGL 1172-7 × Pant Dhan 4 (44.08), NDR 3012 × Pant Dhan 4 (42.26), Pant Dhan 19 × Pant Dhan 23 (41.96), Pant Dhan 22 × Pant Dhan 23 (38.80), UPRI 2008-8 × Pant Dhan 4 (36.44), UPR 3871-8-1-2-2 × Pant Dhan 26 (36.40), NDR 3012 × Pant Dhan 23 (35.73), Pant Dhan 24 × Pant Dhan 23 (29.75), Pant Dhan 22 × Pant Dhan 4 (29.14), Pant Dhan 18 × Pant Dhan 26 (27.38), UPRI 2011-21 × Pant Dhan 23 (27.01), Pant Dhan 18 × Pant Dhan 23 (24.94) and UPRI 2008-6 × Pant Dhan 23 (22.01) showed significant and positive average heterosis for this character.

4.4.6.2 Heterobeltiosis

The heterobeltiosis for number of grains per panicle ranged from -37.19 to 68.42. Out of 51 crosses evaluated, twenty eight cross combinations namely, UPRI 2011-21 × Pant Dhan 26 (68.42), Pant Dhan 22 × Pant Dhan 26 (61.03), JGL 1172-7 × Pant Dhan 23 (31.20), UPRI 2011-21 × Pant Dhan 4 (30.69), UPRI 2008-8 × Pant Dhan 4 (29.75), NDR 3012 × Pant Dhan 4 (28.82), Pant Dhan 22 × Pant Dhan 23 (28.72), UPRI 2011-21 × Pant Dhan 23 (26.85), UPRI 2012-10 × Pant Dhan 26 (26.25), Pant Dhan 19 × Pant Dhan 23 (25.66), Pant Dhan 24 × Pant Dhan 23 (24.94), CR 2644-2-6-4-3-2 × Pant Dhan 26 (23.25), Pant Dhan 19 × Pant Dhan 26 (20.08), JGL 1172-7 × Pant Dhan 4 (19.41), UPRI 2012-19 × Pant Dhan 23 (14.01) and UPRI 2008-8 × Pant Dhan 26 (13.21) exhibited significant and positive heterobeltiosis heterobeltiosis for this character.

4.4.6.3 Standard heterosis

The standard heterosis over the standard parent Govind for number of grains per panicle ranged from -1.60 to 172.44. Almost all crosses showed highly significant and positive standard heterosis which are UPRI 2011-21 × Pant Dhan 26 (172.44), Pant Dhan 22 × Pant Dhan 26 (160.48), JGL 1172-7 × Pant Dhan 23 (156.11), JGL 1172-7 × Pant Dhan 26 (155.89), UPR 3871-8-1-2-2 × Pant Dhan 26 (138.67), CR 2644-2-6-4-3-2 × Pant Dhan 26 (123.40), UPRI 2011-21 × Pant Dhan 4 (106.48), UPRI 2012-10 × Pant Dhan 26 (104.23), Pant Dhan 22 × Pant Dhan 23 (102.84), UPRI 2011-21 × Pant Dhan 23 (100.40), Pant Dhan 19 × Pant Dhan 23 (98.02), Pant Dhan 24 × Pant Dhan 23 (96.88), Pant Dhan 19 × Pant Dhan 26 (94.25), CR 2644-2-6-4-3-2 × Pant Dhan 4 (89.01), UPRI 2008-8 × Pant Dhan 4 (84.64), UPR 3871-8-1-2-2 × Pant Dhan 23 (81.71), UPRI 2012-19 × Pant Dhan 23 (79.66), UPR 3199-464-1-2 × Pant Dhan 26 (79.60), NDR 3012 × Pant Dhan 23 (77.59), UPR 3199-464-1-2 × Pant Dhan 23 (76.24), UPRI 2008-6 × Pant Dhan 23 (75.34), Pant Dhan 24 × Pant Dhan 4 (69.840), UPRI 2014-8 × Pant Dhan 26 (69.32), UPRI 2014-8 × Pant Dhan 23 (62.49), UPR 3199-464-1-2 × Pant Dhan 4 (60.70), Pant Dhan 18 ×

Pant Dhan 26 (59.53), BBL 180-5-1-4-1 × Pant Dhan 26 (58.72), UPRI 2012-10 × Pant Dhan 23 (54.67), Pant Dhan 18 × Pant Dhan 23 (53.86), UPRI 2014-8 × Pant Dhan 4 (49.66) and Pant Dhan 19 × Pant Dhan 4 (44.91) exhibited significant positive standard heterosis over the check parent Govind for this character.

The standard heterosis over the standard parent Pant Dhan 4 for number of grains per panicle ranged from -13.08 to 133.06. Almost all crosses showed highly significant and positive standard heterosis which are UPRI 2011-21 × Pant Dhan 26 (133.06), Pant Dhan 22 × Pant Dhan 26 (122.83), JGL 1172-7 × Pant Dhan 23 (119.09), JGL 1172-7 × Pant Dhan 26 (118.90), UPR 3871-8-1-2-2 × Pant Dhan 26 (104.17), JGL 1172-7 × Pant Dhan 4 (99.39), CR 2644-2-6-4-3-2 × Pant Dhan 26 (91.11), UPRI 2011-21 × Pant Dhan 4 (76.63), UPRI 2012-10 × Pant Dhan 26 (74.71), Pant Dhan 22 × Pant Dhan 23 (73.52), UPRI 2011-21 × Pant Dhan 23 (71.43), Pant Dhan 19 × Pant Dhan 23 (69.39), Pant Dhan 24 × Pant Dhan 23 (68.42), Pant Dhan 19 × Pant Dhan 26 (66.17), CR 2644-2-6-4-3-2 × Pant Dhan 4 (61.69), UPRI 2008-8 × Pant Dhan 4 (56.65), UPR 3871-8-1-2-2 × Pant Dhan 23 (5.44), UPRI 2012-19 × Pant Dhan 23 (53.69), UPR 3199-464-1-2 × Pant Dhan 26 (53.64), UPRI 2008-8 × Pant Dhan 23 (52.59), NDR 3012 × Pant Dhan 23 (51.92), UPR 3199-464-1-2 × Pant Dhan 23 (50.76), UPRI 2008-6 × Pant Dhan 23 (50.00), Pant Dhan 22 × Pant Dhan 4 (45.290), CR 2644-2-6-4-3-2 × Pant Dhan 23 (44.93), UPRI 2014-8 × Pant Dhan 26 (44.84), UPR 3871-8-1-2-2 × Pant Dhan 4 (40.88) and UPR 3199-464-1-2 × Pant Dhan 4 (38.329) over standard parent Pant Dhan 4 for this character. The results were agreement with findings of **Virmani *et al.* (1982)**, **Annadurai and Nadarajan (2001), Raj *et al.* (2007), Parihar and Pathak (2008)**, **Saravanan *et al.* (2008), Kumar *et al.* (2010), Patil *et al.* (2012)**, **Devi *et al.* (2014), Chouhan *et al.* (2016) and Premkumar *et al.* (2017).**

4.4.8 Spikelet fertility (%)

4.4.8.1 Mid parent heterosis

The average heterosis for spikelet fertility ranged from -54.12 to 72.72. Out of 51 cross evaluated, twenty three cross combinations namely, UPRI 2014-8 × Pant Dhan 23 (72.72), NDR 3012 × Pant Dhan 23 (62.54), UPRI 2014-8 × Pant Dhan 4 (53.245), UPRI 2014-8 × Pant Dhan 26 (41.71), UPR 3871-8-1-2-2 × Pant Dhan 26 (34.62), UPRI 2008-8 × Pant Dhan 4 (30.81), NDR 3012 × Pant Dhan 26 (26.99), JGL 1172-7 × Pant Dhan 4 (23.32), UPRI 2008-6 × Pant Dhan 23 (22.97), Pant Dhan 19 × Pant Dhan 26 (22.73), JGL 1172-7 × Pant Dhan 23 (21.20), UPRI 2008-8 × Pant Dhan 23 (20.52), Pant Dhan 22 × Pant Dhan 26 (20.45), Pant Dhan 10 × Pant Dhan 23 (20.42), Pant Dhan 19 × Pant Dhan 23 (18.286), BBL

180-5-1-4-1 × Pant Dhan 4 (17.60) and Pant Dhan 10 × Pant Dhan 26 (16.46) showed significant and positive average heterosis over mid parental values for this character.

4.4.8.2 Heterobeltiosis

The heterobeltiosis for spikelet fertility ranged from -62.36 to 16.69. Out of 51 crosses evaluated, only five cross combinations namely, Pant Dhan 10 × Pant Dhan 23 (16.69), Pant Dhan 10 × Pant Dhan 26 (13.86), Pant Dhan 24 × Pant Dhan 26 (8.81), UPRI 2014-8 × Pant Dhan 23 (6.04) and Pant Dhan 22 × Pant Dhan 26 (5.68) exhibited significant and positive heterosis over the better parent for this character.

4.4.8.3 Standard heterosis

The standard heterosis over the check parent Govind for spikelet fertility ranged from -61.84 to 23.82. Out of 51 crosses evaluated, only five cross combinations namely, Pant Dhan 10 × Pant Dhan 23 (23.82), Pant Dhan 10 × Pant Dhan 26 (20.81), Pant Dhan 24 × Pant Dhan 26 (10.30), Pant Dhan 10 × Pant Dhan 4 (7.09) and Pant Dhan 22 × Pant Dhan 26 (7.06) showed significant and positive heterosis over the standard check Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for spikelet fertility ranged from -42.20 to 74.59. Out of 51 crosses evaluated, thirty five cross combinations namely, Pant Dhan 10 × Pant Dhan 23 (74.59), Pant Dhan 10 × Pant Dhan 26 (70.35), Pant Dhan 24 × Pant Dhan 26 (55.52), Pant Dhan 10 × Pant Dhan 4 (51.00), Pant Dhan 22 × Pant Dhan 26 (50.96), UPRI 2014-8 × Pant Dhan 23 (48.82), Pant Dhan 18 × Pant Dhan 26 (44.46), UPRI 2008-6 × Pant Dhan 23 (42.74), NDR 3012 × Pant Dhan 23 (42.61), UPRI 2008-8 × Pant Dhan 4 (41.09), Pant Dhan 24 × Pant Dhan 23 (38.62), UPR 3871-8-1-2-2 × Pant Dhan 26 (34.86), UPRI 2014-8 × Pant Dhan 23 (33.87), UPRI 2011-21 × Pant Dhan 4 (33.24), Pant Dhan 19 × Pant Dhan 26 (33.07), Pant Dhan 18 × Pant Dhan 4 (32.48), Pant Dhan 22 × Pant Dhan 23 (32.29), BBL 180-5-1-4-1 × Pant Dhan 23 (30.17), UPRI 2008-8 × Pant Dhan 23 (28.56), UPRI 2012-10 × Pant Dhan 4 (27.17), Pant Dhan 19 × Pant Dhan 23 (26.71), UPRI 2011-21 × Pant Dhan 26 (26.13), UPRI 2014-8 × Pant Dhan 26 (23.93), CR 2644-2-6-4-3-2 × Pant Dhan 23 (20.30), UPRI 2012-10 × Pant Dhan 26 (19.99), Pant Dhan 18 × Pant Dhan 23 (18.89), UPRI 2012-19 × Pant Dhan 4 (17.15), JGL 1172-7 × Pant Dhan 26 (14.21), UPR 3871-8-1-2-2 × Pant Dhan 4 (13.47), NDR 3012 × Pant Dhan 26 (13.06), JGL 1172-7 × Pant Dhan 4 (8.07) and UPRI 2012-10 × Pant Dhan 23 (8.05) showed significant and positive heterosis over standard parent Pant Dhan 4 for this character. The findings were supported with the earlier reports of **Satake and Yoshida (1978), Prasad *et al.* (2006), Saravanan *et al.* (2008), Kumar *et al.* (2010), Tiwari *et al.* (2011), Saidaiah *et al.* (2012).**

(Contd.) Table 4.9: Estimates of heterosis for spikelet fertility (%) and 1000 grain weight (g) in rice

Sl. No.	Crosses	Spikelet fertility (%)				1000 grain weight (g)			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	0.01	-6.64	-5.49	33.24**	-25.15	-33.06	2.52	-16.36
2.	UPRI 2011-21 X Pant Dhan 23	-24.43	-28.90	-29.23	-0.22	-28.21	-33.79	-5.31	-22.12
3.	UPRI 2011-21 X Pant Dhan 26	-5.39	-11.74	-10.54	26.13**	-30.66	-39.28	-2.36	-19.95
4.	UPRI 2008-6 X Pant Dhan 4	-18.28	-32.86	-32.03	-4.17	-32.54	-46.16	-17.53	-31.11
5.	UPRI 2008-6 X Pant Dhan 23	22.97**	1.71	1.23	42.74**	2.81	-15.77	20.46	-3.16
6.	UPRI 2008-6 X Pant Dhan 26	-10.80	-26.75	-25.75	4.69	-33.60	-47.95	-16.29	-30.20
7.	BBL 180-5-1-4-1 X Pant Dhan 4	17.60**	-6.77	-5.62	33.06**	46.90**	25.38**	92.05**	49.50**
8.	BBL 180-5-1-4-1 X Pant Dhan 23	16.27**	-7.24	-7.68	30.17**	13.92	0.09	43.15**	13.53
9.	BBL 180-5-1-4-1 X Pant Dhan 26	-11.97	-30.25	-29.30	-0.31	27.95*	7.05	72.16**	34.87*
10.	UPRI 2012-10 X Pant Dhan 4	0.00	-10.90	-9.80	27.17**	-0.00	-9.44	38.71**	10.26
11.	UPRI 2012-10 X Pant Dhan 23	-14.22	-23.00	-23.36	8.05**	-6.04	-12.20	25.57**	0.59
12.	UPRI 2012-10 X Pant Dhan 26	-5.71	-16.04	-14.89	19.98**	9.30	-3.11	55.80**	22.83
13.	UPRI 2008-8 X Pant Dhan 4	30.81**	-1.14	0.06	41.09**	28.45*	-6.21	43.66*	13.90
14.	UPRI 2008-8 X Pant Dhan 23	20.52**	-8.39	-8.82	28.56**	-10.06	-32.86	-3.98	-21.14
15.	UPRI 2008-8 X Pant Dhan 26	-35.91	-51.59	-50.93	-30.81	-40.29	-57.06	-30.94	-40.98
16.	UPRI 2012-19 X Pant Dhan 4	-0.00	-17.91	-16.91	17.15**	0.00	-23.09	17.80	-5.11
17.	UPRI 2012-19 X Pant Dhan 23	-30.83	-42.85	-43.11	-19.79	-15.43	-33.34	-4.66	-21.65

18.	UPRI 2012-19 X Pant Dhan 26	-54.12	-62.36	-61.84	-46.20	32.95*	0.55	61.70**	27.17
19.	Pant Dhan 22 X Pant Dhan 4	-31.67	-40.05	-39.31	-14.43	-46.94	-47.61	-19.75	-32.75
20.	Pant Dhan 22 X Pant Dhan 23	6.65**	-5.73	-6.17	32.29**	4.03	1.83	52.07**	20.09
21.	Pant Dhan 22 X Pant Dhan 26	20.45**	5.62**	7.06**	50.96**	-11.71	-14.86	36.90**	8.93
22.	Pant Dhan 10 X Pant Dhan 4	3.30	0.93	7.09**	51.00**	16.60	6.06	62.47**	27.74
23.	Pant Dhan 10 X Pant Dhan 23	20.42**	16.69**	23.82**	74.59**	5.85	-0.63	42.11*	12.76
24.	Pant Dhan 10 X Pant Dhan 26	16.46**	13.86**	20.81**	70.35**	-0.03	-11.01	43.09*	13.49
25.	Pant Dhan 18 X Pant Dhan 4	0.62	-7.17	-6.03	32.48**	0.25	-6.78	42.79*	13.26
26.	Pant Dhan 18 X Pant Dhan 23	-8.87	-15.28	-15.67	18.89**	16.00	11.40*	59.32**	25.42
27.	Pant Dhan 18 X Pant Dhan 26	9.64**	1.07	2.45	44.46**	-34.68	-40.60	-4.48	-21.51
28.	Pant Dhan 24 X Pant Dhan 4	-7.87	-10.91	-9.81	27.15**	-18.15	-18.54	25.98	0.89
29.	Pant Dhan 24 X Pant Dhan 23	1.30	-1.22	-1.68	38.62**	-21.33	-24.29	17.08	-5.65
30.	Pant Dhan 24 X Pant Dhan 26	12.59**	8.81**	10.30**	55.52**	-20.47	-22.00	25.43	0.49
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	13.38**	-20.49	-19.52	13.47**	34.95**	-10.70	36.79	8.84
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-30.15	-50.78	-51.01	-30.92	-28.04	-51.55	-30.71	-40.81
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	34.62**	-5.63	-4.35	34.86**	24.53	-18.54	30.98	4.57
34.	UPR 3199-464-1-2 X Pant Dhan 4	-8.46	-35.07	-34.27	-7.32	1.78	-30.72	6.12	-13.71
35.	UPR 3199-464-1-2 X Pant Dhan 23	-4.31	-31.78	-32.10	-4.26	-1.22	-31.50	-2.03	-19.71
36.	UPR 3199-464-1-2 X Pant Dhan 26	-4.35	-32.17	-31.25	-3.06	-4.09	-35.54	3.64	-15.53
37.	UPRI 2014-8 X Pant Dhan 4	53.24**	-6.20	-5.05	33.87**	-12.69	-39.29	-7.01	-23.37

38.	UPRI 2014-8 X Pant Dhan 23	72.72**	6.04**	5.55	48.82**	23.62	-12.33	25.38	0.45
39.	UPRI 2014-8 X Pant Dhan 26	41.71**	-13.28	-12.10	23.93**	52.93**	4.91	68.72**	32.33*
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-24.06	-35.88	-35.10	-8.49	21.24	2.01	56.27**	23.18
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.82	-14.28	-14.68	20.30**	-0.00	-13.43	23.81	-0.70
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-41.64	-50.76	-50.08	-29.62	-16.66	-31.23	10.59	-10.42
43.	NDR 3012 X Pant Dhan 4	-3.43	-39.82	-39.09	-14.11	62.78**	2.56	57.11**	23.79
44.	NDR 3012 X Pant Dhan 23	62.54**	1.61	1.14	42.61**	69.42**	8.31	54.90**	22.17
45.	NDR 3012 X Pant Dhan 26	26.99**	-20.89	-19.83	13.06**	42.70**	-10.97	43.17*	13.54
46.	JGL 1172-7 X Pant Dhan 4	23.32**	-24.27	-23.34	8.07**	29.71 *	-18.39	25.01	0.18
47.	JGL 1172-7 X Pant Dhan 23	21.20**	-25.34	-25.69	4.77	23.48	-21.17	12.73	-8.85
48.	JGL 1172-7 X Pant Dhan 26	30.18**	-20.08	-18.99	14.21**	14.96	-28.37	15.18	-7.04
49.	Pant Dhan 19 X Pant Dhan 4	-5.73	-28.45	-27.58	2.11	11.14	-13.19	32.97	6.04
50.	Pant Dhan 19 X Pant Dhan 23	18.28**	-9.70	-10.12	26.71**	137.35**	90.13**	171.92**	108.26**
51.	Pant Dhan 19 X Pant Dhan26	22.73**	-6.89	-5.62	33.07**	11.77	-14.18	38.00	9.73

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

4.4.9 1000 grain weight (g)

4.4.9.1 Mid parent heterosis

The average heterosis for 1000 grain weight ranged from -46.94 to 137.35. Out of 51 crosses evaluated, eleven cross combinations namely, Pant Dhan 19 × Pant Dhan 23 (137.35), NDR 3012 × Pant Dhan 23 (69.42), NDR 3012 × Pant Dhan 4 (62.78), UPRI 2014-8 × Pant Dhan 26 (52.93), BBL 180-5-1-4-1 × Pant Dhan 4 (46.908), NDR 3012 × Pant Dhan 26 (42.70), UPR 3871-8-1-2-2 × Pant Dhan 4 (34.95), JGL 1172-7 × Pant Dhan 4 (29.71), UPRI 2008-8 × Pant Dhan 4 (28.45) and BBL 180-5-1-4-1 × Pant Dhan 26 (27.956) showed significant positive average heterosis over the mid parental values for this character.

4.4.9.2 Heterobeltiosis

The heterobeltiosis for 1000 grain weight ranged from -57.06 to 90.13. Out of 51 crosses evaluated, only three cross combinations namely, Pant Dhan 19 × Pant Dhan 23 (90.13), BBL 180-5-1-4-1 × Pant Dhan 4 (25.38) and Pant Dhan 18 × Pant Dhan 23 (11.40) showed significant and positive heterosis over the better parent for this character.

4.4.9.3 Standard heterosis

The standard heterosis over the check parent Govind for 1000 grain weight ranged from -30.94 to 171.92. Out of 51 crosses evaluated, nineteen cross combinations namely, Pant Dhan 19 × Pant Dhan 23 (171.92), BBL 180-5-1-4-1 × Pant Dhan 4 (92.08), BBL 180-5-1-4-1 × Pant Dhan 26 (72.15), UPRI 2014-8 × Pant Dhan 26 (68.72), Pant Dhan 10 × Pant Dhan 4 (62.47), UPRI 2012-19 × Pant Dhan 26 (61.70), Pant Dhan 18 × Pant Dhan 23 (59.32), NDR 3012 × Pant Dhan 4 (57.11), CR 2644-2-6-4-3-2 × Pant Dhan 4 (56.27), UPRI 2012-10 × Pant Dhan 26 (55.80), Pant Dhan 22 × Pant Dhan 23 (52.07), UPRI 2008-8 × Pant Dhan 4 (43.66), NDR 3012 × Pant Dhan 4 (43.17), Pant Dhan 10 × Pant Dhan 23 (42.11) and UPRI 2012-10 × Pant Dhan 4 (38.71) exhibited significant and positive heterosis over the standard check parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for 1000 grain weight ranged from -40.98 to 108.26. Out of 51 crosses evaluated, only four cross combinations namely, Pant Dhan 19 × Pant Dhan 23 (108.26), BBL 180-5-1-4-1 × Pant Dhan 4 (49.50),

BBL 180-5-1-4-1 × Pant Dhan 26 (34.87) and UPRI 2014-8 × Pant Dhan 26 (32.33) showed significant and positive heterosis over the standard check parent Pant Dhan 4 for this character. These results coincide with the findings of **Parihar and Pathak (2008), Roy *et al.* (2009), Tiwari *et al.* (2011), Kumar *et al.* (2012), Saidaiah *et al.* (2012).**

4.4.10 Grain length (mm)

4.4.10.1 Mid parent heterosis

The average heterosis for grain length ranged from -11.72 to 5.77. Out of 51 crosses evaluated, only four cross combinations namely BBL 180-5-1-4-1 × ant Dhan 23 (5.77), UPRI 2012-19 × Pant Dhan 23 (4.76), UPRI 2008-8 × Pant Dhan 23 (3.811) and Pant Dhan 22 × Pant Dhan 23 (2.285) showed significant positive average heterosis for this character.

4.4.10.2 Heterobeltiosis

The heterobeltiosis for grain length ranged from -15.30 to 4.27. Out of 51 crosses evaluated, only one cross combination i.e. BBL 180-5-1-4-1 × Pant Dhan 23 (4.270) showed significant positive heterobeltiosis over the better parent for this character.

4.4.10.3 Standard heterosis

The standard heterosis over the check parent Govind for grain length ranged from -14.14 to 1.03. Only two crosses i.e. BBL 180-5-1-4-1 × Pant Dhan 23 (1.031) and Pant Dhan 22 × Pant Dhan 23 (0.341) exhibited significant positive heterosis over the standard check parent Govind for this character.

(Contd.) Table 4.9: Estimation of heterosis for Grain length (mm) and Grain width (mm) in rice

Sl. No.	Crosses	Grain length (mm)				Grain width (mm)			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	-10.65**	-10.95**	-10.34**	-7.80**	3.89*	0.00	1.26	-3.62
2.	UPRI 2011-21 X Pant Dhan 23	-10.64**	-12.32**	-11.72**	-9.22**	4.93**	-3.40*	7.52**	2.39*
3.	UPRI 2011-21 X Pant Dhan 26	-10.92**	-11.22**	-10.00**	-7.44**	1.91	-3.61*	1.26	-3.62
4.	UPRI 2008-6 X Pant Dhan 4	1.28	-4.82*	-4.83**	-2.12*	3.14*	2.50*	3.76	-1.21
5.	UPRI 2008-6 X Pant Dhan 23	-0.37	-4.98*	-7.93**	-5.31**	1.79	-3.40*	7.52**	2.39*
6.	UPRI 2008-6 X Pant Dhan 26	-1.63	-8.16**	-6.90**	-4.25*	2.46*	0.00	5.01*	-0.01
7.	BBL 180-5-1-4-1 X Pant Dhan 4	0.88	-2.06	-2.07*	0.70	-1.28	-3.75*	-2.49	-7.24
8.	BBL 180-5-1-4-1 X Pant Dhan 23	5.77**	4.27*	1.03*	3.90*	7.31**	0.00	11.27**	6.01**
9.	BBL 180-5-1-4-1 X Pant Dhan 26	0.52	-3.06	-1.72*	1.06	6.91**	2.41*	7.52**	2.39*
10.	UPRI 2012-10 X Pant Dhan 4	-0.18	-6.20*	-6.21**	-3.54*	0.62	0.00	1.26	-3.62
11.	UPRI 2012-10 X Pant Dhan 23	-1.86	-6.40*	-9.31**	-6.73**	-11.37**	-15.90**	-6.24	-10.85
12.	UPRI 2012-10 X Pant Dhan 26	-2.00	-8.50**	-7.24**	-4.61*	2.46*	0.00	5.01*	-0.01
13.	UPRI 2008-8 X Pant Dhan 4	-6.78**	-10.00**	-10.00**	-7.44**	3.14*	2.50*	3.76	-1.21
14.	UPRI 2008-8 X Pant Dhan 23	3.81**	1.77	-1.38*	1.41*	-5.38*	-10.22**	0.01	-4.83
15.	UPRI 2008-8 X Pant Dhan 26	-8.15**	-11.90**	-10.69**	-8.15**	-2.46*	-4.81*	0.01	-4.83
16.	UPRI 2012-19 X Pant Dhan 4	0.00	-0.69	-0.69*	2.12*	0.00	-3.75*	-2.49	-7.24
17.	UPRI 2012-19 X Pant Dhan 23	4.76**	-5.59*	-6.90**	-4.25*	6.17**	-2.27*	8.77**	3.60*

18.	UPRI 2012-19 X Pant Dhan 26	-8.27**	-9.52**	-8.27**	-5.67*	-3.18*	-8.43**	-3.74	-8.44
19.	Pant Dhan 22 X Pant Dhan 4	-3.46**	-3.79	-3.79**	-1.06	12.82**	10.00**	11.27**	6.01**
20.	Pant Dhan 22 X Pant Dhan 23	2.28**	1.04	0.34*	3.19*	3.65*	-3.40*	7.52**	2.39*
21.	Pant Dhan 22 X Pant Dhan 26	-2.40**	-3.40	-2.07*	0.70	0.62	-3.61*	1.26	-3.62
22.	Pant Dhan 10 X Pant Dhan 4	-6.08**	-6.89*	-6.90**	-4.25*	-2.56	-5.00*	-3.74	-8.44
23.	Pant Dhan 10 X Pant Dhan 23	-3.88**	-4.56*	-6.21**	-3.54*	-3.65*	-10.22**	0.01	-4.83
24.	Pant Dhan 10 X Pant Dhan 26	-6.73**	-8.16**	-6.90**	-4.25*	3.14*	-1.20	3.76	-1.21
25.	Pant Dhan 18 X Pant Dhan 4	0.00	-0.69	-0.69*	2.12*	3.18*	1.25	2.51	-2.42
26.	Pant Dhan 18 X Pant Dhan 23	0.88	-0.00	-1.38*	1.41*	-0.60	-6.81**	3.76	-1.21
27.	Pant Dhan 18 X Pant Dhan 26	-11.72**	-12.92**	-11.72**	-9.22**	-5.00*	-8.43**	-3.74	-8.44
28.	Pant Dhan 24 X Pant Dhan 4	-5.55**	-6.20**	-6.21**	-3.54*	8.28**	6.25**	7.52**	2.39*
29.	Pant Dhan 24 X Pant Dhan 23	-5.11**	-5.94*	-7.24**	-4.61*	-0.66	-6.81**	3.76	-1.21
30.	Pant Dhan 24 X Pant Dhan 26	-10.34**	-11.55**	-10.34**	-7.80**	-8.75**	-12.04**	-7.49	-12.05
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	-6.59**	-12.09**	-12.07**	-9.57**	12.16**	3.75*	5.01*	-0.01
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-5.77**	-9.96**	-12.76**	-10.28**	-6.41**	-17.04**	-7.49	-12.05
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-1.81	-8.16**	-6.90**	-4.25*	-1.98	-10.84**	-6.24	-10.85
34.	UPR 3199-464-1-2 X Pant Dhan 4	0.58	-11.72**	-11.72**	-9.22**	6.49**	2.50*	3.76	-1.21
35.	UPR 3199-464-1-2 X Pant Dhan 23	0.00	-11.03**	-13.79**	-11.34**	-4.93*	-12.50**	-2.49	-7.24
36.	UPR 3199-464-1-2 X Pant Dhan 26	-0.58	-13.26**	-12.07**	-9.57**	5.73**	0.00	5.01*	-0.01
37.	UPRI 2014-8 X Pant Dhan 4	0.72	-4.48*	-4.48**	-1.77	1.25	1.20	2.51	-2.42

38.	UPRI 2014-8 X Pant Dhan 23	0.92	-2.84	-5.86**	-3.19*	-2.38	-6.81**	3.76	-1.21
39.	UPRI 2014-8 X Pant Dhan 26	-1.44	-7.14**	-5.86**	-3.19*	5.51**	3.61*	8.77**	3.60*
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-6.11**	-13.79**	-13.79**	-11.34**	-6.50**	-11.23**	0.01	-4.83
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.19	-6.58**	-9.48**	-6.91**	0.56	0.00	12.53**	7.21**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-7.23**	-15.30**	-14.14**	-11.70**	2.32	-1.12	11.27**	6.01**
43.	NDR 3012 X Pant Dhan 4	-7.93**	-7.93**	-7.93**	-5.31*	-1.20	-4.65*	3.76	-1.21
44.	NDR 3012 X Pant Dhan 23	-1.22	-2.75	-2.76*	0.00	1.14	0.00	11.27**	6.01**
45.	NDR 3012 X Pant Dhan 26	-3.42**	-4.08*	-2.76*	0.00	11.24**	9.30**	18.78**	13.23**
46.	JGL 1172-7 X Pant Dhan 4	1.23	-0.69	-0.69*	2.12*	22.75**	11.25**	12.53**	7.21**
47.	JGL 1172-7 X Pant Dhan 23	1.07	0.71	-2.41*	0.35	3.26*	-10.22**	0.01	-4.83
48.	JGL 1172-7 X Pant Dhan 26	-8.55**	-10.88**	-9.65**	-7.09**	0.00	-10.84**	-6.24	-10.85
49.	Pant Dhan 19 X Pant Dhan 4	-1.43	-4.48*	-4.48**	-1.77	-14.79**	-19.10**	-8.75	-13.26
50.	Pant Dhan 19 X Pant Dhan 23	0.54	-1.08	-4.14**	-1.41	-10.73**	-11.23**	0.01	-4.83
51.	Pant Dhan 19 X Pant Dhan26	-3.53**	-7.14**	-5.86**	-3.19*	0.00	-3.37*	8.77**	3.60*

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

The standard heterosis over the check parent Pant Dhan 4 for grain length ranged from -11.70 to 3.90. Seven cross combinations namely, BBL 180-5-1-4-1 × ant Dhan 23 (3.90), Pant Dhan 22 × Pant Dhan 23 (3.19), UPRI 2012-19 × Pant Dhan 4 (2.12), JGL 1172-7 × Pant Dhan 4 (2.12), Pant Dhan 18 × Pant Dhan 4 (2.12), Pant Dhan 18 × Pant Dhan 23 (1.41) and UPRI 2008-8 × Pant Dhan 23 (1.41) showed significant and positive standard heterosis over standard parent Pant Dhan 4 for this character. For grain length and grain width, heterosis is desirable in positive direction and the results showed considerable heterosis in this direction coincide with the findings of **Roy *et al.* (2009), Sen and Singh (2011), Tiwari *et al.* (2011) and Kumar *et al.* (2012), Gokulakrishnan and Kumar (2013).**

4.4.11 Grain width (mm)

4.4.11.1 Mid parent heterosis

The average heterosis for grain width ranged from -11.37 to 22.75. Out of the 51 crosses evaluated, thirty two cross combinations showed significant mid parent heterosis from which twenty three cross combinations namely JGL 1172-7 × Pant Dhan 4 (22.79), Pant Dhan 22 × Pant Dhan 4 (12.82), UPR 3871-8-1-2-2 × Pant Dhan 4 (12.16), NDR 3012 × Pant Dhan 26 (11.24), Pant Dhan 24 × Pant Dhan 4 (8.20), BBL 180-5-1-4-1 × Pant Dhan 23 (7.31), BBL 180-5-1-4-1 × Pant Dhan 26 (6.91), UPR 3199-464-1-2 × Pant Dhan 4 (6.49), UPRI 2012-19 × Pant Dhan 23 (6.17), UPR 3199-464-1-2 × Pant Dhan 26 (5.73), UPRI 2014-8 × Pant Dhan 26 (5.52), UPRI 2011-21 × Pant Dhan 23 (4.93), UPRI 2011-21 × Pant Dhan 4 (3.89), Pant Dhan 22 × Pant Dhan 23 (3.65), JGL 1172-7 × Pant Dhan 23 (3.26), Pant Dhan 18 × Pant Dhan 4 (3.18) and Pant Dhan 10 × Pant Dhan 26, UPRI 2008-8 × Pant Dhan and UPRI 2008-6 × Pant Dhan 4 (3.14) exhibited significant and positive average heterosis over the mid parental values for this character.

4.4.11.2 Heterobeltiosis

The heterobeltiosis for grain width ranged from -19.10 to 11.25. Out of 51 crosses evaluated, thirty nine cross combinations showed significant heterobeltiosis out of which ten cross combinations namely, JGL 1172-7 × Pant Dhan 4 (11.25), Pant Dhan 22 × Pant Dhan 4 (10.00), NDR 3012 × Pant Dhan 26 (9.30), Pant Dhan 24 × Pant Dhan 4 (6.25), UPR 3871-8-1-2-2 × Pant Dhan 4 (3.75), UPRI 2014-8 × Pant Dhan 26 (3.61), UPR 3199-464-1-2 × Pant Dhan 4, UPRI 2008-6 × Pant Dhan 4 and UPRI 2008-8 × Pant Dhan 4 (2.50) showed significant and positive heterobeltiosis over the better parent for this character.

4.4.11.3 Standard heterosis

The standard heterosis over the check parent Govind for grain width ranged from -8.75 to 18.78. Out of 51 crosses evaluated, twenty five cross combinations exhibited significant standard heterosis out of which nineteen cross combinations namely NDR 3012 × Pant Dhan 26 (18.78), JGL 1172-7 × Pant Dhan 4 (12.53), NDR 3012 × Pant Dhan 23, CR 2644-2-6-4-3-2 × Pant Dhan 26, BBL 180-5-1-4-1 × Pant Dhan 23 & Pant Dhan 22 × Pant Dhan 4 (11.27), Pant Dhan 19 × Pant Dhan 26, UPRI 2014-8 × Pant Dhan 26 & UPRI 2012-19 × Pant Dhan 23 (8.77), UPRI 2011-21 × Pant Dhan 23, UPRI 2008-6 × Pant Dhan 23, BBL 180-5-1-4-1 × Pant Dhan 26 & Pant Dhan 24 × Pant Dhan 4 (7.52), UPR 3871-8-1-2-2 × Pant Dhan 4, UPR 3199-464-1-2 × Pant Dhan 26 and UPRI 2012-10 × Pant Dhan 26 (5.01) showed significant and positive standard heterosis standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for grain width ranged from -13.26 to 13.23. Out of 51 crosses evaluated, thirty nine cross combinations exhibited significant standard heterosis out of which fifteen cross combinations namely NDR 3012 × Pant Dhan 26 (13.23), JGL 1172-7 × Pant Dhan 4, CR 2644-2-6-4-3-2 × Pant Dhan 23 (7.216), NDR 3012 × Pant Dhan 23, BBL 180-5-1-4-1 × Pant Dhan 23 & Pant Dhan 22 × Pant Dhan 4 (6.01), UPRI 2012-19 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 26 & Pant Dhan 19 × Pant Dhan 26 (3.60), Pant Dhan 22 × Pant Dhan 23, BBL 180-5-1-4-1 × Pant Dhan 26, UPRI 2011-21 × Pant Dhan 23 and UPRI 2008-6 × Pant Dhan 23 (2.39) showed significant positive standard heterosis over the standard parent Pant Dhan 4 for this character. These findings are uniformity with the results reported by **Kumar *et al.* (2010), Sen and Singh (2011), Tiwari *et al.* (2011), Gokulakrishnan and Kumar (2013).**

4.4.12 Kernel length (mm)

4.4.12.1 Mid parent heterosis

The average heterosis for kernel length ranged from -17.90 to 23.64. Out of 51 cross evaluated, thirty three cross combinations showed significant average heterosis out of which fifteen cross combinations namely UPRI 2012-19 × Pant Dhan 23 (23.64), Pant Dhan 10 × Pant Dhan 4 (17.03), UPRI 2012-10 × Pant Dhan 23 (16.57), UPRI 2012-19 × Pant Dhan 26 (16.16), Pant Dhan 10 × Pant Dhan 26 (11.93), Pant Dhan 24 × Pant Dhan 4 (7.96), Pant Dhan 24 × Pant Dhan 23 (7.69), Pant Dhan 22 × Pant Dhan 23 (4.44), UPRI 2008-6 × Pant

Dhan 23 (3.13), NDR 3012 × Pant Dhan 23 (2.93), UPRI 2014-8 × Pant Dhan 4 (2.37) and BBL 180-5-1-4-1 × Pant Dhan 23 (2.23) exhibited significant positive mid parent heterosis and eighteen crosses showed significant and negative mid parent heterosis over the mid parental values for this character.

4.4.12.2 Heterobeltiosis

The heterobeltiosis for kernel length ranged from -23.55 to 20.55. Out of 51 cross evaluated, twenty two cross combinations showed significant heterobeltiosis out of which only six cross combinations namely UPRI 2012-19 × Pant Dhan 23 (20.55), Pant Dhan 10 × Pant Dhan 4 (16.39), UPRI 2012-10 × Pant Dhan 23 (13.33), UPRI 2012-19 × Pant Dhan 26 (9.27), Pant Dhan 10 × Pant Dhan 26 (8.76) and Pant Dhan 22 × Pant Dhan 23 (3.44) exhibited significant positive heterobeltiosis and sixteen crosses showed significant and negative heterobeltiosis for this character.

4.4.12.3 Standard heterosis

The standard heterosis over the standard parent Govind for kernel length ranged from -1.75 to 29.82. Out of 51 cross evaluated, thirty seven cross combinations namely Pant Dhan 18 × Pant Dhan 23 (29.82), UPRI 2012-19 × Pant Dhan 23 (26.90), Pant Dhan 10 × Pant Dhan 4 (24.56), UPRI 2012-19 × Pant Dhan 26 (23.97), Pant Dhan 10 × Pant Dhan 26 (23.39), UPRI 2012-10 × Pant Dhan 23 (19.29), Pant Dhan 18 × Pant Dhan 4 (16.95), NDR 3012 × Pant Dhan 26 (15.78), Pant Dhan 19 × Pant Dhan 26 (14.62), UPRI 2014-8 × Pant Dhan 4 (13.45), NDR 3012 × Pant Dhan 23 (12.86), JGL 1172-7 × Pant Dhan 26 (12.28), Pant Dhan 22 × Pant Dhan 26 (11.69), UPRI 2014-8 × Pant Dhan 26 (11.11), Pant Dhan 22 × Pant Dhan 23 (9.94), UPRI 2008-6 × Pant Dhan 26 & Pant Dhan 19 × Pant Dhan 23 (9.35), UPR 3199-464-1-2 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 4 (7.60), Pant Dhan 24 × Pant Dhan 4, NDR 3012 × Pant Dhan 4, UPRI 2014-8 × Pant Dhan 23 & BBL 180-5-1-4-1 × Pant Dhan 23 (7.01), UPRI 2008-8 × Pant Dhan 23 (6.43), UPRI 2008-6 × Pant Dhan 23 (5.84) and UPRI 2008-8 × Pant Dhan 4 (4.09) showed significant and positive standard heterosis over the standard parent Govind for this character.

(Contd.) Table 4.9: Estimates of heterosis for Kernel length (mm) and Kernel breadth (mm) in rice

Sl. No.	Crosses	Kernel length (mm)				Kernel breadth (mm)			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	-5.44*	-8.84**	-3.50	12.24	2.52	0.64	5.19	7.01
2.	UPRI 2011-21 X Pant Dhan 23	-3.44*	-6.66**	-1.75	14.28*	0.81	-4.61*	6.91	8.77
3.	UPRI 2011-21 X Pant Dhan 26	-7.18*	-13.40**	-1.75	14.28*	2.47	-1.58	6.91	8.77
4.	UPRI 2008-6 X Pant Dhan 4	-2.84*	-5.52*	0.00	16.32**	0.92	0.07	5.19	7.01
5.	UPRI 2008-6 X Pant Dhan 23	3.13*	0.55	5.84**	23.12**	-3.17	-6.15*	5.19	7.01
6.	UPRI 2008-6 X Pant Dhan 26	2.46*	-3.60*	9.35**	27.21**	3.22	1.58	10.36*	12.28*
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-6.40*	-7.18**	-1.75	14.26*	-6.97*	-11.76**	3.46	5.26
8.	BBL 180-5-1-4-1 X Pant Dhan 23	2.23*	1.67	7.01**	24.49**	-5.26*	-7.35**	8.63	10.52*
9.	BBL 180-5-1-4-1 X Pant Dhan 26	-4.30*	-8.24**	4.09*	21.08**	-8.39*	-11.76**	3.46	5.26
10.	UPRI 2012-10 X Pant Dhan 4	0.28	-2.76	2.92	19.72**	0.96	0.12	5.19	7.01
11.	UPRI 2012-10 X Pant Dhan 23	16.57**	13.33**	19.29**	38.77**	4.76	1.53	13.81**	15.78**
12.	UPRI 2012-10 X Pant Dhan 26	0.54	-5.67*	7.01**	24.49**	0.06	-1.58	6.91	8.77
13.	UPRI 2008-8 X Pant Dhan 4	-1.38	-1.65	4.09*	21.08**	-1.63	-1.63	3.46	5.26
14.	UPRI 2008-8 X Pant Dhan 23	1.11	1.11	6.43**	23.81**	-1.58	-4.61*	6.91	8.77
15.	UPRI 2008-8 X Pant Dhan 26	-2.13*	-5.67*	7.01**	24.49**	1.61	0.07	8.63	10.52*
16.	UPRI 2012-19 X Pant Dhan 4	0.00	-2.76	2.92	19.72**	0.84	-1.63	3.46	5.26

17.	UPRI 2012-19 X Pant Dhan 23	23.64**	20.55**	26.90**	47.61**	10.56**	4.61*	17.26**	19.29**
18.	UPRI 2012-19 X Pant Dhan 26	16.16**	9.27**	23.97**	44.21**	12.39**	7.93**	17.26**	19.29**
19.	Pant Dhan 22 X Pant Dhan 4	1.38	1.10	7.01**	24.49**	0.74	0.02	5.19	7.01
20.	Pant Dhan 22 X Pant Dhan 23	4.44*	3.44*	9.94**	27.89**	3.17	0.89	12.08**	14.03**
21.	Pant Dhan 22 X Pant Dhan 26	2.13*	-1.54	11.69**	29.93**	3.22	1.58	10.36**	12.28*
22.	Pant Dhan 10 X Pant Dhan 4	17.03**	16.39**	24.56**	44.89**	7.31*	6.45*	13.81**	15.78**
23.	Pant Dhan 10 X Pant Dhan 23	0.82	0.00	7.01**	24.49**	-2.36	-4.61*	6.91	8.77
24.	Pant Dhan 10 X Pant Dhan 26	11.93**	8.76**	23.39**	43.53**	8.80*	7.93**	17.26**	19.29**
25.	Pant Dhan 18 X Pant Dhan 4	-1.47	-11.11**	16.95**	36.05**	9.83**	6.35*	15.53**	17.54**
26.	Pant Dhan 18 X Pant Dhan 23	9.63**	-1.33	29.82**	51.02**	11.11**	7.69**	20.71**	22.80**
27.	Pant Dhan 18 X Pant Dhan 26	-17.90**	-23.55**	0.58	17.00**	-3.22	-4.76*	3.46	5.26
28.	Pant Dhan 24 X Pant Dhan 4	7.96**	1.10	7.01**	24.49**	3.33	1.63	6.91	8.77
29.	Pant Dhan 24 X Pant Dhan 23	7.69**	1.11	6.43**	23.81**	0.46	-4.61*	6.91	8.77
30.	Pant Dhan 24 X Pant Dhan 26	-2.84*	-11.85**	0.00	16.32**	-6.55*	-9.52**	-1.70	0.00
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	1.93	1.65	7.60**	25.170**	4.13	3.27	8.63	10.52
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-5.00*	-5.00*	0.00	16.32**	-10.40**	-13.84**	-3.43	-1.75
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-5.34*	-8.76**	3.50	20.40**	-4.05	-6.34*	1.74	3.50
34.	UPR 3199-464-1-2 X Pant Dhan 4	1.68	0.00	5.84**	23.12**	0.826	0.07	5.19	7.01
35.	UPR 3199-464-1-2 X Pant Dhan 23	1.97	0.55	5.84**	23.12**	-0.80	-4.61*	6.91	8.77
36.	UPR 3199-464-1-2 X Pant Dhan 26	-0.271	-5.15*	7.60**	25.17**	0.81	-1.58	6.91	8.77

37.	UPRI 2014-8 X Pant Dhan 4	2.37*	-2.02	13.45**	31.97**	9.83**	7.84**	15.53**	17.54**
38.	UPRI 2014-8 X Pant Dhan 23	-3.17*	-7.57**	7.01**	24.49**	-1.58	-4.61*	6.91	8.77
39.	UPRI 2014-8 X Pant Dhan 26	-3.06*	-4.04*	11.11**	29.25**	3.22	1.58	10.36*	12.28*
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	0.00	-0.54	6.43**	23.81**	6.87*	2.76	20.71**	22.80**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	-0.27	-1.09	5.84**	23.12**	-2.22	-5.71*	13.81**	15.78**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-8.75**	-11.34**	0.58	17.00**	-8.27*	-12.85**	5.19	7.01
43.	NDR 3012 X Pant Dhan 4	-2.66*	-6.15*	7.01**	24.49**	0.76	-5.71*	13.81**	15.78**
44.	NDR 3012 X Pant Dhan 23	2.93*	-1.02	12.86**	31.29**	5.18*	1.42	22.43**	24.56**
45.	NDR 3012 X Pant Dhan 26	1.79	1.53	15.78**	34.69**	11.27**	5.71*	27.60**	29.82**
46.	JGL 1172-7 X Pant Dhan 4	-3.74*	-6.73*	5.26**	22.44**	0.82	0.02	5.19	7.01
47.	JGL 1172-7 X Pant Dhan 23	-6.70*	-9.84**	1.75	18.36**	-7.20*	-10.76**	0.01	1.75
48.	JGL 1172-7 X Pant Dhan 26	-0.77	-1.03	12.28**	30.61**	2.43	-0.04	8.63	10.52*
49.	Pant Dhan 19 X Pant Dhan 4	-4.71*	-9.45**	6.43**	23.81**	-3.87	-8.82**	6.91	8.77
50.	Pant Dhan 19 X Pant Dhan 23	-1.83	-6.96*	9.35**	27.21**	-2.25	-4.41	12.08**	14.03**
51.	Pant Dhan 19 X Pant Dhan26	-0.75	-2.48	14.62**	33.33**	-0.76	-3.14	12.08**	14.03**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

The standard heterosis over the check parent Pant Dhan 4 for kernel length ranged from 12.24 to 51.02. All crosses showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. Similar trends has been reported by **Singh *et al.* (2011), Patil *et al.* (2012), Reddy *et al.* (2012) and Borah *et al.* (2017)**

4.4.13 Kernel breadth (mm)

4.4.13.1 Mid parent heterosis

The average heterosis for kernel breadth ranged from -10.40 to 12.39. Out of 51 crosses evaluated, twenty cross combinations showed significant average heterosis from which twelve cross combinations namely UPRI 2012-19 × Pant Dhan 26 (12.39), NDR 3012 × Pant Dhan 26 (11.27), Pant Dhan 18 × Pant Dhan 23 (11.11), UPRI 2012-19 × Pant Dhan 23 (10.56), Pant Dhan 18 × Pant Dhan 4 & UPRI 2014-8 × Pant Dhan 4 (9.83), Pant Dhan 10 × Pant Dhan 26 (8.80), Pant Dhan 10 × Pant Dhan 4 (7.31), CR 2644-2-6-4-3-2 × Pant Dhan 4 (6.87), NDR 3012 × Pant Dhan 23 (5.18) and UPR 3871-8-1-2-2 × Pant Dhan 4 (4.13) showed significant positive average heterosis and eight crosses showed significant negative average heterosis over the mid parental values for this character.

4.4.13.2 Heterobeltiosis

The heterobeltiosis for kernel breadth ranged from -13.84 to 7.93. Out of 51 crosses evaluated, twenty eight cross combinations showed significant better parent heterosis from which eight cross combinations namely UPRI 2012-19 × Pant Dhan 26, Pant Dhan 10 × Pant Dhan 26 (7.93), UPRI 2014-8 × Pant Dhan 4 (7.84), Pant Dhan 18 × Pant Dhan 23 (7.69), Pant Dhan 10 × Pant Dhan 4 (6.45), Pant Dhan 18 × Pant Dhan 4 (6.35), NDR 3012 × Pant Dhan 26 (5.71) and UPRI 2012-19 × Pant Dhan 23 (4.61) showed significant and positive heterobeltiosis and twenty cross combinations showed significant positive heterobeltiosis over the better parent for this character.

4.4.13.3 Standard heterosis

The standard heterosis over the standard parent Govind for kernel breadth ranged from -3.43 to 27.60. Out of 51 crosses evaluated, nineteen cross combinations namely NDR 3012 × Pant Dhan 26 (27.60), NDR 3012 × Pant Dhan 23 (22.43), Pant Dhan 18 × Pant Dhan 23 & CR 2644-2-6-4-3-2 × Pant Dhan 4 (20.71), UPRI 2012-19 × Pant Dhan 23, UPRI 2012-

19 × Pant Dhan 26 & Pant Dhan 10 × Pant Dhan 26 (17.26), Pant Dhan 18 × Pant Dhan 4 & UPRI 2014-8 × Pant Dhan 4 (15.53), UPRI 2012-10 × Pant Dhan 23, CR 2644-2-6-4-3-2 × Pant Dhan 23 & NDR 3012 × Pant Dhan 4 (13.81), Pant Dhan 22 × Pant Dhan 23, Pant Dhan 19 × Pant Dhan 23 & Pant Dhan 19 × Pant Dhan 26 (12.08), UPRI 2008-6 × Pant Dhan 26, Pant Dhan 22 × Pant Dhan 26 and UPRI 2014-8 × Pant Dhan 26 (10.36) showed significant and positive standard heterosis over the standard parent Govind for this character.

The standard heterosis over the standard parent Pant Dhan 4 for kernel breadth ranged from -1.75 to 29.82. Out of 51 crosses evaluated, twenty two cross combinations namely NDR 3012 × Pant Dhan 26 (29.82), NDR 3012 × Pant Dhan 23 (24.56), Pant Dhan 18 × Pant Dhan 23 & CR 2644-2-6-4-3-2 × Pant Dhan 4 (22.80), UPRI 2012-19 × Pant Dhan 23, UPRI 2012-19 × Pant Dhan 26 & Pant Dhan 10 × Pant Dhan 26 (19.29), Pant Dhan 18 × Pant Dhan 4 & UPRI 2014-8 × Pant Dhan 4 (17.54), UPRI 2012-10 × Pant Dhan 23, CR 2644-2-6-4-3-2 × Pant Dhan 23 & NDR 3012 × Pant Dhan 4 (15.78), Pant Dhan 22 × Pant Dhan 23, Pant Dhan 19 × Pant Dhan 23 & Pant Dhan 19 × Pant Dhan 26 (14.03), UPRI 2008-6 × Pant Dhan 26, Pant Dhan 22 × Pant Dhan 26 and UPRI 2014-8 × Pant Dhan 26 (12.28), BBL180-5-1-4-1 × Pant Dhan 23, UPRI 2008-8 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 4 and JGL 1172-7 × Pant Dhan 26 (10.52) showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. **Similar results coincide with the earlier reports of Reddy *et al.* (2012), Tiwari *et al.* (2011), Gokulakrishnan and Kumar (2013).**

4.4.13 Length/Breadth ratio

4.4.13.1 Mid parent heterosis

The average heterosis for L/B ratio ranged from -15.17 to 11.78. Out of 51 cross evaluated, thirty four cross combinations showed significant average heterosis out of which twelve cross combinations namely UPRI 2012-19 × Pant Dhan 23 (11.78), UPRI 2012-19 × Pant Dhan 23 (11.28), Pant Dhan 10 × Pant Dhan 4 (9.52), BBL 180-5-1-4-1×Pant Dhan 23 (8.05), Pant Dhan 24 × Pant Dhan 23 (7.71), UPRI 2008-6 × Pant Dhan 23 (6.52), UPR 3871-8-1-2-2 × Pant Dhan 23 (5.71), Pant Dhan 24 × Pant Dhan 26 (4.28), BBL 180-5-1-4-1 × Pant Dhan 26 (4.21) and UPRI 2012-19 × Pant Dhan 26 (3.65) exhibited significant positive mid parent heterosis and twelve crosses namely Pant Dhan 18 × Pant Dhan 26 (-15.17), Pant Dhan 18 × Pant Dhan 4 (-9.82), UPRI 2011-21 × Pant Dhan 26 (-9.42), NDR 3012 × Pant

Dhan 26 (-8.75), UPRI 2011-21 × Pant Dhan 23 (-7.78), UPRI 2014-8 × Pant Dhan 4 (-6.97), UPRI 2014-8 × Pant Dhan 26 (-6.21), UPRI 2011-21 × Pant Dhan 23 (-4.41), UPRI 2008-8 × Pant Dhan 26 (-3.59) and JGL 1172-7 × Pant Dhan 26 (-3.12) showed significant and negative mid parent heterosis over the mid parental values for this character.

4.4.13.2 Heterobeltiosis

The heterobeltiosis for L/B ratio ranged from -22.15 to 10.88. Out of 51 cross evaluated, twenty five cross combinations showed significant heterobeltiosis out of which six cross combinations namely UPRI 2012-10 × Pant Dhan 23 (10.88), Pant Dhan 10 × Pant Dhan 4 (9.21), Pant Dhan 24 × Pant Dhan 23 (6.02), UPRI 2008-6 × Pant Dhan 23 (5.82) and BBL 180-5-1-4-1 × Pant Dhan 23 (5.06) showed significant and positive heterobeltiosis and twenty crosses namely Pant Dhan 18 × Pant Dhan 26 (-22.15), Pant Dhan 18 × Pant Dhan 4 (-18.62), Pant Dhan 18 × Pant Dhan 23 (-13.92), NDR 3012 × Pant Dhan 26 (-13.09), UPRI 2011-21 × Pant Dhan 26 (-12.12), CR 2644-2-6-4-3-2 × Pant Dhan 4 (-10.00), UPRI 2014-8 × Pant Dhan 4 (10.98), UPRI 2014-8 × Pant Dhan 23 (-9.13), UPRI 2011-21 × Pant Dhan 4 (-8.87), UPRI 2014-8 × Pant Dhan 26 (-8.62), JGL 1172-7 × Pant Dhan 4 (-8.29), CR 2644-2-6-4-3-2 × Pant Dhan 26 (-7.79), JGL 1172-7 × Pant Dhan 23 (-6.73), UPRI 2011-21 × Pant Dhan 23 (-6.55), NDR 3012 × Pant Dhan 4 (-5.73), UPRI 2008-8 × Pant Dhan 26 (-5.62), UPRI 2008-8 × Pant Dhan 26 & BBL 180-5-1-4-1 × Pant Dhan 4 (-5.50) and JGL 1172-7 × Pant Dhan 26 (-5.18) showed significant and negative heterobeltiosis for this character.

(Contd.) Table 4.9: Estimates of heterosis for length/breadth ratio and alkali digestion value in rice genotypes

Sl. No.	Crosses	Length/breadth ratio				Alkali digestion value			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	-7.78**	-8.87**	-8.26	4.65	-30.00**	-41.67**	-22.22	-41.67**
2.	UPRI 2011-21 X Pant Dhan 23	-4.41*	-6.55*	-8.15	4.78	-10.00*	-25.00**	0.00	-25.00**
3.	UPRI 2011-21 X Pant Dhan 26	-9.42**	-12.12**	-8.15	4.78	0.00	-25.00**	0.00	-25.00**
4.	UPRI 2008-6 X Pant Dhan 4	-2.83*	-5.50*	-4.87	8.53	-5.88	-11.11*	-11.11	-33.33**
5.	UPRI 2008-6 X Pant Dhan 23	6.52**	5.82*	0.66	14.85**	-29.41**	-33.33**	-33.33*	-50.00**
6.	UPRI 2008-6 X Pant Dhan 26	2.55*	-2.05	2.36*	16.78**	-20.00**	-33.33**	-33.33*	-50.00**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	0.47	-5.50*	-4.87	8.53	10.00*	-8.33	22.22	-8.33*
8.	BBL 180-5-1-4-1 X Pant Dhan 23	8.05**	5.06*	-1.36	12.53**	20.00**	0.00	33.33*	0.00
9.	BBL 180-5-1-4-1 X Pant Dhan 26	4.21*	-3.68	0.66	14.85**	33.33**	0.00	33.33*	0.00
10.	UPRI 2012-10 X Pant Dhan 4	-0.11	-3.14	-2.50	11.24*	0.00	0.00	-11.11	-33.33**
11.	UPRI 2012-10 X Pant Dhan 23	11.28**	10.88**	4.85*	19.62**	-50.00**	-50.00**	-55.55**	-66.67**
12.	UPRI 2012-10 X Pant Dhan 26	0.56	-4.22	0.10	14.20**	0.00	-12.50*	-22.22	-41.67**
13.	UPRI 2008-8 X Pant Dhan 4	0.28	0.00	0.66	14.85**	20.00**	12.50*	0.00	-25.00**
14.	UPRI 2008-8 X Pant Dhan 23	2.62*	-0.56	-0.46	13.56**	20.00**	12.50*	0.00	-25.00**
15.	UPRI 2008-8 X Pant Dhan 26	-3.59*	-5.62*	-1.36	12.53*	7.69	0.00	-22.22	-41.67**
16.	UPRI 2012-19 X Pant Dhan 4	-0.78	-1.12	-0.46	13.56**	4.34	-20.00**	33.33*	0.00
17.	UPRI 2012-19 X Pant Dhan 23	11.78**	8.37**	8.35**	23.62**	-39.13**	-53.33**	-22.22	-41.67**

18.	UPRI 2012-19 X Pant Dhan 26	3.65*	1.40	5.98*	20.91**	23.81**	-13.33*	44.44**	8.33*
19.	Pant Dhan 22 X Pant Dhan 4	1.40	1.12	1.79	16.14**	0.00	0.00	-11.11	-33.33**
20.	Pant Dhan 22 X Pant Dhan 23	0.99	-2.14	-2.04	11.75*	12.50*	12.50*	0.00	-25.00**
21.	Pant Dhan 22 X Pant Dhan 26	-1.16	-3.24	1.12	15.37**	-14.28*	-25.00**	-33.33*	-50.00**
22.	Pant Dhan 10 X Pant Dhan 4	9.52**	9.21**	9.94**	25.43**	-46.66**	-50.00**	-55.55**	-66.67**
23.	Pant Dhan 10 X Pant Dhan 23	3.20*	0.00	0.10	14.20**	-33.33**	-37.50**	-44.44**	-58.33**
24.	Pant Dhan 10 X Pant Dhan 26	2.93*	0.75	5.30*	20.14**	23.07**	14.28*	-11.11	-33.33**
25.	Pant Dhan 18 X Pant Dhan 4	-9.82**	-18.62**	1.79	16.14**	85.71**	62.50**	44.44**	8.33*
26.	Pant Dhan 18 X Pant Dhan 23	-1.65	-13.92**	7.68*	22.85**	0.00	-12.50*	-22.22	-41.67**
27.	Pant Dhan 18 X Pant Dhan 26	-15.17**	-22.15**	-2.61	11.11*	66.67**	66.66**	11.11	-16.67**
28.	Pant Dhan 24 X Pant Dhan 4	3.89*	-1.12	-0.46	13.56**	12.50*	12.50*	0.00	-25.00**
29.	Pant Dhan 24 X Pant Dhan 23	7.71**	6.02*	-0.46	13.56**	-12.50*	-12.50*	-22.22	-41.67**
30.	Pant Dhan 24 X Pant Dhan 26	4.28*	-2.48	1.91	16.27**	14.28*	0.00	-11.11	-33.33**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	-2.17	-2.77	-0.91	13.04**	-16.66*	-37.50**	-44.44**	-58.33**
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	5.71*	1.55	3.49	18.08**	-16.66*	-37.50**	-44.44**	-58.33**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-1.37	-2.59	1.79	16.14**	60.00**	33.33**	-11.11	-33.33**
34.	UPR 3199-464-1-2 X Pant Dhan 4	0.85	0.00	0.66	14.85**	20.00**	0.00	33.33*	0.00
35.	UPR 3199-464-1-2 X Pant Dhan 23	2.63*	0.00	-1.02	12.91**	-10.00*	-25.00**	0.00	-25.00**
36.	UPR 3199-464-1-2 X Pant Dhan 26	-1.05	-3.68	0.66	14.85**	33.33**	0.00	33.33*	0.00
37.	UPRI 2014-8 X Pant Dhan 4	-6.97*	-10.98**	-1.93	11.88*	7.69	-12.50*	-22.22	-41.66**

38.	UPRI 2014-8 X Pant Dhan 23	-1.88	-9.13**	0.10	14.20**	7.69	-12.50*	-22.22	-41.66**
39.	UPRI 2014-8 X Pant Dhan 26	-6.21*	-8.62**	0.66	14.85**	27.27**	16.66*	-22.22	-41.66**
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	-4.41*	-10.00**	-9.39	3.36	-20.00**	-25.00**	-33.33*	-50.00**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	1.48	-1.20	-7.25	5.82	6.67	0.00	-11.11	-33.33**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-0.35	-7.79*	-3.63	9.95*	7.69	0.00	-22.22	-41.66**
43.	NDR 3012 X Pant Dhan 4	-2.78*	-5.73*	-5.10	8.27	38.46**	12.50*	0.00	-25.00**
44.	NDR 3012 X Pant Dhan 23	-2.04	-2.39	-7.70	5.30	-23.07**	-37.50**	-44.44**	-58.33**
45.	NDR 3012 X Pant Dhan 26	-8.75**	-13.09**	-9.17	3.62	-27.27**	-33.33**	-55.56**	-66.66**
46.	JGL 1172-7 X Pant Dhan 4	-4.58*	-8.29*	0.10	14.20**	27.27**	-12.50*	-22.22	-41.66**
47.	JGL 1172-7 X Pant Dhan 23	0.27	-6.73*	1.79	16.14**	27.27**	-12.50*	-22.22	-41.66**
48.	JGL 1172-7 X Pant Dhan 26	-3.12*	-5.18*	3.49	18.08**	55.55**	16.66*	-22.22	-41.66**
49.	Pant Dhan 19 X Pant Dhan 4	-0.95	-1.12	-0.46	13.56**	20.00**	12.50*	0.00	-25.00**
50.	Pant Dhan 19 X Pant Dhan 23	0.64	-2.59	-2.27	11.49**	-20.00**	-25.00**	-33.33*	-50.00**
51.	Pant Dhan 19 X Pant Dhan26	-0.16	-2.16	2.25	16.66**	38.46**	28.57**	0.00	-25.00**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

4.4.13.3 Standard heterosis

The standard heterosis over the standard parent Govind for L/B ratio ranged from -9.39 to 9.94. Out of 51 cross evaluated, nineteen cross combinations showed significant standard heterosis from which eight crosses namely Pant Dhan 10 × Pant Dhan 4 (9.94), UPRI 2012-19 × Pant Dhan 23 (8.35), Pant Dhan 18 × Pant Dhan 23 (7.68), UPRI 2012-19 × Pant Dhan 26 (5.98), Pant Dhan 10 × Pant Dhan 26 (5.30), UPRI 2012-10 × Pant Dhan 23 (4.85) and JGL 1172-7 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 23 (3.49) showed significant positive and eleven crosses showed significant negative standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for L/B ratio ranged from 3.36 to 25.43. Out of 51 cross evaluated, forty cross combinations showed significant and positive standard heterosis which are Pant Dhan 10 × Pant Dhan 4 (25.43), UPRI 2012-19 × Pant Dhan 23 (23.62), Pant Dhan 18 × Pant Dhan 23 (22.85), UPRI 2012-19 × Pant Dhan 26 (20.91), Pant Dhan 10 × Pant Dhan 26 (20.14), UPRI 2012-10 × Pant Dhan 23 (19.62), JGL 1172-7 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 23 (18.08), Pant Dhan 19 × Pant Dhan 26 (16.66), Pant Dhan 24 × Pant Dhan 26 (16.27), UPR 3871-8-1-2-2 × Pant Dhan 26, JGL 1172-7 × Pant Dhan 23, Pant Dhan 22 × Pant Dhan 4 & Pant Dhan 18 × Pant Dhan 4 (16.14), Pant Dhan 22 × Pant Dhan 26 (15.37), UPRI 2014-8 × Pant Dhan 4, UPRI 2008-6 × Pant Dhan 23, UPR 3199-464-1-2 × Pant Dhan 4 & UPRI 2008-8 × Pant Dhan 4 (14.85), UPRI 2014-8 × Pant Dhan 23, JGL 1172-7 × Pant Dhan 4, UPRI 2012-10 × Pant Dhan 26 & Pant Dhan 10 × Pant Dhan 4 (14.20), Pant Dhan 24 × Pant Dhan 23, Pant Dhan 24 × Pant Dhan 4, Pant Dhan 19 × Pant Dhan 4 & UPRI 2008-8 × Pant Dhan 23 (13.56), UPR 3199-464-1-2 × Pant Dhan 23 (12.91), BBL 180-5-1-4-1 × Pant Dhan 23 & UPRI 2008-8 × Pant Dhan 26 (12.53), UPRI 2014-8 × Pant Dhan 23 (11.88), Pant Dhan 22 × Pant Dhan 23 (11.75), Pant Dhan 19 × Pant Dhan 23 (11.49) and Pant Dhan 18 × Pant Dhan 26 (11.11) showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. Long/medium slender grain type is most preferred so, positive significant standard heterosis is desirable. The results found similar with the earlier findings of **Yadav *et al.* (2004), Venkatesan *et al.* (2008), Sanghera and Hussain (2012).**

4.4.14 Alkali digestion value

4.4.14.1 Mid parent heterosis

The average heterosis for alkali digestion value ranged from -50.00 to 85.71. Out of 51 cross evaluated, thirty nine cross combinations showed significant average heterosis from which twenty two cross combinations namely Pant Dhan 18 × Pant Dhan 4 (85.71), Pant Dhan 18 × Pant Dhan 26 (66.66), UPR 3871-8-1-2-2 × Pant Dhan 26 (60.00), JGL 1172-7 × Pant Dhan 26 (55.55), Pant Dhan 19 × Pant Dhan 26 & NDR 3012 × Pant Dhan 4 (38.46), UPR 3199-464-1-2 × Pant Dhan 26, BBL 180-5-1-4-1 × Pant Dhan 26 (33.34), JGL 1172-7 × Pant Dhan 4 & JGL 1172-7 × Pant Dhan 23 (27.27), UPRI 2012-19 × Pant Dhan 26 (23.81), Pant Dhan 10 × Pant Dhan 26 (23.07), BBL 180-5-1-4-1 × Pant Dhan 23, UPRI 2008-8 × Pant Dhan 4 & 23, UPR 3199-464-1-2 × Pant Dhan 4, Pant Dhan 19 × Pant Dhan 4 (20.00), Pant Dhan 24 × Pant Dhan 26 (14.28) and BBL 180-5-1-4-1 × Pant Dhan 4 (10.00) showed significant positive mid parent heterosis and seventeen crosses showed significant and negative mid parent heterosis over the mid parental values for this character.

4.4.14.2 Heterobeltiosis

The heterobeltiosis for alkali value ranged from -8.33 to 66.67. Out of 51 cross evaluated, thirty nine cross combinations showed significant heterobeltiosis out of which thirteen cross combinations namely Pant Dhan 18 × Pant Dhan 26 (66.67), Pant Dhan 18 × Pant Dhan 4 (62.50), UPR 3871-8-1-2-2 × Pant Dhan 26 (33.33), Pant Dhan 19 × Pant Dhan 26 (28.57), JGL 1172-7 × Pant Dhan 26 (16.67), Pant Dhan 10 × Pant Dhan 26 (14.28), Pant Dhan 19 × Pant Dhan 26, NDR 3012 × Pant Dhan 4, Pant Dhan 24 × Pant Dhan 4, Pant Dhan 22 × Pant Dhan 23, UPRI 2008-8 × Pant Dhan 4 & 23 (12.50) showed significant positive heterobeltiosis and twenty seven crosses showed significant and negative heterobeltiosis for this character.

4.4.14.3 Standard heterosis

The standard heterosis over the standard parent Govind for alkali value ranged from -11.11 to 44.44. Out of 51 cross evaluated, nineteen cross combinations showed significant standard heterosis from which seven cross combinations namely Pant Dhan 18 × Pant Dhan 4 & UPRI 2012-19 × Pant Dhan 26 (44.44), UPRI 2012-19 × Pant Dhan 4, BBL 180-5-1-4-1 ×

Pant Dhan 23 & 26, UPR 3199-464-1-2 × Pant Dhan 4 and 26 (33.33) showed significant positive and twelve crosses showed significant negative standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for alkali value ranged from -8.33 to 8.33. Out of 51 crosses evaluated, forty six crosses showed significant standard heterosis from which only two cross combinations namely Pant Dhan 18 × Pant Dhan 4 & UPRI 2012-19 × Pant Dhan 26 (8.33) showed significant positive and forty crosses showed significant and negative standard heterosis over the standard parent Pant Dhan 4 for this character.

4.4.15 Hulling recovery (%)

4.4.15.1 Mid parent heterosis

The average heterosis for hulling recovery ranged from -19.81 to 25.58. Out of 51 crosses evaluated, thirty three cross combinations showed significant average heterosis from which twenty one cross combinations namely CR 2644-2-6-4-3-2 × Pant Dhan 4 (25.58), JGL 1172-7 × Pant Dhan 26 (15.44), UPRI 2014-8 × Pant Dhan 26 (15.10), UPRI 2014-8 × Pant Dhan 23 (15.07), CR 2644-2-6-4-3-2 × Pant Dhan 26 (14.74), UPR 3871-8-1-2-2 × Pant Dhan 4 (14.91), UPRI 2014-8 × Pant Dhan 4 (13.06), JGL 1172-7 × Pant Dhan 23 (11.74), JGL 1172-7 × Pant Dhan 4 (11.22), Pant Dhan 18 × Pant Dhan 26 (11.00), Pant Dhan 24 × Pant Dhan 26 (10.91), UPR 3871-8-1-2-2 × Pant Dhan 26 (9.36), Pant Dhan 10 × Pant Dhan 26 (9.25), Pant Dhan 22 × Pant Dhan 26 (9.09), Pant Dhan 10 × Pant Dhan 4 (8.07), NDR 3012 × Pant Dhan 23 (8.06), NDR 3012 × Pant Dhan 26 (7.84), UPR 3871-8-1-2-2 × Pant Dhan 23 (7.57), UPRI 2012-19 × Pant Dhan 23 (6.39) and Pant Dhan 24 × Pant Dhan 23 (5.93) showed significant positive and twelve crosses showed significant negative mid parent heterosis over the mid parental values for this character.

4.4.15.2 Heterobeltiosis

The heterobeltiosis for hulling recovery ranged from -23.78 to 7.76. Out of 51 cross evaluated, thirty three cross combinations showed significant heterobeltiosis from which only seven cross combinations namely Pant Dhan 10 × Pant Dhan 26 (7.76), CR 2644-2-6-4-3-2 × Pant Dhan 4 (7.04), Pant Dhan 10 × Pant Dhan 4 (6.16), Pant Dhan 24 × Pant Dhan 26

(5.63),UPRI 2014-8 × Pant Dhan 26 (3.75) and UPR 3871-8-1-2-2 × Pant Dhan 4 (3.52), showed significant positive heterobeltiosis and twenty six crosses showed significant and negative heterobeltiosis over better parent for this character.

4.4.15.3 Standard heterosis

The standard heterosis over the standard parent Govind for hulling recovery ranged from -7.10 to 32.78. Out of 51 cross evaluated, forty seven cross combinations showed significant standard heterosis from which forty three cross combinations namely CR 2644-2-6-4-3-2 × Pant Dhan 4 (32.78), Pant Dhan 10 × Pant Dhan 4 (31.69), Pant Dhan 10 × Pant Dhan 26 (28.96), UPR 3871-8-1-2-2 × Pant Dhan 4 (28.41), UPRI 2012-19 × Pant Dhan 23 (27.32), Pant Dhan 10 × Pant Dhan 23 (26.23), UPRI 2014-8 × Pant Dhan 23 (25.13), Pant Dhan 19 × Pant Dhan 23 & Pant Dhan 19 × Pant Dhan 26 (24.59), UPRI 2014-8 × Pant Dhan 4, Pant Dhan 24 × Pant Dhan 26 & UPRI 2012-10 × Pant Dhan 23 (22.95), UPRI 2012-10 × Pant Dhan 4 (22.40), Pant Dhan 24 × Pant Dhan 23 (21.85), Pant Dhan 18 × Pant Dhan 4 (21.31), NDR 3012 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 26, UPRI 2011-21 × Pant Dhan 4 (20.21), Pant Dhan 19 × Pant Dhan 4 (19.67), Pant Dhan 24 × Pant Dhan 4, UPR 3871-8-1-2-2 × Pant Dhan 26, Pant Dhan 22 × Pant Dhan 26 & Pant Dhan 18 × Pant Dhan 23 (18.033), JGL 1172-7 × Pant Dhan 23 & CR 2644-2-6-4-3-2 × Pant Dhan 26 (16.94), NDR 3012 × Pant Dhan 23, 26 & JGL 1172-7 × Pant Dhan 26 (16.39), UPRI 2008-6 × Pant Dhan 23 & BBL 180-5-1-4-1 × Pant Dhan 23 (15.30), Pant Dhan 18 × Pant Dhan 4 (14.75), UPR 3199-464-1-2 × Pant Dhan 4 (13.11), UPR 3199-464-1-2 × Pant Dhan 23 (10.92), UPR 3199-464-1-2 × Pant Dhan 26 (7.65) and CR 2644-2-6-4-3-2 × Pant Dhan 23 (6.01) showed significant and positive and four crosses showed significant negative standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for hulling recovery ranged from -6.59 to 33.51. Out of 51 cross evaluated, forty seven cross combinations showed significant standard heterosis from which forty three cross combinations namely CR 2644-2-6-4-3-2 × Pant Dhan 4 (32.78), Pant Dhan 10 × Pant Dhan 4 (32.41), Pant Dhan 10 × Pant Dhan 26 (29.67), UPR 3871-8-1-2-2 × Pant Dhan 4 (29.12), UPRI 2012-19 × Pant Dhan 23 (28.02), Pant Dhan 10 × Pant Dhan 23 (26.92), UPRI 2014-8 × Pant Dhan 4, Pant Dhan 24 × Pant Dhan 26 & UPRI 2012-10 × Pant Dhan 23 (23.62), UPRI 2014-8 × Pant Dhan 23

(25.82), Pant Dhan 19 × Pant Dhan 23 & Pant Dhan 19 × Pant Dhan 26 (25.27), UPRI 2012-10 × Pant Dhan 4 (23.07), Pant Dhan 24 × Pant Dhan 23 (22.52), Pant Dhan 18 × Pant Dhan 26 (21.97), NDR 3012 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 26 & UPRI 2012-19 × Pant Dhan 4 (21.42), UPRI 2011-21 × Pant Dhan 4 (20.87), Pant Dhan 19 × Pant Dhan 4 (20.32), Pant Dhan 24 × Pant Dhan 4, UPR 3871-8-1-2-2 × Pant Dhan 26, Pant Dhan 22 × Pant Dhan 26 & Pant Dhan 18 × Pant Dhan 23 (18.68), JGL 1172-7 × Pant Dhan 23 & CR 2644-2-6-4-3-2 × Pant Dhan 26 (17.58), NDR 3012 × Pant Dhan 23, JGL 1172-7 × Pant Dhan 23 & 26 (17.03), UPRI 2008-6 × Pant Dhan 23 & BBL 180-5-1-4-1 × Pant Dhan 23 (15.93), Pant Dhan 18 × Pant Dhan 4 (15.38), UPR 3199-464-1-2 × Pant Dhan 4 (13.73), UPR 3199-464-1-2 × Pant Dhan 23 (11.53), UPR 3199-464-1-2 × Pant Dhan 26 (8.24) and CR 2644-2-6-4-3-2 × Pant Dhan 23 (6.59) showed significant and positive and four crosses showed significant negative standard heterosis over the standard parent Pant Dhan 4 for this character.

4.4.16 Milling recovery (%)

4.4.16.1 Mid parent heterosis

The average heterosis for milling recovery ranged from -17.42 to 22.50. Out of 51 cross evaluated, forty cross combinations showed significant average heterosis from which twenty seven cross combinations namely UPRI 2014-8 × Pant Dhan 4 (22.50), UPR 3871-8-1-2-2 × Pant Dhan 4 (20.91), CR 2644-2-6-4-3-2 × Pant Dhan 26 (20.48), Pant Dhan 18 × Pant Dhan 23 (18.68), UPRI 2014-8 × Pant Dhan 26 (17.68), UPRI 2014-8 × Pant Dhan 23 (16.62), JGL 1172-7 × Pant Dhan 26 (16.61), NDR 3012 × Pant Dhan 23 (16.05), NDR 3012 × Pant Dhan 26 (14.78), Pant Dhan 24 × Pant Dhan 26 (14.60), CR 2644-2-6-4-3-2 × Pant Dhan 4 (13.60), Pant Dhan 24 × Pant Dhan 23 (13.11), UPR 3871-8-1-2-2 × Pant Dhan 26 (12.53), Pant Dhan 10 × Pant Dhan 4 (12.12), Pant Dhan 18 × Pant Dhan 26 (11.29), Pant Dhan 24 × Pant Dhan 4 (11.05), JGL 1172-7 × Pant Dhan 23 (10.85), JGL 1172-7 × Pant

(Contd.) Table 4.9: Estimates of heterosis for Hulling recovery (%) and Milling recovery (%) in rice genotypes

Sl. No.	Crosses	Hulling recovery (%)				Milling recovery (%)			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	-1.34	-3.08	20.21**	20.87**	-5.67*	-7.57*	11.58**	18.83**
2.	UPRI 2011-21 X Pant Dhan 23	-17.04**	-18.50**	1.09	1.64	-14.28**	-16.83**	2.43	9.09**
3.	UPRI 2011-21 X Pant Dhan 26	-12.03**	-13.24**	3.82*	4.39*	-15.70**	-16.14**	-1.83	4.54**
4.	UPRI 2008-6 X Pant Dhan 4	-12.28**	-19.82**	-0.54	-0.01	-10.81**	-16.66**	0.60	7.14**
5.	UPRI 2008-6 X Pant Dhan 23	1.68	-7.04*	15.30**	15.93**	-2.13	-9.40**	11.58**	18.83**
6.	UPRI 2008-6 X Pant Dhan 26	-3.24	-8.92**	6.01**	6.59**	0.54	-4.68*	11.58**	18.83**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-8.88**	-11.89**	9.29**	9.89**	-12.10**	-15.65**	1.82	8.44**
8.	BBL 180-5-1-4-1 X Pant Dhan 23	-3.82	-7.04*	15.30**	15.93**	0.00	-4.95*	17.07**	24.67**
9.	BBL 180-5-1-4-1 X Pant Dhan 26	-16.70**	-16.9**	-3.27	-2.74	-18.71**	-20.83**	-7.31	-1.29
10.	UPRI 2012-10 X Pant Dhan 4	0.00	-1.32	22.40**	23.07**	0.00	-0.50	21.34**	29.22**
11.	UPRI 2012-10 X Pant Dhan 23	0.44	-0.88	22.95**	23.62**	-3.48*	-3.96*	18.29**	25.97**
12.	UPRI 2012-10 X Pant Dhan 26	-11.06**	-12.67**	5.46**	6.04**	-16.32**	-18.00**	-0.00	6.49**
13.	UPRI 2008-8 X Pant Dhan 4	-14.56**	-22.46**	-3.82	-3.29	-15.55**	-23.23**	-7.31	-1.29
14.	UPRI 2008-8 X Pant Dhan 23	-16.01**	-23.78**	-5.46	-4.94	-15.93**	-24.25**	-6.70	-0.64
15.	UPRI 2008-8 X Pant Dhan 26	-9.04**	-15.02**	-1.09	-0.55	-5.08*	-12.50**	2.43	9.09**
16.	UPRI 2012-19 X Pant Dhan 4	0.91	-2.64	20.76**	21.42**	0.26	-4.04*	15.85**	23.37**

17.	UPRI 2012-19 X Pant Dhan 23	6.39*	2.64	27.32**	28.02**	3.39*	-1.98	20.73**	28.57**
18.	UPRI 2012-19 X Pant Dhan 26	-19.81**	-20.18**	-7.10	-6.59	-17.42**	-19.79**	-6.09	0.00
19.	Pant Dhan 22 X Pant Dhan 4	-9.75**	-18.50**	1.09	1.64	-9.64**	-17.17**	-0.00	6.49**
20.	Pant Dhan 22 X Pant Dhan 23	3.90	-6.16*	16.39**	17.03**	4.63*	-4.95*	17.07**	24.67**
21.	Pant Dhan 22 X Pant Dhan 26	9.09**	1.40	18.03**	18.68**	8.68**	1.04	18.29**	25.97**
22.	Pant Dhan 10 X Pant Dhan 4	8.07**	6.16*	31.69**	32.41**	12.12**	12.12**	35.36**	44.15**
23.	Pant Dhan 10 X Pant Dhan 23	3.58	1.76	26.23**	26.92**	6.50*	5.44*	29.87**	38.31**
24.	Pant Dhan 10 X Pant Dhan 26	9.25**	7.76**	28.96**	29.67**	8.20*	6.56*	28.65**	37.01**
25.	Pant Dhan 18 X Pant Dhan 4	1.44	-7.48**	14.75**	15.38**	1.66	-7.56*	11.58**	18.83**
26.	Pant Dhan 18 X Pant Dhan 23	4.34*	-4.84*	18.03**	18.68**	18.68**	6.93*	31.70**	40.26**
27.	Pant Dhan 18 X Pant Dhan 26	11.00**	4.22*	21.31**	21.97**	11.29**	2.60	20.12**	27.92**
28.	Pant Dhan 24 X Pant Dhan 4	2.61	-4.84*	18.03**	18.68**	11.05**	1.51	22.56**	30.52**
29.	Pant Dhan 24 X Pant Dhan 23	5.93*	-1.76	21.85**	22.52**	13.11**	2.47	26.21**	34.41**
30.	Pant Dhan 24 X Pant Dhan 26	10.56**	5.63*	22.95**	23.62**	14.60**	6.25*	24.38**	32.46**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	14.91**	3.52	28.41**	29.12**	20.91**	6.56*	28.65**	37.01**
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	7.57*	-3.08	20.21**	20.87**	-7.08*	-18.81**	-0.00	6.49**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	9.36**	1.40	18.03**	18.68**	12.53**	0.52	17.68**	25.32**
34.	UPR 3199-464-1-2 X Pant Dhan 4	0.97	-8.81**	13.11**	13.73**	1.09	-7.07*	12.19**	19.48**
35.	UPR 3199-464-1-2 X Pant Dhan 23	-0.97	-10.57**	10.92**	11.53**	0.54	-8.41*	12.80**	20.13**
36.	UPR 3199-464-1-2 X Pant Dhan 26	-0.50	-7.51*	7.65**	8.24**	1.11	-5.72*	10.36**	17.53**

37.	UPRI 2014-8 X Pant Dhan 4	13.06**	-0.88	22.95**	23.62**	22.50**	8.58*	31.09**	39.61**
38.	UPRI 2014-8 X Pant Dhan 23	15.07**	0.88	25.13**	25.82**	16.62**	2.47	26.21**	34.41**
39.	UPRI 2014-8 X Pant Dhan 26	15.10**	3.75*	20.76**	21.42**	17.68**	5.72*	23.78**	31.81**
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	25.58**	7.04*	32.78**	33.51**	13.60**	-3.03	17.07**	24.67**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	0.25	-14.53**	6.01**	6.59**	0.58	-14.85**	4.87*	11.68**
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	14.74**	0.46	16.94**	17.58**	20.48**	4.16*	21.95**	29.87**
43.	NDR 3012 X Pant Dhan 4	4.15	-6.16*	16.39**	17.03**	4.27*	-7.57*	11.58**	18.83**
44.	NDR 3012 X Pant Dhan 23	8.06**	-2.64	20.76**	21.42**	16.05**	1.98	25.60**	33.76**
45.	NDR 3012 X Pant Dhan 26	7.84**	0.00	16.39**	17.03**	14.78**	3.12	20.73**	28.57**
46.	JGL 1172-7 X Pant Dhan 4	11.22**	-6.16*	16.39**	17.03**	10.38**	-6.06*	13.41**	20.78**
47.	JGL 1172-7 X Pant Dhan 23	11.74**	-5.72*	16.94**	17.58**	10.85**	-6.43*	15.24**	22.72**
48.	JGL 1172-7 X Pant Dhan 26	15.44**	0.00	16.39**	17.03**	16.61**	0.52	17.68**	25.32**
49.	Pant Dhan 19 X Pant Dhan 4	-4.57*	-5.60*	19.67**	20.32**	7.57*	7.57*	29.87**	38.31**
50.	Pant Dhan 19 X Pant Dhan 23	-0.65	-1.72	24.59**	25.27**	4.00*	2.97	26.82**	35.06**
51.	Pant Dhan 19 X Pant Dhan26	2.47	-1.72	24.59**	25.27**	3.14	1.58	24.38**	32.46**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

Dhan 4 (10.38), Pant Dhan 22 × Pant Dhan 26 (8.68), Pant Dhan 10 × Pant Dhan 4 (8.20), Pant Dhan 19 × Pant Dhan 4 (7.57), Pant Dhan 10 × Pant Dhan 23 (6.50), Pant Dhan 22 × Pant Dhan 23 (4.63), NDR 3012 × Pant Dhan 4 (4.27) and Pant Dhan 19 × Pant Dhan 23 (4.00) showed significant positive mid parent heterosis and thirteen crosses showed significant and negative mid parent heterosis over the mid parental values for this character.

4.4.16.2 Heterobeltiosis

The heterobeltiosis for milling recovery ranged from -24.25 to 12.12. Out of 51 cross evaluated, forty five cross combinations showed significant heterobeltiosis from which seventeen cross combinations namely Pant Dhan 10 × Pant Dhan 4 (12.12), UPRI 2014-8 × Pant Dhan 4 (8.58), Pant Dhan 19 × Pant Dhan 4 (7.57), Pant Dhan 18 × Pant Dhan 23 (6.93), UPR 3871-8-1-2-2 × Pant Dhan 4 (6.56), Pant Dhan 10 × Pant Dhan 26 (6.56), Pant Dhan 24 × Pant Dhan 26 (6.25), UPRI 2014-8 × Pant Dhan 26 (5.72), Pant Dhan 10 × Pant Dhan 23 (5.44), CR 2644-2-6-4-3-2 × Pant Dhan 26 (4.16), NDR 3012 × Pant Dhan 26 (3.12), Pant Dhan 19 × Pant Dhan 23 (2.97) and UPRI 2014-8 × Pant Dhan 26 (5.72) showed significant positive heterobeltiosis and eighteen crosses showed significant and negative heterobeltiosis for this character.

4.4.16.3 Standard heterosis

The standard heterosis over the standard parent Govind for milling recovery ranged from -7.31 to 35.36. Out of 51 cross evaluated, forty three cross combinations showed significant standard heterosis from which thirty nine cross combinations namely Pant Dhan 10 × Pant Dhan 4 (35.36), Pant Dhan 18 × Pant Dhan 23 (31.70), UPRI 2014-8 × Pant Dhan 4 (31.09), Pant Dhan 19 × Pant Dhan 4 & Pant Dhan 10 × Pant Dhan 23 (29.87), UPR 3871-8-1-2-2 × Pant Dhan 4 & Pant Dhan 10 × Pant Dhan 26 (28.65), Pant Dhan 19 × Pant Dhan 23 (26.82), Pant Dhan 24 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 23 (26.21), NDR 3012 × Pant Dhan 23 (25.60), Pant Dhan 24 × Pant Dhan 26 & Pant Dhan 19 × Pant Dhan 26 (24.38), UPRI 2014-8 × Pant Dhan 26 (23.78), Pant Dhan 24 × Pant Dhan 4 (22.56), CR 2644-2-6-4-3-2 × Pant Dhan 26 (21.95), UPRI 2012-10 × Pant Dhan 4 (21.34), UPRI 2012-19 × Pant Dhan 23 & NDR 3012 × Pant Dhan 26 (20.73), Pant Dhan 18 × Pant Dhan 4 (20.12), UPRI 2012-10 × Pant Dhan 23 & Pant Dhan 22 × Pant Dhan 26 (18.29), JGL 1172-7 × Pant Dhan 26 (17.68), CR 2644-2-6-4-3-2 × Pant Dhan 4 & BBL 180-5-1-4-1 × Pant Dhan 23 (17.07), UPRI 2012-19 × Pant Dhan 4 (15.85), JGL 1172-7 × Pant Dhan 23 (15.24), JGL

1172-7 × Pant Dhan 4 (13.41), UPR 3199-464-1-2 × Pant Dhan 23 (12.80), UPR 3199-464-1-2 × Pant Dhan 4 (12.19), Pant Dhan 18 × Pant Dhan 4, UPRI 2008-6 × Pant Dhan 23, Pant Dhan 26, UPRI 2011-21 × Pant Dhan 4 & NDR 3012 × Pant Dhan 4 (11.58), Pant Dhan 19 × Pant Dhan 26 (11.69), UPR 3199-464-1-2 × Pant Dhan 26 (10.36) and CR 2644-2-6-4-3-2 × Pant Dhan 4 (4.87) showed significant and positive standard heterosis and four crosses showed significant negative standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for milling recovery ranged from -1.29 to 44.15. Out of 51 cross evaluated, forty seven cross combinations namely Pant Dhan 10 × Pant Dhan 4 (44.15), Pant Dhan 18 × Pant Dhan 23 (40.26), UPRI 2014-8 × Pant Dhan 4 (39.61), Pant Dhan 19 × Pant Dhan 4 & Pant Dhan 10 × Pant Dhan 23 (38.31), UPR 3871-8-1-2-2 × Pant Dhan 4 & Pant Dhan 10 × Pant Dhan 26 (37.01), Pant Dhan 19 × Pant Dhan 23 (35.06), Pant Dhan 24 × Pant Dhan 23, UPRI 2014-8 × Pant Dhan 23 (34.41), NDR 3012 × Pant Dhan 23 (33.76), Pant Dhan 24 × Pant Dhan 26 & Pant Dhan 19 × Pant Dhan 26 (32.46), UPRI 2014-8 × Pant Dhan 26 (31.81), Pant Dhan 24 × Pant Dhan 4 (30.52), CR 2644-2-6-4-3-2 × Pant Dhan 26 (29.87), UPRI 2012-10 × Pant Dhan 4 (29.22), UPRI 2012-10 × Pant Dhan 23 & Pant Dhan 22 × Pant Dhan 26 (18.29), JGL 1172-7 × Pant Dhan 26 (25.32), UPRI 2012-19 × Pant Dhan 23 & NDR 3012 × Pant Dhan 26 (23.37), JGL 1172-7 × Pant Dhan 4 (20.78), UPR 3199-464-1-2 × Pant Dhan 23 (20.13), UPR 3199-464-1-2 × Pant Dhan 4 (19.48), Pant Dhan 18 × Pant Dhan 4, UPRI 2011-21 × Pant Dhan 4 & NDR 3012 × Pant Dhan 4 (18.832), UPR 3199-464-1-2 × Pant Dhan 26 (17.53), CR 2644-2-6-4-3-2 × Pant Dhan 23 (11.68), UPRI 2011-21 × Pant Dhan 23 (9.09), BBL 180-5-1-4-1 × Pant Dhan 4 (8.44), UPRI 2012-10 × Pant Dhan 26, Pant Dhan 18 × Pant Dhan 4 & UPR 3871-8-1-2-2 × Pant Dhan 23 (6.49) and UPRI 2011-21 × Pant Dhan 26 (4.54) showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. These results coincide with the reports of **Virmani *et al.* (1982).**

4.4.17 Harvest index

4.4.17.1 Mid parent heterosis

The average heterosis (mid parent heterosis) for harvest index ranged from –41.98 to 41.45. Out of 51 cross evaluated, thirty nine cross combinations showed significant average heterosis from which eighteen cross combinations namely UPR 3199-464-1-2 × Pant Dhan 4

(41.45), UPRI 2014-8 × Pant Dhan 4 (40.54), JGL 1172-7 × Pant Dhan 4 (34.60), Pant Dhan 19 × Pant Dhan 4 (34.14), JGL 1172-7 × Pant Dhan 26 (30.73), UPR 3199-464-1-2 × Pant Dhan 23 (27.92), UPR 3199-464-1-2 × Pant Dhan 26 (25.08), NDR 3012 × Pant Dhan 26 (24.10), Pant Dhan 19 × Pant Dhan 23 (19.30), Pant Dhan 22 × Pant Dhan 23 (18.07), Pant Dhan 10 × Pant Dhan 23 (15.31), UPRI 2008-8 × Pant Dhan 4 (14.25), Pant Dhan 19 × Pant Dhan 26 (13.33), UPRI 2008-6 × Pant Dhan 4 (11.77), CR 2644-2-6-4-3-2 × Pant Dhan 4 (10.99), JGL 1172-7 × Pant Dhan 23 (6.41), UPRI 2008-6 × Pant Dhan 26 (5.31) and UPR 3871-8-1-2-2 × Pant Dhan 4 (5.16) showed significant positive mid parent heterosis and twenty one crosses showed significant and negative mid parent heterosis over the mid parental values for this character.

4.4.17.2 Heterobeltiosis

The heterobeltiosis for harvest index ranged from -43.79 to 32.92. Out of 51 cross evaluated, forty five cross combinations showed significant heterobeltiosis from which twelve cross combinations namely UPR 3199-464-1-2 × Pant Dhan 4 (32.92), Pant Dhan 19 × Pant Dhan 4 (30.51), UPRI 2014-8 × Pant Dhan 4 (21.14), Pant Dhan 19 × Pant Dhan 23 (18.92), UPR 3199-464-1-2 × Pant Dhan 23 (16.83), JGL 1172-7 × Pant Dhan 4 (14.34), UPRI 2008-8 × Pant Dhan 4 (12.52), Pant Dhan 22 × Pant Dhan 23 (9.32), UPR 3199-464-1-2 × Pant Dhan 26 (8.35), Pant Dhan 10 × Pant Dhan 23 (7.49), Pant Dhan 19 × Pant Dhan 26 (6.56) and UPRI 2008-6 × Pant Dhan 4 (6.45) showed significant positive heterobeltiosis and twenty three crosses showed significant and negative heterobeltiosis for this character.

4.4.17.3 Standard heterosis

The standard heterosis over the standard parent Govind for harvest index ranged from -46.43 to 2.68. All the crosses showed significant standard heterosis out of which only two cross combinations namely Pant Dhan 19 × Pant Dhan 4 (2.68) and Pant Dhan 22 × Pant Dhan 23 (1.70) showed significant and positive standard heterosis and forty nine crosses showed significant negative standard heterosis over the standard parent Govind for this character.

The standard heterosis over the check parent Pant Dhan 4 for harvest index ranged from -5.26 to 81.60. Out of 51 crosses evaluated, eleven cross combinations namely Pant Dhan 19 × Pant Dhan 4 (81.60), Pant Dhan 22 × Pant Dhan 23 (79.87), UPR 3199-464-1-2 ×

Pant Dhan 4 (74.94), UPR 3199-464-1-2 × Pant Dhan 26 (71.25), Pant Dhan 19 × Pant Dhan 26 (68.44), Pant Dhan 19 × Pant Dhan 23 (66.63), UPR 3199-464-1-2 × Pant Dhan 23 (63.68), JGL 1172-7 × Pant Dhan 23 (63.43) and NDR 3012 × Pant Dhan 26 (62.99) showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. Standard heterosis of positive nature was observed by **Tiwari *et al.* (2011)** and **Saidaiah *et al.* (2012)** while, **Narendra Pratap *et al.* (2013)** reported significant negative standard heterosis for spikelet fertility.

4.4.18 Grain yield per plant (g)

4.4.18.1 Mid parent heterosis

The average heterosis for grain yield per plant ranged from -35.75 to 193.50. Out of 51 crosses evaluated, forty four cross combinations namely UPR 3871-8-1-2-2 × Pant Dhan 4 (193.50), Pant Dhan 22 × Pant Dhan 26 (150.89), UPR 3871-8-1-2-2 × Pant Dhan 26 (138.92), CR 2644-2-6-4-3-2 × Pant Dhan 26 (128.82), Pant Dhan 18 × Pant Dhan 23 (127.90), Pant Dhan 22 × Pant Dhan 23 (125.64), UPR 3199-464-1-2 × Pant Dhan 26 (116.07), Pant Dhan 24 × Pant Dhan 23 (113.54), Pant Dhan 19 × Pant Dhan 26 (108.92), UPR 3199-464-1-2 × Pant Dhan 4 (99.43), UPRI 2014-8 × Pant Dhan 26 (99.41), Pant Dhan 19 × Pant Dhan 23 (94.43), Pant Dhan 18 × Pant Dhan 26 (88.88), CR 2644-2-6-4-3-2 × Pant Dhan 4 (85.96), NDR 3012 × Pant Dhan 23 (85.44), Pant Dhan 19 × Pant Dhan 4 (81.57), Pant Dhan 22 × Pant Dhan 4 (72.03), JGL 1172-7 × Pant Dhan 26 (68.30), UPRI 2012-10 × Pant Dhan 26 (67.92), UPRI 2014-8 × Pant Dhan 4 (64.48), JGL 1172-7 × Pant Dhan 4 (62.42), UPRI 2008-6 × Pant Dhan 23 (60.94), Pant Dhan 10 × Pant Dhan 4 (59.27), UPRI 2011-21 × Pant Dhan 26 (58.48), UPRI 2012-19 × Pant Dhan 23 (57.97), UPRI 2011-21 × Pant Dhan 23 (53.38), Pant Dhan 24 × Pant Dhan 4 (52.54), UPRI 2012-19 × Pant Dhan 26 (52.12), UPR 3871-8-1-2-2 × Pant Dhan 23 (51.53), UPRI 2011-21 × Pant Dhan 4 (50.69), UPRI 2008-6 × Pant Dhan 4 (47.40), UPRI 2014-8 × Pant Dhan 26 (41.80), Pant Dhan 10 × Pant Dhan 23 (34.78), UPRI 2008-8 × Pant Dhan 26 (25.26) and JGL 1172-7 × Pant Dhan 23 (25.10) showed significant and positive heterosis over the mid parental value for this character.

(Contd.) Table 4.9: Estimates of heterosis for Harvest index and Grain yield per plant (g) in rice genotypes

Sl. No.	Crosses	Harvest index				Grain yield per plant (g)			
		MPH	HB	SH (Govind)	SH (PD 4)	MPH	HB	SH (Govind)	SH (PD 4)
1.	UPRI 2011-21 X Pant Dhan 4	-9.67*	-19.25**	-23.70**	34.93	50.69**	46.99**	147.23**	38.05**
2.	UPRI 2011-21 X Pant Dhan 23	-4.01	-11.77**	-16.62**	47.45	53.38**	46.48**	146.37**	37.56**
3.	UPRI 2011-21 X Pant Dhan 26	-32.22**	-34.05**	-37.71**	10.15	58.48**	41.34**	203.32**	69.37**
4.	UPRI 2008-6 X Pant Dhan 4	11.77**	6.45*	-12.39**	54.93	47.40**	43.74**	141.90**	35.07**
5.	UPRI 2008-6 X Pant Dhan 23	-2.32	-4.14	-21.14**	39.45	60.94**	53.66**	158.59**	44.39**
6.	UPRI 2008-6 X Pant Dhan 26	5.31*	1.12	-9.64**	59.80	41.80**	26.49**	171.46**	51.58**
7.	BBL 180-5-1-4-1 X Pant Dhan 4	-5.16*	-15.56**	-19.53**	42.31	12.29*	4.67	93.70**	8.16
8.	BBL 180-5-1-4-1 X Pant Dhan 23	2.35	-6.39*	-10.69**	57.94	31.20**	19.86**	121.82**	23.86**
9.	BBL 180-5-1-4-1 X Pant Dhan 26	-41.98**	-43.79**	-46.43**	-5.26	53.22**	42.67**	206.18**	70.96**
10.	UPRI 2012-10 X Pant Dhan 4	0.03	-9.83*	-16.42**	47.89	-0.00	-4.13	67.15**	-6.66
11.	UPRI 2012-10 X Pant Dhan 23	-28.45**	-33.67**	-38.52**	8.73	-35.75**	-39.68**	5.17	-41.27
12.	UPRI 2012-10 X Pant Dhan 26	-9.66*	-11.29**	-17.74**	45.49	67.92**	52.18**	226.59**	82.36**
13.	UPRI 2008-8 X Pant Dhan 4	14.25**	12.52**	-16.28**	48.06	61.63**	52.98**	174.00**	53.00**
14.	UPRI 2008-8 X Pant Dhan 23	-14.10**	-17.91**	-34.97**	15.00	59.10**	47.53**	164.25**	47.55**
15.	UPRI 2008-8 X Pant Dhan 26	-24.29**	-31.57**	-38.85**	8.14	25.26**	14.90**	146.58**	37.68**
16.	UPRI 2012-19 X Pant Dhan 4	-0.03	-3.68	-22.64**	36.80	4.68	3.63	69.15**	-5.54
17.	UPRI 2012-19 X Pant Dhan 23	-3.08	-3.74	-22.7**	36.68	57.97**	53.05**	149.84**	39.50**

18.	UPRI 2012-19 X Pant Dhan 26	-19.05**	-23.16**	-31.35**	21.41	52.12**	33.92**	187.39**	60.47**
19.	Pant Dhan 22 X Pant Dhan 4	-3.71	-13.31**	-19.37**	42.58	72.03**	70.61**	177.47**	54.93**
20.	Pant Dhan 22 X Pant Dhan 23	18.07**	9.32*	1.70**	79.87**	125.64**	119.01**	256.18**	98.88**
21.	Pant Dhan 22 X Pant Dhan 26	-7.47*	-9.27*	-15.60**	49.26	150.89**	120.51**	373.21**	164.23**
22.	Pant Dhan 10 X Pant Dhan 4	-8.90*	-17.45**	-24.36**	33.77	59.27**	39.01**	122.34**	24.15**
23.	Pant Dhan 10 X Pant Dhan 23	15.31**	7.49*	-1.51**	74.18**	34.78**	19.89**	83.52**	2.47
24.	Pant Dhan 10 X Pant Dhan 26	-24.23**	-25.16**	-31.42**	21.27	-27.67**	-43.74**	20.73	-32.58
25.	Pant Dhan 18 X Pant Dhan 4	-22.95**	-28.73**	-37.60**	10.34	-3.46	-6.64	49.31**	-16.62
26.	Pant Dhan 18 X Pant Dhan 23	-13.19**	-17.34**	-27.66**	27.93	127.90**	125.17**	244.66**	92.45**
27.	Pant Dhan 18 X Pant Dhan 26	-15.97**	-16.82**	-25.62**	31.54	88.88**	60.19**	243.78**	91.95**
28.	Pant Dhan 24 X Pant Dhan 4	-6.27*	-9.88*	-27.30**	28.57	52.54**	51.13**	146.29**	37.52**
29.	Pant Dhan 24 X Pant Dhan 23	-10.63**	-11.43**	-28.56**	26.33	113.54**	107.05**	237.44**	88.41**
30.	Pant Dhan 24 X Pant Dhan 26	-11.91**	-16.20**	-25.13**	32.41	15.66*	1.75	118.35**	21.92**
31.	UPR 3871-8-1-2-2 X Pant Dhan 4	5.16*	-8.80*	-7.59**	63.43*	193.50**	174.58**	339.17**	145.22**
32.	UPR 3871-8-1-2-2 X Pant Dhan 23	-23.47**	-31.85**	-30.91**	22.18	51.53**	44.73**	121.54**	23.70**
33.	UPR 3871-8-1-2-2 X Pant Dhan 26	-15.90**	-20.87**	-19.79**	41.84	138.92**	97.02**	322.81**	136.08**
34.	UPR 3199-464-1-2 X Pant Dhan 4	41.45**	32.92**	-1.08*	74.94**	99.43**	93.08**	229.81**	84.16**
35.	UPR 3199-464-1-2 X Pant Dhan 23	27.92**	16.83**	-7.44**	63.68*	96.94**	86.71**	218.93**	78.08**
36.	UPR 3199-464-1-2 X Pant Dhan 26	25.08**	8.35*	-3.17**	71.25**	116.07**	94.03**	316.38**	132.50**
37.	UPRI 2014-8 X Pant Dhan 4	40.54**	21.14**	-9.82**	59.48	64.48**	55.29**	148.38**	38.69**

38.	UPRI 2014-8 X Pant Dhan 23	0.79	-15.31**	-32.96**	18.56	28.89**	24.26**	90.216**	6.21
39.	UPRI 2014-8 X Pant Dhan 26	4.05	-16.60**	-25.49**	31.76	99.41**	65.71**	255.62**	98.57**
40.	CR 2644-2-6-4-3-2 X Pant Dhan 4	10.99**	-10.97**	-33.74**	17.18	85.96**	79.84**	187.64**	60.61**
41.	CR 2644-2-6-4-3-2 X Pant Dhan 23	2.22	-19.87**	-36.55**	12.20	7.04	5.72	61.88**	-9.60
42.	CR 2644-2-6-4-3-2 X Pant Dhan 26	-7.76*	-30.67**	-38.03**	9.59	128.82**	94.06**	316.42**	132.54**
43.	NDR 3012 X Pant Dhan 4	-1.72	-11.85**	-34.41**	16.02	32.26**	23.45**	97.46**	10.25
44.	NDR 3012 X Pant Dhan 23	-3.51	-15.79**	-33.27**	18.05	85.44**	76.71**	170.49**	51.03**
45.	NDR 3012 X Pant Dhan 26	24.10**	3.08	-7.84**	62.99*	19.41*	17.1**	110.91**	17.77**
46.	JGL 1172-7 X Pant Dhan 4	34.60**	14.34**	-14.88**	50.53	62.42**	53.69**	145.82**	37.26**
47.	JGL 1172-7 X Pant Dhan 23	6.41*	-11.83**	-30.19**	23.45	25.10**	20.88**	85.02**	3.31
48.	JGL 1172-7 X Pant Dhan 26	30.73**	3.42	-7.59**	63.43*	68.30**	40.12**	200.70**	67.90**
49.	Pant Dhan 19 X Pant Dhan 4	34.14**	30.51**	2.68**	81.60*	81.5**	78.67**	185.77**	59.57**
50.	Pant Dhan 19 X Pant Dhan 23	19.30**	18.92**	-5.78**	66.63*	94.43**	93.32**	199.34**	67.14**
51.	Pant Dhan 19 X Pant Dhan26	13.33**	6.56*	-4.76**	68.44*	108.92**	79.83**	285.92**	115.49**

** Significant at 5% level, ** significant at 1% level, MPH-mid parent heterosis, HB-heterobeltiosis, SH-over standard parent (Govind and Pant Dhan 4).*

4.4.18.2 Heterobeltiosis

The heterobeltiosis (better parent heterosis) for grain yield per plant ranged from -43.74 to 174.58. Out of 51 crosses evaluated, forty three cross combinations namely UPR 3871-8-1-2-2 × Pant Dhan 4 (174.58), Pant Dhan 18 × Pant Dhan 23 (125.12), Pant Dhan 22 × Pant Dhan 26 (120.51), Pant Dhan 22 × Pant Dhan 23 (119.01), Pant Dhan 24 × Pant Dhan 23 (107.05), UPR 3871-8-1-2-2 × Pant Dhan 26 (97.02), CR 2644-2-6-4-3-2 × Pant Dhan 26 (94.04), UPR 3199-464-1-2 × Pant Dhan 26 (94.03), Pant Dhan 19 × Pant Dhan 23 (93.92), UPR 3199-464-1-2 × Pant Dhan 4 (93.03), UPR 3199-464-1-2 × Pant Dhan 23 (86.71), Pant Dhan 19 × Pant Dhan 26 (79.83), Pant Dhan 19 × Pant Dhan 4 (78.67), NDR 3012 × Pant Dhan 23 (76.76), Pant Dhan 22 × Pant Dhan 4 (70.61), UPRI 2014-8 × Pant Dhan 26 (65.71), Pant Dhan 18 × Pant Dhan 26 (60.19), UPRI 2014-8 × Pant Dhan 4 (55.29), JGL 1172-7 × Pant Dhan 4 (53.69), UPRI 2008-6 × Pant Dhan 23 (53.66), UPRI 2012-10 × Pant Dhan 26 (52.18), UPRI 2008-8 × Pant Dhan 4 (52.98), Pant Dhan 24 × Pant Dhan 4 (51.13), UPRI 2008-8 × Pant Dhan 23 (47.53), UPRI 2011-21 × Pant Dhan 4 (46.99), UPRI 2011-21 × Pant Dhan 23 (46.48), UPRI 008-6 × Pant Dhan 4 (43.74), BBL180-5-1-4-1 × Pant Dhan 26 (42.67), UPRI 2011-21 × Pant Dhan 26 (41.34), JGL 1172-7 × Pant Dhan 26 (40.12), Pant Dhan 10 × Pant Dhan 4 (39.01), UPRI 2012-19 ×P ant Dhan 26 (33.92), UPR 2008-6 × Pant Dhan 26 (26.49), UPRI 2014-8 × Pant Dhan 23 (24.26), NDR 3012 × Pant Dhan 4 (23.458), JGL 1172-7 × Pant Dhan 23 (20.88), Pant Dhan 10 × Pant Dhan 23 (19.89), BBL 180-5-1-4-1 × Pant Dhan 23 (19.86), NDR 3012 × Pant Dhan 26 (17.17) and UPRI 2008-8 × Pant Dhan 26 (14.90) showed significant positive heterobeltiosis over the better parent value for this character.

4.4.18.3 Standard heterosis

The standard heterosis over the standard parent Govind for grain yield per plant ranged from 5.17 to 373.21. Almost all the crosses viz., Pant Dhan 22 × Pant Dhan 26 (373.21), UPR 3871-8-1-2-2 × Pant Dhan 4 (339.17), UPR 3871-8-1-2-2 × Pant Dhan 26 (322.81), CR 2644-2-6-4-3-2 × Pant Dhan 26 (316.46), UPR 3199-464-1-2 × Pant Dhan 26 (316.39), Pant Dhan 19 × Pant Dhan 26 (285.92), Pant Dhan 22 × Pant Dhan 23 (256.18), UPRI 2014-8 × Pant Dhan 26 (255.62), Pant Dhan 18 × Pant Dhan 23 (244.66), Pant Dhan 18 × Pant Dhan 26 (243.78), Pant Dhan 24 × Pant Dhan 23 (237.44), UPR 3199-464-1-2 × Pant

Dhan 4 (229.81), UPRI 2012-10 × Pant Dhan 26 (226.59), UPR 3199-464-1-2 Pant Dhan 23 (218.93), BBL 180-5-1-4-1 × Pant Dhan 26 (206.11), UPRI 2011-21 × Pant Dhan 26 (203.32), JGL 1172-7 × Pant Dhan 26 (200.74), Pant Dhan 19 × Pant Dhan 23 (199.31), CR 2644-2-6-4-3-2 × Pant Dhan 4 (187.64), UPRI 2012-19 × Pant Dhan 26 (187.39), Pant Dhan 19 × Pant Dhan 4 (185.02), Pant Dhan 22 × Pant Dhan 4 (177.47), UPRI 2008-8 × Pant Dhan 4 (174.10), UPRI 2008-6 × Pant Dhan 26 (171.46), NDR 3012 × Pant Dhan 23 (170.46), UPRI 2008-6 × Pant Dhan 23 (158.56), UPRI 2012-19 × Pant Dhan 23 (149.84), UPRI 2014-8 × Pant Dhan 4 (148.38), UPRI 2008-8 × Pant Dhan 26 (146.58), Pant Dhan 24 × Pant Dhan 4 (146.25), JGL 1172-7 × Pant Dhan 4 (145.22), UPRI 2008-6 × Pant Dhan 4 (141.96), Pant Dhan 10 × Pant Dhan 4 (122.34), UPR 3871-8-1-2-2 × Pant Dhan 23 (121.52), BBL 180-5-1-4-1 × Pant Dhan 23 (121.82), NDR 3012 × Pant Dhan 26 (110.91), NDR 3012 × Pant Dhan 4 (97.46), BBL 180-5-1-4-1 × Pant Dhan 4 (93.70), UPRI 2014-8 × Pant Dhan 23 (90.21), JGL 1172-7 × Pant Dhan 23 (85.02), Pant Dhan 10 × Pant Dhan 23 (83.52), UPRI 2012-19 × Pant Dhan 4 (69.15), UPRI 2012-10 × Pant Dhan 4 (67.15), CR 2644-2-6-4-3-2 × Pant Dhan 23 (61.88), Pant Dhan 18 × Pant Dhan 4 (49.31), UPRI 2011-21 × Pant Dhan 4 (47.23) and UPRI 2011-21 × Pant Dhan 23 (46.37) showed significant and positive standard heterosis over the standard parent Govind for this character.

The standard heterosis over the standard parent Pant Dhan 4 for grain yield per plant ranged from -41.27 to 164.23. Almost all the crosses viz., Pant Dhan 22 × Pant Dhan 26 (164.23), UPR 3871-8-1-2-2 × Pant Dhan 4 (145.22), UPR 3871-8-1-2-2 × Pant Dhan 26 (136.08), CR 2644-2-6-4-3-2 × Pant Dhan 26 (132.54), UPR 3199-464-1-2 × Pant Dhan 26 (132.50), Pant Dhan 19 × Pant Dhan 26 (115.49), Pant Dhan 22 × Pant Dhan 23 (98.88), UPRI 2014-8 × Pant Dhan 26 (98.57), Pant Dhan 18 × Pant Dhan 23 (92.45), Pant Dhan 18 × Pant Dhan 26 (91.95), Pant Dhan 24 × Pant Dhan 23 (88.41), UPR 3199-464-1-2 × Pant Dhan 4 (84.12), UPRI 2012-10 × Pant Dhan 26 (82.36), UPR 3199-464-1-2 × Pant Dhan 23 (78.08), BBL 180-5-1-4-1 × Pant Dhan 26 (70.96), UPRI 2011-21 × Pant Dhan 26 (69.37), JGL 1172-7 × Pant Dhan 26 (67.90), Pant Dhan 19 × Pant Dhan 23 (67.14), CR 2644-2-6-4-3-2 × Pant Dhan 4 (60.66), UPRI 2012-19 × Pant Dhan 26 (60.47), Pant Dhan 19 × Pant Dhan 4 (59.57), Pant Dhan 22 × Pant Dhan 4 (54.93), UPRI 2008-8 × Pant Dhan 4 (53.00), UPRI 2008-6 × Pant Dhan 26 (51.58), NDR 3012 × Pant Dhan 23 (51.03), UPRI 2008-8 × Pant Dhan 23 (47.55), UPRI 2008-6 × Pant Dhan 23 (44.33), UPRI 2012-19 × Pant Dhan 23

(39.55), UPRI 2014-8 × Pant Dhan 4 (38.64), UPRI 2011-21 × Pant Dhan 4 (38.05), UPRI 2011-21 × Pant Dhan 23 (37.56), Pant Dhan 24 × Pant Dhan 4 (37.52), JGL 1172-7 × Pant Dhan 4 (37.26), UPRI 2008-6 × Pant Dhan 4 (35.07), Pant Dhan 10 × Pant Dhan 4 (24.15), UPR 3871-8-1-2-2 × Pant Dhan 23 (23.70), BBL 180-5-1-4-1 × Pant Dhan 23 (23.86), Pant Dhan 24 × Pant Dhan 26 (21.92), NDR 3012 × Pant Dhan 26 (17.77) showed significant and positive standard heterosis over the standard parent Pant Dhan 4 for this character. Significant positive standard heterosis for grain yield per plant was reported by **Virmani *et al.* (1982)**, **Datt and Mani (2004), Eradasappa *et al.* (2007), Raj *et al.* (2007), Rashid *et al.* (2007)**, **Parihar and Pathak (2008), Venkatesan *et al.* (2008), Singh *et al.* (2011), Gokulakrishnan and Kumar (2013), Devi *et al.* (2014)**, **Priyanka *et al.* (2014), Bhatti *et al.* (2015)**, **Premkumar *et al.* (2017).**

Superior crosses were summerised in respect to mid parent heterosis, heterobeltiosis and standard heterosis over both standard parents (Govind and Pant Dhan 4) in Table 4.10.

Table 4.10: Summary table depicting promising heterotic crosses for different characters in rice genotypes

SI No.	Characters	Mid parent heterosis	Heterobeltiosis	Standard heterosis	
				Over standard parent Govind	Over standard parent Pant Dhan 4
1.	Days to 50% flowering	BBL 180-5-1-4-1 × PD 23, UPRI 2014-8 × PD 23, CR 2644-2-6-4-3-2 × PD 26	UPRI 2014-8 × PD 23, UPRI 2014-8 × PD 26, PD 10 × PD 23	BBL 180-5-1-4-1 × PD 26, UPRI 2008-8 × PD 26, UPRI 2012-19 × PD 26	BBL 180-5-1-4-1 × PD 26, UPRI 2008-8 × PD 26, UPRI 2012-19 × PD 26
2.	Days to maturity	UPRI 2008-6 × PD 23, BBL 180-5-1-4-1 × PD 23, PD 10 × PD 26	UPRI 2008-6 × PD 23, PD 10 × PD 26, BBL 180-5-1-4-1 × PD 23, PD 24 × PD 23	UPRI 2012-19 × PD 26, UPRI 2008-8 × PD 26, UPRI 2008-6 × PD 4	UPRI 2012-19 × PD 26, UPRI 2008-8 × PD 26, BBL 180-5-1-4-1 × PD 26
3.	Plant height (cm)	UPRI 2008-8 × PD 26, UPRI 2014-8 × PD 26, CR 2644-2-6-4-3-2 × PD 26,	NDR 3012 × PD 4, PD 19 × PD 4, PD 22 × PD 26, NDR 3012 × PD 23	PD 22 × PD 26, JGL 1172-7× PD 23, NDR 3012× PD 4, PD 19× PD 4	PD 10 × PD 26, UPR 3871-8-1-2-2 × PD 26, PD 10 × PD 4
4.	Number of tillers/plant	UPRI 2008-8 × PD 26, BBL 180-5-1-4-1 × PD 26	UPRI 2008-8 × PD 26, BBL 180-5-1-4-1 × PD 26, UPR 3871-8-1-2-2 × PD 26	UPRI 2008-8 × PD 26, BBL 180-5-1-4-1 × PD 26, UPRI 2012-19 × PD 26	UPRI 2008-8 × PD 26, BBL 180-5-1-4-1 × PD 26, UPRI 2012-19 × PD 26
5.	Panicle length (cm)	NDR 3012 × PD 26, UPRI 2008-6 × PD 23, NDR 3012 × PD 23	UPRI 2008-6 × PD 23, UPRI 2014-8 × PD 4, NDR 3012 × PD 26	PD 22 × PD 23, NDR 3012 × PD 26, UPRI 2008-6 × PD 23, UPRI 2014-8 × PD 4	PD 22 × PD 23, UPRI 2008-6 × PD 23, NDR 3012 × PD 26 and JGL 1172-7 × PD 4
6.	Number of grains/panicle	PD 22 × PD 26,UPRI 2011-21 × PD 26, UPRI 2012-10 × PD 26, JGL 1172-7 × PD 23,UPRI 2011-21 × PD 4	UPRI 2011-21 × PD 26, PD 22 × PD 26, JGL 1172-7 × PD 23, UPRI 2011-21 × PD 4, UPRI 2008-8 × PD 4	UPRI 2011-21× PD 26, PD 22 × PD 26, JGL 1172-7 × PD 23, JGL 1172-7 × PD 26	UPRI 2011-21 × PD 26, PD 22 × PD 26, JGL 1172-7 × PD 23, JGL 1172-7 × PD 26
7.	Spikelet fertility (%)	UPRI 2014-8 × PD 23, NDR3012 × PD 23, UPRI 2014-8 × PD 4	PD 10 × PD 23, PD 10 × PD 26, PD 24 × PD 26, UPRI 2014-8 × PD 23 and PD 22 × PD 26	PD 10 × PD 23, PD 10 × PD 26, PD 24 × PD 26, PD 10 × PD 4 and PD 22 × PD 26	PD10 × PD 23, PD 10 × PD 26, PD 24 × PD 26, PD 10 × PD 4, PD 22 × PD 26
8.	1000 grain weight (g)	PD 19 × PD 23, NDR 3012 × PD 23, NDR 3012 × PD 4, UPRI 2014-8 × PD 26	PD 19 × PD 23, BBL 180-5-1-4-1 × PD 4 and PD 18 × PD 23	PD19 × PD 23, BBL 180-5-1-4-1 × PD 26, PD10 × PD 4	PD 19 × PD 23, BBL 180-5-1-4-1 × PD 4, UPRI 2014-8 × PD 26

9.	Grain length (mm)	PD 18 × PD 26, UPRI 2011-21× PD 26, UPRI 2011-21 × PD 4	CR 2644-2-6-4-3-2 × PD 26, PD 18 × PD 26, UPRI 2011-21 × PD 23	CR 2644-2-6-4-3-2 × PD 26, UPR 3199-464-1-2 × PD 23	CR 2644-2-6-4-3-2 × PD 26, UPR 3199-464-1-2 × PD 23
10.	Grain width (mm)	PD 19 × PD 4, UPRI 2012-10 × PD 23, PD 19 × PD 23	UPRI 2012-19 × PD 23, UPR 3871-8-1-2-2 × PD 26	PD19 × PD 4, UPR 3871-8-1-2-2 × PD 23, PD 24 × PD 26	PD19 × PD 4, PD 24 × PD 26, UPR 3871-8-1-2-2 × PD 26
11.	Kernel length (mm)	UPRI 2012-19 × PD 23, PD 10 × PD 4, UPRI 2012-10 × PD 23	UPRI 2012-19 × PD 23, PD 10 × PD 4, UPRI 2012-10 × PD 23	PD 18 × PD 23, UPRI 2012-19 × PD 23, PD 10 × PD 4, UPRI 2012-19 × PD 26	UPRI 2012-19 × PD 26, PD 10 × PD 26, UPRI 2012-10 × PD 23
12.	Kernel breadth (mm)	UPRI 2012-19 × PD 26, NDR 3012 × PD 26, PD 18 × PD 23	UPRI 2012-19 × PD 26, PD 10 × PD 26, UPRI 2014-8 × PD 4	NDR 3012 × PD 26, NDR 3012 × PD 23, PD 18 × PD 23, CR 2644-2-6-4-3-2 × PD 4	NDR 3012 × PD 26, NDR 3012 × PD 23, PD 18 × PD 23, CR 2644-2-6-4-3-2 × PD 4
13.	Length/Breadth ratio	UPRI 2012-19 × PD 23, UPRI 2012-19 × PD 23, PD 10 × PD 4, BBL 180-5-1-4-1 × PD 23, PD 24 × PD 23	UPRI 2012-10 × PD 23, PD 10 × PD 4, PD 24 × PD23, UPRI 2008-6 × PD 23	PD10 × PD 4, UPRI 2012-19 × PD 23, PD18 × PD 23 UPRI 2012-19 × PD26	PD10 × PD 4, UPRI 2012-19 × PD 23, PD 18 × PD 23, PD 19 × PD 26
14.	Harvest index	UPR 3199-464-1-2 × PD 4, UPRI 2014-8 × PD 4, JGL 1172-7 × PD 4, PD 19 × PD 4	UPR 3199-464-1-2 × PD 4, PD 19 × PD 4, UPRI 2014-8 × PD 4, PD 19 × PD 23	PD 19 × PD 4 and PD 22 × PD 23	PD19 × PD 4, PD 22 × PD 23, UPR 3199-464-1-2 × PD 4
15.	Hulling recovery (%)	CR 2644-2-6-4-3-2 × PD 4, JGL 1172-7 × PD 26, UPRI 2014-8 × PD 26	PD 10 × PD 26, CR 2644-2-6-4-3-2 × PD 4, PD 10 × PD 4, UPRI 2014-8 × PD 26 and UPR 3871-8-1-2-2 × PD 4	CR 2644-2-6-4-3-2 × PD 4, PD 10 × PD 4, PD 10 × PD 26	CR 2644-2-6-4-3-2 × PD 4, PD 10 × PD 4, PD 10 × PD 26
16.	Milling recovery (%)	UPRI 2014-8 × PD 4, UPR 3871-8-1-2-2 × PD 4	PD 10 × PD 4, UPRI 2014-8 × PD 4, PD 19 × PD 4, PD 18 × PD 23	PD 10 × PD 4, PD 18 × PD 23, UPRI 2014-8 × PD 4	PD 10 × PD 4, PD 18 × PD 23, UPRI 2014-8 × PD 4
17.	Alkali digestion value	PD 18 × PD 4, PD 18 × PD 26, UPR 3871-8-1-2-2 × PD 26	PD 18 × PD 26, PD 18 × PD 4, UPR 3871-8-1-2-2 × PD 26,	PD 18 × PD 4, UPRI 2012-19 × PD 26, UPRI 2012-19 × PD 4	PD 18 × PD 4 and UPRI 2012-19 × PD 26
18.	Grain yield per plant (g)	UPR 3871-8-1-2-2 × PD 4, PD 22 × PD 26, UPR 3871-8-1-2-2 × PD 26, CR 2644-2-6-4-3-2 × PD 26, PD 18 × PD 23	UPR 3871-8-1-2-2 × PD 4, PD 18 × PD 23, PD 22 × PD 26, PD 22 × PD 23, PD 24 × PD 23, UPR 3871-8-1-2-2 × PD 26	PD 22 × PD 26, UPR 3871-8-1-2-2 × PD 4, PD 19 × PD 26, UPR 3871-8-1-2-2 × PD 26, PD 22 × PD 23	PD 22 × PD 26, UPR 3871-8-1-2-2 × PD 4, UPR 3871-8-1-2-2 × PD 26, PD19 × PD 26, PD 22 × PD 23

Summary and Conclusions

CHAPTER 5 SUMMARY AND CONCLUSION

The present study entitled **"Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice *(Oryza sativa* L.)"** was carried out to evaluate 17 lines *viz.,* UPRI 2011-21, UPRI 2008-6, BBL 180-5-1-4-1, UPRI 2012-10, UPRI 2008-8, UPRI 2012-19, Pant Dhan 22, Pant Dhan 10, Pant Dhan 18, Pant Dhan 24, UPR 3871-8-1-2-2, UPR 3199-464-1-2, UPRI 2014-8, CR 2644-2-6-4-3-2, NDR 3012, JGL 1172-7, Pant Dhan 19 and three testers namely Pant Dhan 4, Pant Dhan 23, Pant Dhan 26 for 18 quantitative and qualitative traits. The Line × tester mating design was used to generate 51 crosses at Norman E. Borlaug Crop Research Centre, Pantnagar during *Kharif* 2016-17. The crosses were evaluated along with their parents at the same location during *Kharif* 2017-18 in a Randomized Block Design (RBD) with 3 replications. The objectives of present study were as follows:

i. To estimate the genetic variability parameters for yield and yield contributing traits.

ii. Selection of good combiner parents and specific combiner crosses for better heterotic output based on the GCA and SCA effects.

iii. To estimate the combining ability of lines and testers with their crosses.

iv. To estimate the magnitude and nature of heterosis in different crosses of rice lines**.**

The characters were taken for the study are days to 50% flowering, days to maturity, plant height (cm), numbers of tillers per plant, panicle length (cm), number of grains per panicle, spikelet fertility (%), 1000 grain weight (g), grain length (mm), grain width (mm), kernel length (mm), kernel breadth (mm), L/B ratio, harvest index, hulling recovery (%), milling recovery (%), alkali digestion value and grain yield per plant (g).

The major findings of the experiment summarized as follows:

- Analysis of variance revealed that there is highly significant genetic variations were reported among 73 genotypes for all the 18 characters studied. Highest phenotypic and genotypic coefficient of variation was observed for grain yield per plant followed by alkali digestion value, 1000 grain weight, spikelet fertility, number of tillers per plant and number of grains per panicle.

- The results of heritability and genetic advance revealed that high heritability was observed for number of grains per panicle followed by spikelet fertility, grain yield per plant, alkali value, harvest index, hulling recovery, kernel length, days to 50% flowering, grain width , kernel length, plant height, days to maturity and 1000 grain weight. Similarly, High heritability was coupled with high genetic advance for important characters such as, number of grains per panicle, spikelet fertility, grain yield per plant and plant height indicated that the characters have greater scope for improvement through direct phenotypic selection by fixing additive genetic effects.

- Estimates of mid parent heterosis, heterobeltiosis and standard heterosis for all 18 characters under study, revealed that crosses namely, BBL 180-5-1-4-1 × Pant Dhan 23 and UPRI 2008-8 × Pant Dhan 4 showed high significant negative mid parent heterosis, and heterobeltiosis, therefore these crosses emerged as best heterotic crosses for days to 50% flowering and days to maturity, respectively.

- For plant height and spikelet fertility, the cross UPR 3871-8-1-2-2 × Pant Dhan 26 identified as best specific combiner and also showed significant negative mid parent and standard heterosis over the best check i.e. Pant Dhan 4 for plant height and significant positive standard heterosis over the best check i.e. Pant Dhan 4 for spikelet fertility.

- The F_1's UPRI 2008-8 × Pant Dhan 26 and UPRI 2008-6 × Pant Dhan 23 were identified as best specific combiner for panicle length and number of tillers per plant, respectively. These crosses also showed significant positive standard heterosis for panicle length and number of tillers per plant over both check varieties (Govind and Pant Dhan 4).

- Crosses namely, Pant Dhan 19 × Pant Dhan 23 (1000 grain weight), UPRI 2008-8 × Pant Dhan 23 (grain length), Pant Dhan 19 × Pant Dhan 26 (grain width), Pant Dhan 18 × Pant Dhan 23 (kernel length), CR 2644-2-6-4-3-2 × Pant Dhan 4 (kernel breadth) and Pant Dhan 10 × Pant Dhan 4 (L/B ratio) showed high and significant standard heterosis over both the standard parents.

- Crosses viz., NDR 3012 × Pant Dhan 26, CR 2644-2-6-4-3-2 × Pant Dhan 4, UPR 3871-8-1-2-2 × Pant Dhan 4 and Pant Dhan 18 × Pant Dhan 4 exhibited significant positive standard heterosis for harvest index, hulling recovery, milling recovery and

alkali digestion value, respectively. Cross UPRI 2012-19 × Pant Dhan 26 showed significant positive standard heterosis for alkali digestion value

- For grain yield per plant, UPR 3871-8-1-2-2 × Pant Dhan 4 and CR 2644-2-6-4-3-2 × Pant Dhan 26 were exhibited significant positive SCA effects and emerged as best specific combiner with highly significant positive standard heterosis over Govind and Pant Dhan 4. These two crosses could be used in breeding programme for further grain yield improvement.

- The lines viz., Pant Dhan 22 (grain yield), Pant Dhan 24 (spikelet fertility), Pant Dhan 10 (1000 grain weight), CR 2644-2-6-4-3-2 (days to maturity, number of grains per panicle & grain yield), UPR 3871-8-1-2-2 (plant height & number of grains per panicle), Pant Dhan 19 (days to 50% flowering, grain width, hulling recovery, milling recovery, harvest index & grain yield), UPRI 2014-8 (days to 50% flowering, number of grains per panicle, hulling recovery, milling recovery & harvest index) and the testers Pant Dhan 23 (plant height, grain width & kernel length) Pant Dhan 26 (days to 50% flowering, plant height, grain length, hulling recovery, milling recovery & grain yield) were found good general combiners for these traits. These lines and testers would be further utilized in future breeding programme for the improvement in these traits.

- The crosses viz., UPRI 2008-6 × Pant Dhan 23, UPRI 2012-10 × Pant Dhan 26, CR 2644-2-6-4-3-2 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 4, Pant Dhan 18 × Pant Dhan 23, Pant Dhan 22 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 23 and BBL 180-5-1-4-1 × Pant Dhan 23 found as best specific combiners and also showed significant standard heterosis for grain yield and its related traits. These crosses can be included in future breeding programme to achieve better heterotic output for grain yield and most of the quality traits.

- The estimation of degree of dominance which is based on the ratio of SCA and GCA variances obtained from line × tester analysis indicated the predominance of non-additive gene action for expression of most of the characters. The SCA variance was higher than GCA variance for most of the characters studied except L/B ratio and alkali digestion value.

Breeding Implications:

The presence of significant variation among the genotypes for all the characters under study indicated that there is suitability to carry out selection for further improvement. High heritability was coupled with high genetic advance for important characters such as, number of grains per panicle, spikelet fertility, grain yield per plant and plant height indicated that the characters having high heritability with high genetic advance have greater scope for improvement through direct phenotypic selection by fixing additive genetic effects. For grain yield per plant, UPR 3871-8-1-2-2 × Pant Dhan 4 and CR 2644-2-6-4-3-2 × Pant Dhan 26 were showed significant positive SCA effects and emerged as best specific combiner with highly significant positive standard heterosis over Govind and Pant Dhan 4 therefore, would be expected in utilize future breeding programme for high grain yield. Based on of GCA effects, the lines viz., Pant Dhan 22 (grain yield), Pant Dhan 24 (spikelet fertility), Pant Dhan 10 (1000 grain weight), CR 2644-2-6-4-3-2 (days to maturity, number of grains per panicle & grain yield), UPR 3871-8-1-2-2 (plant height & number of grains per panicle) and Pant Dhan 19, UPRI 2014-8 for grain width, hulling recovery, milling recovery and the testers Pant Dhan 23 (plant height, grain width & kernel length) Pant Dhan 26 (grain length, hulling recovery, milling recovery & grain yield) were found good general combiners for these traits therefore, these lines and testers would be generate best cross combinations in later generations. Crosses viz., UPRI 2008-6 × Pant Dhan 23 (days to 50% flowering, days to maturity & panicle length), CR 2644-2-6-4-3-2 × Pant Dhan 26 & UPR 3871-8-1-2-2 × Pant Dhan 4 (grain yield) and Pant Dhan 18 × Pant Dhan 23, Pant Dhan 18 × Pant Dhan 26, Pant Dhan 22 × Pant Dhan 26, NDR 3012 × Pant Dhan 4, UPRI 2012-19 × Pant Dhan 23 & BBL 180-5-1-4-1 × Pant Dhan 23 (for quality traits) found as best specific combiners for these traits hence, these crosses should be produce to find out transgressive segregants in later generations.

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Appendices

APPENDIX

Table : Means of parents, crosses and standard parents for different characters in rice

SI. No.	Characters / Genotypes	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of tillers per plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain length (mm)
1.	UPRI 2011-21	92.66	123.33	113.06	22.00	28.16	194.16	63.94	21.63	9.73
2.	UPRI 2008-6	101.66	132.33	101.33	24.00	28.00	159.56	47.44	16.35	8.50
3.	BBL 180-5-1-4-1	100.33	128.67	96.93	21.00	29.16	198.53	43.18	19.39	9.10
4.	UPRI 2012-10	95.33	119.67	103.60	26.67	26.43	138.26	57.67	22.26	8.50
5.	UPRI 2008-8	107.33	130.33	104.03	23.67	26.23	174.90	37.72	12.62	9.00
6.	UPRI 2012-19	107.00	131.00	102.40	29.33	27.23	128.53	47.33	14.76	9.53
7.	Pant Dhan 22	94.67	122.67	115.00	24.00	31.33	165.53	55.68	26.75	9.60
8.	Pant Dhan 10	83.00	114.67	99.00	23.00	26.56	119.90	77.31	22.47	9.50
9.	Pant Dhan 18	100.67	130.33	113.33	23.66	28.50	109.03	62.32	23.58	9.53
10.	Pant Dhan 24	94.33	120.67	117.33	18.00	31.33	179.30	68.90	27.70	9.53
11.	UPR 3871-8-1-2-2	107.67	132.33	100.00	16.33	25.33	231.30	29.68	8.87	8.53
12.	UPR 3199-464-1-2	102.33	128.00	110.33	21.66	29.83	240.33	30.88	9.91	7.30
13.	UPRI 2014-8	104.00	132.00	103.00	24.00	27.43	167.40	16.53	10.71	8.66
14.	CR 2644-2-6-4-3-2	108.33	136.00	122.67	20.33	27.06	222.76	50.70	18.73	8.10
15.	NDR 3012	114.00	135.33	91.00	17.66	24.00	127.93	18.15	7.13	9.66
16.	JGL 1172-7	109.00	134.67	120.33	20.66	31.0	239.90	16.82	7.08	9.30
17.	Pant Dhan 19	94.00	120.67	105.00	23.66	28.70	149.20	38.19	15.42	9.06
18.	Pant Dhan 4	87.33	120.00	96.60	22.66	28.27	157.73	73.75	27.43	9.66
19.	Pant Dhan 23	95.00	127.67	98.00	14.00	27.90	193.66	72.52	25.61	9.36
20.	Pant Dhan 26	96.00	124.00	122.36	17.00	29.66	198.80	73.85	28.80	9.80
21.	UPRI 2011-21 X Pant Dhan 4	94.00	123.00	111.67	22.00	29.53	253.76	68.85	18.36	8.67

22.	UPRI 2011-21 X Pant Dhan 23	94.66	123.00	111.00	22.66	24.03	246.30	51.56	16.96	8.53
23.	UPRI 2011-21 X Pant Dhan 26	104.67	132.33	123.67	23.00	28.73	334.83	65.18	17.48	8.70
24.	UPRI 2008-6 X Pant Dhan 4	108.67	135.67	109.67	22.66	20.17	160.43	49.52	14.77	9.20
25.	UPRI 2008-6 X Pant Dhan 23	92.66	116.00	106.33	21.67	33.33	215.50	73.76	21.57	8.90
26.	UPRI 2008-6 X Pant Dhan 26	100.00	124.33	117.33	21.00	29.33	178.16	54.10	14.99	9.00
27.	BBL 180-5-1-4-1 X Pant Dhan 4	94.00	120.00	94.33	20.33	25.00	178.13	68.76	34.40	9.46
28.	BBL 180-5-1-4-1 X Pant Dhan 23	90.00	117.67	96.33	25.67	29.83	166.06	67.26	25.64	9.76
29.	BBL 180-5-1-4-1 X Pant Dhan 26	110.00	136.33	116.00	32.00	30.66	195.06	51.51	30.84	9.50
30.	UPRI 2012-10 X Pant Dhan 4	91.67	123.33	100.00	25.00	27.35	148.00	65.71	24.84	9.06
31.	UPRI 2012-10 X Pant Dhan 23	103.33	133.00	102.00	17.00	24.17	190.10	55.84	22.49	8.76
32.	UPRI 2012-10 X Pant Dhan 26	94.67	118.33	119.00	22.33	31.00	251.00	62.01	27.91	8.96
33.	UPRI 2008-8 X Pant Dhan 4	95.00	122.00	108.67	25.66	30.00	226.93	72.91	25.73	8.70
34.	UPRI 2008-8 X Pant Dhan 23	103.33	132.00	109.33	21.00	28.33	219.23	66.43	17.20	9.53
35.	UPRI 2008-8 X Pant Dhan 26	110.00	138.33	104.00	38.67	29.16	225.06	35.75	12.39	8.63
36.	UPRI 2012-19 X Pant Dhan 4	97.33	128.67	99.50	27.33	27.75	143.13	60.54	21.10	9.60
37.	UPRI 2012-19 X Pant Dhan 23	104.00	133.00	101.67	22.00	28.73	220.81	41.44	17.07	9.000
38.	UPRI 2012-19 X Pant Dhan 26	110.00	139.00	117.67	31.00	29.33	171.46	27.80	28.96	8.86
39.	Pant Dhan 22 X Pant Dhan 4	95.00	120.67	121.00	24.33	32.00	208.73	44.21	14.37	9.30
40.	Pant Dhan 22 X Pant Dhan 23	91.00	125.00	121.33	21.00	34.00	249.30	68.36	27.24	9.70
41.	Pant Dhan 22 X Pant Dhan 26	93.00	121.33	139.33	24.33	32.33	320.13	78.01	24.52	9.46
42.	Pant Dhan 10 X Pant Dhan 4	87.00	116.67	94.33	16.00	27.00	134.91	78.03	29.10	9.00
43.	Pant Dhan 10 X Pant Dhan 23	86.00	120.67	96.66	20.33	27.000	131.16	90.22	25.45	9.06
44.	Pant Dhan 10 X Pant Dhan 26	95.33	123.67	84.66	9.00	24.16	124.86	88.03	25.63	9.00
45.	Pant Dhan 18 X Pant Dhan 4	94.66	128.33	103.67	20.00	28.83	133.20	68.46	25.57	9.60
46.	Pant Dhan 18 X Pant Dhan 23	100.00	127.33	111.33	19.33	29.00	189.10	61.44	28.54	9.53
47.	Pant Dhan 18 X Pant Dhan 26	102.00	119.00	111.67	9.66	27.33	196.06	74.65	17.11	8.53
48.	Pant Dhan 24 X Pant Dhan 4	94.00	119.33	100.67	30.33	28.33	148.80	65.71	22.56	9.06
49.	Pant Dhan 24 X Pant Dhan 23	92.00	117.67	103.33	23.66	31.00	241.96	71.63	20.97	8.96

50.	Pant Dhan 24 X Pant Dhan 26	92.33	121.67	102.33	23.66	27.50	171.46	80.37	22.46	8.66
51.	UPR 3871-8-1-2-2 X Pant Dhan 4	95.00	122.33	99.33	27.33	25.83	202.40	58.64	24.50	8.50
52.	UPR 3871-8-1-2-2 X Pant Dhan 23	102.00	132.33	109.33	11.00	26.50	223.32	35.69	12.41	8.43
53.	UPR 3871-8-1-2-2 X Pant Dhan 26	95.00	125.67	88.33	25.33	29.83	293.33	69.69	23.46	9.00
54.	UPR 3199-464-1-2 X Pant Dhan 4	93.00	123.33	119.00	22.00	27.90	198.73	47.89	19.00	8.53
55.	UPR 3199-464-1-2 X Pant Dhan 23	95.00	125.33	100.33	26.33	28.43	216.60	49.47	17.54	8.33
56.	UPR 3199-464-1-2 X Pant Dhan 26	94.00	128.33	116.67	25.66	29.83	220.73	50.09	18.56	8.50
57.	UPRI 2014-8 X Pant Dhan 4	94.67	125.67	102.67	21.66	32.00	183.93	69.18	16.65	9.23
58.	UPRI 2014-8 X Pant Dhan 23	92.00	123.00	99.67	19.66	29.33	199.70	76.90	22.46	9.10
59.	UPRI 2014-8 X Pant Dhan 26	91.00	123.67	102.00	29.66	26.83	208.10	64.04	30.22	9.10
60.	CR 2644-2-6-4-3-2 X Pant Dhan 4	95.33	127.67	105.00	23.33	31.33	232.30	47.28	27.99	8.33
61.	CR 2644-2-6-4-3-2 X Pant Dhan 23	102.00	134.00	110.33	17.33	27.43	208.21	62.16	22.17	8.75
62.	CR 2644-2-6-4-3-2 X Plant Dhan 26	94.66	125.67	110.00	25.00	29.67	274.56	36.36	19.81	8.30
63.	NDR 3012 X Pant Dhan 4	94.00	125.00	130.33	18.67	29.00	203.20	44.38	28.14	8.90
64.	NDR 3012 X Pant Dhan 23	94.00	125.00	111.00	17.00	30.83	218.26	73.69	27.74	9.40
65.	NDR 3012 X Pant Dhan 26	94.00	126.00	112.00	15.33	33.33	207.76	58.42	25.64	9.40
66.	JGL 1172-7 X Pant Dhan 4	95.00	126.67	121.67	18.00	32.67	286.46	55.85	22.39	9.60
67.	JGL 1172-7 X Pant Dhan 23	97.00	128.33	133.67	16.00	30.67	314.76	54.14	20.19	9.43
68.	JGL 1172-7 X Pant Dhan 26	98.00	130.00	119.33	26.00	31.00	314.50	59.02	20.63	8.73
69.	Pant Dhan 19 X Pant Dhan 4	92.66	125.00	126.67	27.66	30.00	178.10	52.76	23.82	9.23
70.	Pant Dhan 19 X Pant Dhan 23	92.00	122.67	113.67	22.33	29.67	243.36	65.48	48.71	9.26
71.	Pant Dhan 19 X Pant Dhan26	95.00	126.00	115.67	23.00	29.87	238.73	68.76	24.72	9.10
72.	Govind	76.00	106.67	86.33	13.66	24.27	122.90	72.86	17.91	9.67
73.	Pant Dhan 4	86.66	119.00	102.00	29.33	28.86	143.66	51.67	22.34	9.40
	General mean	97.32	126.09	108.79	22.17	28.72	201.98	57.61	21.69	9.04
	CV	5.75	6.02	8.77	13.25	8.73	10.52	6.52	12.63	2.52
	CD at 1%	5.03	5.48	8.69	8.44	4.99	6.12	3.67	9.1	0.36
	CD at 5%	3.81	4.15	6.58	6.39	3.78	4.63	2.79	6.88	0.27

(Contd.) Table: Means of parents, crosses and standard parents for different characters in rice

SI. No.	Characters / Genotypes	Grain width (mm)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Harvest index	Hulling recovery (%)	Milling recovery (%)	Alkali digestion value	Grain yield per plant (g)
1.	UPRI 2011-21	2.46	5.60	1.93	2.89	0.62	73.00	63.33	4.00	27.63
2.	UPRI 2008-6	2.63	5.70	2.03	2.80	0.54	62.66	57.33	3.00	27.65
3.	BBL 180-5-1-4-1	2.53	5.93	2.26	2.61	0.63	70.66	60.66	4.00	30.41
4.	UPRI 2012-10	2.63	5.66	2.03	2.78	0.61	73.66	66.66	2.67	28.65
5.	UPRI 2008-8	2.63	6.00	2.03	2.95	0.48	61.66	54.00	2.33	29.43
6.	UPRI 2012-19	2.46	5.70	1.93	2.94	0.53	70.33	60.33	5.00	26.82
7.	Pant Dhan 22	2.53	6.00	2.03	2.95	0.61	61.00	55.00	2.66	26.72
8.	Pant Dhan 10	2.53	6.10	2.06	2.95	0.60	73.00	66.00	2.33	19.59
9.	Pant Dhan 18	2.56	7.50	2.03	3.68	0.58	62.33	54.00	2.00	24.55
10.	Pant Dhan 24	2.56	5.26	1.96	2.68	0.53	64.66	54.66	2.66	26.78
11.	UPR 3871-8-1-2-2	2.26	6.00	2.00	3.00	0.67	60.66	50.33	1.33	22.89
12.	UPR 3199-464-1-2	2.46	5.83	2.00	2.91	0.43	61.00	55.33	4.00	28.07
13.	UPRI 2014-8	2.66	6.60	2.03	3.24	0.35	57.00	51.00	1.66	23.34
14.	CR 2644-2-6-4-3-2	2.96	6.10	2.33	2.62	0.29	53.33	46.66	2.33	24.55
15.	NDR 3012	2.86	6.50	2.33	2.78	0.39	60.66	51.00	1.67	22.78
16.	JGL 1172-7	2.16	6.43	2.00	3.21	0.34	52.00	46.33	1.00	23.45
17.	Pant Dhan 19	2.96	6.70	2.26	2.95	0.52	77.33	66.00	2.33	25.44
18.	Pant Dhan 4	2.66	6.03	2.03	2.96	0.49	75.66	66.00	2.67	26.28
19.	Pant Dhan 23	2.93	6.00	2.16	2.76	0.52	75.66	67.33	2.67	25.15
20.	Pant Dhan 26	2.76	6.46	2.10	3.08	0.59	71.00	64.00	2.00	35.26
21.	UPRI 2011-21 X Pant Dhan 4	2.66	5.50	2.03	2.70	0.50	73.33	61.00	2.33	40.62
22.	UPRI 2011-21 X Pant Dhan 23	2.83	5.60	2.06	2.70	0.55	61.66	56.00	3.00	40.48
23.	UPRI 2011-21 X Pant Dhan 26	2.66	5.60	2.06	2.70	0.41	63.33	53.66	3.00	49.84
24.	UPRI 2008-6 X Pant Dhan 4	2.73	5.70	2.03	2.80	0.58	60.66	55.00	2.67	39.75
25.	UPRI 2008-6 X Pant Dhan 23	2.83	6.03	2.03	2.96	0.52	70.33	61.00	2.00	42.49

Appendix.....

26.	UPRI 2008-6 X Pant Dhan 26	2.76	6.23	2.13	3.01	0.60	64.66	61.0	2.00	44.61
27.	BBL 180-5-1-4-1 X Pant Dhan 4	2.56	5.60	2.00	2.80	0.535	66.66	55.67	3.67	31.83
28.	BBL 180-5-1-4-1 X Pant Dhan 23	2.93	6.10	2.10	2.97	0.59	70.33	64.00	4.00	36.45
29.	BBL 180-5-1-4-1 X Pant Dhan 26	2.83	5.93	2.00	2.9	0.35	59.00	50.66	4.00	50.31
30.	UPRI 2012-10 X Pant Dhan 4	2.66	5.86	2.03	2.87	0.55	74.66	66.33	2.67	27.46
31.	UPRI 2012-10 X Pant Dhan 23	2.46	6.80	2.20	3.09	0.40	75.00	64.66	1.33	17.28
32.	UPRI 2012-10 X Pant Dhan 26	2.76	6.10	2.06	2.95	0.54	64.33	54.66	2.33	53.66
33.	UPRI 2008-8 X Pant Dhan 4	2.73	5.93	2.00	2.96	0.55	58.66	50.66	3.00	45.02
34.	UPRI 2008-8 X Pant Dhan 23	2.63	6.06	2.06	2.93	0.43	57.66	51.00	3.00	43.42
35.	UPRI 2008-8 X Pant Dhan 26	2.63	6.10	2.10	2.90	0.40	60.33	56.00	2.33	40.52
36.	UPRI 2012-19 X Pant Dhan 4	2.56	5.86	2.00	2.93	0.51	73.66	63.3	4.00	27.79
37.	UPRI 2012-19 X Pant Dhan 23	2.86	7.23	2.26	3.19	0.51	77.66	66.00	2.33	41.056
38.	UPRI 2012-19 X Pant Dhan 26	2.53	7.06	2.26	3.12	0.45	56.66	51.33	4.33	47.22
39.	Pant Dhan 22 X Pant Dhan 4	2.93	6.10	2.03	3.00	0.53	61.66	54.66	2.67	45.59
40.	Pant Dhan 22 X Pant Dhan 23	2.83	6.26	2.16	2.88	0.67	71.00	64.00	3.00	58.53
41.	Pant Dhan 22 X Pant Dhan 26	2.66	6.36	2.13	2.98	0.56	72.00	64.66	2.00	77.76
42.	Pant Dhan 10 X Pant Dhan 4	2.53	7.10	2.20	3.24	0.50	80.33	74.00	1.33	36.53
43.	Pant Dhan 10 X Pant Dhan 23	2.63	6.10	2.06	2.95	0.65	77.00	71.00	1.66	30.15
44.	Pant Dhan 10 X Pant Dhan 26	2.73	7.03	2.26	3.10	0.45	78.66	70.33	2.66	19.84
45.	Pant Dhan 18 X Pant Dhan 4	2.70	6.66	2.23	3.00	0.41	70.00	61.00	4.33	24.53
46.	Pant Dhan 18 X Pant Dhan 23	2.73	7.40	2.33	3.17	0.48	72.00	72.00	2.33	56.63
47.	Pant Dhan 18 X Pant Dhan 26	2.53	5.73	2.00	2.87	0.49	74.00	65.66	3.33	56.49
48.	Pant Dhan 24 X Pant Dhan 4	2.83	6.10	2.06	2.93	0.48	72.00	67.00	3.00	40.47
49.	Pant Dhan 24 X Pant Dhan 23	2.73	6.06	2.06	2.93	0.47	74.33	69.00	2.33	55.45
50.	Pant Dhan 24 X Pant Dhan 26	2.43	5.70	1.90	3.00	0.49	75.00	68.00	2.66	35.88
51.	UPR 3871-8-1-2-2 X Pant Dhan 4	2.76	6.13	2.10	2.92	0.61	78.33	70.33	1.66	72.17
52.	UPR 3871-8-1-2-2 X Pant Dhan 23	2.43	5.70	1.86	3.05	0.45	73.33	54.66	1.66	36.40
53.	UPR 3871-8-1-2-2 X Pant Dhan 26	2.46	5.90	1.96	3.00	0.53	72.00	64.33	2.66	69.48

54.	UPR 3199-464-1-2 X Pant Dhan 4	2.73	6.03	2.03	2.96	0.65	69.00	61.33	4.00	54.19
55.	UPR 3199-464-1-2 X Pant Dhan 23	2.56	6.03	2.06	2.91	0.61	67.66	61.66	3.00	52.41
56.	UPR 3199-464-1-2 X Pant Dhan 26	2.76	6.13	2.06	2.96	0.64	65.66	60.33	4.00	68.42
57.	UPRI 2014-8 X Pant Dhan 4	2.70	6.46	2.23	2.89	0.60	75.00	71.66	2.33	40.81
58.	UPRI 2014-8 X Pant Dhan 23	2.73	6.10	2.06	2.95	0.44	76.33	69.00	2.33	31.25
59.	UPRI 2014-8 X Pant Dhan 26	2.86	6.33	2.13	2.96	0.49	73.66	67.66	2.33	58.43
60.	CR 2644-2-6-4-3-2 X Pant Dhan 4	2.63	6.06	2.33	2.67	0.44	81.00	64.00	2.00	47.26
61.	CR 2644-2-6-4-3-2 X Pant Dhan 23	2.96	6.03	2.20	2.73	0.42	64.66	57.33	2.66	26.60
62.	CR 2644-2-6-4-3-2 X Pant Dhan 26	2.93	5.73	2.03	2.84	0.41	71.33	66.66	2.33	68.43
63.	NDR 3012 X Pant Dhan 4	2.73	6.10	2.20	2.79	0.43	71.00	61.00	3.00	32.44
64.	NDR 3012 X Pant Dhan 23	2.93	6.43	2.36	2.72	0.44	73.66	68.66	1.66	44.45
65.	NDR 3012 X Pant Dhan 26	3.13	6.60	2.46	2.67	0.61	71.00	66.00	1.33	34.66
66.	JGL 1172-7 X Pant Dhan 4	2.96	6.00	2.03	2.95	0.56	71.00	62.00	2.33	40.39
67.	JGL 1172-7 X Pant Dhan 23	2.63	5.80	1.93	3.00	0.46	71.33	63.00	2.33	30.40
68.	JGL 1172-7 X Pant Dhan 26	2.47	6.40	2.10	3.05	0.61	71.00	64.33	2.33	49.41
69.	Pant Dhan 19 X Pant Dhan 4	2.40	6.06	2.06	2.93	0.68	73.00	71.00	3.00	46.96
70.	Pant Dhan 19 X Pant Dhan 23	2.63	6.23	2.16	2.88	0.62	76.00	69.33	2.00	49.19
71.	Pant Dhan 19 X Pant Dhan26	2.86	6.53	2.16	3.01	0.63	76.00	68.00	3.00	63.41
72.	Govind	2.63	5.70	1.93	2.94	0.66	61.00	54.667	3.00	16.43
73.	Pant Dhan 4	2.76	5.90	1.90	2.88	0.37	60.66	51.33	4.00	29.43
	General mean	2.68	6.15	2.1	2.93	0.52	69.09	61.43	2.63	39.44
	CV	2.12	3.68	5.36	4.90	8.33	3.25	2.93	9.71	8.63
	CD at 1%	0.13	0.23	0.24	0 .30	0 .36	2.95	3.05	1.8	4.53
	CD at 5%	0.10	0.17	0 .18	0 .23	0 .31	2.23	2.31	1.38	3.43

VITAE

The author was born on 10th October, 1994 at place Baran, (Rajasthan). He passed his High School examination in 2009 from Maa Sharda Bal Vidyalaya, Chhinod, Baran and Intermediate examination in 2011 from Descent Public Senior Secondary School, Baran. He has completed his B.Sc. (Ag) degree from Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra in 2016. He joined the G. B. Pant University of Agriculture and Technology, Pantnagar for the degree of M.Sc. Agriculture with major in Genetics & Plant Breeding in the year 2016.

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ABSTRACT

Name	**:** Dhanraj Meena	**Id. No.** **:**	51151
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Thesis title	**: "Studies on heterosis and combining ability analysis using Line × Tester Mating design in rice *(Oryza sativa* L.)"**		
Advisor	**: Dr. M.K. Karnwal**		

The present investigation was carried out by using 17 lines and 3 testers crossed in Line × Tester fashion to generate 51 F_1's during *kharif* 2016. These F_1's were subjected to evaluation along with their parents and 2 checks i.e. Govind and Pant Dhan 4 in a replicated trial using Randomized Block Design at NEBCRC, Pantnagar, Uttarakhand, during *kharif* 2017. These 73 genotypes were evaluated to study genetic variability parameters, combining ability (GCA and SCA) and magnitude of heterosis for various quantitative and qualitative traits in rice.

Analysis of variance revealed highly significant genetic variations among 73 genotypes for all the 18 characters studied. Highest PCV and GCV was observed for grain yield per plant (37.096% & 36.699%) followed by alkali digestion value (40.945% & 25.419%), 1000 grain weight (34.95% & 29.014%), spikelet fertility (28.266% & 28.106%), number of tillers per plant (27.138% & 20.572%) and number of grains per panicle (25.51% & 25.469%). High heritability coupled with high genetic advance was reported for traits such as, number of grains per panicle, spikelet fertility, grain yield per plant and plant height indicated that these characters have greater scope for improvement through direct phenotypic selection by fixing additive genetic effects.

The lines Pant Dhan 22 (grain yield), Pant Dhan 24 (spikelet fertility), Pant Dhan 10 (1000 grain weight), CR 2644-2-6-4-3-2 (days to maturity, number of grains per panicle & grain yield), UPR 3871-8-1-2-2 (plant height & number of grains per panicle), Pant Dhan 19 (days to 50% flowering, grain width, hulling recovery, milling recovery, harvest index & grain yield), UPRI 2014-8 (days to 50% flowering, number of grains per panicle, hulling recovery, milling recovery & harvest index) and the testers Pant Dhan 23 (plant height, grain width & kernel length) Pant Dhan 26 (days to 50% flowering, plant height, grain length, hulling recovery, milling recovery & grain yield) were found good general combiners for quantitative and qualitative traits in rice. On the basis of SCA effects, eight crosses namely, UPRI 2008-6 × Pant Dhan 23, UPRI 2012-10 × Pant Dhan 26, CR 2644-2-6-4-3-2 × Pant Dhan 26, UPR 3871-8-1-2-2 × Pant Dhan 4, Pant Dhan 18 × Pant Dhan 23, Pant Dhan 22 × Pant Dhan 26, UPRI 2012-19 × Pant Dhan 23 and BBL 180-5-1-4-1 × Pant Dhan 23 found as best specific combiners and also showed significant standard heterosis for grain yield and its related traits. For grain yield per plant, UPR 3871-8-1-2-2 × Pant Dhan 4 (16.60) and CR 2644-2-6-4-3-2 × Pant Dhan 26 (13.34) were exhibited significant positive SCA effects and emerged as best specific combiner with highly significant positive standard heterosis over Govind and Pant Dhan 4.

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Advisor

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षटमास एवं प्रवेश का वर्षः प्रथम, **2016-17** **उपाधि : कृषि स्नातकोत्तर**

प्रमुख विषय : **आनुवंशिकी एवं पादप** प्रजनन विभाग : **आनुवंशिकी एवं पादप** प्रजनन

शोध शीर्षक : □चावल (***ऑराईजा सेटाइवा*** एल.) में लाइन × **टेस्टर पध्दति** का उ□योग कर **संकर ओज** □र अध्ययन और संयोजन क्षमता **का** विश्लेषण।□

सलाहकार : डॉ. एम.के. कर्ण**वाल**

खरीफ **2016** के दौरान लाइन × **टेस्टर (17** लाइन **एवं 3 टेस्टर) पध्दति व्दारा धान** की **उन्नत प्रवष्ठियों का संकरण कराया गया फलस्वरुप 51 संकर प्रवष्ठियाँ** उत्□न्न की **गयी अगले वर्ष सभी जनित संकर प्रवष्ठियों** को **इनके जनक एवं 2 चैक प्रजातियों क्रमशः** गोविंद और □ंत धन **4** का मूल्यांकन चावल में विभिन्न मात्रात्मक और गुणात्मक गुणों की **आनुवांशिक विविधता, वंशागत गुणों,** संयोजन क्षमता (जीसीए और एससीए) और **संकर ओज** क्षमता (हेटरोसिस) **परखने हेतु नारमॅान इ. बोरलॅाग फसल अनुसंधान केन्द्र,** □ंतनगर, उत्तराखंड **पर** खरीफ **2017** में यादृच्छिक **खण्ड अभिकल्पना** का उ□योग कर **दोहराई गयी प्रतिकृति मे शोध सम्पादित** किया गया।

शोध में किए गए भिन्नता विश्लेषण में सभी **18** मात्रात्मक और गुणात्मक गुणों के लिए सभी **73 प्रवष्ठियों (जिसमे जनक प्रवष्ठियाँ एवं चैक भी सम्मलित है) मे परस्पर आनुवंशिकीय भिन्न्ता देखी गई।** उच्चतम □ीसीवी और जीसीवी, **दाना** उ□ज प्रति □ौधे (37.09 % **एवं** 36.69%) के बाद क्षार □ाचन **मान** (40.94% **एवं** 25.41%), 1000 **दाना** वजन (34.95% **एवं** 29.01%), **बाली** प्रजनन **भरण** क्षमता (28.26% **एवं** 28.10%), **कलमों** की संख्या (27.13% **एवं** 20.57%) और प्रति **बाली दानों** की संख्या (25.51% **एवं** 25.46%) के लिए **अंकित की गई**। **जिन गुणों** में उच्च आनुवंशिक अग्रिम के साथ-साथ उच्च आनुवंशिकता **दर्ज** की गई **उदाहरणवस,** प्रति □ैनिकल **दानों** की संख्या, **बाली** प्रजनन **भरण** क्षमता और प्रति **पौधा दाना** उ□ज **आदि** के योजक आनुवांशिक प्रभावों को **लेते हुए** प्रत्यक्ष फेनोटाइ□िक चयन के माध्यम से सुधार के लिए अधिक गुंजाइश **प्रस्तावित** है।

प्रवष्ठियाँ क्रमशः □ंत **धान** 22 (**दाना** उ□ज), □ंत **धान** 24 (**बाली** प्रजनन **भरण** क्षमता), □ंत **धान** 10 (1000 **दाना** वजन), **सीआर 2644-2-6-4-3-2** (□रि□क्वता **अवधि**, प्रति **बाली दानों** की संख्या और **दाना** उ□ज), यू□ीआर 3871-8-1-2-2 (□ौधे की ऊंचाई **एवं** प्रति **बाली दानों** की संख्या), □ंत **धान** 19 (50% **फुलावधि**, **दानों** की चौड़ाई, **गिरी झडत, चावल झडत,** फसल सूचकांक **एवं दाना** उ□ज), यू□ीआरआई 2014-8 (50% **फुलावधि**, प्रति **बाली दानों** की संख्या, **गिरी झडत, चावल झडत एवं** फसल सूचकांक) और **टेस्टर** □ंत **धान** 23 (□ौधों की ऊंचाई, **दानों** की चौड़ाई **एवं गिरी** की लंबाई) □ंत **धान** 26 (50% **फुलावधि**, □ौधों की ऊंचाई, **दानों** की लंबाई, **गिरी झडत, चावल झडत** और **दाना** उ□ज) **आदि** इन **गुणों** के लिए अच्छे सामान्य संयोजक □ाए गए। एस सी ए प्रभाव के आधार □र, **आठ संकर प्रवष्ठियाँ क्रमशः** यू□ीआरआई 2008-6 × □ंत **धान** 23, यू□ीआरआई 2012-10 × □ंत **धान** 26, **सीआर 2644-2-6-4-3-2** × □ंत **धान** 26, यू□ीआर 3871-8-1-2-2 × □ंत **धान** 4, □ंत **धान** 18 × □ंत **धान** 23, □ंत **धान** 22 × □ंत **धान** 26, यू□ीआरआई 2012-19 × □ंत **धान** 23 और बीबीएल 180-5-1-4-1 × □ंत **धान** 23 को सर्वश्रेष्ठ विशिष्ट संयोजक के रू□ में और **दाना** उ□ज **एवं** इसके संबंधित **गुणों** के लिए महत्व□ूर्ण मानक **संकर ओज** के लिए **अंकित** किए गए। **दो संकर प्रवष्ठियों व्दारा** प्रति **पौधा दाना** उ□ज के लिए **क्रमशः** यू□ीआर 3871-8-1-2-2 × □ंत **धान** 4 (16.60) और **सीआर 2644-2-6-4-3-2** × □ंत **धान** 26 (13.34) के **व्दारा** महत्व□ूर्ण सकारात्मक एस सी ए प्रभाव प्रदर्शित किया गया और सर्वश्रेष्ठ विशिष्ट संयोजन के रू□ में **उभरते हुये** गोविंद **एवं** □ंत **धान** 4 के **प्रतिपेक्ष** में अत्यधिक महत्व□ूर्ण सकारात्मक मानक **संकर ओज** प्रदर्शित **की गयी**।

(एम.के.कर्णवाल)
सलाहकार

(धनराज मीना)
लेखक