

Evaluation of Inter and Intra- subspecific Rice Hybrids for Quantitative and Qualitative Traits

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By

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CERTIFICATE-1

This is to certify that the thesis entitled "**Evaluation of Inter and Intra-specific Rice Hybrids for Quantitative and Qualitative Traits**" submitted in partial fulfillment of requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE (Plant Breeding and Genetics)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Ms. Milimol M. Bastian** under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published /published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by her.

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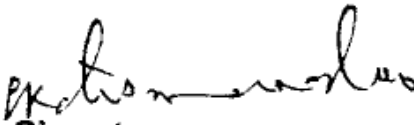
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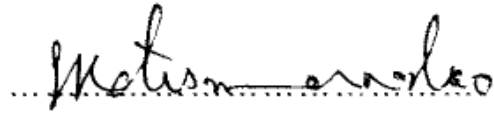
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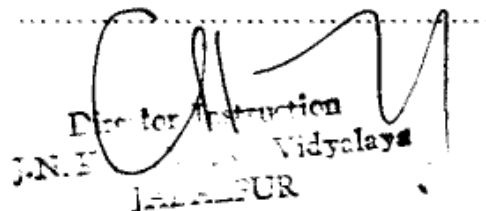
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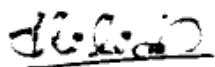
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LIST OF ABBREVIATIONS

DFF	Days to 50% flowering (days)
PHT	Plant height (cm)
PAN/PT	Panicles / plant
PANWT/PT	Panicle weight / plant (g)
PAN LGH	Panicle length (cm)
PAN/M	Panicle / square metre
NOS/PL	Number of spikelets / panicles
FG/PL	Filled grains / panicle
SP FER	Spikelet fertility percentage (%)
TILL/PT	Number of tillers / plant
PRTILL/PT	Number of productive tillers per plant
PT/P	Number of primary tillers per plant
ST/P	Number of secondary tillers per plant
TT/P	Number of tertiary tillers per plant
GL/B	L/B ratio (grain)
GY/PL	Grain yield / plant (g)
HI%	Harvest index (%)
BY/PL	Biological yield / plant (g)
MILL%	Milling percentage (%)
HULL%	Hulling percentage (%)
HRR%	Head rice recovery (%)
KLBC	Kernel length before cooking (mm)
KBBC	Kernel breadth before cooking (mm)
KL/B	L/B ratio (before cooking)
KLAC	Kernel length after cooking (mm)
KBAC	Kernel breadth after cooking (mm)
L/B CR	L/B ratio (cooked rice)
ER	Elongation ratio
EI	Elongation Index
GC	Grain Chalkiness
GT	Gelatinization temperature (GT)
df	Degrees of freedom

CHAPTER - I

INTRODUCTION

INTRODUCTION

Rice is one of the most important food crop of the world. It is a staple food for Indians, providing 43% of caloric requirement for more than 70% of Indian population. Rice occupies the largest area among all the crops grown in India. The area under rice in India (44 mha) is the largest in the world among all the rice growing countries. Annual production of rice in the country is around 89 million tonnes. By 2030, the world must produce 60% more rice than it produced in 1995 to meet the demand created by increasing population and rising income. This increase must be achieved using less land, less labour, less water, and fewer pesticides, and it must be sustainable. To meet this challenge, increasing the yield potential of rice beyond that of the current day semi dwarf varieties is an important strategy.

The dwarf plant type evolved in late 60's resulted in the development of many high yielding varieties. They provide self-sustainability to many countries of Asia including India. To sustain in coming decades in the self-sufficiency achieved in rice, the production needs to be increased every year by almost 3 million tones. The dwarf plant type varieties currently in cultivation showed yield stagnation and there is a need to address this situation immediately. This is a daunting task in view of plateauing trend observed in yield potential of high yielding varieties and depleting natural resource base.

Among the various approaches being explored, hybrid rice technology appears to be the most potential and practically feasible option. In China, about 30 % of rice area is covered with hybrid rice, which gives about 15-20% higher yield than normal varieties under the same agronomical conditions. Hybrid rice varieties have a mean yield advantage of 10-15% over the inbred varieties. Although, the

current level of heterosis attracts the farmers for adoption of hybrid rice, but to sustain this innovative technology in a long run, there is a need to enhance the level of heterosis. The inter-sub specific rice hybrids have showed a higher heterosis i.e. indica/tropical japonica crosses compared to indica/indica crosses. The early efforts to combine good traits from indica and japonica lines in the form of hybrids have met with little success due to semi sterility. Efforts to exploit the inter sub-specific heterosis were initiated through identification of genotypes possessing wide compatible genes and to develop compatible restorers. These lines are being used as donors for developing wide compatible potential materials, which is required for inter sub-specific hybridization programme to develop normally fertile commercial F_1 hybrids.

The high heterosis level for yield in indica/tropical japonica crosses seems to be promising and prospects for large-scale adoption of this technology in India appears to be bright.

JNKVV started the development of Jawahar New Plant Type (JNPT) of rice for its deployment in hybrid rice breeding in the year 1989. The efforts made so far resulted in the development of many indica / tropical japonica JNPT lines. Some of these lines were used for the development of intra sub-specific rice hybrids. In the present investigation 11 indica/JNPT and 14 indica/indica hybrids will be evaluated for judging their relative merits and demerits.

The quality characters of rice, such as physical appearance, cooking characteristics and nutritional traits are the important factors, which determines ultimate acceptability of new types by farmers and consumers. Grain quality in rice is controlled by many physico-chemical traits like grain dimension, hulling, milling, head rice recovery, gelatinization temperature, kernel elongation or swellings degrees of splitting are profoundly affect the cooking

quality. The hybrids developed needs to be evaluated for quality traits also.

The present investigation will be conducted with the following objectives:

1. To estimate the magnitude of standard heterosis
2. To know the association of yield, its components and quality traits
3. To identify direct and indirect effects of yield attributing traits on seed yield
4. To identify better hybrids for yield and quality traits

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A successful Plant Breeding programme will necessitate the existence of variability in the base population and adequate information of genetic control of the character under improvement. The development of hybrid rice is a strategic tool for enhancing yield, thereby, meeting the futures projected demand. The combination for quality traits along with yield and its components is an important aspect to study for evolving high yielding hybrids with good grain quality.

The work done on yield, its component and quality attributes of indica/indica and indica/JNPT rice hybrids has been reviewed and presented in this chapter.

Estimation of standard heterosis

The 'Heterosis' often used synonymously with hybrid vigour, refers to the superiority of F_1 hybrids over its parents. Shull (1914) coined the term heterosis for the special stimulus of heterozygosis upon "cell division, growth and other physiological activities of an organism and later defined heterosis to cover the real, observable phenomena" when unlike gametes are brought together to form a hybrid. Heterosis in relation to the best commercial cultivar of the crop is known as "Standard or Economic heterosis".

The first commercial exploitation of heterosis phenomenon was reported by Shull (1911) in maize. Heterosis in rice was first reported by Jones (1926), who observed that F_1 hybrids had more culms and higher yield than their parents. During the next 35 years, several other researchers viz., Kadam *et al.* (1937), Capinpin and Singh (1938), and Sen and Mitra (1958) also confirmed its occurrence in rice, which is a strictly self-pollinated crop. None of these researchers however, showed interest in commercial

exploitation of this phenomenon. During the 1980's, suggestion for commercial exploitation of heterosis in rice was made in India (Richharia, 1962), USA (Stansel and Craigmiles, 1966), Japan (Shinjyo and Omura, 1966a b), and China (Yuan and Ding, 1966). Although the commercial exploitation of heterosis in rice demonstrated, only by Chinese scientists, Yuan (1977), Lin and Yuan (1980), Yuan *et al.* (1989) Yuan and Fu (1995) developed and used commercial rice hybrids which increased the yield by about 20% over commercial varieties.

Kim and Rutger (1988), and Virmani (1994) reviewed literature on heterosis in rice until 1990 and reported the presence of significant heterosis for yield and yield contributing traits. They also reported heterosis for several other traits viz., plant height, days to flowering, dry matter production and harvest index.

Virmani *et al.* (1981) reviewed the literature until 1978, for extent of heterosis for several agronomic traits and noted several reports showing significant heterosis for yield (9.17 to 369.6%), grains per panicle (-70.4 to 55%), grain weight (-31.0 to 99.1%) panicles per plant (-37.0 to 63.8%) and days to flowering (-37.0 to 27%). Between 1972 to 1975, China for the first time tested, experimental rice hybrid in the field in comparison with standard varieties and parents. The most promising hybrids yielded 22.1 to 34.6% more than the best available inbred checks.

Yuan *et al.* (1989) reported 14.4 tons / ha yield of single crop of rice hybrid compared to 10.4 tons / ha from an improved inbred variety in Jiangsu province of China, indicating 38% potential standard heterosis. Peng *et al.* (1988) in a study of 75 rice hybrids reported (-59 to 34%) significant standard heterosis for grain yield. Suh and Cho (1987) in study of 11 rice hybrids reported 15.2% standard heterosis.

Gu *et al.* (1989) reported 7.4-41% greater yield of indica /japonica F₁ hybrids viz., Zaoxiandang x 02428 and 3037x02428 in comparison to indica cultivar Shanyou 63.

Lin *et al.* (1990) studied the panicle structure of indica – japonica rice hybrids and reported the large panicles of the hybrids compared with indica cultivars.

Evaluating three indica x japonica rice hybrids Yamamoto *et al.* (1991) reported a high heterosis for yield. Kabaki *et al.* (1992) and Kabaki (1993) developed japonica-indica hybrids, which showed 110-125% heterosis for yield over standard check. High heterosis for grain yield per plant (103.3%) was observed by Zhang *et al.* (1993) in indica x japonica rice hybrids

Dhanakodi *et al.* (1994) observed 6-5% significant standard heterosis for grain yield. Pandey *et al.* (1996) evaluated 36 hybrids, their parents and standard cultivar 'Jaya' and found that most of the hybrids manifested significant heterosis for grain. Yolanda and Das (1996), in a study of 36 hybrids and 12 testers found that hybrids IR 62829A × CO-37 had significant positive heterosis for grain yield per plant.

Dwivedi *et al.* (1998) studied 45 hybrids under different environments, they found that hybrids had higher heterosis for grain yield in respective of environments. Mishra *et al.* (1998) studied four hybrids and their parents and noted high magnitude of heterosis for grain yield in all the hybrids. Yadav (1999) in a study of 30 hybrids found standard heterosis ranging from 9.28-75.48% for grain yield per plant.

Malik *et al.* (1978) found most of the hybrids flowered earlier than their earlier parent.

Richharia and Singh (1983) observed positive heterosis for early flowering. Patel *et al.* (1994) in a study of 30 F₁ hybrids reported the highest heterotic effect of days to 50% flowering.

Gopalkrishnan and Ganapathy (1996) observed superior estimates of heterosis for days to flowering. Dwivedi *et al.* (1998) reported negative heterosis for flowering across environments in their study of 45 hybrids.

An ideal plant morphology associated with low tillering ability was reported by Yang *et al.* (1993) in indica-japonica rice hybrids.

Ramiah and Ramaswamy (1941), Namboodri (1963), Purohit (1972) and Rajagopalan *et al.* (1973), observed in their studies that the number of ear bearing tillers were more in hybrids in comparison to mid-parent value of the parents. Reddy and Nerkar (1995) and Lin *et al.* (1996) on their studies on two hybrids observed high standard heterosis for productive tillers per plant.

Chang *et al.* (1973), Malik *et al.* (1978) Singh and Pandey *et al.* (1998), obtained negative heterosis for panicle length. Gopalakrishnan and Ganapathy (1996) and Pandey *et al.* (1996) observed high heterosis estimated for panicle length. Pandey *et al.* (1985) concluded that plant height, panicle length and 1000-grain weight were the direct positive contributing traits towards grain yield in rice.

Panwar (1998) in a study of 22 F₁ hybrids developed using male sterile line, observed significant standard heterosis over commercial cultivar "HKK 126" for panicles per plant. Yolanda and Das (1996) studied 361 rice hybrids in which one of the hybrids (IR 62828 A × CO37) showed significant positive heterosis for panicles per plant.

Miah *et al.* (1996) studied rice cultivars of high yielding japonica/indica hybrids, observed 20 to 31% heterosis per panicle weight compared with japonica type cultivars.

Ramana *et al.* (1998) observed that hybrids produced more panicles per square meter than conventional cultivars.

Richharia and Singh (1983), Shanmugasundaram and Sivasubramanian (1983), Patel *et al.* (1994), Pandey *et al.* (1996), Yuan *et al.* (1995), Dwivedi *et al.* (1998) and Sitaramaiah *et al.* (1998) reported positive heterosis for spikelets and grains per panicle.

Yang *et al.* (2001) reported that both New Plant Type (NPT) and japonica/indica hybrid rice have large sink (total spikelets number) and a higher source sink ratio at heading stage.

Ramalingam *et al.* (1994) studied 25 rice hybrids and reported positive heterosis for filled grains per panicle in 4 hybrids.

Wu and Zhang (1991) in a study on the two-line hybrid rice observed, 31.3% standard heterosis for filled grains per panicle.

Virmani *et al.* (1981) reviewed the literature published until 1978 and found heterosis of -0.7 to 55.0% for spikelet fertility percentage. Shen and Xue (1997) reported considerable lower spikelet fertility in F_1 generations of indica-japonica hybrids.

Quan *et al.* (1999) observed that the aberration of the ratio between source and sink in japonica-indica hybrids caused a low grain filling. Gupta (1999) in a study of 105 rice hybrids observed that the magnitude of standard heterosis for spikelets fertility percentage was moderate to high (7.35-121.86%) in positive direction.

Panwar *et al.* (1998) studied 21 F₁ rice hybrids and reported negative standard heterosis for 1000-grain weight (-34.55 to 5.82%).

Sharma and Mani (1989) studied a cross between IR 46830A × Basmati 370 found positive heterosis for 1000-grain weight. Wu and Zhang (1991) studied N985/Teqing, a two-line hybrid and observed standard heterosis of 5.2% over a commercial cultivar Hua Yaugui 44 for 1000-grain weight.

Cai *et al.* (1989) observed that high biological yield and dry matter production before and after heading led to significant increase in grain yield.

Lu *et al.* (1988) reported that hybrid rice with higher grain yield possessed higher biomass. Virmani (1996) remarked that increase in total biomass was one of attributes for increased yields.

Yoshida (1972) Virmani *et al.* (1981), Ponnuthurai *et al.* (1984), Kim (1985) and Patel *et al.* (1994) reported significant standard heterosis for harvest index. Heterosis for harvest index was attributed to heterosis for spikelets number and 1000 grain weight.

Sreedhar and Kulkarni (1993) reported both positive and negative standard heterosis for characters viz., days to 50% flowering, plant height, no. of productive tillers per plant, panicle length, no. of filled spikelets per panicle, spikelets fertility percent, 1000 grain weight, grain yield per plant. Dong *et al.* (1995) studied the growth duration in 80 indica × japonica combinations and reported maximum heterosis for days to maturity in inter-subspecific F₁^s in contrast with indica × indica or japonica × japonica combinations.

Sathya *et al.* (1999) studied heterobeltiosis for the characters viz., number of productive tillers per plant, panicle length, number of

filled spikelets per panicle, 1000 grain weight, grain yield per plant and reported both positive and negative heterobeltosis.

Singh and Maurya (1999) reported negative and positive standard heterosis for days to 50% flowering, plant height, panicle length, 1000-grain weight, and grain yield per plant.

Kumar and Singh (2002) studied 27 rice hybrids to determine the nature and extent of standard heterosis for 8 characters. Most of the crosses manifested significant heterosis for grain yield. The range of heterosis for grain yield per plant was -91.16 to 111.28% over the standard cultivar.

Bhave *et al.* (2002) evaluated thirty-two rice hybrids for standard heterosis for grain yield per plant, plant height, tiller number per plant, 50% flowering, and maturity, panicle length, grain number per panicle, 100-grain weight and harvest index. For grain yield per plant, standard heterosis ranged from -84.96 to 132.32%.

Singh *et al.* (2002) evaluated thirty-six hybrids for heterosis in seed yield and yield components (number of days to 50% flowering, plant height, panicle length, number of filled grains per panicle, 1000-grain weight, spikelet density of fertile grains, biological yield and harvest index). Approximately 38-50% of the hybrids exhibited standard heterosis for grain yield per plant.

Banumathy *et al.* (2003) studied the magnitude of standard heterosis of 100 rice hybrids for grain yield and its related traits. Most of the high yielding hybrids manifested positive heterosis for long panicles, filled grains and spikelet fertility.

Ying *et al.* (2003) studied the agronomic traits and dry matter production of indica-japonica and japonica-javanica hybrid rice. The F₁ hybrids had greater plant height, growth and dry matter production compared with the control.

Yadav *et al.* (2004) reported both positive and negative heterobeltiosis for characters viz. days to 50% flowering (-8.27 to 22.06), plant height (-1.31 to 16.58), no. of productive tillers per plant (-31.51 to 42.27) and panicle length (-27.37 to 42.29).

Major determinants of grain quality in hybrid rice are hulling, milling, head rice recovery, size, shape, appearance, cooking quality and eating characteristics.

Khush *et al.* (1988) critically studied grain quality of several rice hybrids in comparison to their divergent parents and concluded that the cooking characteristics were intermediate between those of parents and hybrids have superior head rice recovery if both parents have high head recovery.

Gravios (1994) studied eight F_1 hybrids and reported significant heterosis for hulling percentage and head rice recovery.

Wang *et al.* (1999) on a study on indica hybrid rice Dyou 68 reported significant heterosis for hulled rice (52.1%), milled (72.2%) and head rice recovery (66.5%).

Correlation studies

The association of several component characters of yield and cooking quality and their knowledge of relationship with other component characters help breeders to attempt a simultaneous improvement of several character in selection programme.

The literature available on these aspects is reviewed in the following paragraphs.

High significant positive association between grain yield and number of tillers per plant had been reported by Aly (1979), Singh (1980), Kaul and Kumar (1982), Gopinath *et al.* (1984), Chauhan *et al.* (1986), Choubey and Singh (1994) and Padmavati *et al.* (1996).

Dzyuba (1980) reported significant positive association of yield with plant height.

Mazur *et al.* (1980), Chauhan *et al.* (1986), Panwar *et al.* (1989), Choubey and Singh (1994), Vijayakumar *et al.* (1997) reported positive correlation between yield and plant height.

By utilizing the progenies of crosses between indica and japonica rice Yang *et al.* (1993) observed the association between plant height with respect to ideal plant morphology.

Prasad *et al.* (1998) reported significant positive correlation between plant height and panicle length.

Choubey and Singh (1994) found positive correlation between panicle length and number of spikelets per panicles.

Lin *et al.* (1989) reported that the number of productive panicles / ha had the most significant positive effect on grain yield. Murthy and Murthy (1981) reported positive significant association between spikelets number, number of panicles per plant and spikelets sterility.

Kabaki *et al.* (1992) and Zhang *et al.* (1997) reported that there is significant positive association between 1000-grain weight and high yield in inter- subspecific rice hybrids.

Dong *et al.* (1995) and Lu *et al.* (1999) reported that the growth period was significantly and positively correlated with grain yield in indica x japonica cross combinations.

Padmavati *et al.* (1996) reported positive association of grain yield with panicles per plant.

Rangel *et al.* (1980) reported positive correlation of yield with spikelets per panicle. Yolanda and Das (1995) observed positive

association between grain yield, spikelets per panicle and grains per panicle.

Zhong *et al.* (1997) reported that the potential production of hybrid "Xieyou 46" was closely associated with the number of spikelets per panicle.

Mani *et al.* (1997) reported positive association between grain yield and number of filled grains per panicle.

Studying the genetic correlation, Shi and Shen (1996) observed that the grain yield traits were correlated with grains per panicles, fertility percentage and grain weight. Zhen *et al.* (1996) reported significant positive correlation between quality characters and rice grain length, whereas significant negative correlation was observed with rice grain width.

Venketaswarlu and Prasad (1981) reported positive association of days to flowering with biomass production. Chauhan *et al.* (1995) found significant and positive association between days to flowering and grain yield.

Singh and Stoskopf (1971) reported high genotypic correlation (0.88) between biological yield and grain yield. Similar findings were also reported by Venkateshwarlu and Prasad (1980), Takeda *et al.* (1984).

Singh and Stoskopf (1971) found that reduction in plant height lowered the dry weight of vegetative parts and thereby lowering the straw yield, which resulted in an increased harvest index. They also reported that harvest index was positively correlated with grain yield, but it had negative association with vegetative growth. Mehan and Saini (1979) observed highly significant positive association between grain yield and harvest index. Xiang *et al.* (1986) and Lu *et al.* (1988) reported positive correlation between these traits Lu *et al.*

(1988) reported that the grain yield per hill was positively correlated with HI ($r=0.6358$), grains per panicle ($r=0.7725$), filled grains per panicle ($r=0.8399$) and plant height ($r=0.8178$) and negatively with plants per hill. Bagali *et al.* (1999) observed a significant genotypic correlation of grain yield with the harvest index in indica x japonica hybrid rice

Positive and significant correlation between yield and 1000-grain weight were observed by Singh (1980), Prasad *et al.* (1998), Yolanda and Das (1995), Padmavati *et al.* (1996), Surek *et al.* (1998), however Gopinath *et al.* (1984) and Gupta *et al.* (1999) observed negative association between these traits.

Deosarkar and Nerkar (1994) reported that the grain length and breadth ratio was positively and significantly correlated with grain elongation ratio. Chauhan *et al.* (1995) reported that kernel elongation ratio was positively and significantly correlated with cooked kernel length.

Chauhan *et al.* (1995) also reported significant positive association of kernel length after cooking (KLAC) with elongation ratio and head rice recovery with milling percentage.

Lie *et al.* (1987) recorded non-significant correlation between grain shape and cooking quality characters including gelatinization temperature. However, grain width was positively correlated with gelatinization temperature.

Goswami *et al.* (2000) reported significant positive correlation of grain yield with grains number per panicle, filled grains percent and L/B ratio of grain. A significant positive association of huge panicles and grain yield was observed by Wang *et al.* (2001) in Super rice Hybrid "Xieyov 9308".

Shrirame and Muley (2003) carried out correlation studies of different biometric and morphological plant characters with grain yield in rice hybrids. Grain yield exhibited a very strong positive correlation with harvest index. Grain yield was also significantly correlated with number of filled grains per panicle.

Chaturvedi *et al.* (2004) studied the newly released commercial rice hybrids and evaluated them for their agronomic and morpho-physiological traits. The grain yield (t/ha) was positively and significantly correlated with number of filled spikelets/m², days to 50% flowering and biological yield.

Path coefficient studies

This technique was originally developed by Wright (1921) and was used for the first time in plants by Dewey and Lu (1959).

Path coefficient analysis measures the direct and indirect contributions of independent variables on dependent variable. It further reveals the different ways in which characters influence the yield and quality traits. The available reports of several workers have been summarized here in.

Rao *et al.* (1976) reported that number of panicle bearing tillers had the highest positive direct effect on grain yield. Aly (1979), Sinha and Banerjee (1987), Ibrahim *et al.* (1990), Deosarkar and Nerkar (1996) and Rao *et al.* (1997) observed similar findings.

Sarathe (1984) reported the kernel elongation was found to be influenced by direct and positive effects of L/B ratio after cooking, grains per panicle, gelatinization temperature and days to flowering while the effect of L/B ratio before cooking, plant height and 1000-grain weight were negative.

Fu *et al.* (1994) reported the direct path coefficient, from grain length grain weight, 1000 grain wt. to L/B ratio were 0.4881, -0.7477

and 0.0793 respectively but the indirect path coefficient from 1000 grain wt to L/B via length width reached 0.1266 and 0.5630 respectively.

Kim (1985) analysed the path coefficients and showed that spikelets number plant and 1000-grain weight had higher direct effects on grain yield per plant.

Awasthi and Borthakur (1986) reported that panicle length, 1000-grain weight and fertile grains per panicle had direct effect on the grain yield per plant.

Prasad *et al.* (1998) reported that in parents (20) and crosses (36F₁), the grain yield was influenced mainly by direct effects of fertile grains per panicle followed by panicle number and 1000 grain weight.

Lu *et al.* (1988) reported the path analysis showed that the direct effect of yield related characters on grain yield was positive except for filled grains per panicle (-0.771) and the indirect effect was negative except for filled grains per panicle (0.0234).

Soares *et al.* (1990) reported that spikelets per panicle, percentage of filled grains and 1000-grain weight showed positive direct effect on grain yield of rice. It was concluded that percentage of filled grains and 1000 grain weight should be used as a selection criteria to increase the grain yield.

Murthy and Babu (1992) analysed the path coefficient of physiological parameters on grain yield in hybrid rice and indicated that panicle number and spikelet sterility exerted a direct influence on the grain yield during dry season. Spikelet sterility alone had major influence on the grain yield of hybrid rice. Choubey and Singh (1994) observed that the greatest direct positive effects on grain yield were recorded for number of ear-bearing tillers followed by

plant height, 1000-grain weight and total number of spikelets. The results indicated the importance of number of ear-bearing tillers as a selection criterion for rice improvement programme.

Babu (1996) reported that number of productive tillers and number of filled grain had a positive direct effect on grain yield.

Deosarkar and Nerkar (1994) showed that panicle length and number of effective tillers per plant had the highest direct effect on grain yield per plant.

In a study for ten yield components in six cultivars and their F_1 hybrids, Gopalakrishnan and Ganapathy (1996) reported that grains per panicle, panicle length, grain yield, thousand grain weight, spikelet sterility percentage, days to 50 percent flowering, number of filled grains per panicle and plant height had positive direct effect, whereas spikelets per panicle had negative direct effect on grain yield.

Rao *et al.* (1997) evaluated 23 quality genotypes of rice for 8 yield components and reported that productive tillers per plant had the highest direct effect on grain yield, followed by plant height and panicle length. Sarawgi *et al.* (1997) reported from association analysis studied in 128 indica rice varieties that direct selection for number of fertile spikelets per panicles would probably be effective for increasing grain yield. Direct selection of number of effective tillers per plant, grain yield per plant, 1000-grain weight and grain width would increase harvest index or yield. There was no common causal factor that directly influenced both grain yield and harvest index.

Gupta *et al.* (1999) studied path analysis of grains per plant with other characters in F_2 generation of eight crosses of basmati rice. Path analysis revealed that panicles per plant, grains per plant and grains per panicles were found to be the important component

characters of grain yield in basmati rice and provide a greater selection emphasis.

Kaw *et al.* (1999) evaluated 94 rice genotypes (38 japonica / indica F₁, 36 indica / indica F₁ and 20 parents) for genetic variability and character association under which fertile spikelets had the highest positive influence where as panicle length had a negative influence upon fertility.

Ganesan (2001) studied the direct and indirect effects of yield component characters of forty eight rice hybrids, filled grains per panicle (0.895) had the highest significant positive direct effect on yield/plant followed by number of tillers/ plant (0.688), panicle exertion (0.172), panicle length (0.167) and plant height (0.149), days to flowering, no. of tillers/plant had both positive and negative indirect effects on yield.

CHAPTER - III

MATERIAL AND METHODS

MATERIAL AND METHODS

3.1 Experimental material and other details

3.1.1 Experimental material

The experimental material comprised of eleven indica/JNPT and fourteen indica/indica rice hybrids along with five standard checks (Kranti, IR-64, JR-201, Mahamaya, IR-36). The list of hybrids and checks is furnished in table 1.

3.1.2 Experimental site and location:

The experiment was carried out at Seed Breeding Farm, Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P. during kharif 2005-06. Jabalpur is situated at 411.78 meters above the mean sea level at 23.9 N altitude and 79.58E longitude.

3.1.3 Climate and season

The climate of Jabalpur is typically semi-humid and subtropical with severe winter and summer. Jabalpur traditionally comes under rice – wheat crop zone of Madhya Pradesh and classified as “Kymore plateau and Satpura hills agro-climate zone”. The maximum temperature during the month of May and June reaches up to 46⁰C, whereas minimum temperature goes down to 3⁰C in the month of December or January. The average rainfall in this region is 1258.4 mm which is mostly received between mid-June to end of September with little occasional showers in other months.

Table 1 List of hybrids and checks

S.No.	Entries
1	APRMS6A X JNPT-70
2	APRMS 6A X 25 JNPT 70-1
3	APRMS 6A X JNPT-10
4	APRMS 6A X SPS-71
5	APRMS 6A X 25J NPT-10
6	APRMS 6A XJ NPT 71-01
7	APRMS 6A XJ NPT 70-32
8	APRMS 6A X 25 JNPT-70
9	APRMS 6A X IR 42342
10	IR58025A X JNPT-10
11	IR58025A X JNPT 29
12	IR58025A X ABHYA
13	IR58025A X R 304
14	IR58025A X IR 54742
15	IR70369A X JNPT 70
16	IR68888A X R 321
17	IR68888A X ABHYA
18	IR68888A X R548
19	IR68888A X R-42
20	IR68897A X JNPT-10
21	IR68897A X R 304
22	IR68897A X R704
23	IR68897A XIR-42342
24	IR68897A X R-42
25	IR68899A X IR42342
26	Kranti (Check)
27	IR-64 (Check)
28	JR-201 (Check)
29	Mahamaya (Check)
30	IR-36 (Check)

On the basis of National Bureau of Soil Science and Land Use Planning of ICAR this area belongs to agro-ecological sub region number 10.1 (sub humid dry eco-region). The soil of experimental area was clay loam with uniform topography. The data related to weekly maximum and minimum temperature, relative humidity, wind velocity, rainfall, number of rainy days, sunshine hours and evaporation of entire crop growing period of experiment has been presented in Appendix-1.

3.1.4 Experimental methods

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Twenty-one days old seedlings of each hybrid were transplanted in the experimental site. Each entry was transplanted in 10 sq. m plot size. The spacing between plants and rows were kept 15 cm, keeping single seedling per hill. Gap filling wherever necessary was done within a week of transplanting to maintain uniform plant population. Fertilizer dose of 120 Kg N, 60 Kg P₂O₅ and 60 Kg K₂O/ ha was applied. Entire dose of P₂O₅ and K₂O along with half dose of N was applied as basal dose at the time of final field preparation, remaining amount of nitrogen was split in to two equal splits and were applied at the time of active tillering and 50% flowering stages. The standard agronomic practices and plant protection measures were adopted for normal crop growth.

3.2 Observations recorded

Ten random plants from any row except border rows and border plants were selected randomly for the evaluation of panicle traits in hybrid and checks. Mean of main, average and the smallest panicle from each of the ten randomly selected plants were used to record the observations.

The data was recorded as per the standard procedures and listed here under.

3.2.1 Morphological characters

3.2.1.1 Days to 50% flowering

It was measured in days at which 50% of plants attained flowering, from the date of sowing was recorded as days to 50% flowering.

3.2.1.2 Plant height (cm)

It was measured in centimeter from the base of plant to the tip of top most panicle (excluding awns if any) on random ten plants in both replications.

3.2.1.3 Number of tillers per plant

Tillers were counted for each randomly selected ten plants at the end of active tillering stage.

3.2.1.4 Number of primary, secondary and tertiary tillers per plant

Total number of primary, secondary and tertiary tillers per plant were counted at maturity.

3.2.1.5 Number of productive tillers per plant

Total number of panicle bearing tillers per plant was counted.

3.2.1.6 Panicles per plant

Total number of panicles per plant was counted at maturity.

3.2.1.7 Panicle length (cm)

Length of main culm, average and the smallest panicle measured from neck node to tip of the topmost spikelets excluding awns if any are recorded in centimeter.

3.2.1.8 Panicle per square meter

Total number of panicles is counted in per square meter.

3.2.1.9 Panicle weight per plant (g)

Panicle weight of main culm average and the smallest panicle of each selected plant was taken by weighing and their mean was calculated.

3.2.1.10 Filled spikelets per plant

Total number of fertile spikelets (filled grains) of main culm, average and the smallest panicle of each of selected plant was counted.

3.2.1.11 Spikelet fertility percent

This was computed with the help of following formula.

$$\text{Spikelet fertility} = \frac{\text{No. of filled spikelets per panicle}}{\text{Total no. of spikelets per panicle}} \times 100$$

3.2.1.12 Spikelets per panicle

This was counted from main culm, average and the smallest panicle for each of the plant selected.

3.2.1.13 Grain L/B ratio

Length and breadth ratio of grain was computed by using the formula

$$\text{L: B ratio} = \frac{\text{Length of grain (mm)}}{\text{Breadth of grain (mm)}}$$

3.2.1.14 Biological yield per plant (g)

Average dry weight of ten plants (including grains and excluding roots) was recorded.

3.2.1.15 Grain yield per plant (g)

Grain yield per plant was recorded in selected plants and weighed by balance in g.

3.2.1.16 1000-grain weight (g)

One thousand sound filled grains were taken randomly after sun drying at 12 per cent moisture level and weighed in g.

3.2.1.17 Harvest index (HI %)

It was calculated by using formula

$$\text{HI \%} = \frac{\text{Grain yield per plant (g)}}{\text{Biological yield per plant(g)}} \times 100$$

3.2.2 Physical quality characters

3.2.2.1 Hulling percentage

100-g sample of each entry was subjected to dehusking in a dehusker. The dehusked kernel were weighed and percentage was determined by the following formula:

$$\text{Hulling \%} = \frac{\text{Weight of dehusked kernel}}{\text{Weight of paddy}} \times 100$$

3.2.2.2 Milling percentage

This was calculated by following formula

$$\text{Milling percentage} = \frac{\text{Weight of milled rice}}{\text{Weight of paddy}} \times 100$$

3.2.2.3 Head rice recovery

Observation on milling and head rice recovery percentage were recorded on the basis of 100-g seed sample, which was collected from plot of each replication. These samples were hulled and milled by satake huller and miller. The percentage of milling and head rice recovery was calculated.

$$\text{Head rice recovery} = \frac{\text{Weight of polished grains}}{\text{Weight of paddy}} \times 100$$

3.2.2.4 Kernel length (mm) before cooking

Ten milled grains were taken randomly and average length was recorded in millimeter.

3.2.2.5 Kernel width (mm) before cooking

Ten same milled grains were measured and average was recorded in millimeter.

3.2.2.6 Kernel length breadth ratio before cooking

This was calculated by the following formula

$$\text{L/B ratio} = \frac{\text{Length of milled grain}}{\text{Breadth of milled grain}}$$

3.2.2.7 Kernel length after cooking (mm)

Sample of 5 gm milled rice was taken for each entry and was imbibed in 12 ml of distilled water for 10-12 minutes followed by cooking for 15 minutes. Then cooked kernels were transferred to petriplate covered with filter paper. Ten-cooked rice were taken and average length was measured.

3.2.2.8 Kernel width after cooking (mm)

Ten-cooked rice were taken and average width was recorded in millimeter.

3.2.2.9 Length: Breadth ratio of cooked rice

This was calculated by the following formula

$$\text{L/B ratio of cooked rice} = \frac{\text{Length of cooked rice}}{\text{Breadth of cooked rice}}$$

3.2.2.10 Elongation ratio

This was calculated by the following formula

$$\text{Elongation ratio} = \frac{\text{Length of cooked kernel}}{\text{Length of raw kernel}}$$

3.2.2.11 Elongation index

This was calculated by the following formula

$$\text{Elongation index} = \frac{\text{Length breadth ratio of cooked rice}}{\text{Length breadth ratio of raw kernel}}$$

3.2.2.12 Grain chalkiness

Milled grain with opaque areas (translucent) in the endosperm is comes under grain chalkiness. There are three categories of grain chalkiness.

Table 2 Categorization of grain chalkiness

S.No.	Category	Characters
1.	Very occasionally (VOC)	Grain with opaque is frequently present in a sample
2.	Occasionally present (OC)	Less grain with opaque in a sample
3.	Absent	Grain with clear (Transparent) endosperm

3.2.2.13 Gelatinization temperature (GT)

Alkali spreading and clearing test was carried out as per the procedure suggested by Little *et. al.* (1958). Whole milled rice kernels were placed in a petriplate containing 10 ml. of 1.7 % potassium hydroxide solution. The petriplate was kept for 23 hours at a room temperature of 30⁰ C. After 23 hours interval, spreading and clearing scales were recorded in the following manner.

Table 3. Numerical scale for scoring Gelatinization temperature of rice

Score	Spreading scale	Clearing scale
1.	Kernel not affected	Kernel chalky
2.	Kernel swollen	Kernel chalky
3.	Kernel swollen, collar complete or narrow	Collar powdery kernel chalky, collar cottony or cloudy
4.	Kernel swollen, collar complete and wide	Center cottony, collar cloudy
5.	Kernel split or segmented collar complete and wide	Center cottony collar clearing
6.	Kernel dispersed merging with collar	Center cloudy, collar clear
7.	Kernel completely dispersed and intermingled	Center and collar clear

Table 4 Rating of Gelatinization

S. No	Rating	Gelatinization temperature
1.	1-3	High
2.	4-5	Intermediate
3.	6-7	Low

3.2.2.14 Kernel elongation

Proportionate change in L/B ratio of kernel after cooking was used as criteria of kernel elongation in the present study. Previously, kernel elongation was determined by taking the proportionate average length of raw kernel. This modification on the estimation of degree of kernel elongation was introduced with the fact that most preferred rice tends to show predominantly lengthwise elongation rather than breadth wise swelling. In the present study, changes in both length and breadth of kernel on cooking were, therefore taken in to consideration to measure more precisely the

degree of kernel elongation. The proportionate L/B ratio (PC) was worked out as shown below:

$$P_c = \frac{L_f/B_f - L_o/B_o}{L_o/B_o}$$

where,

L_f and B_f = length and breadth respectively of the kernels after cooking

L_o and B_o = Length and breadth respectively of the kernels before cooking

Statistical analysis

The data in respect of various characters studied were subjected to the following analysis.

1. Analysis of variance.
2. Standard Heterosis (Heterosis over commercial cultivar)
3. Estimation of phenotypic and genotypic correlations.
4. Path coefficient analysis.

1. Analysis of variance

The variance is the measure of the variability and is defined as the average of the square deviation from the mean. The procedure of Cochran and Cox (1951) was used to analyze the data statistically. The skeleton of variance is as follows:

Table 5 Arrangement of data from RCBD

Treatment	Replication					Total
	1	2	3	4	r	
1.						T ₁
2.						T ₂
3.	Y ₃₁	Y ₃₂	Y ₃₃	-	Y _{3r}	T ₃
-	-	-	-	-	-	-
T	Y _{t1}	Y _{t2}	Y _{t3}	-	Y _{tr}	T _t
Total	R ₁	R ₂		-	R _t	

Model $Y_{ij} = \mu + t_i + r_j + e_{ij}$

where,

Y = Performance of jth genotype in ith block

μ = The overall mean

t = The ith treatment effect

r = The jth replication effect, and

e = Random error

Table 6. ANOVA for Randomized Complete Block Design

Source of variation	D.F.	Sum of square	Mean sum of square	F value
Replication	r-1	R.S.S.	R.M.S.	R.M.S./ E.M.S.
Treatment	t-1	T.S.S.	T.M.S.	T.M.S./ E.M.S.
Error	(r-1) (t-1)	E.S.S.	E.M.S.	
Total	rt-1			

where,

r = Number of replications

t = Number of treatments

D.F. = Degree of freedom

R.S.S. = Replication sum of square

T.S.S. = Treatment sum of square

E.S.S. = Error sum of square

R.M.S. = Replication mean sum of square

T.M.S. = Treatment mean sum of square

E.M.S. = Error mean sum of square

A significant value of F-test indicates that the test entries differ significantly among themselves which requires computing C.D.

$$C.V. = \sqrt{\frac{E.M.S.}{G.M.}} \times 100$$

$$S.E.(d) = \sqrt{\frac{2E.M.S}{r}}$$

$$C.D. = t(0.05) \times SE(d)$$

where,

C.V. = Coefficient of variation

S.E. (d) = Standard error of difference

G.M. = Grand mean

C.D. = Critical difference

T (0.05) = t-value at 5% probability level

$$\text{Genotypic variance } (\sigma^2g) = \frac{T.M.S. - E.M.S.}{r}$$

where,

T.M.S. = Treatment mean sum of square

E.M.S. = error mean sum of square

r = number of replications

$$\text{Phenotypic variance } (\sigma^2p) = \sigma^2g + \sigma^2e$$

where,

σ^2g = genotypic variance

σ^2e = environmental variance

2. Standard Heterosis (Heterosis Over Commercial Cultivar)

This was calculated for all the 31 characters of all the hybrids.

$$SH = \frac{\overline{F_1} - \overline{CC}}{\overline{CC}} \times 100$$

where,

$\overline{F_1}$ = mean value of hybrid

\overline{CC} = mean value of commercial cultivar

Testing of standard heterosis for significance

To test the significance of heterosis t_c values is compared with t table value

$$'t_c' = \frac{\overline{F_1} - \overline{CC}}{S.E.(\overline{F_1} - \overline{CC})} \times 100$$

$$S.E.(\overline{F_1} - \overline{CC}) = \sqrt{S^2(\frac{1}{4} + \frac{1}{4})}$$

$$S.E.(\overline{F_1}, \overline{CC}) = \sqrt{S^2 \times 1/2}$$

where, S^2 is error mean sum of square from the ANOVA table of the particular hybrid and character.

S.E. = Standard error

F_1 = Hybrid

CC = Commercial check

If $t_c \geq 1.96$ significant at 5% level of significance

If $t_c \geq 2.3$ significant at 1% level of significance

3. Estimation of genotypic and phenotypic correlation coefficients

All correlation coefficients were calculated at genotypic and phenotypic levels using the formula suggested by Miller *et al.* (1958).

$$r(xy) = \frac{\text{Cov. } (X_i Y_j)}{\sqrt{(\text{var. } x_i) (\text{var. } y_j)}}$$

where,

$r(xy)$ = coefficient of correlation between character x_i and y_j

$\text{cov.}(X_i Y_j)$ = covariance of characters X_i and Y_j

$\text{var. } y_j$ = variance of character Y_j

$\text{var. } X_i$ = variance of character X_i

Genotypic and phenotypic correlation coefficients were computed by substituting corresponding variance and covariance for all possible character combinations.

$$\text{Genotypic } r (X_i Y_j) = \frac{\text{Genotypic cov. } (X_i Y_j)}{\sqrt{\text{VG } (X_i). \text{VG } (Y_j)}}$$

$$\text{Phenotypic } r (X_i Y_j) = \frac{\text{Phenotypic cov. } (X_i Y_j)}{\sqrt{\text{VP } (X_i). \text{VP } (Y_j)}}$$

where,

VG (X_i) = genotypic variance of characters x_i

VG (Y_j) = genotypic variance of characters Y_j

VP (X_i) = phenotypic variance of characters X_i

Vp (Y_j) = phenotypic variance of characters Y_j

Testing of correlation for significance

T-test – to test the significance of the phenotypic correlations, the correlation coefficients were compared with the table values at (n-2) degree of freedom at 5% and 1% level, where 'n' denotes the number of entries tested.

$$'tc' = \frac{|r|}{\sqrt{1-r^2}} \sqrt{n-2} \text{ at } (n-2) \text{ degree of freedom}$$

where,

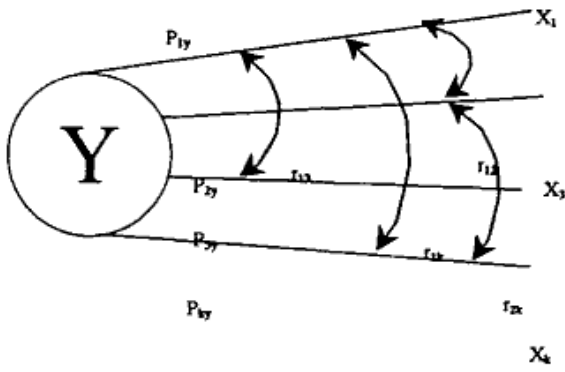
'tc' = calculated value of 't'

r = estimated value of correlation coefficient

n = number of observations

3. Path coefficient analysis

The direct and indirect contribution of various independent characters on a dependent character, yield was calculated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The following set of simultaneous equations were formed and used for the estimation of direct and indirect effects.



$$\begin{aligned}
 r_{1y} &= P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \dots + r_{1y} P_{1y} \\
 r_{2y} &= P_{2y} + r_{23} P_{3y} + \dots + r_{21y} P_{1y} \\
 r_{ky} &= P_{ky} + r_{k-1} P_{2y} + r_k P_{3y} + \dots + P_{ky} \\
 r_{xky} &= r_{xk1} P_{1y} + r_{xk2} P_{2y} + r_{xk3} P_{3y} + \dots + P_{xky}
 \end{aligned}$$

r_{xky} = Coefficient of correlation between independent character P_{1y} to P_{3y} = Direct effect of character 1 to 3 character y

Direct Effects

The direct effects were calculated as follows

$$P_{ky} = \sum_{i=1}^k C_{kir} Y$$

Indirect effects

Indirect effect of any independent traits on the dependent one (yield) via other independent traits are computed by multiplying the direct effects (P_{ky}) of that independent variables with the corresponding correlation coefficient as follows:

$$K^{th} \text{ trait via } (n-1) = r_k (n-1) P (n-1) Y$$

Later on the path coefficients were rated based on the scales given below (Lenka and Mishra, 1973).

0.0 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
> 1.00	Very high

CHAPTER - IV

RESULTS

RESULTS

The results of the present investigation are presented here under the following headings.

4.1 Mean performance, genetic variability and analysis of variance in intra-sub-specific (indica/indica) and inter sub-specific (indica/ JNPT) hybrids and checks

4.2 Magnitude of standard heterosis

4.3 Evaluation of yield components

1. Phenotypic and genotypic correlation

2. Path coefficient analysis

4.1 Mean performance, genetic variability and analysis of variance in indica/indica and indica/JNPT hybrids and checks

Mean performance and genetic variability studied in characters for twenty-five hybrids and five checks of rice cultivars were estimated and furnished in appendix – II.

ANOVA showed high degree of significance, indicating existence of considerable variability for the characters under study in twenty-five hybrids and checks (Table 7).

4.1.1 Days to 50% flowering

Genetic variability for days to 50% flowering was ranging from 75.67 (IR68888A x R548) to 95.67 (IR-36) with a mean of 85.01 days.

Table 7 ANOVA for 32 characters in twenty-five hybrids and checks

Source of variation	DF	DFF	PHT	TILL/PT	PR.TILL /PT	PT/P	ST/P	TT/P	PAN/PT	PAN LGH	PAN/m ²
Replication	2	1.4111	11.2111	3.2111	12.1333	1.2333	0.4778	0.01111	8.0444	3.81111	2744.45
Treatments	29	73.3215**	187.58**	13.0513**	9.2218**	5.7241**	2.8525**	0.8663**	9.9421**	10.8261**	22533.52
Error	58	1.2042	1.6479	1.3950	1.0069	1.0609	0.3628	0.0916	1.5847	2.8341	2801.92

Source of variation	DF	PAN WT/PT	NO. S/PL	FG/PL	SP FER	GL/B	BY/PL	GY/PL	1000 GW	HI%	HULL%
Replication	2	12.3160	21.2333	22.0444	0.4168	0.0270	0.4071	5.2854	0.5641	14.779	8.4271
Treatments	29	220.879**	14789.76**	12173.1**	167.583**	0.6174**	352.331**	224.744**	15.8295**	158.338**	84.795**
Error	58	7.3676	3.5322	1.9180	0.2813	0.0009	1.1271	1.881	0.0108	1.1279	1.0247

Source of variation	DF	MILL%	HRR%	KLBC	KBBC	K L/B	KLAC	KBAC	L/B CR	ER	EI	GC	GT
Replication	2	1.91011	4.8360	0.0323	0.0188	0.0146	0.0114	0.1471	0.1468	0.0009	0.0108	0.011	0.0111
Treatments	29	78.9353**	172.929**	0.7132**	0.1521**	0.510**	0.7755**	0.2157**	0.3479**	0.0137**	0.0159**	0.6548**	3.6720**
Error	58	1.4844	2.5649	0.0068	0.0045	0.0153	0.0119	0.0067	0.0055	0.0009	0.0018	0.011	0.0341

**significant at 1% level of significance

*significant at 5% level of significance

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) estimates observed for this traits were 5.77% and 5.91%, respectively.

4.1.2 Plant height (cm)

Range of variation observed for this trait was 82.67 cm (IR68888AxR-42) to 107.67cm (APRMS 6AxNPT71-01) with a mean of 94.19cm. GCV and PCV of this trait were 8.36% and 8.47%, respectively.

4.1.3 Tillers per plant

Range of variation observed for this trait was 7.33 (APRMS 6A x 25 JNPT-10) to 14 (IR58025A x ABHYA, IR68888A xR321) with a mean value of 10.04. GCV and PCV for this trait were 19.62% and 22.88%, respectively.

4.1.4 Productive tillers per plant

Range of variation observed for this trait was 5.67 (IR68897AxJNPT-10) to 12.33 (IR58025A x ABHYA) with a mean value of 8.57. GCV and PCV for this trait were 19.32% and 22.88%, respectively.

4.1.5 Primary tillers per plant

This trait showed a variation ranging from 5.33 (APRMS 6A x SPS-71, IR68897A x JNPT-10) to 12.33 (IR58025A x ABHYA) with a mean of 7.67. Genotypic and phenotypic coefficient of variation for this trait were 16.26% and 21.09%, respectively.

Table 8 Estimation of mean, range, GCV, PCV in twenty-five hybrids and checks

S. No.	Characters	Mean	Range		GCV (%)	PCV (%)
			Min.	Max.		
1.	Days to 50% flowering	85.01	75.67	95.67	5.77	5.91
2.	Plant height (cm)	94.19	82.67	107.67	8.36	8.47
3.	Tillers/plant	10.04	7.33	14.0	19.62	22.88
4.	Prod. Tillers/plant	8.57	5.67	1233	19.32	22.59
5.	Primary tillers/plant	7.67	5.33	10.33	16.26	21.09
6.	Secondary tillers/plant	1.94	1.00	4.33	46.85	56.16
7.	Tertiary tillers/plant	0.48	0.00	2.00	106.36	123.79
8.	Panicles/plant	8.54	5.33	12.33	19.53	24.47
9.	Panicle length (cm)	24.58	20.67	27.67	6.64	9.54
10.	Panicle/sq.m	430.56	283.33	616.67	18.98	22.25
11.	Panicle weight/plant (g)	33.52	20.07	48.57	25.17	26.44
12.	Spikelets/panicle	186.20	116.00	472.67	37.70	37.72
13.	Filled grain/panicle	15.12	85.67	425.0	42.43	42.44
14.	Spikelet fertility percentage	80.19	67.77	95.27	9.31	9.34
15.	Grain l/b ratio	3.19	2.12	3.87	14.20	14.23
16.	Biological yield/plant (g)	55.09	38.53	73.63	19.64	19.73
17.	Grain yield/plant (g)	30.99	17.87	47.43	27.81	28.16
18.	1000 grain weight	26.71	22.60	29.73	8.89	8.61
19.	Harvest index (%)	56.35	43.00	67.80	12.84	12.98
20.	HULL (%)	66.91	57.00	76.80	7.89	8.04
21.	MILL (%)	62.52	53.00	71.30	8.13	8.36
22.	HRR (%)	50.95	35.87	61.40	14.79	15.12
23.	KLBC (mm)	6.29	5.23	6.97	7.72	7.83
24.	KBBC (mm)	1.97	1.63	2.47	11.23	11.74
25.	K L/B	3.22	1.98	3.76	12.62	13.19
26.	KLAC (mm)	9.13	8.07	9.80	5.52	5.65
27.	KBAC (mm)	3.06	2.60	3.67	8.84	9.05
28.	L/B CR	3.01	2.30	3.59	11.21	11.48
29.	Elongation ratio	1.46	1.37	1.63	4.48	4.94
30.	Elongation index	0.94	0.82	1.16	7.31	8.56
31.	GC	1.62	1.00	2.00	35.03	35.92
32.	GT	5.49	3.00	7.00	20.06	20.34

4.1.6 Secondary tillers per plant

This trait varied from 1.0 (APRMS 6A x 25JNPT 70-1, IR58025A x JNPT-29, IR70369A x JNPT 70, IR68897A x R-42 and IR68899A x IR42342) to 4.33 (IR58025A x ABHYA) with a mean of 1.94. Genotypic and phenotypic coefficient of variance for this trait were 46.85% and 56.16%.

4.1.7 Tertiary tillers per plant

This character exhibited genetic variability ranging from 0.0 (APRMS 6A x JNPT-70, APRMS 6A x 25 JNPT-10, APRMS 6A x JNPT71-01, IR68888A x R-42, IR68897A x NPT-10 and IR68897A x R304) to 2.0 (IR68897A x IR 42342) with a mean of 0.48. Genotypic and phenotypic coefficient of variation were 102.36% and 123.79%.

4.1.8 Panicles per plant

This character exhibited high genetic variability ranging from 5.33 (APRMS 6A x 25 JNPT70) to 12.33 (IR58025A x ABHYA) with a mean of 8.54. GCV and PCV were 19.53% and 24.47%, respectively.

4.1.9 Panicle length (cm)

This trait showed high genetic variability ranging from 20.67 (IR70369A x JNPT70) to 27.67 (APRMS 6A x JNPT71-01) with a mean value 24.58 cm. GCV and PCV for this trait were 6.64% and 9.54%, respectively.

4.1.10 Panicles per sq.m.

Range of variation for this character was from 283.33 (IR68897A x JNPT-10) to 616.67 (IR 58025A x ABHYA) with a mean value of

430.56 .GCV and PCV for this trait were 18.98% and 22.25%, respectively.

4.1.11 Panicle weight per plant (g)

This trait showed a high genetic variability ranging from 20.07 (JR-201) to 48.57 (IR68897A x IR42342) with a mean value 33.52 g. GCV and PCV% of this trait were 25.17% and 26.44%, respectively.

4.1.12 Spikelets per panicle

Range of variation for this character was from 116 (IR68888A X R321) to 472.67 (APRMS 6A X 25NPT-10) with a mean value of 186.20. GCV and PCV of this trait were 37.70% and 37.72%, respectively.

4.1.13 Filled grains per panicle

Range of variation for this character was from 85.67 (25A x IR54742) to 425 (6A x 25NPT-10) with a mean value of 150.12. GCV and PCV of this trait were 42.43% and 42.44%, respectively.

4.1.14 Spikelet fertility percentage

Range of variation for this trait was observed from 67.77 (IR58025A x R304) to 89.93 (Mahamaya) with a mean value of 80.19. Genotypic and phenotypic coefficient of variation were 9.31% and 9.34%, respectively.

4.1.15 Grain L/B ratio

This character showed a considerable genetic variability ranging from 2.12 to (APRMS 6A x JNPT71-01) to 3.87 (IR58025A x JNPT 29) with a mean of 3.19. GCV and PCV were 14.20% and 14.23%, respectively.



4.1.16 Biological yield per plant (g)

This trait showed a high genetic variability ranging from 38.53 (IR-64) to 73.63 (APRMS 6A x JNPT-70) with a mean value of 55.09. GCV and PCV of this trait were 14.20% and 14.23%, respectively.

4.1.17 Grain yield per plant (g)

Range of variation for this character was from 17.87 (JR-201) to 47.43 (IR68897A x R704) with a mean value of 30.99. GCV and PCV for this trait were 27.81% and 28.16%, respectively.

4.1.18 1000 grain weight (g)

This character showed a considerable genetic variability ranging from 22.60 (IR-36) to 29.73 (IR68897A x R304) with a mean value of 26.71g. GCV and PCV% of this character were 8.59% and 8.61%, respectively.

4.1.19 Harvest index

This character showed variability ranging from 43 (IR68897A X R-42) to 67.80 (IR68888A X R 321) with a mean value of 56.35. GCV and PCV were found to be 12.84% and 12.98%, respectively.

4.1.20 Hulling percentage

Genetic variability for hulling percentage ranged from 57 (IR58025A x ABHYA) to 76.8 (APRMS 6A x 25 JNPT-10) with a mean value of 66.91%. Observed GCV and PCV were 7.89% and 8.04%, respectively.

4.1.21 Milling percentage

Genetic variability for milling percentage ranged from 53 (APRMS 6A x JNPT-10) to 71.3 (APRMS 6A x IR42342) with a mean value of 62.52. GCV and PCV were 8.13% and 8.36%, respectively.

4.1.22 Head rice recovery

This character showed a considerable genetic variability ranging from 35.87 (IR58025A x ABHYA) to 61.40 (APRMS 6A x 25 NPT-10) with a mean value of 50.95. Observed GCV and PCV were 14.79% and 15.12%, respectively.

4.1.23 Kernel length before cooking (mm)

This trait showed a considerable variability ranging from 5.23 (IR-36) to 6.97 (IR68897A x IR42342) with a mean value of 6.29. GCV and PCV were 7.72% and 7.83%, respectively.

4.1.24 Kernel width before cooking (mm)

Range of variation for this trait was from 1.63 (IR68888A x R-42) to 2.47 (IR70369A x JNPT 70) with a mean value of 1.97. Observed GCV and PCV were 11.23% and 11.74%, respectively.

4.1.25 L/B ratio before cooking (mm)

This character showed a considerable genetic variability ranging from 1.98 (KRANTI) to 3.76 (IR68897A X R-42) with a mean value of 3.22. Observed GCV and PCV were 12.62% and 13.19%, respectively.

4.1.26 Kernel length after cooking (mm)

This character showed a variation ranging from 8.07 (IR-36) to 9.8 (IR68897A x R304) with a mean value of 9.12. GCV and PCV were 5.52% and 5.65%, respectively.

4.1.27 Kernel width after cooking (mm)

This character showed a considerable genetic variability ranging from 2.6 (APRMS 6A x JNPT 70-32) to 3.67 (KRANTI) with a mean value of 3.06. Observed GCV and PCV were 8.64% and 9.05%, respectively.

4.1.28 L/B ratio of cooked rice

This character showed a considerable genetic variability ranging from 2.3 (KRANTI) to 3.59 (IR68897A x R-42) with a mean value 3.01. GCV and PCV were 11.21% and 11.48%, respectively.

4.1.29 Elongation ratio (ER)

Range of variation for this trait was from 1.37 (IR68897A x IR42342) to 1.63 (IR68888A x R548) with a mean value of 1.46. GCV and PCV were 4.48% and 4.94%, respectively.

4.1.30 Elongation index (EI)

This character showed a considerable genetic variability ranging from 0.82 (IR68888A x R321) to 1.16 (KRANTI) with a mean value of 0.94. GCV and PCV were 35.03% and 35.92%.

4.1.31 Grain chalkiness

Range of variation for this trait was from 1.0 to 12.00 with a mean value of 1.32. Observed GCV and PCV were 35.03% and 35.92%, respectively.

4.1.32 Gelatinization temperature (GT)

This character showed a considerable genetic variability ranging from 3 to 7 with a mean value of 5.49. GCV and PCV were 20.06% and 20.34%, respectively.

4.2 Magnitude of standard heterosis

Heterosis is the superiority of the F_1 over its parents. Traditionally, the deviation of F_1 performance from mean of the parents is considered as an estimate of heterosis. Economic heterosis, when drawn in comparison with the standard check variety of the region (standard heterosis) is a practical utility. The aim of hybrid rice breeding is to develop hybrids better than existing high yielding varieties. Hence, heterosis over best check variety (best among the checks) kranti of the region has been considered for the estimation of heterosis for thirty-two quantitative and quality traits.

4.2.1 Days to 50% flowering

Almost all of the hybrids except IR58025A x JNPT29 (-0.43), IR58025A x ABHYA (-1.29), IR68888A x R321 (-7.30), IR68888A x ABHYA (-0.43), IR68888A x R548 (-7073), IR68897A x R42 (-1.72), IR68899A x IR 42342 (-1.72) showed a positive and significant heterosis for this character. Heterosis ranged from -0.43 (IR58025A x JNPT 29, IR68888A x ABHYA) to 12.89 (APRMS 6A x SPS-71).

Table 9 Estimation of percentage standard heterosis in twenty-five hybrids over 'Kranti'

Genotype/ characters	DFP	PHT	TLL/PT	PR TLL/PT	PT/P	ST/P	TT/P	PAN/PT	PAN LGH	PAN/M	PAN WT/P	NOS/PL	FG/PL	SP FER	GLB	BY/PL	GY/PL	1000 GW	HI%
APRMS 6A x JNPT-70	8.59**	0.37	-0.80	-2.82**	1.37	-1.57	-4.67**	-2.25*	1.68	-2.83**	-3.96**	36.62**	35.74**	-12.09**	53.74**	7.56**	19.14**	-6.81**	-7.51**
APRMS 6A X 25 JNPT-70-1	6.87**	-0.37	-3.59**	-2.36**	-1.83	-2.36**	-3.12**	-1.87	0.56	-2.36**	-1.53**	30.36**	8.85**	-36.18**	37.82**	-34.55*	-2.20*	-61.75**	-10.32**
APRMS 6A x JNPT-10	7.73**	4.41**	-2.39**	0.00	-3.20**	1.57	0.00	0.00	0.00	0.00	-3.32**	26.84**	15.32**	-23.20**	41.64**	-10.92**	12.79**	-17.25**	-0.84
APRMS 6A x SPS-71	12.89**	1.84	-3.99**	-0.94	-4.12**	0.00	-1.56	-0.75	2.80**	-0.94	-4.67**	65.97**	50.72**	-32.35**	39.65**	-17.49**	9.49**	1.82	-0.89
APRMS 6A x 25 JNPT-10	5.59**	5.14**	-3.59**	-0.47	-2.29*	-0.78	-4.67**	-0.37	1.96*	-0.47	0.17	228.50**	274.01**	-7.02**	26.79**	-3.91**	18.01**	-25.88**	2.57**
APRMS 6A x JNPT-71-01	9.88**	6.96**	-2.79**	-0.47	-1.37	-0.78	-4.67**	-0.37	3.36**	-0.47	-5.47**	96.32**	81.35**	-34.49**	-16.54**	5.28**	11.75**	-53.58**	-17.27**
APRMS 6A x JNPT- 70-32	7.30**	-4.04**	-2.79**	94	-2.29*	-0.78	-1.56	0.75	0.56	0.94	-12.45**	41.36**	12.25**	-45.87**	29.24**	-37.03**	-2.65**	118.06**	-6.62**
APRMS 6A x 25 JNPT-70	7.30**	-8.45**	-4.79**	-0.94	-3.20**	-1.57	-3.12**	-3.00**	-2.24*	-94	-11.01**	47.66**	31.32**	-31.82**	14.85**	-35.83**	-1.92	-58.12**	-1.12**
APRMS 6A x IR 42342	3.01**	-8.08**	-1.20	0.94	-0.46	-0.78	-1.56	0.75	1.96*	0.94	-1.16**	17.56**	1.70	-27.91**	53.43**	-19.27**	0.27	-21.80**	-21.04**
RS8025A x JNPT-10	3.01**	-9.91**	-3.19**	-0.47	-0.46	-3.13**	-4.67**	-0.37	1.96*	-0.47	-6.62**	5.02**	-6.13**	-18.13**	43.79**	-21.80**	3.47	-19.98**	-10.79**
RS8025A x JNPT-29	-0.43	-8.08**	-4.39**	-0.47	-2.29*	-2.36**	-4.67**	-0.37	1.12	-0.47	-1.94**	25.08**	13.62**	-22.84**	63.84**	-18.65**	-0.76	-66.29**	-24.06**
RS8025A x ABHYA	-1.29	-17.99**	3.19**	6.11**	1.83	5.48**	-4.67**	4.87	-1.96*	6.13**	-5.04**	-31.60**	-72.16**	-65.33**	58.49**	-11.01**	10.93**	-15.89**	-4.84**
RS8025A x R304	2.58**	-14.69**	-2.79**	-0.47	-0.92	-1.57	-4.67**	-0.37	1.12	-0.47	-8.56**	-0.25	-43.23**	-66.13**	61.70**	-30.24**	2.03*	-26.34**	-4.11**
RS8025A x RS4742	9.88**	-1.02**	1.20	4.23**	0.00	3.13**	0.00	3.37**	0.56	4.24**	-5.18**	-35.87**	-72.50**	-58.67**	11.48**	-8.30**	8.87**	-78.55**	-1.81
IR70369A x JNPT-70	0.86	-6.24**	-2.39**	0.47	0.00	-2.36**	-4.67**	1.12	-2.52**	1.41	-5.00**	0.50	-38.12**	-59.29**	-8.11**	-21.58**	4.91**	0.45	-7.23**
IR68888A x R 321	-7.30**	-4.41**	3.19**	5.64**	0.92	4.70**	0.00	4.49**	1.68	5.65*	-0.07	-39.88**	-68.08**	-40.09**	49.61**	-0.67	2.28**	-13.17**	3.73**
IR68888A x ABHYA	-0.43	-17.99**	0.40	3.29**	0.00	3.13**	-4.67**	2.62**	1.68	3.30**	-8.67**	-34.36**	-49.70**	-13.60**	30.62**	-18.96**	4.40**	-59.46**	-11.41**
IR68888A x R548	-7.73**	-13.59**	2.39**	4.23**	2.75**	0.00	0.00	3.37**	-0.56	4.24**	-5.59**	-23.83**	-41.53**	-21.78**	22.81**	-9.95**	9.62**	-9.54**	-8.66**
IR68888A x R-42	3.87**	-20.56**	2.39**	-0.94	-1.83	-0.78	-4.67**	-0.75	-0.28	-0.94	-12.19**	-19.31**	-44.59**	-36.98**	36.13**	-29.44**	-3.27**	-28.15**	-20.02**
IR68897A x JNPT-10	5.58**	-3.67**	-3.19**	-3.29**	-4.12**	-1.57	-4.37**	-2.62**	2.52**	-3.30**	-10.54**	25.08**	-9.87**	-53.07**	35.37**	-18.21**	-1.58	-11.35**	-26.41
IR68897A x R304	6.44**	1.10	-5.59**	0.00	0.00	-1.57	-4.67**	0.00	3.08**	0.00	-8.68**	36.62**	-5.45**	-61.07**	17.61**	-15.19**	2.54**	7.72**	-19.40
IR68897A x R704	1.31**	-7.34**	-2.00*	3.76**	1.83	0.00	1.56	3.00**	0.84	3.77**	-8.16**	23.58**	-2.38**	-40.27**	57.57**	6.94**	22.03**	-14.98**	-0.27
IR68897A x IR-42342	3.44**	-10.65**	1.20	3.29**	0.46	-0.78	4.67**	2.62**	1.68	3.30**	0.21	-14.80**	-31.32**	-21.96**	31.69**	2.26*	21.21**	-23.16**	2.57**
IR68897A x R-42	-1.72	-15.79**	-3.99**	-1.88	-3.20**	-2.36**	0.00	-0.75	1.40	-0.94	-13.53**	0.00	-20.08**	-30.58**	35.21**	-31.13**	-3.71**	-79.46**	-29.29**
IR68899A x IR-42342	-2.58**	-11.38**	-0.80	1.88	0.92	-2.36**	-1.56	1.50	1.96*	1.88	-5.07**	-7.27**	-30.29**	-35.91**	39.35**	-5.15**	9.97**	-44.04**	-12.29**

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Table 9 Estimation of percentage standard heterosis in twenty-five hybrids over 'Kranti'

Genotype / character	HULL%	MILL%	HRR%	KLBC	KBBC	KL/B	KLAC	KBAC	L/B CR	ER	EI	GC	GT	GY/PL
APRMS 6A x JNPT-70	6.29**	6.23**	4.77**	4.00**	-20.32**	12.46**	0.59	-9.74**	10.32**	1.40	-7.76**	13.42**	-7.66**	19.14**
APRMS 6A x 25 JNPT-70-1	-7.50**	-0.97	-11.13**	3.43**	-22.43**	14.18**	0.80	-9.17**	10.51**	1.71	-9.22*	13.42**	-7.66**	-2.20*
APRMS 6A x JNPT-10	-14.81**	-10.45**	-16.60**	3.43*	-19.62**	11.66**	0.86	-9.17**	10.83**	2.02*	-6.97**	13.42**	-22.98**	12.79**
APRMS 6A x SPS-71	-0.47	3.48**	3.18**	2.85**	-22.43**	13.95**	0.59	-17.19**	19.23**	0.93	-4.27-	00	0.00	9.49**
APRMS 6A x 25 JNPT-10	11.60	10.45**	5.00**	2.85**	-18.92**	10.56**	-0.32	-10.32**	7.39**	-2.48**	-7.65**	13.42**	-10.21**	18.01**
APRMS 6A x JNPT-71-01	-7.64**	-5.61**	-5.62**	1.71	-18.22**	10.02**	0.05	-9.17**	7.71**	-0.93	-7.20**	8.94**	-10.21**	11.75**
APRMS 6A x JNPT-70-32	-3.54**	3.79**	-2.71**	4.57**	-22.43*	14.52**	0.70	-18.34**	21.40**	0.16	-3.60**	0.00	-15.32**	-2.65**
APRMS 6A x 25 JNPT-70	1.82	2.32**	-0.03	4.00**	-22.43**	14.41**	0.80	-16.05**	18.47**	1.09	-4.95**	0.00	-12.76**	-1.92
APRMS 6A x IR 42342	7.73**	10.80**	3.59**	1.71	-20.32**	11.66**	0.43	-9.74**	9.68**	0.93	-7.54**	0.00	-7.66**	0.27
IR58025A x JNPT-10	-3.12**	-1.20	-5.68**	2.28*	-21.72**	13.1**	0.75	-8.02**	9.23**	2.17*	-9.11**	0.00	-22.98**	3.47**
IR58025A x JNPT-29	-12.1**	-6.19**	-11.21**	18.84**	-19.62**	16.88**	1.71	-7.045**	11.65**	-3.57**	-10.69**	0.00	-7.66**	-0.76
IR58025A x ABHYA	-16.07**	-9.79**	-17.54**	19.98**	-22.43**	20.01**	2.03*	-10.89**	17.13**	-2.79**	-10.24**	0.00	0.00	10.93**
IR58025A x R304	1.26	3.52**	-10.30**	18.84**	-21.02**	18.18**	1.77	-14.33**	20.32**	-3.26**	-7.31**	13.42**	0.00	2.03*
IR58025A x IR54742	-7.73**	-2.51**	-2.88**	19.41**	-21.72**	19.05**	1.98*	-10.89**	17.70**	-2.79**	-9.34**	13.42**	7.66**	8.87**
69A x JNPT-70	-1.63	1.24	-5.80**	4.00**	-9.81**	5.34**	1.07	0.00	3.50**	2.64**	-4.95**	0.00	-7.66**	4.91**
IR68888A x R 321	-4.66**	0.77	0.71	19.41**	-22.43**	19.82**	2.19*	-8.02**	14.58**	-1.86	-11.36**	0.00	-15.32**	20.28**
IR68888A x ABHYA	-1.82	0.54	-2.65**	3.43**	-21.02**	12.88**	1.02	-4.58**	7.01**	2.79**	-10.12**	0.00	0.00	4.40**
IR68888A x R548	-2.93**	-1.32	-2.00*	2.28*	-18.921**	10.75**	1.98*	-4.01**	8.92**	8.23**	-7.20**	13.42**	7.66**	9.62**
IR68888A x R-42	2.19*	2.13*	-1.50	4.00**	-27.33**	19.63**	2.09*	-14.33**	20.57**	7.45**	-8.89**	13.42**	-7.66**	-3.27**
IR68897A x JNPT-10	5.03**	5.77**	3.09**	2.28*	-18.92**	10.75**	0.59	-9.17**	9.81**	1.24	-6.75**	0.00	0.00	-1.58
IR68897A x R304	0.09	0.74	-6.92**	11.99	-20.32**	15.36**	2.19*	-14.90**	22.93**	2.48**	-3.37**	0.00	7.66**	2.57**
IR68897A x R704	-8.62**	-6.50**	-7.12	19.41**	-21.2**	18.37**	1.82	-10.89**	16.24**	-3.42**	-9.56**	0.00	7.66**	22.03**
IR68897A x IR-42342	-11.88**	-7.24**	-15.66**	19.98**	-19.62**	17.19**	1.77	-11.46**	16.75**	-3.88**	-8.32**	13.42**	0.00	21.21**
IR68897A x R-42	7.92**	9.40**	2.15*	18.84**	-23.13**	20.39**	2.03*	-16.62**	24.71**	-2.17*	-6.86**	0.00	0.00	-3.71**
99A x IR-42342	-8.99**	-3.25**	-12.72**	19.41**	-21.72**	19.13**	2.03*	-14.90**	22.29**	-2.48**	-7.09**	0.00	7.66**	9.97**

**significant at 1% level of significance

*significant at 5% level of significance

4.2.2 Plant height

The hybrids APRMS 6A x JNPT 70 (0.37), APRMS6A xJNPT10 (4.41), APRMS 6A x SPS71 (1.84), APRMS 6A x 25 JNPT10 (5.14), APRMS 6A x JNPT71-01 (6.98), and IR68897 A x R304 (1.10) had shown positive heterosis for this character and others had shown negative heterosis. Heterosis ranged from -20.56 (IR68888A x R-42) to 6.98 (APRMS 6A x JNPT71-01).

4.2.3 Tillers per plant

All of the hybrids except IR58025A x IR54742 (1.20), IR68888A x R321 (3.19) IR68888A x ABHYA (0.40), IR68888A x R548 (2.39), IR68897A x R704 (2.0) and IR68897A x IR42342 (1.20) had shown a negative heterosis for this character. The heterosis ranged from -5.59 (IR68897A x JNPT-10) to 3.19 (IR58025A x ABHYA, IR68888A x R321).

4.2.4 Productive tillers per plant

Out of 25 hybrids studied seven, exhibited positive and significant heterosis while another seven hybrids showed positive non-significant heterosis. Eleven hybrids had shown negative heterosis for this character. The heterosis ranged from -3.29 (IR68897A x JNPT-10) to 6.11 (IR58025A x ABHYA).

4.2.5 Primary tillers per plant

Out of the twenty-five hybrids, all others except APRMS 6A x JNPT-70 (1.37), IR58025A x ABHYA (1.83), IR68888A x R321 (0.92), IR68888A x R548 (2.75), IR68897A x R704 (1.83), IR68897A x IR42342 (0.46) and IR68899A x IR42342 (0.46) had shown positive heterosis for this character. One hybrid (NRH-10) had shown negative

heterosis for this character. The heterosis ranged from -4.12 (IR68897A x JNPT 10, APRMS 6A x SPS-71) to 2.75 (IR68888A x R548).

4.2.6 Secondary tillers per plant

All hybrid except APRMS6A x JNPT10 (1.57), IR58025A x ABHYA (5.48) IR58025A x IR54742 (3.13), IR68888A x R321 (4.70) showed negative heterosis. Heterosis ranged from -2.35 (IR68897A x IR42, IR68899A x IR 42342, APRMS 6A x 25 JNPT 70-1) to 5.48 (IR58025A x ABHYA).

4.2.7 Tertiary tillers per plant

All the hybrids except IR68897A x R704 (1.56) and IR68897A x IR 42342 (4.67) had shown negative heterosis for this trait. The heterosis ranged from -4.67 to 4.67.

4.2.8 Panicles per plant

Most of the hybrids except APRMS 6A x JNPT-70 (-2.25), APRMS 6A x IR58025 x NPT 70-1 (-1.87), APRMS 6A x SPS71 (-0.75) APRMS 6A x 25 JNPT 10, APRMS 6A x JNPT 71-01, IR58025 A x JNPT 10, IR58025A x JNPT29 (-0.37), APRMS 6A x 25 JNPT 70 (-3.00), IR68888A x R-42, IR68897A x R-42 (-0.75) IR68897A x JNPT 10 (-2.62) exhibited positive heterosis for this trait. The heterosis ranged from -3.0 (APRMS 6A x 25 JNPT70) to 4.49 (IR68888A X R 321).

4.2.9 Panicle length (cm)

Most of the hybrids except APRMS 6A x 25JNPT (-2.24), IR58025A x ABHYA (-1.96), IR70369A x NPT70 (-2.52), IR68888A x R548 (-0.56), IR68888A x R-42 (-0.28) exhibited positive heterosis.

Five hybrids exhibited positive significant heterosis for this trait. Heterosis ranged from -2.52 (IR70369A x JNPT70) to 3.36 (APRMS 6A x JNPT71-01).

4.2.10 Panicle per square meter

Out of twenty-five hybrids, twelve hybrids have shown negative heterosis, while seven hybrids have shown positive and significant heterosis. Heterosis ranged from -3.30 (IR68888A x ABHYA) to 4.24 (IR58025A x IR54742, IR68888A x R548).

4.2.11 Panicle weight per plant

All the hybrids except APRMS 6A x 25JNPT10 (0.17), IR68897A x IR-42342 (0.21) have shown negative heterosis for this trait. Heterosis swept from -13.53 (97A x R-42) to 0.21 (97A x IR-42342).

4.2.12 Number of spikelets per panicle

Almost all the hybrids except IR58025A x ABHYA (-31.60), IR58025A x R304 (-0.25), IR58025A x IR54742 (-35.87), IR68888A x R321 (-39.88), IR68888A x ABHYA (-34.36), IR68888A x R548 (-23.83), IR68888A x R-42 (-19.31), IR68897A x IR42342 (-14.8), IR68899A x IR42342 (-7.27) had shown highly significant and positive heterosis for this trait. A minimum heterosis was observed in IR68888A x R321 (-39.88) and maximum in APRMS 6A x 25JNPT-10 (228.5).

4.2.13 Filled grains per panicle

The hybrids APRMS 6A x JNPT-70 (35.74), APRMS 6A x 25 JNPT70-1 (8.85), APRMS 6A x JNPT-10 (15.32), APRMS 6A x SPS-71 (50.72), APRMS 6A x 25JNPT-10 (274.01), APRMS 6A x JNPT71-01 (81.35), APRMS 6A x JNPT 70-32 (12.25), APRMS 6A x 25 JNPT-70 (31.32), APRMS 6A x IR 42342 (1.70) showed highly significant and

positive heterosis for this trait. Range of heterosis varied from -72.50 (IR58025A x IR54742) to 274.01 (APRMS 6A x 25 JNPT-10).

4.2.14 Spikelet fertility percentage

Almost all of the hybrids exhibited negative and significant heterosis. Heterosis ranged from -66.13 (IR58025 A x R304) to -7.02 (APRMS 6A x 25 JNPT-10).

4.2.15 Grain L/B ratio

Almost all of the hybrids, except APRMS 6A x JNPT 71-01 (-16.54), IR70369A x JNPT70 (-8.11) had shown highly significant and positive heterosis.

4.2.16 Biological yield per plant

The hybrids APRMS 6A x JNPT-70 (7.55), APRMS 6A x JNPT71-01 (5.28), IR68897A x R704 (6.97), IR68897A x IR42342 (2.26) exhibited positive and significant heterosis. All others had shown negative heterosis for this trait. Heterosis ranged from -37.03 (APRMS6A x JNPT70-32) to 7.55 (APRMS 6A x JNPT-70).

4.2.17 Grain yield per plant

Majority of hybrids except APRMS 6A x 25JNPT70-1 (2.20), APRMS 6A x JNPT70-32 (-2.65), APRMS6A x 25JNPT70-1 (-1.92), IR58025A x JNPT-29 (-0.76), IR68888A x R-42 (-3.27) IR68897A x JNPT-10 (-1.58), IR68897A x R 42 (-3.71) showed positive heterosis for the trait grain yield per plant. Heterosis ranged from -3.71 (IR68897 A x R-42) to 22.03 (IR68897A x R 704).

4.2.18 1000 Grain weight (g)

The hybrids APRMS 6A x SPS- 71 (1.82), IR70369A x JNPT70 (45), IR68897A x R 304 (7.72) had shown positive heterosis for this trait. All others had shown negative heterosis. Heterosis ranged from -118.06 (APRMS 6A x JNPT70-32) to 22.03 (IR68897 A x R 704).

4.2.19 Harvest index (HI%)

Hybrids APRMS 6A x 25JNPT-10, IR68897A x IR 42342 (2.57), IR68888A x R 321 (3.73) had shown positive and significant heterosis for this trait. All others had shown negative heterosis. Heterosis ranged from -29.29 (IR68897A x R-42) to 3.73 (IR68888 A x R321).

4.2.20 Hulling percentage

The hybrids APRMS6A x JNPT-70 (6.29), APRMS6A x25 JNPT10 (11.60), APRMS6A x IR42342 (7.73), IR68888A x R-42 (2.19) showed positive and significant heterosis. Hybrids APRMS6Ax 25 JNPT-70 (1.82), IR58025 A x R304 (1.26), IR68897A x R304 (0.09) showed positive and non-significant heterosis. Heterosis ranged from -16.07 (IR58025A x ABHYA) to 11.60 (APRMS 6A x 25NPT-10).

4.2.21 Milling percentage

Almost all of the hybrids except APRMS 6A x 25JNPT-70-1 (-0.97), APRMS 6A x JNPT-10 (-10.45), APRMS 6A x JNPT 71-01 (-5.61), IR58025A x JNPT10 (-1.20), IR58025A x JNPT29 (-6.19), IR58025A x ABHYA (-9.79), IR58025A x IR54742 (-2.51), IR68888A x R548 (-1.32), IR68897A x R704 (-6.50), IR68897A x IR42342 (-7.24), IR68899A x IR 42342 (-3.25) showed positive and significant heterosis.

4.2.22 Head rice recovery (HRR%)

The hybrids APRMS 6A x JNPT-70 (4.77), APRMS 6A x SPS-71 (3.18), APRMS 6A x 25JNPT-10 (5.0), APRMS 6A x IR42342 (3.59), IR68897A x JNPT-10 (3.09) and IR68897Ax R-42 (2.15) showed significant and positive heterosis for this trait. However, hybrid IR68888A x R321 (0.71) had shown positive non-significant heterosis. All other hybrids had shown negative heterosis for this character. Heterosis ranged from -17.54 (IR58025A x ABHYA) to 5.0 (APRMS 6A x 25NPT-10).

4.2.23 Kernel L/B ratio

All the hybrids had shown positive and significant heterosis for this trait. The hybrid IR70369A x JNPT70 (5.34) had the minimum positive heterosis for this trait while IR68897A x R-42 (20.39) showed maximum positive heterosis for this trait.

4.2.24 Kernel length before cooking (KLBC)

Almost all of the hybrids except APRMS 6A x JNPT71-01 (1.71), APRMS 6A x IR42342 (1.71) showed highly significant and positive heterosis for this trait. Range of heterosis went from 1.71 (APRMS 6A x JNPT71-01, APRMS 6A x IR 42342) to 19.98 (IR58025 A x ABHYA, IR68897 A x IR 42342).

4.2.25 Kernel breadth before cooking (KBBC)

All hybrids showed negative and highly significant heterosis for this trait. Heterosis ranged from -27.33 (IR68888A x R-42) to -9.81 (IR70369 A x JNPT70).

4.2.26 Kernel length after cooking (KLAC)

Hybrids IR58025A x ABHYA (2.03), IR58025A x IR54742 (1.98), IR68888A x R321 (2.19), IR68888A x R548 (1.98), IR68888A x R42 (2.09), IR68897A x R304 (2.19), IR68897A x R-42, IR68899A x IR42342 (2.03) had shown highly significant and positive heterosis for this trait. Heterosis ranged from -0.32 (APRMS 6A x 25 JNPT-10) to 2.19 (IR68888A x R 321, IR68897A x R304).

4.2.27 Kernel breadth after cooking (KBAC)

Almost all of the hybrids have shown negative heterosis for this trait. Heterosis ranged from -18.34 (APRMS 6A x JNPT70) to 24.71 (IR68897A xR-42).

4.2.28 L/B ratio after cooking (L/B CR)

All of the hybrids had shown positive and significant heterosis for this trait. The hybrid IR68897A x R 42 (24.71) had the maximum heterosis while hybrid IR70369A x JNPT70 (3.50) had the minimum heterosis for this trait.

4.2.29 Elongation ratio (ER)

Hybrids APRMS 6A x JNPT70 (1.40), APRMS 6A x 25JNPT70-1 (1.71), APRMS6A x SPS-71 (0.93), APRMS 6A x JNPT70-32 (0.16), APRMS6A x 25 JNPT 70 (1.09), APRMS 6A x IR42342 (0.93), IR68897A x JNPT-10 (1.24) showed positive heterosis for this trait, however positive significant heterosis was shown by APRMS 6A X JNPT-10 (2.02), IR58025A X JNPT-10 (2.17), IR70369A X JNPT70 (2.64), IR68888A X ABHYA (2.79), IR68888A x R548 (8.23), IR68888AxR-42 (7.45) and IR68897A x R304 (2.48). Rest of the

hybrids had shown negative heterosis for this trait. Heterosis ranged from -3.88 (IR68897A x IR42342) to 8.23 (IR68888A x R548).

4.2.30 Elongation Index (EI)

All the hybrids had shown negative heterosis for this trait. Heterosis ranged from -11.36 (IR68888A x R321) to -3.37 (IR68897A x R304).

4.2.31 Grain Chalkiness (GC)

Hybrids APRMS 6A x JNPT70 (13.42), APRMS 6A x 25JNPT70-1, APRMS 6A x JNPT10, APRMS 6A x 25JNPT-70, IR58025A x R304, IR58025A x IR54742, IR68888A x R548, IR68888A x R-42, IR68897A x IR42342 and APRMS 6A x JNPT71-01 showed positive and significant heterosis.

4.2.32 Gelatinization Temperature (GT)

Hybrids IR58025A x IR54742, IR68897A x R304, IR68897A x R704 showed significant and positive heterosis for this character.

4.3. Evaluation of yield components and quality attributes

4.3.1 Genotypic & phenotypic correlation

Genotypic and phenotypic correlation for morphological and quality characters were estimated using replicated mean of 30 genotypes with grain yield per plant. In general, genotypic correlation coefficient was higher in magnitude than phenotypic correlation in almost all the characters. Genotypic and phenotypic correlation of morphological characters and quality characters has been presented in table 10 and table 11 respectively and results obtained from phenotypic coefficient for both the parameters are presented.

Table 10 Estimation of genotypic and phenotypic correlation coefficients between grain yield per plant and its components in twenty-five hybrids and checks

		PHT	TILL/PT	PR TILL/PT	PT/P	ST/P	TT/P	PAN/PT	PAN LGH	PAN/m ²	PAN WT/P	NOS/PL	FG/PL	SP FER	GL/B	BY/PL	1000 GW	HI	GY/PL
DFF	P	0.1261	-0.1536	-0.1743	-0.1726	-0.0247	-0.066	-0.2069	-0.0620	-0.1957	-0.1633	0.2781	0.2234	-0.1346	-0.1933	-0.0818	-0.1302	-0.0466	-0.0571
	G	0.1317	-0.1884	-0.2169	-0.2538	-0.0142	0.0121	-0.2462	-0.0820	-0.2395	-0.1898	0.2852	0.2290	-0.1395	-0.1996	-0.0867	-0.1321	-0.0491	-0.0569
PHT	P		-0.2975	-0.3627*	-0.2029	-0.3146	-0.0575	-0.3413	0.3150	-0.3741*	0.3948*	0.6077**	0.6133**	0.3004	-0.2311	0.3857*	0.3555*	0.3159	0.3288
	G		-0.3658*	-0.4296	-0.2771	-0.3877	-0.0887	-0.4333	0.4486	-0.4456	0.4097	0.6159	0.6217	0.3065	-0.2325	0.3930	0.3614	0.3278	0.3449
TILL/PT	P			0.8385**	0.8424**	0.6401**	0.4051*	0.8039**	-0.0966	0.8265**	0.3886*	-0.3989*	-0.3755*	-0.1038	0.0238	0.4573*	0.1077	0.3674*	0.4540*
	G			0.9352	0.8714	0.7390	0.4439	0.9633	-0.2226	0.9314	0.4452	-0.4640	-0.4368	-0.1232	0.0260	0.5236	0.1270	0.4220	0.5341
PR TILL/PT	P				0.6731**	0.5995**	0.3170	0.9426**	-0.4171	0.9881**	0.2673	-0.3827*	-0.3741*	-0.1753	0.0031	0.2755	-0.0223	0.3182	0.3511
	G				0.7152	0.8359	0.4260	0.9986	-0.3029	1.0000	0.3327	-0.4449	-0.4358	-0.2107	0.0034	0.3268	-0.0273	0.3604	0.4217
PT/P	P					0.2072	0.1346	0.6507**	-0.0908	0.6706**	0.3511	-0.2803	-0.2645	-0.0675	-0.0299	0.4603**	0.2084	0.2900	0.4142*
	G					0.4006	0.1796	0.7529	-0.1244	0.7142	0.4314	-0.3620	-0.3415	-0.0881	-0.0439	0.5898	0.2722	0.3578	0.5432
ST/P	P						0.1483	0.5580**	-0.0889	0.5747**	0.1558	-0.3107	-0.3010	-0.1575	0.0355	0.1304	-0.0732	0.1762	0.1714
	G						0.1717	0.8252	-0.3035	0.8243	0.1938	-0.3718	-0.3598	-0.1906	0.0413	0.1452	-0.0889	0.2208	0.2063
TT/P	P							0.3201	-0.0334	0.3208	0.2571	-0.2218	-0.1980	0.0254	0.0694	0.2599	-0.0839	0.3114	0.3053
	G							0.4224	-0.0935	0.4327	0.3178	-0.2568	-0.2297	0.0321	0.0908	0.2950	-0.0956	0.3778	0.3582
PAN/PT	P								-0.1058	0.9539**	0.2648	-0.3829*	-0.3744*	-0.1757	0.0095	0.2852	0.0000	0.2700	0.3492
	G								-0.2316	1.0000	0.3507	-0.4837	-0.4650	-0.2289	0.0145	0.3589	0.0008	0.3221	0.4308
PAN LGH	P									-0.1738	0.1884	0.2859	0.2765	0.124	0.0970	0.3073	0.0485	-0.0394	0.2262
	G									-0.3262	0.1990	0.4135	0.3996	0.1573	0.1251	0.4351	0.0692	-0.0707	0.3212
PAN/m ²	P										0.2617	-0.3929*	-0.3801*	0.1911	-0.0191	0.2631	-0.0264	0.3046	0.3515
	G										0.3263	-0.4572	-0.4510	-0.2303	-0.0226	0.3128	-0.0335	0.3453	0.4076
PAN WT/P	P											0.2600	0.2909	0.1014	-0.1299	0.7845**	0.4179*	0.7794**	0.7781**
	G											0.2736	0.3063	0.1079	-0.1382	0.8290	0.4421	0.8097	0.8319
NOS/PL	P												0.9779**	0.1560	-0.1537	0.2321	0.0133	0.2383	0.2752
	G												0.9781	0.1571	-0.1542	0.2336	0.0133	0.2411	0.2791
FG/PL	P													0.3474	-0.1492	0.2542	0.0502	0.2509	0.2817
	G													0.3480	-0.1494	0.2557	0.0500	0.2534	0.2851
SP FER	P														-0.0967	0.1163	0.1984	0.0326	0.0151
	G														-0.0956	0.1165	0.1980	0.0313	0.0130
GL/B	P															0.0640	0.0078	0.0407	0.1088
	G															-0.0646	0.0080	0.0420	0.1095
BY/PL	P																0.3918*	0.5239**	0.8641**
	G																0.3944	0.5359	0.8741
1000 GW	P																	0.2980	0.3351
	G																	0.3011	0.3381
HI	P																		0.7270**
	G																		0.7367

**significant at 1% level of significance

*significant at 5% level of significance

Table 11. Estimation of genotypic and phenotypic correlation coefficients between grain yield per plant and quality characters in twenty-five hybrids and checks

		MILL%	HRR%	KLBC	KBBC	KL/B	KLAC	KBAC	L/B CR	ER	EI	GC	GT	GY/PL
HULL%	P	0.9488**	0.8424**	-0.2234	0.0568	0.1598	-0.2275	-0.1184	0.0012	0.0896	0.2420	-0.0701	0.0198	-0.3019
	G	0.9703	0.8783	-0.2277	0.0657	-0.1734	-0.2440	-0.1304	0.0000	0.0860	0.2939	-0.0718	0.0192	-0.3094
MILL%	P		0.8286**	-0.1615	-0.0229	-0.0722	-0.1975	-0.2037	0.0856	0.0159	0.2065	-0.1168	-0.015	-0.3428
	G		0.8644	-0.1677	-0.0153	-0.0870	-0.2031	-0.2123	0.0842	0.0329	0.2629	-0.1217	-0.0052	-0.3554
HRR%	P			-0.2786	0.0719	-0.1951	-0.2632	-0.0485	-0.0789	0.1267	0.2014	-0.1450	-0.0192	-0.1607
	G			-0.2885	0.0825	-0.2153	-0.2692	-0.0426	-0.0783	0.1575	0.2719	-0.1454	-0.0144	-0.1675
KLBC	P				-0.2154	0.7377**	0.7819**	-0.2904	0.6000**	-0.6797**	-0.3394	-0.0110	0.3174	0.2864
	G				-0.2314	-0.7685	0.8153	-0.3187	0.6331	-0.7096	-0.3634	-0.0107	0.3257	0.2969
KBBC	P					-0.7987**	-0.3180	0.6755**	-0.6184**	-0.0357	0.5696**	-0.1016	0.0493	0.0457
	G					-0.7861	-0.3489	0.7163	-0.6493	-0.0505	0.5666	-0.1177	0.0509	0.0548
KL/B	P						0.6990**	-0.6429**	0.8003**	-0.3577	-0.5719**	0.0423	0.1628	0.0896
	G						0.7615	-0.6886	0.8523	-0.3685	-0.5464	0.0526	0.1736	0.0903
KLAC	P							-0.2272	0.6471**	-0.0841	-0.2462	0.0513	0.3346	0.1507
	G							-0.2783	0.6813	-0.1713	-0.3131	0.6042	0.3484	0.1586
KBAC	P								-0.8782**	0.2101	-0.0830	0.0338	-0.0539	0.1580
	G								-0.8879	0.2105	-0.0183	0.0320	-0.0670	0.1668
L/B CR	P									-0.2162	0.0204	-0.0396	0.2176	-0.0779
	G									-0.2579	-0.0384	-0.0347	0.2334	0.0765
ER	P										0.2287	0.1161	-0.1038	-0.2477
	G										0.1976	0.1403	-0.1202	-0.2777
EI	P											-0.1544	0.0526	-0.2264
	G											-0.1869	0.0710	-0.2611
GC	P												-0.0693	0.3615
	G												-0.0939	0.3774
GT	P													-0.0262
	G													-0.0276

**significant at 1% level of significance

*significant at 5% level of significance

4.3.2 Correlation studies for morphological characters and quality traits

4.3.3 Morphological characters

4.3.3.1 Days to 50% flowering

This trait showed a positive non-significant association with plant height (0.1261), no. of spikelets per panicle (0.2781) and filled grain per panicle (0.2234). It showed negative non-significant association with tillers per plant (-0.1536), productive tillers per plant (-0.1743), primary tillers per plant (-0.1726), secondary tillers per plant (-0.0247), tertiary tillers per plant (-0.0066), panicles per plant (-0.2069), panicle length (-0.0620), panicle per square meter, (-0.1957), panicle weight /plant (-0.1633), spikelet fertility (-0.1346), grain L/B ratio (-0.1933), biological yield per plant (-0.0818), grain yield per plant (-0.0571), 1000 grain weight (-0.1302) and harvest index (-0.0966).

4.3.3.2 Plant height (cm)

It showed a positive and highly significant association with no. of spikelets per panicle (0.6077), filled grain per panicle (0.6133), 1000 grain weight (0.3555) and panicle wt per/plant (0.3948). It showed positive non significant association with panicle length (0.3150), spikelet fertility (0.3004), 1000 grain weight (0.3288) and harvest index (0.3159). It showed negative significant association with productive tillers per plant (-0.3627) and panicle per sq.m (-0.3741). A negative non-significant association was shown with tillers per plant (-0.2975), primary tillers per plant (-0.2029), secondary tillers per plant (-0.3146), tertiary tillers per plant (-0.0575), panicles per plant (-0.3413) and grain L/B ratio (-0.2311).

4.3.3.3 Tillers per plant

Highly significant positive correlation of this trait was shown with productive tillers per plant (0.8385), primary tillers per plant (0.8424), secondary tillers per plant (0.6401), tertiary tillers per plant (0.4051), panicles per plant (0.8039), panicle per sq.m (0.8265), panicle wt per/plant (0.3886), biological yield per plant (0.4573), grain yield per plant (0.4540) and harvest index (0.3674). It showed positive non-significant association with grain L/B ratio (0.0238) and 1000 grain weight (0.1077). It showed negative significant association with no. of spikelets per panicle (-0.3989) and filled grain per panicle (-0.3755). A negative non significant association was shown with panicle length (-0.0966) and spikelet fertility percentage (-0.1038).

4.3.3.4 Productive tillers per plant

It showed highly significant and positive association with primary tillers per plant (0.6731), secondary tillers per plant (0.5995), panicles per plant (0.9426) and panicle per sq.m (0.9881). A positive non-significant association was shown with tertiary tillers per plant (0.3170), panicle wt per/plant (0.2673), grain L/B ratio (0.0031), biological yield per plant (0.2755), grain yield per plant (0.3511) and harvest index (0.3182). No. of spikelets per panicle (-0.3827) and filled grain per panicle (-0.3741) had a negative significant association with this trait while panicle length (-0.1471), spikelet fertility (-0.1753) and 1000 grain weight (-0.0223) had negative non significant association.

4.3.3.5 Primary tillers per plant

It showed a highly significant and positive association with panicles per plant (0.6507), panicle per sq.m. (0.6706), biological yield per plant (0.4603) and grain yield per plant (0.4142). A positive non-significant association was shown with secondary tillers per plant

(-0.2072), tertiary tillers per plant (0.1346), 1000 grain weight (0.2084) and harvest index (0.2900). Panicle length (-0.0908), number of spikelets per panicle (-0.2803), filled grains per panicle (-0.2645), spikelet fertility percentage (-0.0675), grain L/B ratio (-0.0299) showed negative non-significant association with this trait.

4.3.3.6 Secondary tillers per plant

Secondary tillers per plant had a positive and highly significant association with panicles per plant (0.5580) and panicles per sq. m. (0.5747), It showed positive but non significant association with tertiary tillers per plant (0.1483), panicle weight per plant (0.1558), grain L/B ratio (0.0355), biological yield per plant (0.1304), harvest index (0.1762) grain yield per plant (0.1714) and grain yield per hectare (0.0105) It showed negative non significant association with panicle length (-0.0889), number of spikelets per panicle (-0.3107), filled grains per panicle (0.3010), spikelet fertility percentage (-0.1575) and 1000 grain weight (-0.0732).

4.3.3.7 Tertiary tillers per plant

It showed a significant and positive association with number of spikelets per panicle (0.3795), filled grain per panicle (0.3069), grain L/B ratio (0.3221), grain yield per hectare (0.3394), harvest index (0.2771) and grain yield per plant (0.3107). It showed negative association with panicle length (-0.0631) and spikelet fertility percentage (-0.3500).

4.3.3.8 Panicles per plant

Highly significant positive association of this trait was shown with panicles per sq.m. (-0.9539). Non-significant positive association of this trait was shown with panicle weight per plant (0.2648), grain L/B

ratio (0.0095), biological yield per plant (0.2852), harvest index (0.2700) and grain yield per plant (0.3492). Number of spikelets per panicles (-0.3829) and filled grain per panicle (-0.3744) had negative significant while panicle length (-0.0334) and spikelet fertility percentage (-0.0254), had negative non-significant association with this trait.

4.3.3.9 Panicle length (cm)

This trait showed non significant and positive association with panicle weight per plant (0.1884), number of spikelets per panicle (0.2859), filled grain per panicle (0.2765), grain L/B ratio (0.0970), spikelet fertility percentage (0.1124), biological yield per plant (0.3073), 1000grain weight (0.0485) and grain yield (0.2262). Negative non-significant association with harvest index (-0.0394) and panicle per sq.m. (-0.1738) was shown.

4.3.3.10 Panicle per sq.m.

It showed non -significant and positive association with panicle weight per plant (0.2617), spikelet fertility percentage (0.1911), biological yield per plant (0.2631), harvest index (0.3046) and grain yield per plant (0.3515). Number of spikelets per panicle (-0.3923) and filled grains per panicle (-0.3816), had negative significant association while grain L/B ratio (0.4548) and 1000-grain weight (-0.0264) had negative non significant association.

4.3.3.11 Panicle weight per plant (g)

It showed highly significant and positive association with biological yield per plant (0.7845), and 1000-grain weight (0.4179) harvest index (0.7794) and grain yield per plant (0.7781). It also showed positive non-significant association with number of spikelets

per panicle (0.2600), filled grains per panicles (0.2909), and spikelet fertility percentage (0.1014). Negative non-significant association was shown with grain L/B ratio (-0.1299).

4.3.3.12 Number of spikelets per panicle

It showed highly significant and positive association with filled grains per panicle (0.9779). Positive non significant association was shown with spikelets fertility percentage (-0.1560), biological yield per plant (-0.2321), harvest index (0.2383) 1000 grain weight (0.0133) and grain yield per plant (0.2752).It also showed negative association grain L/B ratio (-0.1537).

4.3.3.13 Filled grains per panicle

It showed a positive and non-significant association with spikelet fertility percentage (0.3474) biological yield per plant (0.2542), 1000-grain weight (0.0502), harvest index (0.2509) and grain yield per plant (0.2817). A negative non-significant association showed with grain L/B ratio (-0.1492).

4.3.3.14 Spikelet fertility percentage

It showed a positive and significant association with 1000-grain weight (0.1984), biological yield per plant (0.1163) harvest index (0.0326) and grain yield per plant (0.0151). It also showed negative non-significant association with grain L/B ratio (-0.1088).

4.3.3.15 Grain L/B ratio

This trait showed positive and non-significant correlation with biological yield per plant (0.0640), 1000-grain weight (0.0078) and harvest index (0.0407) and grain yield per plant (0.1088).

4.3.3.16 Biological yield per plant

It showed positive and highly significant association with 1000-grain weight (0.3918), harvest index (0.5239) and grain yield per plant (0.6332).

4.3.3.17 1000-grain weight

It showed positive non-significant association with harvest index (0.2980) and grain yield per plant (0.3351).

4.3.3.18 Harvest index

It showed highly significant and positive association with grain yield per plant (0.7270).

4.3.4 Quality traits

4.3.4.1 Hulling percentage

Hulling percentage had a positive and significant association with milling percentage (0.9488) and head rice recovery (0.8424). It showed positive non-significant association with L/B ratio before cooking (0.0012), kernel width before cooking (0.0568), L/B ratio after cooking (0.0012), elongation ratio (0.0896), elongation index (0.2420), gelatinization temperature (0.0198). It showed negative non-significant association with kernel length before cooking (-0.2234), kernel length after cooking (-0.2275), grain chalkiness (-0.0701) and grain yield per plant (-0.3019).

4.3.4.2 Milling percentage

It showed highly significant and positive association with head rice recovery (0.8286), L/B ratio before cooking (0.3198) and kernel length before cooking (0.2613). It showed positive non-significant

association with L/B ratio after cooking (0.0856), elongation ratio (0.0159) and elongation index (0.2065). However it showed negative non-significant association with L/B ratio before cooking- (0.0722), kernel length before cooking (-0.1615), kernel width before cooking (-0.0229), kernel length after cooking (-0.1975), kernel width after cooking (-0.2037), gelatinization temperature (-0.0115), grain chalkiness (-0.01168) and grain yield per plant (-0.3428).

4.3.4.3 Head rice recovery (HRR%)

This trait showed positive but non-significant association with kernel width before cooking (0.0719), elongation ratio (0.1267) and elongation index (0.2014). It showed negative non-significant association with L/B ratio before cooking (-0.2786), kernel length before cooking (-0.1951), kernel length after cooking (-0.2632), kernel width after cooking (-0.0485), L/B ratio after cooking (-0.0789), gelatinization temperature (-0.0192), grain chalkiness (-0.1450) and grain yield per plant (-0.1607).

4.3.4.4 L/B ratio before cooking

This trait showed highly significant positive association with kernel length after cooking (0.6990) and L/B ratio after cooking (0.8003). It showed positive non-significant association with grain chalkiness (0.0423) gelatinization temperature (0.1628) and grain yield per plant (0.0896) however a negative significant association was shown with kernel width after cooking (-0.6429) and elongation index (-0.5719). It showed negative non-significant association with elongation ratio (-0.3577).

4.3.4.5 Kernel length before cooking

This trait showed positive significant association with L/B ratio before cooking (0.7377), kernel length after cooking (0.7819) and L/B ratio after cooking (0.6000). It showed positive non-significant association with gelatinization temperature (0.0493) and grain yield per plant (0.0457). It showed negative significant association with elongation ratio (-0.6797). A negative non-significant association was shown with, kernel width before cooking (-0.2154), kernel width after cooking (-0.2904), elongation index (-0.3394) and grain chalkiness (-0.0110).

4.3.4.6 Kernel width before cooking

This trait had a positive significant association with kernel width after cooking (0.6755) and elongation index (0.5696). However, it showed positive non-significant association with gelatinization temperature (0.0493) and grain yield per plant (0.0457). It showed negative significant association with L/B ratio before cooking (-0.7987) and L/B ratio after cooking (-0.6184). It showed negative non-significant association with kernel length after cooking (-0.3180), elongation ratio (-0.0357) and grain chalkiness (-0.1016).

4.3.4.7 Kernel length after cooking

Significant positive association of this trait with L/B ratio after cooking (0.6471) was noticed. It showed positive non-significant association with gelatinization temperature (0.3346) grain chalkiness (0.0513) and grain yield per plant (0.1507)

It showed negative non-significant association with kernel width after cooking (-0.2272), elongation ratio (-0.0841) and elongation index (-0.2462).

4.3.4.8 Kernel width after cooking

It showed positive but non-significant association with elongation ratio (0.2101), grain chalkiness (0.0338) and grain yield per plant (0.1580). Negative correlation of this trait was observed with L/B ratio after cooking (-0.8782) elongation index (-0.8338) and gelatinization temperature (-0.0539),

4.3.4.9 L/B ratio after cooking

This trait showed positive non-significant association with elongation index (0.0204) and gelatinization temperature (0.2176) however, it showed negative non-significant association with elongation ratio (-0.2162), grain chalkiness (-0.3346) and grain yield per plant (0.0779).

4.3.4.10 Elongation ratio

It showed positive non-significant association with elongation index (0.0204) and grain chalkiness (0.1161). However, it showed negative correlation with gelatinization temperature (-0.1038) and grain yield per plant (-0.2477).

4.3.4.11 Elongation index

It showed positive non-significant association with gelatinization temperature (0.0526). However negative non-significant association was shown with grain chalkiness (-0.1544) and grain yield per plant (-0.2264).

4.3.4.12 Grain Chalkiness

It showed positive significant association with grain yield per plant (0.3615). This trait also showed negative non-significant association with gelatinization temperature (-0.0693).

4.3.4.13. Gelatinization temperature

It showed negative but non-significant association with grain yield per plant (-0.0262).

4.4 Path coefficient analysis

Path coefficient analysis was carried out for grain yield per plant and other morphological characters in twenty-five hybrids and five checks.

Path coefficient analysis was used to partition the observed phenotypic and genotypic correlation coefficients between grain yield per plant as dependent variable and its component character (morphological) into direct and indirect effects.

The estimates of path coefficients are furnished in table 12 and 13. The results obtained from phenotypic direct and indirect effects are presented character-wise.

4.4.1 Days to 50% flowering

Direct contribution of this trait on grain yield was found positive (0.0376). This character exhibited a positive indirect effect through plant height (0.0047), number of spikelets per panicle (0.0105) and filled grain per panicle (0.0084). Its indirect effects through tillers per plant (-0.0058), productive tillers per plant (0.0066), primary tillers per

Table 12. Genotypic, path coefficients of various yield traits influencing grain yield in rice hybrids

	DF	PHT	TILL/PT	PR TILL/PT	PTP	STP	TTIP	PANPT	PAN LGH	PANm ²	PAN WTP	NOSPL	FGPL	SP FER	GLB	BY/PL	1000 GW	H	GY/PL
DF	-14.330	-1.8876	2.7005	3.1088	3.6376	0.2034	-0.1741	3.5277	1.1749	3.4322	2.7199	-4.0869	-3.2820	1.9988	2.8596	1.2431	1.8928	0.7033	-0.0569
PHT	0.4484	3.4037	-1.2452	-1.4621	-0.9433	-1.3195	-0.3020	-1.4748	1.5269	-1.5169	1.3944	2.0952	2.1160	1.0432	-0.7912	1.3377	1.2300	1.1156	0.3449
TILL/PT	47.3154	91.8529	-261.07	-234.81	-218.7956	-185.5471	-111.45	-241.86	55.8994	-233.85	-111.7727	116.4971	109.6769	30.9267	-6.5316	-131.4734	-31.8744	-105.9459	0.5341
PR TILL/PT	-15.3104	-30.3158	66.0017	70.6726	50.4713	58.9940	3.0546	70.4772	-21.3740	70.5980	23.4773	-31.3990	-30.758	-14.8691	0.2390	23.0597	-1.9277	25.4340	0.4217
PTP	-36.2417	-39.5663	124.412	102.1044	142.7696	57.1923	25.6424	107.4853	-17.7550	101.9625	61.5940	-51.6873	-48.7596	-12.5801	-6.2741	84.1994	38.8613	51.0763	0.5432
STP	-1.5270	-41.6982	79.4878	89.9140	43.0880	107.6610	18.4720	88.7646	-32.6501	88.6615	20.8434	-39.9860	-38.6962	-20.4975	4.4383	15.6179	9.5578	23.7521	0.2063
TTIP	0.8343	-6.0941	30.4863	29.2583	12.3354	11.7947	68.6799	29.0077	-6.4245	29.7204	21.8293	-17.6389	-15.7740	2.2079	6.2329	20.2634	-6.3644	25.9491	0.3682
PAN/PT	22.6314	39.8339	-88.5605	-91.8079	-69.2125	-75.8669	-38.8286	-91.9321	21.2950	-91.9525	-32.2412	43.5598	42.7455	21.0394	-1.3300	-32.9922	-0.0763	-29.6119	0.4308
PAN LGH	-3.7554	20.5469	-10.1974	-13.8720	-5.6961	-13.9034	-4.2845	-10.6096	46.8026	-14.9408	9.1131	18.9381	18.3042	7.2025	5.7300	19.9278	3.1692	-3.2405	0.3212
PANm ²	-2.8457	-5.2949	11.0660	11.8855	8.4853	9.7936	5.1414	11.8838	-3.8756	11.8812	3.8768	-5.4323	-5.3581	-2.7368	-0.2685	3.7163	-0.3986	4.1023	0.4076
PAN WTP	22.4964	-48.5612	-52.7675	-39.4323	-51.1378	-22.9696	-37.6746	-41.5703	-23.5837	-38.6766	-118.6329	-32.4346	-36.3071	-12.7922	16.3762	-98.2628	-52.3982	-95.9702	0.8319
NOS/PL	-221.2891	-477.85	380.0118	345.2164	280.9048	288.44	199.2753	367.6455	-320.81	354.7577	-212.3149	-776.9082	-758.8851	-121.9276	119.6191	-181.2868	-10.3512	-187.0730	0.2791
FG/PL	180.6812	490.44	-344.6095	-343.8047	269.4297	-283.81	-181.18	-366.8126	315.26	-355.7719	241.6422	771.5897	788.8977	274.5143	-117.8304	201.6860	39.4821	199.8972	0.2851
SP FER	23.6501	-51.9671	20.8854	35.7246	14.9406	32.3120	-5.4510	38.8046	-26.663	39.0575	-18.298	-26.6446	-59.0014	-169.6579	16.2101	-19.7613	-33.5662	-5.3064	0.0130
GLB	7.6838	8.9507	-1.0017	-0.1304	1.6921	-1.5889	-3.4945	-0.5571	-4.8170	0.8702	5.3198	5.9362	5.7512	3.6812	-38.6061	2.4659	-0.3099	-1.6165	0.1095
BY/PL	-4.0282	18.2490	24.3150	15.1727	27.3853	6.7424	13.7002	16.6643	20.2029	14.5241	38.4942	10.8493	11.8713	5.4118	-2.9976	46.4349	18.3132	24.8840	0.8747
1000 GW	-3.2765	8.9641	3.1492	-0.6776	6.7522	-2.2043	-2.3710	0.0206	1.7164	-0.8322	10.9668	0.3309	1.2415	4.9107	0.1997	9.7833	24.8063	7.4695	0.3381
H	-3.1959	21.3429	27.4773	23.4681	23.2961	14.3795	24.6032	20.9748	-4.6070	22.4834	52.7226	15.7000	16.5001	2.0379	2.7337	34.8960	19.6079	66.1177	0.7367

Table 13. Phenotypic path coefficients of various yield traits influencing grain yield in rice hybrids

	DFP	PHT	TILL/PT	PR TILL/PT	PT/P	ST/P	TT/P	PAN/PT	PAN LGH	PANm ²	PAN WTP	NOS/PL	FG/PL	SP FER	GL/B	BY/PL	1000 GW	H	GY/PL
DFP	0.0376	0.0047	-0.0058	-0.0066	-0.0065	-0.0009	-0.0002	-0.0078	-0.0023	-0.0074	-0.0061	0.0105	0.0084	-0.0051	-0.0073	-0.0031	-0.0049	-0.0018	-0.0571
PHT	-0.0003	0.0020	0.0006	0.0007	0.0004	0.0006	0.0001	0.0007	-0.0006	0.0008	-0.0008	-0.0012	-0.0012	-0.0006	0.0005	-0.0008	-0.0007	-0.0006	0.3288
TILL/PT	0.0538	0.1042	-0.3601	-0.2936	-0.2950	-0.2241	-0.1418	-0.2815	0.0338	-0.2894	-0.1361	0.1397	0.1315	0.0363	-0.0083	-0.1601	-0.0377	-0.1287	0.4540
PR TILL/PT	0.1308	0.2723	-0.6294	-0.7607	-0.5053	-0.4500	-0.2380	-0.7076	0.1104	-0.7417	-0.2007	0.2873	0.2809	0.1316	-0.0023	-0.2068	0.0168	-0.2389	0.351
PT/P	-0.0328	-0.0386	0.1602	0.1280	0.1902	0.0394	0.0256	0.1238	-0.0173	0.1276	0.0668	-0.0533	-0.0503	-0.0128	-0.0057	0.0876	0.0396	0.0552	0.4142
ST/P	-0.0034	-0.0436	0.0888	0.0831	0.0287	0.1387	0.0206	0.0774	-0.0123	0.0797	0.0216	-0.0431	-0.0417	-0.0128	0.0049	0.0181	-0.0102	0.0244	0.1714
TT/P	-0.0005	-0.0047	0.0329	0.0257	0.0109	0.0120	0.0812	0.0260	-0.0027	0.0261	0.0209	-0.0180	-0.0161	0.0021	0.0056	0.021	-0.0068	0.0253	0.3053
PAN/PT	0.0166	0.0273	-0.0543	-0.0754	-0.0521	-0.0447	-0.0256	-0.0800	0.0065	-0.0763	-0.0212	0.0306	0.0300	0.0141	-0.0008	-0.0228	0.0000	-0.0216	0.3492
PAN LGH	-0.0049	0.0246	-0.0076	-0.015	-0.0071	-0.0070	-0.0026	-0.0083	0.0782	-0.0136	0.0147	0.0224	0.0216	0.0088	0.0076	0.0240	0.0038	-0.0031	0.2262
PANm ²	-0.1921	-0.3673	0.8114	0.9700	0.6584	0.5642	0.3150	0.9365	-0.1706	0.9818	0.2569	-0.3852	-0.3791	-0.1877	-0.0188	0.2583	-0.0259	0.2991	0.3615
PAN WTP	0.0290	-0.0702	-0.0691	-0.0475	-0.0624	-0.0277	-0.0457	-0.0471	-0.0335	-0.0465	-0.1778	-0.0462	-0.0517	-0.0180	0.0231	-0.1395	-0.0743	-0.1386	0.7781
NOS/PL	-0.1616	-0.3532	0.2318	0.2224	0.1629	0.1806	0.1289	0.2225	-0.1662	0.2280	-0.1511	-0.5812	-0.5684	-0.0907	0.0894	-0.1349	-0.0077	-0.1385	0.2752
FG/PL	0.1573	0.4320	-0.2645	-0.2635	-0.1863	-0.2120	-0.1395	-0.2637	0.1948	-0.2720	0.2049	0.6888	0.7044	0.2447	-0.1051	0.1791	0.0354	0.1768	0.2817
SP FER	0.0239	-0.0533	0.0184	0.031	0.0120	0.0279	-0.0045	0.0312	-0.0200	0.0339	-0.0180	-0.0277	-0.0617	-0.1776	0.0172	-0.0206	-0.0352	-0.0058	0.0151
GL/B	-0.0268	-0.0321	0.0033	0.0004	-0.0041	0.0049	0.0096	0.0013	0.0135	-0.0027	-0.0180	-0.0214	-0.0207	-0.0134	0.1389	-0.0089	0.0011	0.0057	0.1088
BY/PL	-0.0607	0.2862	0.3394	0.2044	0.3416	0.0968	0.1929	0.2117	0.2280	0.1953	0.5822	0.1723	0.1887	0.0863	-0.0475	0.7421	0.2907	0.3888	0.8641
1000 GW	-0.0033	0.0080	0.0027	-0.0006	0.0053	-0.0019	-0.0021	0.0000	0.0012	-0.0007	0.0106	0.0003	0.0013	0.0050	0.0002	0.0099	0.0263	0.0075	0.3351
H	-0.0197	0.1335	0.1553	0.1345	0.1225	0.0745	0.1316	0.1141	-0.0167	0.1287	0.3294	0.1007	0.1060	0.0138	0.0172	0.2214	0.1259	0.4226	0.7278

plant (-0.0065), secondary tillers (-0.0065), tertiary tillers (-0.0002), panicles per plant (-0.0078), panicle length (-0.0023) panicles per square meter (-0.0074), panicle weight per plant (-0.0061), spikelet fertility percentage (-0.0051), grain L/B ratio (-0.0073), biological yield (-0.0031), harvest index (0.0066) and 1000 grain weight (-0.0100) were found to be negative.

4.4.2 Plant height (cm)

Direct contribution of this trait on grain yield was found negative (-0.0020). It showed positive indirect effect through tillers per plant (0.0006), productive tillers / plant (0.0007), primary tillers per plant (0.0004), secondary tillers per plant (0.0006), tertiary tillers per plant (0.0001), panicles per plant (0.0007), panicles per square meter (0.0008), grain L/B ratio (0.0005), and had negative indirect effects through days to 50% flowering (-0.0003), panicle length (-0.0006), spikelet fertility percentage (-0.0006), 1000 grain weight (-0.0007.) panicle weight (-0.0008), number of spikelets per panicle (-0.0012), filled grains per panicle (-0.0012), biological yield per plant (-0.0008) and harvest index (-0.0006).

4.4.3 Tillers per plant

Direct contribution of this trait on grain yield was found negative (-0.3501). It showed positive indirect effect through days to 50% flowering (0.0538), plant height (0.1042), panicle length (0.0338), number of spikelets per panicle (0.1397), filled grain per panicles (0.1315) and spikelet fertility percentage (0.0363). It expressed negative indirect effects through tillers per plant (-0.3501), productive tillers per plant (-0.2936), primary tillers per plant (-0.2950), secondary tillers per plant (-0.2241), tertiary tillers per plant (-0.1418), panicles per plant (-0.2815), panicles per square meter (-0.2899), panicle

weight per plant (-0.1361), grain L/B ratio (-0.0083), biological yield per plant (-0.1601), 1000-grain weight (-0.0377) and harvest index (-0.1287).

4.4.4 Productive tillers per plant

This trait exhibited a negative direct effect on grain yield per plant (-0.7507). Its indirect positive effects were manifested through days to 50% flowering (0.1308), plant height (0.2723), panicle length (0.1104), number of spikelets per panicle (0.2873), filled grains per panicle (0.2809), spikelet fertility percentage (0.1316) and 1000 grain weight (0.0168). This trait also expressed negative indirect effect through tillers per plant (-0.6294), primary tillers per plant (-0.5053), secondary tillers per plant (-0.4500), tertiary tillers per plant (-0.2380), panicles per plant (-0.7076), panicle per square meter (-0.7417), panicle weight (-0.2007), grain L/B ratio (-0.0023), biological yield per plant (-0.2068) and harvest index (-0.2389).

4.4.5 Primary tillers per plant

Direct effect of this trait on grain yield was positive (0.1902). This trait exhibited positive indirect effects through tillers per plant (0.1602), productive tillers per plant (0.1280), secondary tillers per plant (0.0394), tertiary tillers per plant (0.0256), panicles per plant (0.1238), panicles per sq. m. (0.1276), panicle weight per plant (0.0668), 1000-grain weight (0.0396) biological yield per plant (0.0876), and harvest index (0.0552). This trait exhibited negative indirect effects through days to 50% flowering (-0.0328), plant height (-0.0386), panicle length (-0.0173), number of spikelets per panicle (-0.0533), filled grain per panicle (-0.0503) spikelet fertility percentage (-0.0128) and grain L/B ratio (-0.0057).

4.4.6 Secondary tillers per plant

This trait exhibited a positive direct effect on grain yield per plant (0.1387). Its indirect positive effects were manifested through tillers per plant (0.0888), productive tillers per plant (0.0831), primary tillers per plant (0.0287), secondary tillers per plant (0.1387), tertiary tillers per plant (0.0206), panicles per plant (0.0774), panicles per sq. m (0.0797), panicle weight per plant (0.0216), grain L/B ratio (0.0049), biological yield per plant (0.0181), and harvest index (0.0244). This trait also exhibited negative indirect effects through days to 50% flowering (-0.0034), plant height (-0.0936), panicle length (-0.0123), number of spikelets per panicles (-0.0431), filled grains per panicle (-0.0417), spikelet fertility percentage (-0.0128) and 1000 grain weight (-0.0102).

4.4.7 Tertiary tillers per plant

Direct effect of this trait on grain yield was found to be positive (0.0812). This trait manifested positive indirect effect through tillers per plant (0.0329), productive tiller per plant (0.0257), primary tillers per plant (0.0109), secondary tillers per plant (0.0120), panicles per plant (0.0260), panicles per sq m (0.0261), panicle weight per plant (0.0209), spikelet fertility percentage (0.0021), grain L/B ratio (0.0056), biological yield per plant (0.0211) and harvest index (0.0253). This trait also exhibited negative indirect effect through days to 50% flowering (-0.0005), panicle length (-0.0027), plant height (-0.0047), number of spikelets per panicle (-0.0180), filled grains per panicle (-0.0161) and 1000 grain weight (-0.0068).

4.4.8 Panicles per plant

This trait exhibited a negative direct effect on grain yield per plant (-0.0800). It showed positive indirect effect through days to 50% flowering (0.0166), plant height (0.0273), panicle length (0.0085), number of spikelets per panicle (0.0306), filled grains per panicle (0.0300) and spikelet fertility percentage (0.0141). Negative indirect effects were exhibited through tillers per plant (-0.0643), productive tillers per plant (-0.0754), primary tillers per plant (-0.0521), secondary tillers per plant (-0.0447) tertiary tillers per plant (-0.0256), panicles per sq.m. (-0.0763), panicle weight (-0.0212), grain L/B ratio (-0.0008), biological yield per plant (-0.0228) and harvest index (-0.0216).

4.4.9 Panicle length (cm)

Direct effect of this trait on grain yield was found positive (0.0782). This trait manifested positive indirect effects through plant height (0.0246), panicle weight per plant (0.0147), number of spikelets per panicle (0.0224), filled grain per panicle (0.0216), grain L/B ratio (0.0076), spikelet fertility percentage (0.0088), 1000-grain weight (0.0038) and biological yield per plant (0.0240). Its indirect effect were found negative via days to 50% flowering (-0.0049), tillers per plant (-0.0076), productive tillers per plant (-0.0115), primary tillers per plant (-0.0071), secondary tillers per plant (-0.0070), tertiary tillers per plant (-0.0026), panicles per plant (-0.0083), panicle per sq. m. (-0.0136) and harvest index (-0.0031).

4.4.10 Panicle per sq. m.

Direct contribution of this trait on grain yield per plant was estimated positive (0.9818). This trait exhibited positive indirect effect on grain yield per plant via tillers per plant (0.8114), productive tillers

per plant (0.9700), primary tillers per plant (0.6584), secondary tillers per plant (0.5642), tertiary tillers per plant (0.3150), panicles per plant (0.2569), panicle weight per plant (0.2569), biological yield per plant (0.2583) and harvest index (0.2991). This trait contributed indirect negative effects through days to 50% flowering (-0.1921), plant height (-0.3673), panicle length (-0.1706), number of spikelets per panicle (-0.3852), filled grains per panicle (-0.3791), spikelet fertility percentage (-0.1877), grain L/B ratio (-0.0188) and 1000-grain weight (-0.0259).

4.4.11. Panicle weight per plant

This trait expressed a negative direct effect on grain yield per plant (-0.1778). It showed indirect positive contribution through days to 50% flowering (-0.0290) and grain L/B ratio (0.0231). It had indirect negative contribution to yield through plant height (-0.0702), tillers per plant (-0.0691), productive tillers per plant (-0.0475), primary tillers per plant (-0.0624), secondary tillers per plant (-0.0277), tertiary tillers per plant (-0.0457) panicle length (-0.0335), panicles per plant (-0.0471), panicles per sq. m (-0.0465), number of spikelets per panicle (-0.0462), filled grains per panicle (-0.0517), spikelet fertility percentage (-0.0180) biological yield per plant (-0.1395), harvest index (-0.1386) and 1000 grain weight (-0.0743).

4.4.12 Spikelets per panicle

This trait expressed a negative direct effect on grain yield per plant (-0.5812). It exhibited positive indirect effect on yield per plant via tillers per plant (0.2318), productive tillers per plant (0.2224), primary tillers per plant (0.1629) secondary tillers per plant (0.1629), tertiary tillers per plant (0.1289), panicles per plant (0.2225), panicle per sq. m. (0.2280) and grain L/B ratio (0.0894). Further this trait

contributes indirect negative effects through days to 50% flowering (-0.1616), plant height (-0.3532), panicle length (-0.1662), panicle weight (-0.1511) filled grains per panicle (-0.5684), spikelet fertility percentage (-0.0907) biological yield per plant (-0.1349), harvest index (-0.1385) and 1000 grain weight (-0.0077).

4.4.13 Filled grains per panicle

Direct contribution of this trait on grain yield was found positive (0.7044). This trait exhibited positive indirect effects through days to 50% flowering (0.1573), plant height (0.4320), panicle length (0.1948), panicle weight per plant (0.2049), number of spikelets per panicle (0.6888), spikelet fertility percentage (0.2447), biological yield per plant (0.1791), 1000 grain weight (0.0354) and harvest index (0.1768).

This trait expressed negative indirect effects through tillers per plant (-0.2645), productive tillers per plant (-0.2635), primary tillers per plant (-0.1863), secondary tillers per plant (-0.2120), tertiary tillers per plant (-0.1395), panicles per plant (-0.2637), panicles per sq. m. (-0.2720) and grain L/B ratio (-0.1051).

4.4.14 Spikelet fertility percentage

Direct effect of this trait on grain yield was found negative (-0.1775). It manifested positive indirect effects through days to 50% flowering (0.0239), tillers per plant (0.0184), productive tillers per plant (0.0311), secondary tillers per plant (0.0279) primary tillers per plant (0.0120), panicle per plant (0.0312), panicles per sq.m. (0.0339), grain L/B ratio (0.0172) and 1000 grain weight (0.0304). This trait expressed a negative indirect effect through plant height (-0.0533), tertiary tillers per plant (-0.0045), panicle length (-0.0200), panicles weight per plant (-0.0180), number of spikelets per panicle (-0.0277), filled grain per

panicle (-0.0617), biological yield per plant (-0.0206), 1000grain weight (-0.0352) and harvest index (-0.0058).

4.4.15 Grain L/B ratio

Direct contribution of grain L/B ratio on grain yield per plant was found positive (0.1389). It had indirect positive effects via tillers per plant (0.0033), productive tillers per plant (0.0004), secondary tillers per plant (0.0049), tertiary tillers per plant (0.0096), panicles per plant (0.0013), panicle length (0.0135), 1000-grain weight (0.0011) and harvest index (0.0057). It had indirect negative contribution via days to 50% flowering (-0.0268), plant height (-0.0321), primary tillers per plant (-0.0041), panicles per sq. m. (-0.0027), panicle weight per plant (-0.0009), number of spikelets per panicle (-0.0020), filled grains per panicle (-0.0180), spikelet fertility percentage (-0.0134) and biological yield per plant (-0.0089).

4.4.16 Biological yield per plant

This trait showed positive direct contribution on grain yield per plant (0.7421). It exhibited indirect positive effects via plant height (0.2862), tillers per plant (0.3394), productive tillers per plant (0.2044), primary tillers per plant (0.3416), secondary tillers per plant (0.0968), tertiary tillers per plant (0.1929), panicles per plant (0.2117), panicle length (0.2280), panicles per sq. m. (0.1953), panicle weight (0.5822), number of spikelets per panicle (0.1723), filled grains per panicles (0.1887), spikelet fertility percentage (0.0863), 1000 grain weight (0.2907) and harvest index (0.3888). It had indirect negative effect via days to 50% flowering (-0.0607) and grain L/B ratio (-0.0475).

4.4.17 1000-grain weight (g)

This trait exhibited a positive direct effect on grain yield per plant (0.0253) and its indirect positive effects were manifested through plant height (0.0090), tillers per plant (0.0027) primary tillers per plant (0.0053), panicle length (0.0012), number of spikelets per panicle (0.0003), grain L/B ratio (0.0002), biological yield (0.0099) and harvest index (0.0075).

It had indirect negative contribution on yield through days to 50% flowering (-0.0033), productive tillers per plant (-0.0006), secondary tillers per plant (-0.0019), tertiary tillers per plant (-0.0021) and panicles per sq. m. (-0.0007).

4.4.18 Harvest Index

Direct contribution of this trait on grain yield per plant was found positive (0.4226). It had indirect positive effect on yield via plant height (0.1335), tillers plant (0.1553), productive tillers per plant (0.1345), primary tillers plant (0.1225), secondary tillers per plant (0.0745), tertiary tillers per plant (0.1316), panicles per plant (0.1141), panicle per sq. m. (0.1287), panicle weight per plant (0.3294), number of spikelets per panicles (0.1007), filled grain per panicle (0.1060) spikelet fertility percentage (0.0138), grain L/B ratio (0.0172), biological yield per plant (0.2214) and 1000 grain weight (0.1259). It had negative indirect effect via panicle length (-0.0167).

CHAPTER - V

DISCUSSION

DISCUSSION

The immediate challenge to food security is maintaining its sustainability while simultaneously the diversified demand of the population is needed to attain self-sufficiency in food production.

Heterosis breeding, which exploits the phenomenon of hybrid vigour, has provided to be practical method of crop improvement, especially for increasing yield potential in many crops, including rice. Rice is a staple food providing about 35-39% of the total calorie intake of the people in South and South East Asia. The demand of rice would be 800 million tons by 2020. This means that additional 350 million tons of more rice need to be produced to feed the ever-increasing population. The task of producing more rice is not easy as there is no scope of expansion of cultivated land; availability of water is also a serious concern. The problem is serious, deserve immediate attention. Among the various options contemplated to meet this challenge, hybrid rice technology has already shown its potential. China is the first country benefited greatly by this innovative technology. More than 50% of total rice area in China is planted under hybrid rice. The additional production helps China to reduce the area under rice and diversification to some other crops. About 5 million hectare out of total 35 million hectare of rice has been released for other crops because of the yield gain from cultivation of rice hybrids. Out side China, India is the second country in the world, where more than 16 rice hybrids for commercial cultivation have been released. Although, the hybrids has been released, but the area of hybrid adoption and cultivation is very less. About 4.8 lakhs hectare area has been so far covered by these hybrids. The hybrids released and under cultivation have a problem of quality grain. They are inferior to conventional rice cultivars that hindered faster adoption of hybrid in a large acreage.

Looking to the constraints related with the grain quality and other quality parameters, the present investigation was designed to look little bit close towards the quality attributes of the hybrids. A set of 25 hybrids was evaluated alongwith kranti as a check variety to be the high yielder and good quality cultivar to judge the merit of hybrids. This study was further strengthened by carrying out association and path analysis to understand the role of various morphological and quality traits and their interrelationship. The information obtained on these aspects will be useful to decide the suitable criteria to be applied for the identification of superior hybrids. The experimental findings of present investigation have been discussed in the light of available literature under following heads.

- i. Genetic variability
- ii. Magnitude of heterosis
- iii. Correlation coefficient analysis
- iv. Path coefficient analysis

5.1 Genetic variability

The genetic variability present in the material decides the success of the breeding programme and is also one of the key constituents in hybrid rice breeding. The knowledge of genetic variability present in rice hybrids, for the characters under improvement, plays important role for identification of traits where careful breeding manipulation provide an opportunity to enhance the yield. The genotypic coefficient of variation measures the range of variability in hybrid and also enables to compare the amount of variability present in different characters. The phenotypic expression of a character is the result of interaction between the genotype and the environment. Therefore, the total variance needs

to be partitioned into heritable and non-heritable components to assess the true breeding value of that particular trait. Such trait can be improved and these traits will be useful for development of better hybrids using them as parental lines. The results obtained from nineteen morphological and thirteen quality traits in the present investigation of 25 rice hybrids showed high genetic variability and moderate to high genotypic and phenotypic coefficient of variations.

Hybrids and checks studied had high genetic variability and high genotypic and phenotypic coefficient of variations for secondary tillers per plant, tertiary tillers per plant, spikelets per panicle, filled grains per panicle and panicle weight per plant. Moderate estimates of phenotypic and genotypic coefficient of variations were observed for the rest of the traits.

5.2 Magnitude of standard heterosis

Heterosis, a powerful tool to boost the production per unit area significantly, has been utilized in large scale for production of hybrids. Although, it is used widely, its complex genetic nature remains poorly understood. The current understanding of heterosis phenomenon, its minimization and exploitation in different crops has been elaborated by Banga and Banga (1999) and Mukherjee (1995).

The commercialization of rice hybrids in China, and later in India and elsewhere, revealed that the extent of heterosis present in rice hybrids ranges from 10-20%, which is considered optimum for widespread adoption of this technology provided grain quality consideration are also given importance. Rice hybrids with good quality coupled with yield advantage of 10-20% will facilitate widespread adoption of this innovative technology by the farmers.

An effort has been made to identify the hybrids, which had higher yield and acceptable grain quality.

5.2.1 Magnitude of heterosis of morphological character

The grain yield of indica based rice hybrids in the present investigation showed high yield advantage over standard check variety. High heterosis for grain yield per plant was observed in hybrid IR68897A x R704.(22.03). Most of the hybrids also showed a higher level of heterosis for yield. Heterosis for grain yield was mainly because of simultaneous manifestation of heterosis for other yield components. Similar findings were reported by Yuan (1977), Lin and Yuan (1980), Yuan *et al.* (1989), Yuan and Fu (1995), Kim and Rutger (1988), Virmani (1994), Panwar *et al.* (1998). Standard heterosis for grain yield per plant ranged from -3.71 (IR68897A x R42) to 22.03 (IR68897A x R704). Standard heterosis of mixed trend was observed in their studies by Sreedhar and Kulkarni (1993), Sharma and Mani (1996), Yolanda and Vijendradas (1996), Devasia and Rangaswamy (1999), Lingaraju *et al.* (1999), Sathya *et al.* (1999), Singh and Maurya (1999), Panwar *et al.* (2002), Anand Kumar and Singh (2002), Bhave *et al.* (2002), Singh *et al.* (2002) and Banumathy *et al.* (2003).

In the present investigation, most of the hybrids showed significant positive heterosis for the trait days to 50% flowering. The findings of present investigation showed that most of the hybrids under study are late compared to check Kranti. The findings of the present investigation are in confirmation with the findings of Patel *et al.* (1994), Virmani *et al.* (1981), Gopalkrishan and Ganapathy (1996), Dwivedi *et al.* (1998) and Richharia and Singh (1983).

Most of the hybrids were shorter and showed negative heterosis while a few were taller and showed positive heterosis. Several authors viz., Sreedhar and Kulkarni (1993), Singh and Maurya (1999) reported both the positive and negative standard heterosis in their investigation.

In the present study, the standard heterosis estimated for tillers per plant was obtained negative in majority of the hybrids, while few other hybrids showed a positive heterosis. The findings of present investigation are in conformity with the finding of Yang *et al.* (1993) who advocated low tillering ability, while Ramiah and Ramaswamy (1941), Namboodri (1963), Purohit (1972), Rajagopalan *et al.* (1973), Reddy and Nerkar (1995) and Lin *et al.* (1996) observed more number of tillers in hybrids.

The estimation of heterosis for the traits primary tillers per plant, secondary tillers per plant and tertiary tillers per plant was found both in negative and positive direction.

In the present study, the standard heterosis estimated for number of productive tillers per plant was found both in negative and positive direction. Standard heterosis of similar nature was observed in their studies by Sreedhar and Kulkarni (1993), Devasia and Rangaswamy (1999), Sathya *et al.* (1999) and Banumathy *et al.* (2003).

Most of the hybrids under study had positive standard heterosis and majority of them had significant positive estimates for number of panicles per plant. Similar findings were reported by Panwar (1998) and Yolanda and Das (1996).

Longer panicle is generally associated with more number of spikelets resulting higher productivity. Out of 25 hybrids 20 hybrids recorded positive heterosis for this trait and in most of the cases it was significant. Five hybrids had shown negative heterosis for this trait. Standard heterosis of positive nature was reported by Lin *et al.* (1990) and Banumathy *et al.* (2003). Both positive and negative nature of heterosis was observed in their studies by Sreedhar and Kulkarni (1993), Singh and Maurya (1999) and Sathya *et al.* (1999).

. Number of spikelets per panicle is one of the most important component of economic sink capacity which is defined as the minimum size of sink organs to be harvested (Kato and Takeda, 1996). In fact, spikelet number set the upper limit of yield per plant. Most of the hybrids had positive and significant standard heterosis for this trait. Richharia and Singh (1983), Patel *et al.* (1995), Yuan *et al.* (1995) Sitaramariah *et al.* (1998), Yang *et al.* (2001) reported positive heterosis for this trait as observed in the present investigation.

The enhancement in yield of rice mostly depends upon two important component traits i.e., number of spikelets per panicle and number of filled grains per panicle. Most of the hybrids studied in present investigation surpassed the standard check variety for filled grains per panicle. Such a positive heterosis was reported by Ramalingam *et al.* (1994), Wu and Zhang (1991).

All of the hybrids under study exhibited significant negative standard heterosis for spikelet fertility percentage. Low grain yield in rice hybrids are mainly attributed to the high sterility percentage.

Significant negative heterosis measurement in majority of hybrids in the present study nullified the advantage of heterosis for spikelet number per panicle. Various rice workers like Yamamoto *et al.* (1991) observed that increase in the number of spikelets per panicle, however is accompanied by over production of spikelets on secondary branches where the proportion of filled grain is low. There seems to be another possibility of a poor balance between source and sink that may also lead to poor grain filling. This was in accordance with the findings given by Quan *et al.* (1999).

In the present study most of the hybrids showed significant positive heterosis for the trait grain L/B ratio. Biological yield is the sum total of grains and rest of plant parts (excluding roots). Almost all of the hybrids showed negative standard heterosis for biological

yield per plant exhibiting an imbalance of source & sink. Lu *et al.* (1988) and Virmani *et al.* (1996) observed that high biological yield led to higher grain yield. These findings are in agreement with the results of the present investigation.

Harvest index was negatively associated with grain yield. However hybrids APRMS 6Ax25JNPT-10, IR68888A x ABHYA and IR68897A x IR42342 showed significant positive heterosis for harvest index, had better accumulation of dry matter and its balanced translocation to economic sink. This was also in agreement with the findings of Yoshida *et al.* (1972), Virmani *et al.* (1981), Ponnuthurai *et al.* (1984), Kim (1985) and Patel (1994).

5.2.2 Heterosis of quality attributes

In the present investigation, an attempt has been made to estimate various quality parameters to judge the superiority of various hybrids. Although, the present day hybrids showed yield advantage over commercial cultivars, they are lacking in one or more quality aspects, which is a hindrance in acceptance by the consumers. Hence, in the present investigation, hybrids were subjected to estimation of various quality parameters for identification of heterotic hybrids coupled with quality traits. In the foregoing paragraphs, the results of estimation of heterosis are discussed with the limited available literature.

Majority of the hybrids under study showed negative estimates and in most of the cases significant heterosis was obtained. The negative heterosis for this trait revealed that the hybrids under study had poor hulling percentage compared to check Kranti. Nine hybrids had shown positive heterosis for this character. The findings of Gravios (1994) reported significant heterosis for this trait.

Majority of the hybrids were found to have significant positive heterosis for milling percentage. Eleven hybrids had shown positive

heterosis for this trait. Wang *et al.* (1999) reported positive heterosis for this trait.

Except seven hybrids, all the hybrids under study were found to have negative standard heterosis for head rice recovery percentage and in most of the cases its magnitude was moderate. The findings of present investigation are not in agreement with the findings of Gravios (1994) and Wang *et al.* (1999).

As expected from the estimates of heterosis for L/B ratio of grain, similar trend was also observed in case of L/B ratio before cooking.

Apart from milling percentage and head rice recovery percentage, kernel length before cooking is considered to be an important quality parameter, which decides the grain dimension. In the present investigation, all the hybrids were found to have high to moderate significant heterosis for this trait.

Kernel breadth is a quality trait and fix kernel in terms of length is always desirable, whereas kernel breadth must be as low as possible in rice hybrids. In the present investigation all the hybrids had negative standard heterosis for this trait. Hence, these hybrids are considered to have good grain quality in terms of grain dimension.

Significant positive heterosis for kernel length after cooking was observed in almost all of the hybrids. The magnitude of heterosis was moderate to high in majority of the cases. This indicates that most of the hybrids under study possessed a high grain quality as compared to check Kranti.

Most of the hybrids had shown significant negative heterosis for the trait kernel width after cooking. The lower width wise expansion is a desirable trait, as food habit of this sub continent

prefers the cooked rice, which has more lengthwise elongation and less width wise expansion. Majority of the hybrids exhibited negative heterosis for elongation ratio.

All the hybrids under study were found to have low elongation index as compared to the standard cultivar Kranti.

The inheritance of grain yield in rice is a complex trait and is dependent on several component factors. In the present investigation, none of the hybrids showed standard heterosis for grain yield alone. The hybrids viz., IR68897A x R704, IR68897A x IR-42342, IR68888A x R321, APRMS6A x NPT-70, APRMS6A x 25 NPT-10, APRMS6A x NPT-10 were found to be the best six hybrids. They showed higher significant positive standard heterosis over the commercial cultivar Kranti for grain yield, which was due to the cumulative effect of positive heterosis of all the quantitative traits. These hybrids also had accumulation of desired quality traits. The hulling percentage, milling percentage and head rice recovery were found to be high for the hybrids APRMS6A x NPT-70 and APRMS6A x NPT25-10 over the commercial cultivar Kranti. It established their superiority over other hybrids as well as the commercial cultivar Kranti.

5.3 Association analysis

Correlation studies are of considerable importance in understanding the relationship of any two given characters or any number of characters with each other by simple or multiple correlation measurements. Galton (1989) was first to suggest the use of this index to describe the degree of association between two variables. Yield is a final product of its components characters, which influence the yield directly or indirectly. A change in any of the component characters may bring a change in other characters and finally in the end product i.e., grain yield. Association analysis reveals whether the characters are associated or not, but from this

analysis it is difficult to know which of them is affecting the other because correlation gives the total multiple relationship between the components. In a biological system, most of the characters are associated with each other.

In the present investigation, an attempt has been made to estimate the phenotypic and genotypic correlation in all the character combinations for different set of character viz., morphological and quality parameters with the objective to get the information about the nature, extent and direction of selection pressure which should be extended to achieve practical and usable results. The association analysis has been discussed in the following paragraphs.

5.3.1 Association analysis for morphological characters

Days to 50% flowering exhibited positive and significant association with grain yield per plant. This was also reported by Chauhan *et al.* (1986). This trait was negatively associated with grain L/B ratio, 1000 grain weight, secondary tillers per plant, tertiary tillers per plant, filled grains per panicle and spikelet fertility percentage.

Plant height had positive association with grain yield per plant, panicle length, primary tillers per plant, panicle weight per plant, number of spikelets per panicle, filled grains per panicle and biological yield and negative association with grain L/B ratio.. From the above results it is clear that increase of other component traits of yield resulted finally in increased grain yield. These results are in conformity with the findings of Mazur *et al.* (1980), Chauhan *et al.* (1986), Panwar *et al.* (1989), Yang *et al.* (1993), Vijay Kumar *et al.* (1997), Prasad *et al.* (1986) and Singh and Stoskopt (1971).

Number of tillers per plant had positive and significant association with grain yield per plant. Same association was found

with productive tillers per plant and primary tillers per plant. The results are reasonable as more number of tillers bearing panicle per plant contribute towards more yields. The results are in accordance with the findings of Aly (1979), Singh (1980), Kaul and Kumar (1982), Gopinath *et al.* (1984), Chauhan *et al.* (1986), Choubey and Singh (1994) and Padmavati *et al.* (1996).

Panicles per plant was positively correlated with grain yield per plant. The directional selection for this trait may lead to improvement of grain yield. Findings are in agreement with that of Padmavati *et al.* (1996) and Murthy and Murthy (1981).

Prasad *et al.* (1988) reported significant positive correlation of panicle length with plant height, similar findings were also observed in the present investigation. Positive correlation between panicle length and spikelets per panicle observed in the present investigation are in agreement with the findings of Choubey and Singh (1994) and Wang *et al.* (2001).

Number of spikelets per panicle had positive association with grain yield per plant and filled grains per panicle may result in higher grain yield per panicle. The present results are in accordance with the findings of Rangel *et al.* (1980), Yolanda and Das (195), Zhong *et al.* (1997) and Mani *et al.* (1997).

Biological yield per plant was found to have positive association with grain yield per plant, plant height, tillers per plant, productive tillers per plant, primary tillers per plant, panicles per plant, panicles per square metre, panicle weight per plant, spikelets per panicle, filled grain per panicle and grain L/B, 1000 grain weight. This is in accordance with the findings of Chaturvedi *et al.* (2004).

A positive association of 1000 grain weight with grain yield per plant was observed in present investigation in accordance with the

findings of Bagali *et al.* (1999), Kabaki *et al.* (1992) and Zhang *et al.* (1997).

Harvest index was found to have positive association with grain yield per plant, spikelets per panicle and panicle weight. This is in agreement with the findings of Shrirame and Muley (2003).

Present results infer that high harvest index is a prerequisite for more filled grain per panicle which resulted in higher grain yield. This is in conformity with the findings of Mohan and Saini (1979) and Lu *et al.* (1984).

Grain yield per plant had positive correlation with filled grains per panicle, spikelet fertility and L/B ratio of grain. This is in accordance with the findings of Goswami *et al.* (2000).

Based on the association analysis studies, it can be concluded that the selection based on spikelets per panicle, filled grains per panicle, biological yield per plant, harvest index, productive tillers per plant and panicle length can give better results for improvement of seed yield.

5.3.2 Association analysis for quality attributes

A set of thirteen characters was studied and association of these traits with each other and with grain yield per plant was worked out. The basic aim in studying quality traits association among themselves and with grain yield per plant was to understand the basic component character, which can be considered together for improvement in grain quality, coupled with grain yield.

Chauhan *et al.* (1995) reported kernel length after cooking was positively correlated with elongation ratio. They had also reported milling percentage and head rice recovery percentage are not influenced by gelatinization temperature. Similar findings were observed in present investigation.

Positive and significant association of head rice recovery percentage with milling percentage observed in the present study is in confirmation with the findings of Chauhan *et al.* (1995).

Positive and significant association of elongation ratio with elongation index observed in the present study is in agreement with the findings of Gupta (1999).

Based on the association analysis for quality parameters, hulling percentage, head rice recovery, milling percentage, kernel length before cooking, L/B ratio before cooking, L/B ratio after cooking, kernel length after cooking should be considered as a selection criteria and selection for morphological traits should be done considering these quality traits in mind for enhancing the yield as well as their quality. If weightage is given to various yield-contributing traits, alone, then only grain yield will improve and quality aspects will remain poor which ultimately result in low acceptance by the consumers. Hence, equal importance should be given to both the parameters and such a balanced approach will be more rewarding.

5.4 Path coefficient analysis

Path coefficient analysis was done for morphological characters to identify the causal factor and to identify the common components, which are responsible for producing grain yield. The ultimate correlation coefficient calculated between two variables, is in fact, the resultant of all paths connecting to the two characters. Thus the path coefficient analysis helps in understanding the causal system in a better way because it enables partitioning the total correlation of the components into direct and indirect effect it causes through other characters. The path coefficients are also called standardized partial regression coefficients. These are free from units, are directional, and may be more or less than unity and are therefore easy to interpret. The basic assumption of path

analysis is that the path diagram utilizes a complete representation of the causal factor involved in determining the end product i.e., grain yield in present case. The experimental findings have been discussed in the following paragraphs in the light of available literature.

Path coefficient analysis of different characters revealed that panicle per square metre, had the highest positive direct effect on grain yield per plant followed by biological yield per plant, filled grains per panicle, primary tillers per plant, secondary tillers per plant, tertiary tillers per plant, harvest index, panicle length, days to 50% flowering and 1000-grain weight. These traits also had positive & significant association in most of the cases with grain yield per plant.

Negative direct effect on grain yield per plant was the highest in case of productive tillers per plant followed by number of spikelets per panicle, panicle weight per plant, spikelet fertility percentage, panicles per plant, tillers per plant and plant height.

Positive direct effects observed in the present study for different characters on grain yield are in confirmation with the findings of 1000 grain weight by Awasthi and Borthakur (1986), Prasad *et al.* (1988) and Deosarkar and Nerkar (1996) for panicle length, Gopalkrishnan and Ganapathy (1996) for 1000 grain weight, days to 50% flowering and Lu *et al.* (1988) for biological yield per plant.

In the present investigation, the characters viz., days to 50% flowering, primary tillers per plant, secondary tillers per plant, tertiary tillers per plant, panicle length, panicle per sq.m., filled grain per panicle, grain L/B ratio, biological yield per plant, 1000 grain weight and harvest index were found to have positive direct effect on grain yield. Most of these characters also had positive association with grain yield. Hence, directional selection through

these traits will be very effective for improvement of grain yield. The traits viz., plant height, productive tillers per plant, tillers per plant, panicles per plant, number of spikelets per panicle and spikelet fertility had negative direct effect on grain yield per plant. However, all of them had positive association with grain yield, indicating that restricted selection model could be used for nullifying the undesirable effect of these traits.

An overall observation of the association analysis and path coefficient analysis in the present investigation appears to indicate that biological yield per plant, harvest index, number of tillers per plant, days to 50% flowering, primary tillers per plant, secondary tillers per plant, tertiary tillers per plant panicle length, panicles per square metre, filled grains per panicle and 1000 grain weight are important casual factors influencing the grain yield and common genes may play an important role for their expression. Therefore, due consideration must be given to these traits while practicing selection for yield improvement.

The hybrids IR68897A x R704, IR68897A x IR42342, IR68888A x R321, APRMS6A x NPT-70, APRMS6A x 25 NPT-10 and APRMS6A x NPT-10 were identified as best hybrids for yield potential. However, these hybrids were also found to have excellent grain quality coupled with good cooking qualities.

CHAPTER - VI

SUMMARY, CONCLUSION AND
SUGGESTIONS FOR FUTURE WORK

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

6.1 SUMMARY

The present investigation entitled "Evaluation of inter and intra-subspecific rice hybrids for quantitative and qualitative traits" was conducted at Seed Breeding Farm, Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during kharif 2005-06. The experimental material comprised of eleven inter sub specific (indica/JNPT) and fourteen intra sub-specific (indica/indica) rice hybrids along with five standard checks viz., Kranti, IR 64, JR-201, Mahamaya and IR 36. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Twenty-one days old seedlings of each hybrid were transplanted in 10 sq.m. plot keeping 15cm. distance between plants and rows. Single seedling per hill was planted. Fertilizer dose of 120 kg N, 60kg P₂O₅ and 60kg K₂O/ha was applied. The data was collected on 19 morphological and 13 quality traits for judging the superiority or inferiority of the hybrids over standard check variety Kranti. The observations were recorded as per the standard procedure prescribed. The data was subjected to various statistical analysis as per the standard procedure.

The results obtained from 19 morphological and 13 quality traits in the present investigation showed considerable genetic variability and moderate to high GCV and PCV.

The hybrids namely IR68897A x R 704, IR68897A x IR-42342, IR68888A x R321, APRMS6A x JNPT-70, APRMS6A x25 JNPT-10, APRMS6A x JNPT-10 based on the yield superiority coupled with excellent quality attribute over commercial check variety Kranti were

found to be the best hybrids. Based on the association analysis and path analysis harvest index, biological yield per plant, primary tillers per plant, secondary tillers per plant, tertiary tillers per plant, panicles per sq.m., filled grains per panicle, panicle length were found to be important components that directly influenced the grain yield. Their positive association with grain yield observed in the present investigation suggests that directional selection for this trait will be beneficial for improvement of grain yield.

6.2 CONCLUSION

Hybrids and checks studied in the present investigation showed considerable amount of genetic variability for majority of the traits.

In the present investigation, none of the hybrids showed heterosis for grain yield alone as yield is a complex trait influenced greatly by its component traits, therefore the ultimate product that is grain yield depending on the magnitude of heterosis of various traits. In this investigation the hybrids namely IR68897A x R704, IR68897A x IR-42342, IR68888A x R 321, APRMS6A x JNPT-70, APRMS6A x 25 JNPT-10 and APRMS6A x JNPT-10 found to had high heterosis over Kranti and also had excellent quality traits. This suggests that the present investigation was able to identify the hybrids, which are not only higher yielding but also having good quality traits.

The findings of the present investigation is highly relevant as current day hybrids although shows yield superiority over commercial varieties but lack in quality attributes which is considered to be a constraint for wide spread adoption of the hybrids. Association analysis of various morphological and quality traits suggests that selection of parental lines based on harvest index, biological yield per plant, primary tillers, secondary tillers,

tertiary tillers, filled grains per panicle and panicle length will give better results for breeding heterotic hybrid. Due consideration also be given while selecting the parental lines for heterosis breeding for quality traits viz., milling percentage, HRR, gelatinization temperature, kernel length after cooking, elongation ratio and elongation index. That will result in the development of hybrid, which is not only superior in term of yield, but also have balance of the good quality attributes, as the grain quality characteristics are very important parameters for wider acceptability and marketability of the hybrid rice by the consumers in the domestic as well as international markets.

The hybrids IR68897A x R704, IR68897A x IR42342, IR68888A x R321, APRMS6A x JNPT-70, APRMS6A x 25 JNPT-10 and APRMS6A x JNPT-10 were identified as best hybrids for yield potential. However, these hybrids were also found to have excellent grain quality coupled with good cooking qualities. They should be tested in multilocation trials for judging their adaptability and superiority across the seasons and locations.

6.3 SUGGESTIONS FOR FUTURE WORK

- ☞ The hybrids identified as high yielders viz., IR68897A x R704, IR68897A x IR 42342, IR68888A x R 321, APRMS6A x JNPT-70, APRMS6A x 25 JNPT-10, APRMS6A x JNPT-10 should be tested in multi-location trials for judging their adaptability and superiority across the seasons and locations.
- ☞ High yielding parental lines with good grain quality should be identified for evolving hybrids with acceptable grain quality along with high yield.
- ☞ Characters having positive association and direct effects with grain yield should be given due consideration for improvement of grain yield.
- ☞ The hybrids showing good quality traits with optimum of average yields may be tested under different agro-climatic conditions.
- ☞ Gel consistency, amylose content and quality of aroma should be included in the study of quality characters.

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APPENDICES

APPENDICES

Appendix-I. Meteorological data during the crop seas.

Months	Meteo. week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days	Sun sh. (hrs)	
		Max.	Min.	Max.	Min.				
June	23	42.5	28.4	32	13	-	-	7.5	
	24	43.3	30.2	33	15	-	-	6.2	6
	25	40.1	27.5	60	34	051.4	02	3.9	8
	26	30.6	24.4	88	78	094.1	04	1.5	5
July	27	28.9	23.3	95	83	474.0	06	3.3	12
	28	30.6	24.5	91	78	151.8	0	4.1	4
	29	30.5	24.5	86	74	090.8	04	3.5	4
	30	31.4	24.6	89	74	088.5	05	4.0	4
	31	29.4	24.6	94	83	120.2	06	3.2	5
August	32	29.3	24.0	91	70	019.4	02	6.0	7
	33	29.1	24.3	81	80	118.4	04	5.7	5
	34	27.7	23.5	91	77	010.8	04	6.1	5
	35	33.0	24.6	84	55	001.0	01	8.9	3
September	36	31.9	24.2	91	81	091.8	06	5.6	1
	37	29.8	23.8	93	79	251.2	07	6.2	6
	38	30.0	24.1	89	69	018.2	03	4.3	6
	39	30.6	23.0	87	60	017.8	02	6.1	4
October	40	32.2	20.6	85	43	000.0	00	8.7	2
	41	32.1	19.3	89	45	000.0	00	8.8	2
	42	29.0	21.1	92	66	005.2	01	4.8	2
	43	28.7	16.7	93	43	000.0	00	8.2	2
	44	28.1	12.2	92	28	000.0	00	7.2	1
November	45	27.6	10.1	92	26	000.0	00	5.4	1
	46	29.1	10.4	94	23	000.0	00	8.7	1
	47	29.0	9.7	89	24	000.0	00	9.0	1
	48	28.4	12.3	89	32	000.0	00	7.3	1
December	49	25.4	6.2	93	27	000.0	00	7.5	1
	50	23.3	5.1	94	28	000.0	00	8.2	1
	51	24.4	7.4	94	44	007.2	01	7.6	1
	42	23.6	7.0	94	33	000.0	00	7.6	1

APPENDICES

Appendix-I. Meteorological data during the crop season

Months	Meteo. week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days	Sun shine (hrs.)	Wind Vel. (km/hr)
		Max.	Min.	Max.	Min.				
June	23	42.5	28.4	32	13	-	-	7.5	4.9
	24	43.3	30.2	33	15	-	-	6.2	5.0
	25	40.1	27.5	60	34	051.4	02	3.9	6.2
	26	30.6	24.4	88	76	094.1	04	1.5	6.7
July	27	26.9	23.3	95	83	474.0	06	3.3	12.0
	28	30.6	24.5	91	78	151.8	03	4.1	4.5
	29	30.5	24.5	86	74	090.8	04	3.5	4.5
	30	31.4	24.6	89	74	088.6	05	4.0	4.6
	31	29.4	24.6	94	83	120.2	06	3.2	5.1
August	32	29.3	24.0	91	70	019.4	02	6.0	7.3
	33	29.1	24.3	91	80	116.4	04	5.7	5.4
	34	27.7	23.5	91	77	010.8	04	6.1	5.8
	35	33.0	24.6	84	55	001.0	01	8.9	3.7
September	36	31.9	24.2	91	81	091.8	06	5.6	1.5
	37	29.8	23.8	93	79	251.2	07	6.2	6.0
	38	30.0	24.1	89	69	018.2	03	4.3	6.1
	39	30.6	23.0	87	60	017.8	02	6.1	4.1
October	40	32.2	20.6	85	43	000.0	00	8.7	2.1
	41	32.1	19.3	89	45	000.0	00	8.8	2.2
	42	29.0	21.1	92	66	005.2	01	4.8	2.8
	43	28.7	16.7	93	43	000.0	00	8.2	2.4
	44	28.1	12.2	92	28	000.0	00	7.2	1.1
November	45	27.6	10.1	92	26	000.0	00	8.4	1.9
	46	29.1	10.4	94	23	000.0	00	8.7	1.7
	47	29.0	9.7	89	24	000.0	00	9.0	1.2
	48	28.4	12.3	89	32	000.0	00	7.3	1.3
December	49	25.4	8.2	93	27	000.0	00	7.5	1.8
	50	23.3	5.1	94	28	000.0	00	8.2	1.7
	51	24.4	7.4	94	44	007.2	01	7.6	1.7
	42	23.6	7.0	94	33	000.0	00	7.6	1.5

Appendix-II Mean performance of twenty-five hybrids and five checks

	Variety	HILL%	MILL%	HRR%	KLBC	KBBC	LK/B	KLAC	KBACK	L/BCR	ER	B	GC	GT	GY/PL
1	APRMS 6A · JNPT-70	73.0000	67.3667	61.1333	6.0333	1.9667	3.0700	8.8000	3.1000	2.8400	1.4833	0.9300	2.0000	5.0000	14.6333
2	APRMS 6A X 25 JNPT-70-1	63.1333	61.1667	43.1333	6.0000	1.8667	3.2200	8.9333	3.1333	2.8500	1.4900	0.8867	2.0000	5.0000	23.9333
3	APRMS 6A · JNPT-10	57.9000	53.0000	36.9333	6.0000	2.0000	3.0000	8.9667	3.1333	2.8667	1.4967	0.9533	2.0000	3.0000	38.4667
4	APRMS 6A · SPS-71	68.1667	65.0000	59.3333	5.9667	1.8667	3.2000	8.8000	2.6667	3.3067	1.4733	1.0333	1.0000	6.0000	35.2667
5	APRMS 6A × 25 JNPT-10	76.8000	71.0000	61.4000	5.9667	2.0333	2.9033	8.2333	3.0667	2.6867	1.4000	0.9333	2.0000	4.6667	43.5333
6	APRMS 6A · JNPT-71-01	63.0333	57.1667	49.3667	5.9000	2.0667	2.8567	8.4667	3.1333	2.7033	1.4333	0.9467	1.6667	4.6667	37.4667
7	APRMS 6A · JNPT- 70-32	65.9667	65.2667	52.6667	6.0667	1.8667	3.2500	8.8667	2.6000	3.4200	1.4567	1.0533	1.0000	4.0000	23.5000
8	APRMS 6A · 25 JNPT-70	69.8000	64.0000	55.7000	6.0333	1.8667	3.2400	8.9333	2.7333	3.2667	1.4767	1.0133	1.0000	4.3333	24.2000
9	APRMS 6A · IR 42342	74.0333	71.3000	59.8000	5.9000	1.9667	3.0000	8.7000	3.1000	2.8067	1.4733	0.9367	1.0000	5.0000	26.3333
10	IR58025A · JNPT-10	66.2667	60.9667	49.3000	5.9333	1.9000	3.1267	8.9000	3.2000	2.7833	1.5000	0.8900	1.0000	3.0000	29.4333
11	IR58025A · JNPT-29	59.9000	56.6667	43.0333	6.9000	2.0000	3.4567	9.5000	3.2333	2.0100	1.3767	0.8433	1.0000	5.0000	25.3333
12	IR58025A · ABHYA	57.0000	53.5667	35.8667	6.9667	1.8667	3.7300	9.7000	3.0333	3.1967	1.3933	0.8567	1.0000	6.0000	36.6667
13	IR58025A × R304	69.4000	65.0333	44.0667	6.9000	1.9333	3.5700	9.5333	2.8333	3.3633	1.3833	0.9433	2.0000	6.0000	28.0333
14	IR58025A · IR54742	62.9667	59.8333	52.4667	6.9333	1.9000	3.6467	9.6667	3.0333	3.2267	1.3933	0.8833	2.0000	7.0000	34.6667
15	IR70369A · JNPT-70	67.3333	63.0667	49.1667	6.0333	2.4667	2.4467	9.1000	3.6667	2.4833	1.5100	1.0133	1.0000	5.0000	30.8333
16	IR68888A · R 321	65.1667	62.6667	56.5333	6.9333	1.8667	3.7133	9.8000	3.2000	3.0633	1.4133	0.8233	1.0000	4.0000	45.7333
17	IR68888A · ABHYA	67.2000	62.4667	52.7333	6.0000	1.9333	3.1067	9.0667	3.4000	2.6667	1.5133	0.8600	1.0000	6.0000	30.3333
18	IR68888A · R548	66.4000	60.8667	53.4667	5.9333	2.0333	2.9200	9.6667	3.4333	2.7667	1.6300	0.9467	2.0000	7.0000	35.4000
19	IR68888A · R-42	70.0667	63.8333	54.0333	6.0333	1.6333	3.6967	9.7333	2.8333	3.3767	1.6133	0.8967	2.0000	5.0000	22.9000
20	IR68897A · JNPT-10	72.1000	66.9667	59.2333	5.9333	2.0333	2.9200	8.8000	3.1333	2.8133	1.4800	0.9600	1.0000	6.0000	24.5333
21	IR68897A · R304	68.5667	62.6333	47.9000	6.5000	1.9667	3.3233	9.8000	2.8000	3.5000	1.5067	1.0600	1.0000	7.0000	28.5333
22	IR68897A · R704	62.3333	56.4000	47.6667	6.9333	1.9333	3.5867	9.5667	3.0333	3.1500	1.3800	0.8767	1.0000	7.0000	47.4333
23	IR68897A · IR-42342	60.0000	55.7667	38.0000	6.9667	2.0000	3.4833	9.5333	3.0000	3.1767	1.3700	0.9133	2.0000	6.0000	46.6333
24	IR68897A · R-42	74.1667	70.1000	58.1667	6.9000	1.8333	3.7633	9.7000	2.7000	3.5933	1.4067	0.9567	1.0000	6.0000	22.4667
25	IR68899A · IR-42342	62.0667	59.2000	41.3333	6.9333	1.9000	3.6533	9.7000	2.8000	3.4667	1.4000	0.9500	1.0000	7.0000	35.7333
26	KRANTI	68.5000	62.0000	55.7333	5.8000	2.9333	1.9800	8.4333	3.6667	2.3000	1.4533	1.6000	1.0000	6.0000	26.0667
27	IR64	72.4000	67.3333	55.3333	6.8000	1.8333	3.7167	9.4000	2.8000	3.3567	1.3833	0.9033	1.0000	6.0000	18.9000
28	JR204	70.0000	66.8667	56.7000	6.1000	1.8667	3.2700	9.1333	2.8333	2.2233	1.5067	0.9833	1.0000	6.0000	17.8667
29	Mahamaya (Check)	74.3667	69.2000	57.6333	6.0667	2.0667	2.9367	8.5333	3.2333	2.6433	1.4033	0.9000	1.0000	6.0000	22.4333
30	IR-36 (Check)	59.3333	57.7667	40.5667	5.2333	1.8333	2.8567	8.0667	3.1333	2.5767	1.5433	0.9033	1.0000	6.0000	22.4000

Appendix-II Mean performance of twenty-five hybrids and five checks

	Variety	DFF	PHT	TILL/PT	PTILL/P	PT/P	ST/P	TT/P	PAN/PT	PAN LGH	PAN/M
1	APRMS6A X JNPT-70	88.3333	101.6667	10.6667	6.0000	9.3333	1.3333	0.0000	6.0000	25.6667	300.0000
2	APRMS 6A X 25 JNPT 70-1	87.0000	101.0000	8.3333	6.3333	7.0000	1.0000	0.3333	6.3333	24.3333	316.6667
3	APRMS 6A X JNPT-10	87.6667	105.3333	9.3333	8.0000	6.0000	2.6667	1.0000	8.0000	23.6667	400.0000
4	APRMS 6A X SPS-71	91.6667	103.0000	8.0000	7.3333	5.3333	2.0000	0.6667	7.3333	27.0000	366.6667
5	APRMS 6A X 25J NPT-10	86.0000	106.0000	8.3333	7.6667	6.6667	1.6667	0.0000	7.6667	26.0000	383.3333
6	APRMS 6A XJ NPT 71-01	89.3333	107.6667	9.0000	7.6667	7.3333	1.6667	0.0000	7.6667	27.6667	383.3333
7	APRMS 6A XJ NPT 70-32	87.3333	97.6667	9.0000	8.6667	6.6667	1.6667	0.6667	8.6667	24.3333	433.3333
8	APRMS 6A X 25 JNPT-70	87.3333	93.6667	7.3333	7.3333	6.0000	1.3333	0.3333	5.3333	21.0000	366.6667
9	APRMS 6A X IR 42342	84.0000	94.0000	10.3333	8.6667	8.0000	1.6667	0.6667	8.6667	26.0000	433.3333
10	IR58025A X JNPT-10	84.0000	92.3333	8.6667	7.6667	8.0000	0.6667	0.0000	7.6667	26.0000	383.3333
11	IR58025A X JNPT 29	81.3333	94.0000	7.6667	7.6667	6.6667	1.0000	0.0000	7.6667	25.0000	383.3333
12	IR58025A X ABHYA	80.6667	85.0000	14.0000	12.3333	9.6667	4.3333	0.0000	12.3333	21.3333	616.6667
13	IR58025A X R 304	83.6667	88.0000	9.0000	7.6667	7.6667	1.3333	0.0000	7.6667	25.0000	383.3333
14	IR58025A X IR 54742	89.3333	91.3333	12.3333	11.0000	8.3333	3.3333	1.0000	11.0000	24.3333	550.0000
15	IR70369A X JNPT 70	82.3333	95.6667	9.3333	8.3333	8.3333	1.0000	0.0000	9.0000	20.6667	450.0000
16	IR68888A X R 321	76.0000	97.3333	14.0000	12.0000	9.0000	4.0000	1.0000	12.0000	25.6667	600.0000
17	IR68888A X ABHYA	81.3333	85.0000	11.6667	10.3333	8.3333	3.3333	0.0000	10.3333	25.6667	516.6667
18	IR68888A X R548	75.6667	89.0000	13.3333	11.0000	10.3333	2.0000	1.0000	11.0000	23.0000	550.0000
19	IR68888A X R-42	84.6667	82.6667	8.6667	7.3333	7.0000	1.6667	0.0000	7.3333	23.3333	366.6667
20	IR68897A X JNPT-10	86.0000	98.0000	6.6667	5.6667	5.3333	1.3333	0.0000	5.6667	26.6667	283.3333
21	IR68897A X R 304	86.6667	102.3333	9.6667	8.0000	8.3333	1.3333	0.0000	8.0000	27.3333	400.0000
22	IR68897A X R704	89.6667	94.6667	13.0000	10.6667	9.6667	2.0000	1.3333	10.6667	24.6667	533.3333
23	IR68897A XIR-42342	84.3333	91.6667	12.3333	10.3333	8.6667	1.6667	2.0000	10.3333	25.6667	516.6667
24	IR68897A X R-42	80.3333	87.0000	8.0000	6.6667	6.0000	1.0000	1.0000	7.3333	25.3333	366.6667
25	IR68899A X IR42342	79.6667	91.0000	10.6667	9.3333	9.0000	1.0000	0.6667	9.3333	26.0000	466.6667
26	Kranti (Check)	81.6667	101.3333	11.3333	8.0000	8.3333	2.0000	1.0000	8.0000	23.6667	400.0000
27	IR-64 (Check)	89.6667	90.3333	8.3333	7.3333	5.6667	1.6667	1.0000	7.3333	21.3333	366.6667
28	JR-201 (Check)	76.0000	90.0000	9.0000	8.0000	6.3333	2.6667	0.0000	8.0000	25.6667	400.0000
29	Mahamaya (Check)	93.0000	98.0000	10.3333	9.3333	8.3333	2.0000	0.0000	9.3333	22.6667	446.6667
30	IR-36 (Check)	95.6667	71.0000	13.0000	10.6667	8.6667	4.0000	0.6667	10.6667	22.6667	533.3333

Appendix-II Mean performance of twenty-five hybrids and five checks

	Variety	PANW/P	NOS/PL	FG/PL	SE FER	GL/B	BY/PL	GY/PL	1000GW	HI%
1	APRMS6A X JNPT-70	40.5667	217.6667	191.6667	88.0333	3.6467	73.6333	44.6333	28.6667	59.3633
2	APRMS 6A X 25 JNPT 70-1	26.0333	209.3333	165.3333	79.0000	3.3000	42.0333	23.9333	24.6333	57.2467
3	APRMS 6A X JNPT-10	41.8000	204.6667	171.6667	83.8667	3.3833	59.7667	38.4667	27.9000	64.3667
4	APRMS 6A X SPS-71	39.2000	256.6667	206.3333	80.4333	3.3400	54.8333	35.2667	29.3000	64.3333
5	APRMS 6A X 25J NPT-10	48.5000	472.6667	425.0000	89.9333	3.0600	65.0333	43.5333	27.2667	66.9333
6	APRMS 6A XJ NPT 71-01	37.6667	297.0000	236.3333	79.6333	2.1167	71.9333	37.4667	25.2333	52.0333
7	APRMS 6A XJ NPT 70-32	24.2667	224.0000	168.6667	75.3667	3.1133	40.1667	23.5000	20.5000	58.5267
8	APRMS 6A X 25 JNPT-70	27.0333	232.3333	187.3333	80.6333	2.8000	41.0667	24.2000	24.9000	58.9000
9	APRMS 6A X IR 42342	28.6667	192.3333	158.3333	82.1000	3.6400	53.5000	26.3333	27.5667	49.2000
10	IR58025A X JNPT-10	35.4667	175.6667	150.6667	85.7667	3.4300	51.6000	29.4333	27.7000	56.9000
11	IR58025A X JNPT 29	27.1667	202.3333	170.0000	84.0000	3.8667	53.9667	25.3333	24.3000	46.9333
12	IR58025A X ABHYA	38.5000	127.0000	86.0000	68.0667	3.7500	59.7000	36.6667	28.0000	61.3667
13	IR58025A X R 304	31.7333	168.6667	114.3333	67.7667	3.8200	45.2667	28.0333	27.2333	61.9100
14	IR58025A X IR 54742	38.2333	121.3333	85.6667	70.5667	2.7267	61.7333	34.6667	23.4000	56.1333
15	IR70369A X JNPT 70	38.5667	169.6667	119.3333	70.3333	2.3000	51.7667	30.8333	29.2000	59.5667
16	IR68888A X R 321	48.0333	116.0000	90.0000	77.5333	3.5567	67.4667	45.7333	28.2000	67.8000
17	IR68888A X ABHYA	31.5333	123.3333	108.0000	87.4667	3.1433	53.7333	30.3333	24.8000	56.4333
18	IR68888A X R548	37.4333	137.3333	116.0000	84.0000	2.9733	60.5000	35.4000	28.4667	58.5000
19	IR68888A X R-42	24.7667	143.3333	113.0000	78.7000	3.2633	45.8667	22.9000	27.1000	49.9667
20	IR68897A X JNPT-10	27.9333	202.3333	147.0000	72.6667	3.2467	54.3000	24.5333	28.3333	45.1667
21	IR68897A X R 304	31.5000	217.6667	151.3333	69.6667	2.8600	56.5667	28.5333	29.7333	50.4333
22	IR68897A X R704	32.5000	200.3333	154.3333	77.4667	3.7300	73.2000	47.4333	28.0667	64.8000
23	IR68897A XIR-42342	48.5667	149.3333	126.0000	84.3333	3.1667	69.6667	46.6333	27.4667	66.9333
24	IR68897A X R-42	22.2000	169.0000	137.0000	81.1000	3.2433	44.6000	22.4667	23.3333	43.0000
25	IR68899A X IR42342	38.4333	159.3333	127.0000	79.1000	3.3333	64.1000	35.7333	25.9333	55.7667
26.	Kranti (Check)	48.1667	169.0000	156.6667	92.5667	2.4767	67.9667	26.0667	29.1667	65.0000
27.	IR-64 (Check)	21.7333	119.0000	95.3333	80.2333	3.7067	38.5333	18.9000	26.3333	49.0333
28.	JR-201 (Check)	20.0667	123.3333	112.0000	90.6333	3.2933	39.2667	17.8667	26.5667	45.5333
29.	Mahamaya (Check)	23.7667	137.6667	131.3333	95.2667	2.5033	45.6333	22.4333	29.4333	49.1333
30.	IR-36 (Check)	25.4667	147.6667	102.0000	69.2000	2.9633	45.3333	22.4000	22.6000	49.4000

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