Principal component analysis for selection of heterotic hybrids for yield component traits in mid and mid-early duration rice genotypes

E Pandit*$, SR Barik$, SP Mohanty, DP Mohanty, Lipi Das, ON Singh and SK Pradhan

ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India

Corresponding author e-mail: elsambio@gmail.com
$Equal contribution

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ABSTRACT

Hybrid rice offers a viable option to increase the yield beyond the level of semi dwarf rice cultivars as improvement in productivity and profitability in rice farming system is required on sustainable basis. Mid and mid early duration group of rice varieties are grown in rich environments with good harvest. Hence, targeting this rice ecology for hybrid cultivation for boosting up the production will be a good approach. Identification of best heterotic hybrids against three best popular varieties of the irrigated rice ecology can be useful to break the yield barrier. In the present study, 31 cross combinations were studied for identification of heterotic combiners. The cross combinations namely Reeta / CR3854, CR3813-2-2-5-1-1 / R261 and Improved Tapaswini / MTU1010 were considered to be best heterotic lines possessing good agro-morphologic traits like yield, fertility, panicle length, panicle number and harvest index using principal component analysis. The cross between Reeta and CR3854 showed highest heterosis for yield manifesting longer panicle, increased panicle number and fertility with more harvest index as compared to the standard checks used. The parental lines of these heterotic hybrids will be useful for conversion to male sterile and restorer lines through marker system to produce marker free F_1 *hybrids.*

Key words: *heterosis, biplot analysis, heterotic combiners*

Millions of people depend on rice as major carbohydrate source as well as a source of income. A continuous improvement in productivity and profitability in rice farming system is required on sustainable basis. Hybrid rice offers a viable option to increase the yield beyond the level of semi dwarf rice cultivars as observed in China, Vietnam and India (Joshi 2001). Heterosis, or hybrid vigor, refers to the superior performance of hybrids relative to their parents or commercially growing popular varieties. Utilization of heterosis has tremendously increased the global productivity of many crops. In rice, heterosis has been exploited commercially mostly in China, India, Vietnam and the Philippines. Davis and Rutger (1976), Virmani et al. (1981) reviewed on heterosis in various agronomic traits of rice. Goff and Zhang (2013) reviewed the genetic and biochemical mechanism governing heterosis in rice.

Both positive and negative heterosis is desirable depending upon the trait. For example, positive heterosis desired for yield and yield relating traits and negative heterosis for plant height and early maturity (Nuruzzaman *et al.* 2002). Generally heterosis is expressed in three ways according to the performance of the hybrids over its parents (mid parent and better parent heterosis) and commercially growing rice varieties (standard heterosis). Heterosis breeding is very important genetic tool in conventional breeding for the enhancement of yield and many other yield related traits both qualitative and quantitative in all crops under stress conditions (Ashfaq *et al.* 2013).

variety is more relevant than others. Hence, estimation of standard heterosis over three most popular varieties (MTU1010, IR64 and Naveen) was undertaken in the present investigation.

Mid and mid early duration group of rice varieties are planted in rich environment with assured good harvest. Therefore, this rice ecology should be targeted to be covered by hybrids cultivation for boosting up of production. A two and half decade hybrid rice research efforts in the country has resulted in release of 77 rice hybrids. But, the progress in adoption of hybrid rice is very slow with a mere coverage of <5% rice area of the country. The main reasons may be the stable yield advantage of the hybrids over the best inbreeds variety of a region and high seed cost. Therefore, the current investigation was under taken to find out best heterotic hybrids compared against three popular varieties of the irrigated rice ecology. The parental lines of the identified heterotic hybrids will be converted to male sterile and restorer lines through Cre-lox system to produce marker free F1 hybrids.

MATERIALS AND METHODS

Seeds of 36 genotypes were collected from the ICAR-NRRI Gene bank and were sown in nursery bed and transplanted during the month of July 2013 in three staggered dates with an interval of seven days in order to coincide the flowering dates for hybridisation. Need based plant protection measures and other package of practices were followed to get healthy plant. Thirty one numbers of crosses were made by taking 14 female lines and 26 male lines (Table 1). Duration of the selected genotypes was within 100-140 days. Hybridization was performed manually using vacuum emasculator.

The F_1 seeds were harvested in November, 2013. The F_1 seeds of 31 crosses were raised during summer season, 2014. These cross seeds were germinated in petriplates followed by transplanted in shallow pots. Finally, the potted F_1 plants were transferred to the main field after 25 days. The F_1s, parents and standard varieties were transplanted in main field in RBD with two replications. Two rows of each F_1s were planted with 20 F_1 seedlings of each entry per row. The data were recorded for various agro-morphologic parameters like biomass, harvest index, yield, tiller number, sterility-fertility ratio, panicle length, and days to 50% flowering from parents, standard varieties and F1s in order to get the best heterotic lines. Three high yielding and popular varieties of India namely, IR64, MTU1010 and Naveen were taken as standard checks. Standard heterosis was computed using the formula:

$$\text{Standard heterosis} = \left[\left(\text{F1-SAV}\right)/\text{MSV}\right]\text{x100}$$

Where, F1 = Mean value of F_1 progeny for a trait

MSV = Mean value of three standard varieties for a trait

F_1seeds of the top ten heterotic crosses observed during *summer*, 2014 were generated again during the *kharif*, 14 to confirm the standard heterosis estimates of the crosses during *summer*, 2015.

The data were analysed through the SPSS v.20 software (IBM Corp.2011). Principal Component Analysis (PCA) was performed using the PAST v.3 software (Harper and Ryan 2001).

RESULTS AND DISCUSSION

F1seeds of thirty one cross combinations were generated during *kharif*, 2013 and grown during dry season, 2014 for estimating standard heterosis for grain yield and its component traits. The summary of standard heterosis of 31 combinations obtained against the standard check varieties Naveen, IR64 and MTU1010 for yield, harvest index, spikelet fertility, panicle number, panicle length and days to 50% flowering has been depicted in Table 1. The standard heterosis for single plant yield ranged from 23% (Swarna/BPT5204) to 49% (Chandan / CR 3696-5-5-2-2-1). Similarly, harvest index ranged from -4.69 to 10.87% and spikelet fertility ranged between 0.1 to 7.47%. Positive heterosis was observed for panicle length and panicle number ranging from 4.93 to 30.83% and 6.9 to 24.3%, respectively. The heterosis for days to 50% flowering varied greatly among the combinations studied that ranged between -3.07% as observed in Naveen/CR 2699-1-1-2-1 cross to 12.03% in case of Chandan / CR 3696-5-5-2-2-1.

The best ten crosses identified from the above study were again confirmed for their heterosis during summer 2015. For days to 50% flowering, the combinations showing negative heterosis can be

Table 1. Standard heterosis over three check varieties IR64, Naveen and MTU1010 estimated during summer 2014

Sl no.	Cross combination	Mean Standard heterosis (%)					
		Days to 50% flowering	panicle length	panicle number	Spikelet Fertility	Harvest Index	Single plant yield
1	Chandan/CR 3696-5-5-2-2-1	12.03*	27.16*	23.13*	7.47*	10.87*	49.09*
2	Reeta/CR 3854	6.97*	30.83*	24.30*	6.10*	9.20*	48.49*
3	Naveen/Chandan	-1.73*	25.08*	23.77*	5.87*	8.86*	43.32*
4	CR 3813-2-2-5-1-1/R 261	5.23*	24.72*	21.30*	6.17*	5.07*	41.27*
5	Improved Tapaswini/ MTU 1010	4.26*	21.21*	21.03*	6.80*	7.73*	41.70*
6	Reeta/CR 3300-1-2-1-1	6.23*	22.83*	19.70*	5.24*	7.83*	40.30*
7	Swarna MAS/Saket 4	9.73*	20.19*	19.47*	5.57*	5.60*	38.15*
8	Lalat MAS/IET 21918	-1.53*	19.06*	20.13*	4.57*	3.97*	35.66*
9	Naveen/CR 2699-1-1-2-1	-3.07*	19.91*	21.20*	3.77*	1.43	35.35*
10	Tapaswini/Kamesh	-1.43*	18.94*	19.97*	3.00*	2.50*	32.40*
11	Swarna MAS/Pyari	-0.37	15.73*	18.50*	2.13*	-2.27*	17.00*
12	Naveen/Pusa Sugandha 2	2.67*	14.90*	14.23*	2.27*	3.25*	16.67*
13	Chandan/Hiranmayi	3.63*	9.93*	13.70*	3.07*	-2.90*	16.23*
14	Reeta/CR Dhan 300	0.27	15.97*	16.43*	1.37*	3.68*	16.12*
15	Mammy Hunger/Lalat MAS	4.43*	19.00*	-3.20*	-1.80	1.77	5.33*
16	Naveen/CR Dhan 300	3.53*	11.40*	12.23*	4.55*	2.76*	15.13*
17	Lalat MAS/CR 2699-1-2-1-1-2	2.67*	15.23*	16.67*	0.53	5.17*	14.34*
18	Lalat/Kalachampa	-0.77	15.78*	18.43*	1.60*	-4.69*	13.75*
19	Naveen/IR 64 MAS	2.50*	9.84*	15.53*	1.93*	-4.25*	13.06*
20	Tapaswini/Pyari	-1.27*	6.81*	12.73*	1.13*	-1.84	12.13*
21	Lalat MAS/Pyari	1.23*	11.24*	9.14*	1.17*	5.47*	11.96*
22	Kalinga III/ Tapaswini	-0.20	10.43*	9.36*	2.03*	3.56*	11.49*
23	Chandan/ Rajeswari	1.10*	8.57*	16.53*	0.10	3.27*	10.99*
24	Swarna/ CR 3607-21-1-2-1	2.33*	7.14*	9.30*	2.17*	-2.41*	10.96*
25	IR 64 MAS/CR Dhan 601	2.53*	7.83*	8.83*	1.67*	1.87	10.85*
26	Naveen/Hue	-2.00*	9.55*	12.33*	1.72*	-3.16*	10.76*
27	Kalinga III/CR 3727-11-1	-0.23	5.27*	11.13*	1.39*	3.28*	10.42*
28	Tapaswini/Hue	2.00*	4.93*	8.26*	1.08*	-3.00*	10.34*
29	Sampad/Karjat-6	0.60	7.17*	11.57*	1.67*	-2.06*	8.15*
30	Lalat/ IET 21918	2.13*	6.01*	8.17*	2.34*	3.21*	4.12*
31	Swarna/BPT-5204	-0.13	6.57*	6.90*	1.49*	-2.46*	7.02*

* indicates significant at 5% level of probability

considered as the better ones while positive heterosis are considered for late duration variety development. The mean standard heterosis for DFF varied from -3.1 to 9.7% (Table 2). The cross combinations of Tapaswini/Kamesh, LalatMAS/IET 21918, Naveen/ CR 2699-1-1-2-1 and Improved Tapaswini/MTU 1010 showed negative mean standard heterosis as observed in the previous dry season. Earlier reports of Reddy *et al.* (2012) also showed significant negative heterosis over mid parent in five crosses and 6 crosses exhibited significant negative heterosis over better parent for days to 50% flowering in aromatic rice.

The average heterosis for panicle length varied from 5.73 to 27.5 cm (Table 1 and 2). The cross combination Reeta with CR3854 showed highest SH of 27.5% for the trait. The cross may produce superior progenies for longer panicle length. Naveen/Chandan and Swarna MAS/ Saket 4 considered to be good combinations for average panicle number. The standard heterosis ranged from 8.6 to 25.1% for panicle number (Table 2).The F_1s observed to be heterotic during last year were again reconfirmed.

The combinations like CR3696-2-2-5-1-1/ R-261, Swarna MAS / Saket-4, Tapaswini / Kamesh, Lalat MAS / IET 21918, Chandan / CR 3696-5-5-2-2-1, Naveen / CR2699-1-1-2-1, Lalat MAS / Pyari, Reeta / CR 3854 and Naveen /Chandan also exhibited positive heteosis for spikelet fertility. The mean standard heterosis of all the combinations ranged from -2.03 to 7.47. Harvest index ranged from 0.392 to 0.512. The checks Naveen, IR64 and MTU1010 showed the harvest index of 0.42, 0.41 and 0.415 respectively. Naveen / Chandan, Reeta /CR 3300-1-2-1-1, Swarna MAS / Saket-4, Chandan /CR3621-2-3-1-2-1, CR3813-

2-2-5-1-1/R261, Improved Tapaswini/ MTU1010, Tapaswini/Kamesh, Lalat MAS/IET 21918 and Naveen/CR 2699-1-1-2-1 were again found to be with mean SH ranging from -4.57 to 17.83% over the checks (Table 2). Hence, the crosses are confirmed to be heterotic for high grain yield.

The combinations like Reeta / CR3854, Chandan / CR 3696-5-5-2-2-1, CR3813-2-2-5-1-1 / R261 and Improved Tapaswini / MTU1010 and Naveen/ Chandan were observed to show promising heterosis (Table 1 and 2) with mean SH more than 35%. The mean SH ranged from 24.32 to 48.53%.

Positive heterosis for grain yield per plant and other parameters were reported in many earlier works (Joshi 2001; Li *et al.* 2002; Hong *et al.* 2002; Alam *et al.* 2004, Jarwar *et al.* 2013, Huang *et al.* 2015). Many rice hybrids have been released from different countries with yield advantage of 15 to 20% more than the commercial growing rice varieties under different environments (Yuan *et al.* 2000).

Considering the standard heterosis for the agro-morphologic parameters like yield, fertility, panicle length, panicle number and harvest index, the cross combinations of Reeta / CR3854, CR3813-2-2-5-1-1 / R261 and Improved Tapaswini / MTU1010 were considered to be best heterotic lines possessing good traits. The cross between Reeta and CR3854 showed highest heterosis for yield showing longer panicle, increased panicle number and fertility with more harvest index as compared to the standard checks used. Similarly the crosses of CR3813-2-2-5-1-1/ R261 and Improved Tapaswini / MTU1010 also possessed the characters except for heterotic for harvest index. The combination of Tapaswini/ Kamesh showed positive heterosis for yield, fertility as well as negative heterosis for days to 50% flowering.

Rahimi *et al.* (2010) studied heterosis in rice through the traits like growth period, reproductive period, flag leaf area, plant height, panicle length, number of panicles per plant, number of grains per panicle, 1000-grain weight, grain yield, brown grain length and brown grain width. They also reported significant standard heterosis for all the traits studied in the 15 hybrids. The significance of specific combining ability (SCA) and general combining ability (GCA) for all studied traits revealed that both additive and non-additive gene effects contributed to the inheritance of the traits.

The combinations like Reeta/CR 3854, CR 3813-2-2-5-1-1/R 261, Chandan/CR 3696-5-5-2-2-1, Improved Tapaswini/ MTU 1010, Naveen/Chandan, Swarna MAS/Saket 4, Reeta/CR3300-1-2-1-1, Tapaswini/Kamesh, Lalat MAS/IET 21918, Naveen/ CR 2699-1-1-2-1 were observed to have promising heterosis for the traits under study. These heterotic crosses identified during summer, 2014 were hybridized again during *kharif*, 2014 for re-confirmation of the high heterosis. The comparative study of mean standard heterosis for all the traits under study against the three standard checks used has been summarised in Figure 1.

Standard heterosis for yield ranging from 16 to 63% was reported by Rutger and Shinjyo (1980) and from 29 to 45% by Yuan *et al.* (1994). Virmani *et al.* (1982) observed 54 and 34% heterosis for better parent and standard heterosis, respectively. In China yield

Table 2. Reconfirmation of heterotic crosses for yield component traits during summer 2015 against standard varieties IR64, Naveen and MTU1010

Sl.No.	Cross combination	Mean Standard heterosis (%)					
		Days to 50% flowering	panicle length	panicle number	Spikelet Fertility	Harvest Index	Single plant yield
1	Reeta/CR 3854	7.2*	27.5*	12.3*	3.38*	10.53*	48.53*
2	Chandan/CR 3696-5-5-2-2-1	14*	22.16*	12.8*	5.37*	8.2*	48.09*
3	CR 3813-2-2-5-1-1/R 261	3.8*	24.72*	8.6*	7.47*	-2.4*	38.6*
4	Improved Tapaswini/ MTU1010	-0.7	23.55*	17.7*	2.93*	23.4*	39.37*
5	Naveen/Chandan	4.7*	15.75*	25.1*	2.2*	10.53*	36.66*
6	Swarna MAS/Saket 4	7.2*	15.86*	23.1*	1.9*	17.6*	31.48*
7	Reeta/CR 3300-1-2-1-1	9.7*	22.16*	21*	4.24*	17.83*	32.97*
8	Tapaswini/Kamesh	-3.1*	8.94*	14.6*	1.67*	-5.53*	28.06*
9	Lalat MAS/IET 21918	-3.1*	5.73*	19.5*	-2.03*	4.13*	24.32*
10	Naveen/CR 2699-1-1-2-1	-3.1*	11.91*	24.5*	3.93*	-4.57*	29.01*

** indicates significant at 5% level of probability

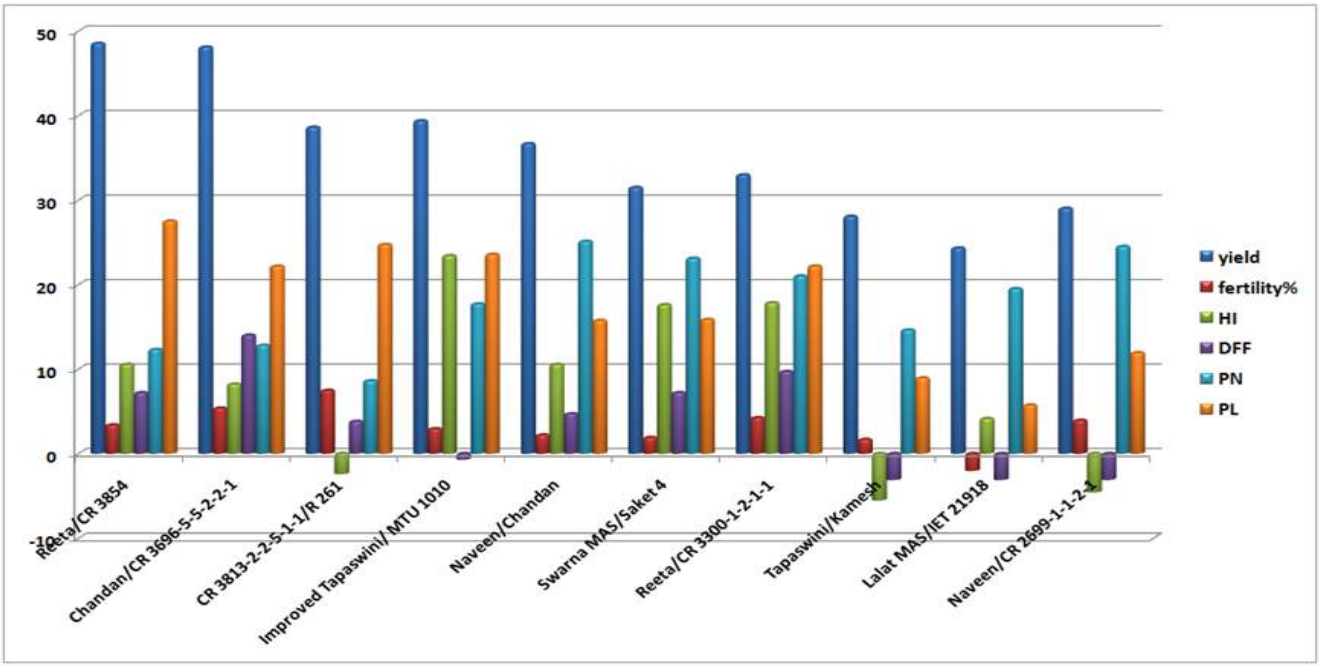

Fig. 1. Comparison of mean standard heterosis of best ten combinations against the standard check vatiety IR64, Naveen and MTU1010 for yield, percentage of fertility, harvest index, days to 50% flowering, panicle length and panicle number estimated during summer 2015

under the large-scale production exceeded the best conventionally bred cultivars by 20 to 30% (Lin and Yuan 1980).

Joshi (2001) observed significant heterobeltiosis and standard heterosis in five rice crosses. Heterobeltiosis ranging from -55 to 139% and standard heterosis from -11 to 369% were observed. Highest heterotic effect among the yield components was for panicle number plant-1 followed by spikelet number and panicle length (Joshi 2001). Venaja and Babu (2004) studied eight genetically diverse high-yielding rice cultivars selected from clusters formulated through Mahalanobis D2 statistics crossed in a diallel fashion where five highly heterotic crosses were identified. Jarwar *et al.* (2013) studied heterosis for yield and its related characters like spikelet per panicle, number of filled grains, 1000 grain weight and panicle length in aromatic rice varieties and their hybrids under lowland and upland environments. Huang *et al.* (2015) reported heterosis expression of hybrid rice in natural and short-day length conditions for various traits like earlier heading, reduced plant height and reduced grain number per panicle.

The phenotyping data considered to study standard heterosis of all the hybrids against the three standard check varieties *i.e.*, IR64, Naveen and MTU1010 were utilised for biplot analysis. The scree plot showed that two major components existed out of total five components (Fig. 2). The first component explained 88.13% of variance, whereas second component explained 6.6% variance. The first and second components were used to construct the biplot

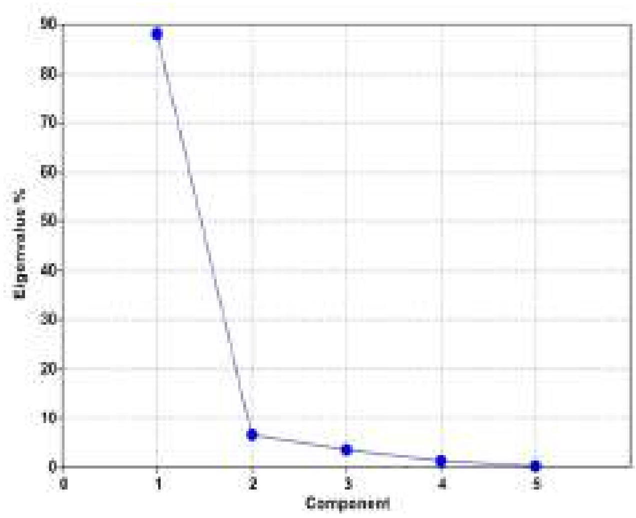

Fig. 2. Scree plot showing the eigenvalues associated with the components that explain most of the variability in the data

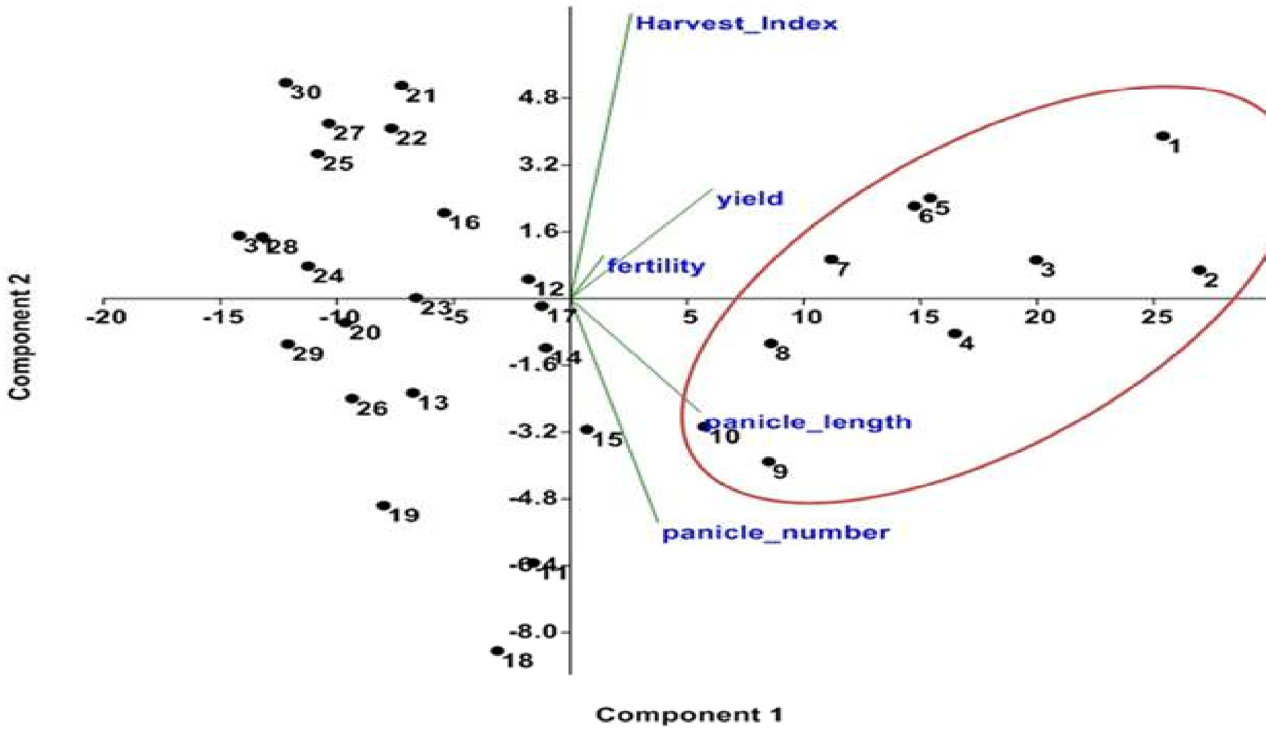

Fig. 3. Biplot analysis of the hybrids for first two principal components (PC1 and PC2) identified from scree plot. The numbers depict the cross combinations presented in Table 1

graph (Fig. 3). The yield, fertility percentage and harvest index lied in one quarter (right top) and panicle length and panicle number lied in another quarters i.e. right bottom. All the ten combinations showing better heterosis were grouped at one place encircled in the biplot graph (Fig. 3). This showed more number of filled grains as well as harvest index along with panicle length and panicle number contributes more towards increasing the yield thereby increasing yield heterosis.

The cross combinations namely Reeta / CR3854, CR3813-2-2-5-1-1 / R261 and Improved Tapaswini / MTU1010 were considered to be best heterotic lines possessing good agro-morphologic traits like yield, fertility, panicle length, panicle number and harvest index. Principal component analysis applied to find out heterotic combinations from large number of hybrids with simulteneous selection of many traits could select superior hybrids. The cross between Reeta and CR3854 showed highest heterosis for grain yield manifesting through longer panicle, increased panicle number and fertility with more harvest index as compared to the standard checks used. The parental lines of the above heterotic hybrids will be useful for conversion to male sterile and restorer lines through marker system to produce marker free F_1 hybrids.

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