

Heterosis, Combining ability and Phenotypic Correlation for Some Economic Traits in Rice (*Oryza sativa* L.)**¹E. I. Zaazaa and ²G.B. Anis**¹*Agronomy Dept., Fac., of Agric. Al-Azhar Univ., Cairo, Egypt.*²*Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, Field Crops Research Inst. (FCRI), Agric. Research Center.***ABSTRACT**

This investigation was carried out to study heterosis, combining ability and phenotypic correlation in a diallel mating design among 6 Egyptian rice genotypes (excluding reciprocals), including 3 varieties (Sakha 101, Sakha 104 and Sakha 105), and 3 promising lines (Gz6903, Gz7576 and Gz8479). An experiment was conducted at the research Farm of Rice Research and Training Center (RRTC), Sakha, Kafr EL-sheikh, Egypt during 2013 growing season and designed in a randomized complete block with three replications. Data were recorded on nine traits; days to maturity, chlorophyll content, flag leaf area, plant height, number of panicles / plant, panicle fertility (%), Panicle weight, 1000-grain weight and grain. The results revealed that, the genotypes were highly significant different in all studied characters. The cross (Sakha 101 × GZ6903) showed positive and significant heterosis for mid and better parents for most studied traits. The parent (Sakha 101) was good general combiner for most studied traits. The cross (Sakha 101 × GZ6903) showed positive and highly significant for specific combining ability effects for grain yield and its components. Grain yield was significantly and positively correlated with days to maturity, chlorophyll content, plant height, number of panicles/plant and panicle weight. On the contrary, plant height had significant negative association with days to maturity.

Key words: Rice (*Oryza sativa* L.), Heterosis, Combining ability, Phenotypic correlation.

Introduction

The world population is expected to reach eight billion by 2030 and rice production must increase by 50 per cent in order to meet the growing demand (Khush & Brar, 2002). Rice (*Oryza sativa* L.) is the major food crop of more than half of the global population and will continue to occupy the pivotal place in global food and livelihood security systems. Genetic variability for agronomic traits is the key component of breeding programs for broadening the gene pool of rice and other crops. In Egypt, rice constitutes one of the main agricultural exports. During 2012 season, the area cultivated with rice was 1.42 million feddans with an average of 4.15 t fed⁻¹, and total production of 5.89 million tons (Rice Research Training Center Proceeding, 2012). Heterosis or hybrid vigor is a phenomenon in which an F₁ hybrid has superior performance over its parents. It has been observed in many plant and animal species. The utilization of heterosis is responsible for the commercial success of plant breeding in many species and leads to the widespread use of hybrids in several crops. The value of heterosis relative to mid and better parent in rice for yield and its components characters were studied by many investigators, such as Reddy *et al.* (2012) and Gnanamalar and Vivekanandan (2013). The success of any breeding programme depends on the choice of right parents for hybridization programme. Combining ability analysis of the parents and their crosses provide information on the two variance viz., additive and dominance, which are important to decide the parents and crosses to be selected for eventual success and also the appropriate breeding procedures to be followed to select desirable segregants (Kumar *et al.* 2010). The general combining ability (GCA) identifies superior parental genotypes while specific combining ability (SCA) helps in identification of good hybrid combinations which may ultimately lead to the development of hybrids (Saleem *et al.*, 2010). Yield is a complex character which is controlled by a number of components most of which are under polygenic control. Thus the identification of important components and information about their association with yield and other traits are very useful for developing efficient breeding strategy for evolving high yielding varieties (Pratap *et al.* 2012).

The diallel analysis was used in many studies to estimate general and specific combining ability gives very useful information to classify lines in terms of their ability to combine in hybrids combinations. In addition, this analysis helps the breeder to partition the total genetic variance into GCA and SCA which referred to additive and non-additive components of the genetic variance. (Rahimi *et al.* 2010 and Muthuramu *et al.* 2010). The main objective of the present investigation is to study the genetic parameters such as heterosis and

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combining ability as well as phenotypic correlation for the yield, its components and some agronomic characters in six rice genotypes of diverse origin and their F_1 hybrids.

Materials and Methods

The present investigation was carried out at the research Farm of Rice Research and Training Center (RRTC), Sakha, Kafr EL-sheikh, Egypt during 2012 and 2013 growing seasons. Three Egyptian rice cultivars (Sakha 101, Sakha 104 and Sakha 105) as well as three promising lines (Gz6903, Gz7576 and Gz8479) were used in this study. These varieties and lines represented a wide range of diversity in several of the studied traits.

Table 1: List of six parents of rice used in the study.

Parent	Parentage
Sakha 101 (P_1)	(Giza 176/Milyang 79)
Sakha 104 (P_2)	(GZ4096/GZ4100)
Sakha 105 (P_3)	(GZ 5581/GZ 4316)
GZ6903-1-2-2-1 (P_4)	(GZ 4596/SUWEON 313)
GZ7576-10-3-2-1 (P_5)	(GZ5418/Milyang 79)
GZ8479-6-2-3-1 (P_6)	(GZ6214/EMPSSK 104)

Seeds of these parent were sown on three successive dates of planting at ten days intervals in order to, overcome the differences in flowering time of each parent. After 30 days from sowing each parent was individually transplanted in the permanent field. The six parents were crossed in all possible combinations excluding reciprocals to produce seeds of 15 F_1 crosses. In 2013 season, 30 days old seedlings of the parents and their F_1 crosses were individually transplanted in a randomized complete block design with 3 replications. Each genotype was planted in four rows per replicate; row was five meters length with the spacing 20 x 20 cm between rows and plants within rows. Nitrogen fertilizer was applied at the recommended dose and time of applications. Hand weeding was done when it was needed. Data were recorded on 10 individual guarded plants for parents and F_1 plants for the following traits; days to maturity, chlorophyll content (SPAD), flag leaf area (cm^2), plant height (cm), number of panicles / plant, panicle fertility(%) [(no. of grains/panicle)/ (no. of spikelets/panicle)] $\times 100$, panicle weight (gm), 1000-grain weight (gm) and grain yield/plant (gm). The data were statistically analyzed by using the ordinary analysis of variance to test the significant of differences among the twenty one genotypes under study, (Snedecor and Cochran, 1982). L.S.D. was computed to compare differences among means at 5% and 1% levels of propability. Heterosis relatively to mid and better parents was estimated according to Bhatt (1971). Also phenotypic correlation coefficient was computed for different pairs of the studied traits. If the genotypes mean squares were found to be significant, there is a need to proceed for further analysis using Griffing (1956) analysis "Method 2, Model 1".

Results and Discussions

Analysis of variance

The analysis of variance showed significant differences among the genotypes for all the traits studied (Tables 2), indicating the existence of wide variation among genotypes for different traits. Similar results were obtained by Jayasudha and Sharma (2010). Also, the results indicated that, there were highly significant mean squares for both general and specific combining ability, revealing the relative importance of both additive and non-additive gene effects in the inheritance of all studied characters. The ratios of GCA/SCA were less than unity in all studied characters except days to maturity and no. of panicles/plant, indicating that dominance gene effects were more important than additive gene effects in the expression of most traits

Mean performance

Mean performance of the six parents and their respective F_1 's of the diallel crosses for the all studied traits are presented in Table (3). As revealed in this Table, the mean performance for the studied traits varied from cross to another. For days to maturity, the line Gz7576 was the earliest in maturity date which recorded the lowest value of 122.33 days, while the cultivar Sakha 101 was the latest in maturity date which recorded the highest value of 142.33 days. The crosses ($P_1 \times P_4$), ($P_2 \times P_6$) and ($P_1 \times P_6$) gave the highest mean values of 141.66, 141.00 and 140.33 days, respectively, while the crosses ($P_5 \times P_6$), ($P_3 \times P_5$) and ($P_3 \times P_6$) gave the lowest mean values of 119.66, 120.00 and 120.33 days, respectively. For total chlorophyll content, Table (3) showed that, among parents, Sakha 101 scored the highest mean value of 45.43, while the line Gz8479 scored the lowest mean value of 38.41 SPAD. Among crosses, the cross ($P_1 \times P_5$) recorded the highest mean value of 48.80 SPAD. On the other hand, the cross ($P_3 \times P_6$) recorded the lowest mean value of 39.13 SPAD. Regarding the flag leaf

area, the line Gz7576 showed the highest mean value of 39.56 cm², while the line Gz8479 showed the lowest mean value of 31.81 cm². The cross (P₄× P₅) showed the highest mean value of 45.77 cm², while the cross (P₁× P₅) showed the lowest mean with value 31.21 cm², for flag leaf area.

Table 2: Mean squares of genotypes, general combining ability (GCA) and specific combining ability (SCA) and their ratios for the studied traits.

S.O.V	d.f	Days to maturity	Chlorophyll Content (SPAD)	Flag leaf area (cm ²)	Plant height (cm)	No. of panicles /plant	panicle fertility (%)	Panicle weight (gm)	1000-grain weight (gm)	Grain yield /plant (gm)
Replications	2	2.21	7.26	2.62	0.78	7.76	5.69	0.01	0.67	2.28
Genotypes	20	169.90**	24.19**	32.44**	459.11**	55.22**	79.34**	0.82**	5.55**	172.91**
Error	40	0.97	1.66	1.89	2.18	4.35	3.79	0.02	0.15	5.15
GCA	5	171.74**	7.72**	6.30**	141.74**	21.21**	7.25**	0.11**	0.36**	36.52**
SCA	15	18.26**	8.18**	12.31**	156.80**	17.47**	32.85**	0.33**	2.35**	64.68**
Error	40	0.32	0.55	0.63	0.73	1.45	1.26	0.01	0.05	1.72
GCA/SCA		9.40	0.94	0.51	0.90	1.21	0.22	0.33	0.15	0.56

** = significant at 0.01 level of probability.

Table 3: Mean performance of parental genotypes and their F₁ crosses for the studied traits.

Genotypes	Days to maturity	Chlorophyll Content (SPAD)	Flag leaf area (cm ²)	Plant height (cm)	No. of panicles /plant	Panicle fertility (%)	Panicle weight (gm)	1000-grain weight (gm)	Grain yield /plant (gm)
Sakha101 (P ₁)	142.33	45.43	33.44	91.00	28.33	90.00	4.13	27.30	45.70
Sakha104 (P ₂)	134.33	42.41	38.66	108.00	26.33	93.00	3.93	27.03	42.56
Sakha105 (P ₃)	124.00	43.15	34.40	101.00	23.00	96.00	3.70	27.43	36.87
Gz6903 (P ₄)	136.00	38.61	36.28	96.00	29.67	86.00	4.00	26.47	40.54
Gz7576 (P ₅)	122.33	42.50	39.56	104.00	21.00	87.00	3.60	29.03	36.93
Gz8479 (P ₆)	127.00	38.41	31.81	98.67	27.00	93.00	3.90	29.43	43.74
P ₁ ×P ₂	133.33	42.43	36.87	106.33	30.67	89.54	5.13	28.67	57.09
P ₁ ×P ₃	132.66	46.63	36.73	125.67	33.67	96.24	4.43	27.87	60.31
P ₁ ×P ₄	141.66	42.80	40.34	112.00	37.33	97.75	4.70	29.97	55.50
P ₁ ×P ₅	130.00	48.80	31.21	116.00	37.67	95.85	4.73	28.00	60.65
P ₁ ×P ₆	140.33	43.46	39.87	99.67	30.33	97.63	4.00	26.17	43.90
P ₂ ×P ₃	125.00	45.13	38.57	108.33	34.33	79.91	4.20	28.53	55.87
P ₂ ×P ₄	136.33	44.20	33.13	128.00	32.33	95.56	5.00	28.30	53.16
P ₂ ×P ₅	134.33	40.13	35.47	120.67	29.33	96.00	3.63	27.77	50.86
P ₂ ×P ₆	141.00	43.23	36.10	99.00	30.67	97.87	3.90	29.87	54.57
P ₃ ×P ₄	125.00	48.76	36.10	130.67	33.00	93.04	4.60	30.30	53.74
P ₃ ×P ₅	120.00	43.50	39.50	122.67	27.67	91.46	4.70	28.27	46.31
P ₃ ×P ₆	120.33	39.13	37.01	130.00	33.00	94.56	4.07	26.77	44.47
P ₄ ×P ₅	125.00	43.76	45.77	118.33	31.00	96.22	3.17	30.28	43.13
P ₄ ×P ₆	134.00	44.70	35.39	100.67	33.00	83.00	4.47	26.07	59.95
P ₅ ×P ₆	119.66	45.26	37.63	98.00	24.67	98.19	4.97	26.40	46.19
L.S.D at 5%	1.63	2.13	2.27	2.43	3.44	3.21	0.23	0.64	3.74
1%	2.17	2.84	3.04	3.25	4.60	4.29	0.31	0.86	5.01

For plant height, Sakha 104 showed the highest mean value of 108.00 cm, while Sakha 101 showed the lowest mean value of 91.00 cm. Among crosses, the cross (P₃× P₄) recorded the highest mean value of 130.67 cm, while the cross (P₅× P₆) showed the lowest mean value of 98.00 cm. Regarding number of panicles/plant, the parent Gz6903 gave the highest mean value of 29.67 panicles, while the parent Gz7576 gave the lowest mean value of 21.00 panicles. The mean performances of F₁ crosses ranged from 37.67 for the cross (P₁× P₅) to 24.67 panicles for the cross (P₅× P₆) for panicles/plant. For panicle fertility (%) (Table 3), the parent, Sakha 105 scored the highest value of 96%, while the parent Gz6903 scored the lowest mean value of 86.00 %. Also, the cross, (P₅× P₆) showed the highest mean value in this respect 98.19%. Regarding the panicle weight, the mean performance ranged from 4.13 gm for the parent Sakha 101 to 3.60 gm for the parent Gz7576. The cross, (P₁× P₂) gave the highest mean value of 5.13 gm, while the cross, (P₄× P₅) gave the lowest mean value of 3.17 gm. Concerning the 1000-grain weight, the means ranged from 29.43 gm for the parent Gz8479 to 26.47 gm for the parent Gz6903. The cross, (P₃× P₄) gave the highest mean value of 30.30 gm and was superior in this respect while, the cross (P₄× P₆) gave the lowest mean value of 26.07 gm. The mean values for the grain yield /plant ranged from 45.70 gm for the parent Sakha 101 to 36.87 gm for the parent Sakha 105. Among F₁ crosses, the crosses (P₁× P₅) and (P₁× P₃) recorded the highest mean values of 60.65 and 60.31 gm, respectively. In contrast, the crosses (P₁× P₆) and (P₄× P₅) showed the lowest mean performances with values 43.90 and 43.13 gm, respectively.

Heterosis

The heterosis percentages observed for different traits over mid and better parents are given in Table (4). In case of days to maturity, heterosis over mid-parents was significant in most crosses of which 5 were positive and 8 were negative. Significant positive heterosis over better parent was noticed in one cross only, and significant negative in 10 crosses which means that, these crosses were earlier and could be used in rice breeding programs for developing F_1 crosses and/or early maturity lines. Negative heterosis for earliness in maturity was also reported by Nuruzzaman *et al.* (2002).

Table 4: Heterosis as percentage of mid-parents (M.P) and better parent (B.P) in the F_1 crosses for the studied traits.

Traits Crosses.	Days to maturity		Chlorophyll content (SPAD)		Flag leaf area (cm ²)		Plant height (cm)	
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P
P ₁ x P ₂	-3.61**	-0.74**	-3.40	-6.60**	2.28	-4.63	6.87**	-1.55
P ₁ x P ₃	-0.38	-0.67**	5.28*	2.64	8.30**	6.77*	30.90**	24.42**
P ₁ x P ₄	1.80**	-0.47	1.84	-5.79*	15.72**	11.19**	19.79**	16.66**
P ₁ x P ₅	-1.76**	-0.09	10.99**	7.41**	-14.50**	-21.10**	18.97**	11.53**
P ₁ x P ₆	4.21**	-0.01*	3.67	-4.35	22.20**	19.23**	5.10*	1.01
P ₂ x P ₃	-3.23**	-6.94**	5.50*	4.59	5.58*	-0.23	3.67*	0.30
P ₂ x P ₄	0.86	0.24	9.10**	4.22	-11.57**	-14.30**	25.49**	18.51**
P ₂ x P ₅	7.91**	000	-5.47*	-5.58*	-9.31**	-10.34**	13.84**	11.73**
P ₂ x P ₆	4.70**	4.96**	6.97**	1.93	2.46	-6.62*	-4.19**	-8.33**
P ₃ x P ₄	-3.85**	-8.09**	19.29**	13.00**	2.16	-0.49	32.66**	29.37**
P ₃ x P ₅	-2.57**	-3.23**	1.58	0.81	6.83*	0.15	19.67**	17.95**
P ₃ x P ₆	-4.12**	-5.25**	-4.05	-9.32**	11.79**	7.59*	30.22**	28.71**
P ₄ x P ₅	-3.23**	-8.09**	7.91**	2.96	20.69**	15.70**	18.33**	13.77**
P ₄ x P ₆	1.90**	-1.47*	16.06**	15.77**	3.94	-2.45	3.42*	2.02
P ₅ x P ₆	-4.01**	-5.78**	11.88**	6.49*	5.46	-4.88	-3.29*	-0.68

Table 4: Cont.

Traits Crosses.	No. of panicles/plant		Panicle fertility (%)		Panicle weight (gm)		1000-grain weight (gm)		Grain yield/plant (gm)	
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P
P ₁ x P ₂	12.20*	8.25	-2.15	-3.72*	27.27**	24.21**	5.52**	5.01**	29.38**	24.92**
P ₁ x P ₃	31.17**	18.84**	3.48*	0.25	13.19**	7.26**	1.83	1.60	46.08**	31.96**
P ₁ x P ₄	28.74**	25.81**	11.08**	8.61**	15.57**	13.80**	11.47**	9.78**	28.70**	21.44**
P ₁ x P ₅	52.70**	32.96**	8.31**	6.50**	22.41**	44.52**	-0.59	-3.55**	46.81**	32.71**
P ₁ x P ₆	9.64	7.05	6.70**	4.97**	-0.41	-3.25	-7.76**	-11.07**	-1.83	-3.94
P ₂ x P ₃	39.19**	30.38**	-15.44**	-16.76**	10.04**	6.87*	4.77**	4.01**	40.68**	31.27**
P ₂ x P ₄	15.48**	8.96	6.77**	2.75	26.05**	25.00**	5.79**	4.69**	27.95**	24.90**
P ₂ x P ₅	23.94**	11.39	6.67**	3.22	-3.54	-7.63**	-0.95	-4.34**	27.96**	19.50**
P ₂ x P ₆	15.00**	13.59*	5.23**	5.23**	-0.43	-0.76	5.79**	1.50	26.46**	24.75**
P ₃ x P ₄	25.32**	11.22	2.24	-3.08	19.48**	15**	12.43**	10.46**	38.83**	32.56**
P ₃ x P ₅	25.76**	20.30**	-0.04	-4.73*	28.77**	27.02**	0.12	-2.61	25.49**	25.39**
P ₃ x P ₆	32.00**	22.22**	0.06	-1.5	7.02	4.18	-5.86	-9.03**	10.33**	1.66
P ₄ x P ₅	22.37**	4.48	11.24**	10.59**	-16.67**	-20.75**	9.13**	4.31**	11.35**	6.38
P ₄ x P ₆	16.47**	15.10*	-7.26**	-10.75**	13.08**	11.75**	-6.71**	-11.41**	42.26**	37.05**
P ₅ x P ₆	2.78	-8.62	9.10**	5.58**	32.44**	21.53**	-9.69**	-10.29**	14.51**	5.60

* and ** = significant at 0.05 and 0.01 levels of probability, respectively

P₁ = Sakha101 P₂ = Sakha104 P₃ = Sakha104_{p4} = Gz6903 P₅ = Gz7576 P₆ = Gz8479

For total chlorophyll content, four crosses exhibited positive and significant heterosis over mid and better parents. On the other hand, one cross exhibited negative and significant heterosis over mid and better parents. The crosses (P₄ × P₆) and (P₃ × P₄) gave the highest values for heterosis over mid and better parents. Three crosses exhibited high significant positive over mid and better parents for flag leaf area, while three crosses showed highly significant and negative heterosis. The crosses (P₃ × P₄) and (P₁ × P₃) showed highly significant positive values of heterosis over mid and better parents for plant height, while the cross (P₂ × P₆) showed highly significant negative value for heterosis over mid and better parents. Negative heterosis for plant height is desirable for breeding short statured hybrids and varieties in rice (Ammar *et al.*, 2014). For number of panicles/plant, most of crosses showed highly significant positive heterosis over mid and better parents. The crosses (P₁ × P₅) and (P₂ × P₃) gave the highest positive significant values. Gouri Shankar *et al.* (2010) found both positive and negative heterosis for number of panicles/plant in rice. For panicle fertility (Table 4), six crosses exhibited highly significant and positive heterosis over mid and better parents. On the other hand, two crosses exhibited negative heterosis over mid and better parents. Latha *et al.* (2013) and Ammar *et al.* (2014) obtained highly significant positive and negative heterosis for panicle fertility %. Highly significant positive

heterosis over mid and better parents was observed for 1000- grain weight in six crosses. On contrast, three crosses showed highly significant and negative heterosis over mid and better parents for 1000- grain weight. These results are in agreement with the findings of Stalin (1999). Heterosis for grain yield and its components is very important consideration in heterosis breeding. Yield is a complex character and ultimate aim of plant breeding. Highly significant and maximum positive heterosis as a deviation from mid and better parents was observed for grain yield/plant in the most crosses under study. The crosses ($P_1 \times P_5$), ($P_1 \times P_3$) and ($P_4 \times P_6$) recorded the highest values over mid and better parents. Consequently, one or more of these crosses might be used in breeding programs for producing hybrid rice. Li *et al.* (1997), Nuruzzaman *et al.* (2002), Rashid *et al.* (2007), Parihar and Pathak (2008) and Reddy *et al.* (2012) found high heterosis for grain yield and its components in rice.

General combining ability effects

The results in Table (5) revealed that most of the parents showed positive or negative significant GCA effects for all the traits studied. Negative GCA effects were desirable for days to maturity and plant height, while in other traits positive GCA effects are desirable. For days to maturity, estimates of general combining ability effects were significant for all parents. The cultivar Sakha 105 was the best general combiner (-5.49), so this parent can be recommended as donor in rice breeding programs for earliness. The parent Sakha 101 was the best general combiner for chlorophyll content, number of panicles/plant, panicle weight and grain yield/plant while, the parent Gz7576 was the best general combiner for flag leaf area and 1000- grain weight.

Table 5: Estimates of general combining ability effects of the six rice parents for the studied traits.

Parents	Traits	Days to maturity	Chlorophyll content (SPAD)	Flag leaf area (cm ²)	Plant height (cm)	No. of panicles/plant	Panicle fertility %	Panicle weight (gm)	1000-grain weight (gm)	Grain yield/plant (gm)
Sakha 101		5.97**	1.36**	-0.79**	-3.74**	1.88**	0.97**	0.20**	-0.17*	3.10**
Sakha 104		2.97**	-0.53*	-0.06	0.85**	-0.17	-0.55	0.01	0.07	1.58**
Sakha 105		-5.49**	0.66**	-0.15	5.97**	-0.46	-0.26	-0.03	-0.01	-1.20**
Gz6903		2.39**	-0.34	0.67**	1.26**	1.83**	-1.46**	0.03	0.15*	0.32
Gz7576		-5.15**	0.29	1.34**	1.51**	-2.38**	0.31	-0.16**	0.27**	-2.88**
Gz8479		-0.69**	-1.44**	-1.04**	-5.86**	-0.71	1.00**	-0.06*	-0.31*	-0.93*
SE(gi)		0.183	0.240	0.256	0.274	0.388	0.326	0.0261	0.721	0.423
L.S.D. (gi-gj) 0.05		0.58	0.73	0.78	0.83	1.18	1.10	0.08	0.22	1.28
L.S.D. (gi-gj) 0.01		0.77	0.96	1.02	1.10	1.55	1.45	0.10	0.29	1.69

*and** = significant at 0.05 and 0.01 levels of probability, respectively.

The parent Gz8479 was the best general combiner for plant height and panicle fertility. Investigation of GCA effects revealed that, among parents Sakha; 101 and Sakha 104 were good general combiners for grain yield/plant. In conclusion, the abovementioned good general combiners of parents may be extensively used in rice breeding programs for improving these traits.

Specific combining ability effects

The usefulness of a particular cross in the exploitation of heterosis is judged by specific combining ability effects. Table (6) showed that, for days to maturity, six F_1 cross combinations exhibited positive and significant SCA effects, while seven cross combinations exhibited negative and significant SCA effects. For chlorophyll content trait, the estimations of SCA effects were positive and significant for seven crosses and were negative and significant for four crosses. The cross ($P_3 \times P_4$) recorded the highest positive value (4.99). Five crosses exhibited significant positive SCA effects for flag leaf area and the cross ($P_4 \times P_5$) recorded the highest positive value (6.91) while, three crosses exhibited negative and significant SCA effects. Regarding the plant height trait, estimates of specific combining ability effects were positive and significant for nine crosses and were negative and significant for four crosses. The crosses ($P_2 \times P_3$) and ($P_5 \times P_6$) gave the highest negative values for the estimates of specific combining ability effects (-8.71) and (-7.88), respectively. These crosses were the best combiners and could be used in breeding programs for improving shortness in rice. Table (6) also reveals that, the estimates of specific combining ability effects for number of panicles/plant were positive and significant in four crosses, but were negative and significant in one cross. The cross ($P_1 \times P_5$) recorded the highest positive value (7.98), therefore it could be used in hybrid rice breeding programs for improving this trait. The estimates of specific combining ability effects for spikelet fertility% were positive and significant in nine crosses but were negative and significant in three crosses. The cross ($P_1 \times P_4$) recorded the highest positive value (5.49). The positive estimates of specific combining ability effects for spikelet fertility (%) decreased sterility percentage which could be useful for rice breeder who breeds for improving fertility percentage.

Table 6: Estimates of specific combining ability effects in the F_1 crosses for the studied traits

Crosses	Traits	Days to maturity	Chlorophyll content (SPAD)	Flag leaf area (cm ²)	Plant height (cm)	No. of panicles/plant	Panicle fertility (%)	Panicle weight (gm)	1000-grain weight (gm)	Grain yield/plant (gm)
$P_1 \times P_2$		-6.13**	-1.85**	-0.84	-1.00	-1.23	-3.63**	0.69**	0.68**	3.26**
$P_1 \times P_3$		1.48**	1.16	0.79	13.21**	2.06	2.78**	0.03	-0.05	9.26**
$P_1 \times P_4$		2.61**	-1.67*	3.58**	4.25**	3.43**	5.49**	0.23**	1.89**	2.93*
$P_1 \times P_5$		-1.52**	3.70**	-6.23**	8.00**	7.98**	1.82	0.45**	-0.19	11.28**
$P_1 \times P_6$		4.36**	0.10	4.81**	-0.96	-1.02	2.92**	-0.38**	-1.44**	-7.42**
$P_2 \times P_3$		-3.18**	1.54*	1.93**	-8.71**	4.77**	-12.03**	-0.01	0.38	6.34**
$P_2 \times P_4$		0.27	1.61*	-4.32**	15.67**	0.48	4.82**	0.72**	-0.01	2.12
$P_2 \times P_5$		5.82**	-3.08**	-2.67**	8.08**	1.68	3.49**	-0.46**	-0.66**	3.01**
$P_2 \times P_6$		8.02**	1.75**	0.35	-6.21**	1.35	4.67**	-0.29**	2.02**	4.77**
$P_3 \times P_4$		-2.60**	4.99**	-1.26	13.21**	1.43	2.00**	0.36**	2.06**	5.47**
$P_3 \times P_5$		-0.06	-0.90	146*	4.96**	0.31	-1.34	0.65**	-0.09	1.24
$P_3 \times P_6$		-4.18**	-3.54**	1.35	19.67**	3.98**	1.07	-0.08	-1.01**	-2.55*
$P_4 \times P_5$		-2.93**	0.36	6.91**	5.33**	1.35	4.63**	-0.95**	1.77**	-3.45**
$P_4 \times P_6$		1.61**	3.03*	-1.09	-4.96**	1.68	-9.29**	0.25**	-1.86**	11.42**
$P_5 \times P_6$		-5.18**	2.97**	0.48	-7.88**	-2.44*	4.13**	0.94**	-1.65**	0.85
S.E.(sij)		0.50	0.659	0.702	0.755	1.06	0.996	0.071	0.197	1.161
L.S.D.(sij-sik) 0.05		1.52	1.93	2.06	2.06	3.12	2.92	0.21	0.58	3.40
L.S.D.(sij-sik) 0.01		2.04	2.54	2.70	2.70	4.10	3.83	0.27	0.76	4.47
L.S.D.(sij-ski) 0.05		1.41	1.79	1.90	1.90	2.89	2.70	0.19	0.54	3.15
L.S.D.(sij-ski) 0.01		1.89	2.35	2.50	2.50	3.80	3.55	0.25	0.70	4.13

*and** = significant at 0.05 and 0.01 levels of probability, respectively

For the panicle weight, eight crosses showed positive and significant specific combining ability effects, whereas four crosses showed negatively significant estimates. The crosses ($P_5 \times P_6$) and ($P_2 \times P_4$) gave the highest positive values for the estimates of specific combining ability effects, therefore these crosses could be of great values for varietal improvement programs. The values of specific combining ability effects for 1000-grain weight were positive and significant in five crosses. Also were negative and significant in five cross. The cross ($P_3 \times P_4$) recorded the highest positive value (2.06). The results of the specific combining ability effects for grain yield/plant presented in Table 6, show that nine crosses gave highly significant and positive estimates. Such estimates were maximized in case of the crosses ($P_4 \times P_6$) and ($P_1 \times P_5$) with values of 11.42 and 11.28, respectively. On the contrary, highly significant negative estimates of specific combining ability effects were recorded for three crosses. Generally, the crosses; ($P_1 \times P_4$), ($P_2 \times P_6$), ($P_3 \times P_4$) and ($P_1 \times P_2$) exhibited positive significant SCA effects for yield and one or more its components. Therefore, these crosses are expected to produce desirable segregants and could be exploited successfully in varietal improvement programs. In conclusion the present study revealed the importance of both additive and non-additive gene effects in governing yield and most of the yield attributes with predominance of non-additive gene action for most of the yield attributes, indicating selection could be delayed to late segregation generations.

Phenotypic correlation coefficient

Complete knowledge on interrelationship of plant character like grain yield with other characters is of paramount importance to the breeder for making improvement in complex quantitative character like grain yield for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield. Phenotypic correlation coefficient among the nine characters was assessed and presented in Table (7). Grain yield was significantly and positively correlated with days to maturity, chlorophyll content, plant height, number of panicles/plant and panicle weight, indicating the importance of these traits as selection criteria in yield enhancement programmes. Mohammed *et al.* (2007) and Babu *et al.* (2010) found that, Grain yield was significantly and positively correlated with number of panicles/plant and panicle weight in rice. Lakshmi *et al.* (2014) and Sarker *et al.* (2014) reported that, days to maturity had significant positive correlation with grain yield/plant. Plant height exhibited significant and positive phenotypic correlation with number of panicles/plant, panicle weight and 1000-grain weight, also chlorophyll content showed significant positive correlation with number of panicles/plant and panicle weight. Lakshmi *et al.* (2014) reported that, plant height exhibited significant positive phenotypic correlation with 1000-grain weight. At last, the phenotypic correlation coefficient was positive and significant between days to maturity and number of panicles/plant and between panicle weight and number of panicles/plant. On the contrary, plant height had significant negative association with days to maturity; also, panicle weight had significant negative association with flag leaf area.

Table 7: Estimates of phenotypic correlation coefficient between the studied traits.

Traits	Days to maturity	Chlorophyll content (SPAD)	Flag leaf area (cm ²)	Plant height (cm)	No. of panicles /plant	Panicle fertility (%)	Panicles weight (gm)	1000-grain weight (gm)	Grain yield/ Plant (gm)
Days to maturity	—	-0.012	-0.16	-0.30*	0.31*	0.11	0.19	-0.06	0.29*
Chlorophyll content (SPAD)		—	-0.06	0.20	0.26*	0.05	0.32**	0.09	0.46**
Flag leaf area (cm ²)			—	0.12	-0.05	0.03	-0.31*	0.20	-0.23*
Plant height (cm)				—	0.39**	0.23	0.29*	0.29*	0.31*
No. of panicles/plant					—	0.03	0.49**	0.18	0.69**
Panicle fertility (%)						—	-0.09	0.14	-0.03
Panicles weight (gm)							—	0.04	0.63**
1000-grain weight (gm)								—	0.15
Grain yield/plant (gm)									—

*and** = significant at 0.05 and 0.01 levels of probability respectively

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