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Combining Ability and Heterosis Studies in Maize (*Zea mays* L.) under *Kharif* Season

Niranjan Kumar Chaurasia, R. B. P. Nirala* and Birender Singh

Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur-813210, India

**Corresponding author*

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ABSTRACT

Present investigation was carried out in *Kharif* 2019 at Experimental Area, Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur with seven parental inbred lines and their twenty one F_1's generated through half diallel matting scheme during Rabi, 2018-19. The experiment was performed in randomized block design with three replications. Analysis of variance for diallel analysis (method II model I) revealed the mean squares due to genotypes, parents, hybrids and parent vs. hybrids were highly significant for all the fourteen quantitative characters under study. Analysis of variance for combining ability revealed the mean squares due to GCA and SCA were highly significant for all the characters study. The parents, P1 and P7 had significant to highly significant positive GCA effects for grain yield per plant and its attributes indicated these two parents were good general combiners for this trait. The cross combinations, P1 x P2, P1 x P4, P1 x P5, P2 x P3, P2 x P4, P2 x P5, P2 x P6, P3 x P4, P3 x P5, P3 x P6, P3 x P7, P4 x P5, P5 x P6, and P6 x P7 had significant to highly significant SCA effects for grain yield per plant. The estimates of variance ratios of gca and sca were smaller than unity for all the characters study. The estimates of standard heterosis over the best check, DMRH-1308 for grain yield per plant revealed the top five cross combinations, namely P2 x P3, P6 x P7, P1 x P4, P3 x P4 and P3 x P6 exhibited highly significant positive standard heterosis. On the basis of standard heterosis, high SCA effects and high GCA effects for at least female parent for grain yield per plant and its attributes the hybrids, namely, P1 x P2, P1 x P4 and P1 x P5 were considered as promising experimental hybrids and may be exploited commercially after critical evaluation for their superior and stable performance over environments.

Introduction

Maize (Zea mays L., 2n=20) third major cereal crop that contribute to food security after rice and wheat. Besides the human food, it has great potential toward animal's feed and industrial raw material. Maize offers range of nutritional benefits and has clinical implications in various diseases (Murdia *et al.*, 2016). According to National Collateral Management service, Special report (2017), nearly 13 per cent of the total maize consumed directly as food, 7 per cent as processed food, 47 per cent as poultry feed, 14 per cent as industrial raw materials, 13 per cent as animal feed and 6 per cent as export and others. In Bihar, maize is grown under the three crop growing seasons such as kharif, rabi and summer. Maize grown under kharif season faced allot of biotic and abiotic stresses such as irregular rain fall, water logging, pest and disease incidence etc which lead to severe reduction in grain yield. To boost the increment in grain yield heterosis breeding is one of an important tool. Selection of the parental lines used in hybridization programmes is critical task for breeder or researcher. Phenotypic selection of parental lines not always fulfils breeder's needs because phenotype is always associated with environments. Hence it is essential to select the parental lines on the basis of their genetic parameters. Combining ability analysis helps breeder to identify best combining inbred lines which may be used as parents for hybridization to exploit heterosis or to accumulate productive genes. Keeping this point the present investigation was carried out with the objectives, (I) to study the general combining ability and specific combining ability effects of parental inbred lines and hybrids, respectively and (II) to study the standard heterosis of hybrids.

Materials and Methods

The experimental material comprises seven inbred lines and their twenty one F_1's generated during Rabi 2018-19 using half diallel matting design and one hybrid as check. All these were evaluated for their agronomic performance during the Kharif, 2019 at experimental area, Bihar Agricultural College, Sabour. The experiment was carried out in randomized block design with three replications and 5m row length having row to row distance 60 cm and plant to plant distance 20cm. The two seeds per hill were sown and after one week of germination thinning operation were performed to maintain single plant per hill. The recommended package of practices was followed for raising healthy crops. The data were recorded on fourteen quantitative traits on ten competitive plants from each replication viz., days to anthesis, days to silk, anthesis silking interval, days to 50 per cent physiological maturity, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), kernel row per ear, kernels per row, grains per plant, 1000-kernel weight (g), shelling (%) and grain yield per plant. The mean values on different traits were analysed using INDOSTAT 9.2 software following the method II model I suggested by Griffing (1956).

Results and Discussion

Analysis of variance for diallel analysis (Method II Model 1) for fourteen quantitative traits (Table 1) revealed the mean squares due to genotypes, parents, hybrids and parent vs. hybrids were highly significant for all the characters studied indicated the existence of significant difference among the genotypes, parents, hybrids and parent vs hybrids. Analysis of variance for combining ability (Table 2) revealed the mean squares due to GCA and SCA were highly significant for all the characters studied indicated that all the traits might be governed by both additive and non-additive gene effects. The variance ratios of GCA and SCA (Table 5) were lower than unity indicated a non-additive gene effect was predominated for expression of characters studied.

General combining ability (GCA) effects

The estimates of GCA effects for different traits were either negative or positive (Table 3). For grain yield per plant positive GCA effects is desirable. The parents, P1 and P7 had highly significant positive GCA effects and were grouped as good general combiners for grain yield per plant. The parents, P2, P3 and P6 were average general combiners, whereas, P4 and P5 were poor general combiners for grain yield per plant. The parent, P1 was also good general combiner for shelling per cent, grains per plant, kernels per row, kernel rows per ear, ear diameter and ear length and had highly significant positive GCA effects. The parent, P7 had highly significant positive GCA effects for the characters like shelling per cent, grains per plant, kernels per row and ear diameter and was grouped as good general combiner for these traits. Hence these two parents, P1 and P7 can be used directly for development of high yielding hybrids and synthetic by contributing desirable alleles. Significant positive GCA effects for inbred lines indicated that they are desirable parents for hybrid maize development and involvement in the maize breeding program as they can be source of good alleles in the process of varietal development (Rawi, 2016). Negative GCA effects are desirable for days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval and days to 50 per cent maturity. The parents, P1 had highly significant negative GCA effects for days to 50 per cent physiological maturity, anthesis-silking interval, days to 50 per cent silk and days to 50 per cent anthesis, while, the parent, P6 had significant to highly significant negative GCA effects for anthesis-silking interval, days to 50 per cent silk and days to 50 per cent anthesis. Hence these two parents, P1 and P6 were good general combiners these traits and can be used as parent for development of early maturing hybrids. For the plant height, negative GCA effects are desirable. The parent, P3 had highly significant negative GCA effects for plant height and ear height and was grouped as good general combiner for these traits. These finding are close conformity with the results of Elmyhun *et al.,* (2020), Singh *et al.,* (2019), Kumar *et al.,* (2017), Singh *et al.,* (2017), Kumar and Babu (2016), Kumar *et al.,* (2015), Dar *et al.,* (2015), Gouda *et al.,* (2013)

Specific Combining Ability (SCA) effects

The estimates of specific combining ability (SCA) effects for fourteen quantitative traits (Table 4) revealed that the cross combinations, namely, P2 x P3, P3 x P4, P3 x P6, P1 x P4, P6 x P7, P2 x P6, P3 x P5, P5 x P6, P2 x P4, P2 x P5, P4 x P5, P3 x P7, P1 x P5 and P1 x P2 had significant to highly significant positive SCA effects for grain yield per plant and were grouped as good specific combinations for this traits. All these hybrids also exhibited significant to highly significant positive SCA effects for one or more yield contributing characters. High estimates of SCA effects for these cross combination revealed the preponderance of non-additive gene effects and may be exploited commercially for this trait after critical evaluation over locations/ years. Negative SCA effects are desirable for days to 50 per cent anthesis, days to 50 per cent silk, anthesis-silking interval and days to 50 per cent maturity for earliness. The top five cross combinations exhibited highly significant negative SCA effects were P2 x P6, P6 x P7, P1 x P4, P3 x P4 and P4 x P5 for days to 50 per cent anthesis and P6 x P7, P1 x P4, P3 x P4, P2 x P6 and P2 x P7 for days to 50 per cent silk. Almost all the cross combinations except P1 x P2, P1 x P7, P2 x P6, P3 x P55, P4 x P5 and P5 x P7 exhibited highly significant negative SCA effects for anthesis-silking interval. Two cross combinations P1 x P4 and PP1 x P6 had highly significant negative SCA effects for days to 50 per physiological maturity. P4 x P6 exhibited highly significant negative SCA effects for plant height, whereas, none of the crosses exhibited significant negative SCA effects for ear height. Hence, all these hybrids were grouped as good specific combinations for their respective traits in desirable direction.

Table.1 Analysis of variance for diallel analysis (Method II and Model I) for fourteen quantitative characters in maize

Source of variation	D. F.	Mean squares						
		DA	DS	ASI	DPM	PH	EH	EL
Genotypes	27	42.71**	62.38**	3.65**	72.99**	1669.92**	635.81**	11.72**
Parents	6	27.05**	54.00**	7.71**	39.87**	1876.43**	1022.87**	12.20**
Hybrids	20	13.20**	20.76**	1.90**	59.42**	407.07**	213.59**	2.72**
Parent Vs. Hybrids	1	726.92**	945.02**	14.29**	543.25**	25687.94**	6757.83**	188.95**
Error	54	1.54	1.54	0.00	11.51	67.74	38.43	0.81

* & **: level of significance at 5 % and 1 %, respectively. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length

***Contd.* Table.1** Analysis of variance for diallel analysis (Method II and Model I) for fourteen quantitative characters in maize

Source of variation	D. F.	Mean squares						
		ED	KRPE	KPR	GPP	1000-KW	SP	GYP
Genotypes	27	0.77**	24.48**	135.39**	34258.41**	1944.78**	327.45**	2691.46**
Parents	6	1.24**	48.49**	171.89**	27995.96**	2514.66**	771.57**	1641.24**
Hybrids	20	0.12**	2.51**	21.04**	6664.28**	1643.47**	9.65**	520.63**
Parent Vs. Hybrids	1	11.11**	319.88**	2203.55**	623715.80**	4551.75**	4018.81**	52409.49**
Error	54	0.01	0.317	5.17	870.09	415.00	3.17	106.83

* & **: level of significance at 5 % and 1 %, respectively. ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant

Table.2 Analysis of variance for combining ability for fourteen quantitative characters in maize

Sources	D. F.	Mean Squares													
		DA	DS	ASI	DPM	PH	EH	EL	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
GCA	6	16.68**	33.20**	3.03**	59.49**	687.27**	431.03**	2.03**	0.14**	6.40**	44.33**	8265.13**	1185.15**	146.08**	280.24**
SCA	21	13.54**	17.25**	0.70**	14.29**	519.32**	149.34**	4.44**	0.29**	8.66**	45.36**	12320.71**	494.86**	98.60**	1073.41**
Error	54	0.52	0.52	0.00	3.84	22.58	12.81	0.27	0.01	0.11	1.72	290.03	138.33	1.06	35.61

* & **: level of significance at 5 % and 1 %, respectively.

Table.3 Estimates of general combining ability (GCA) effects of seven parental inbred lines for fourteen quantitative characters in maize

Sources	DA	DS	ASI	DPM	PH	EH	EL
P1	-2.70**	-3.76**	-1.06**	-5.70**	2.56	5.11**	0.66**
P2	0.52*	0.79**	0.27**	0.82	4.14**	-1.14	-0.83**
P3	1.23**	1.94**	0.71**	1.19	-18.63**	-14.26**	-0.05
P4	1.23**	1.50**	0.27**	0.45	4.70**	2.81*	0.31
P5	-0.29	-0.69**	-0.40**	0.52	1.82	-1.65	-0.06
P6	-0.48*	-0.54*	-0.06**	0.67	7.58**	3.12**	-0.27
P7	0.49*	0.76**	0.27**	2.04**	-2.16	6.02**	0.25
SE(gi)	0.22	0.22	0.00	0.60	1.47	1.11	0.16
SE(gi-gj)	0.34	0.34	0.00	0.92	2.24	1.69	0.25

* & **: level of significance at 5 % and 1 %, respectively. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length.

Contd. **Table.3** Estimates of general combining ability (GCA) effects of seven parental inbred lines for fourteen quantitative characters in maize

Sources	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
P1	0.07**	1.19**	2.46**	37.65**	-15.58**	1.26**	7.14**
P2	0.167**	0.72**	-0.85*	2.31	-0.96	0.02	0.64
P3	-0.22**	-1.43**	-2.63**	-17.29**	-2.53	-7.59**	-2.94
P4	0.01	-0.16	-0.53	-29.67**	10.76**	-0.02	-6.39**
P5	-0.08**	-0.33 **	-1.02*	-17.95**	1.69	-1.96**	-4.28*
P6	0.01	0.27**	-1.07*	-21.25**	17.45**	3.95**	-2.12
P7	0.04*	-0.26*	3.65**	46.20**	-10.83**	4.33**	7.95**
SE(gi)	0.02	0.10	0.41	5.26	3.63	0.32	1.85
SE(gi-gj)	0.03	0.15	0.62	8.03	5.55	0.48	2.81

* & **: level of significance at 5 % and 1 %, respectively. ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

Table.4 Estimate of specific combining ability (SCA) effects for fourteen quantitative characters in maize

F1's	DA	DS	ASI	DPM	PH	EH	EL
P1 x P2	-1.78*	-1.56*	0.22**	0.43	-1.01	-5.85	0.27
P1 x P3	-1.15	-1.37*	-0.22**	-1.28	0.88	-0.67	-0.27
P1 x P4	-3.48**	-4.26**	-0.78**	-5.87**	15.32**	9.14**	0.98*
P1 x P5	-1.96**	-2.07**	-0.11**	-1.28	10.14*	8.01*	0.82
P1 x P6	-0.78	-1.22	-0.44**	-5.76**	3.18	-2.67	-0.55
P1 x P7	-0.41	-0.19	0.22**	-2.13	6.31	2.88	0.25
P2 x P3	-2.04**	-2.59**	-0.56**	0.20	19.80**	15.76**	2.12**
P2 x P4	-2.04**	-2.19**	-0.11**	-2.06	11.39*	6.94*	0.36
P2 x P5	-2.19**	-2.63**	-0.44**	-3.46	18.59**	13.78**	1.53**
P2 x P6	-3.67**	-3.44**	0.22**	-2.94	11.84*	6.73*	1.89**
P2 x P7	-1.63*	-2.74**	-1.11**	-2.65	10.51*	6.96*	0.52
P3 x P4	-3.07**	-3.63**	-0.56**	-2.426	24.82**	13.58**	2.48**
P3 x P5	-1.89**	-0.78	1.11**	-1.83	19.71**	5.40	1.69**
P3 x P6	-1.37*	-2.59**	-1.22**	0.69	20.24**	6.70*	2.45**
P3 x P7	0.33	-0.22	-0.56**	1.65	7.76	3.58	0.90
P4 x P5	-2.89**	-2.33**	0.55**	-1.76	8.45	3.11	0.80
P4 x P6	1.96**	1.19	-0.78**	-0.24	-14.10**	-2.85	-1.65**
P4 x P7	-1.67*	-1.78*	-0.11**	0.39	2.62	2.76	0.47
P5 x P6	-1.85**	-1.96**	-0.11**	-0.98	16.71**	1.96	1.09*
P5 x P7	-0.48	0.07	0.56**	1.65	0.17	1.04	0.39
P6 x P7	-3.63**	-4.41**	-0.78**	-1.17	18.70**	12.48**	1.65**
SE(Sij)	0.64	0.64	0.00	1.76	4.27	3.21	0.47
SE(Sij-Sik)	0.96	0.96	0.00	2.61	6.34	4.77	0.69
SE(Sij-Skl)	0.89	0.90	0.00	2.44	5.93	4.46	0.65

* & **: level of significance at 5 % and 1 %, respectively. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length.

***Contd.* Table.4** Estimate of specific combining ability (SCA) effects for fourteen quantitative characters in maize

F1's	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
P1 x P2	0.13	-0.14	2.41	41.68*	8.47	2.34*	11.91*
P1 x P3	0.42**	2.42**	2.85*	39.34*	3.23	10.44**	4.76
P1 x P4	0.07	0.08	3.76**	78.13**	8.35	2.40*	25.46**
P1 x P5	0.15*	1.72**	2.18	81.94**	-18.52	3.04**	13.68*
P1 x P6	0.03	-0.36	-0.90	-4.89	6.99	-0.52	-1.52
P1 x P7	0.06	-0.76*	0.75	4.45	18.13	-0.35	5.88
P2 x P3	0.75**	3.76**	5.94**	89.55**	34.55**	10.01**	37.38**
P2 x P4	0.19**	0.88**	2.44	69.47**	-1.54	3.32**	19.18**
P2 x P5	0.28**	1.92**	5.31**	85.14**	-14.00	5.42**	17.65**
P2 x P6	0.18**	-0.02	4.05**	72.51**	1.24	-0.06	23.55**
P2 x P7	-0.02	0.25	1.24	18.79	-29.62*	0.66	-4.49
P3 x P4	0.55**	2.70**	6.75**	97.46**	21.29	10.77**	34.36**
P3 x P5	0.51**	3.41**	6.66**	94.56**	-9.37	10.51**	22.02**
P3 x P6	0.53**	2.00**	5.86**	68.24**	32.61**	8.04**	27.77**
P3 x P7	0.30**	2.53**	4.62**	65.12**	3.35	8.95**	14.07*
P4 x P5	0.13*	1.20**	3.06*	81.19**	-21.45	3.69**	15.70**
P4 x P6	-0.36**	-1.01**	-3.12*	-52.91**	-16.81	1.32	-20.59**
P4 x P7	-0.06	0.46	2.07	21.11	-0.80	2.69**	6.50
P5 x P6	0.35**	1.04**	1.92	29.03	31.92**	-0.25	20.61**
P5 x P7	0.10	0.76*	-0.46	-17.95	19.27	1.15	4.58
P6 x P7	0.13	0.82*	4.73**	82.82**	11.98	0.29	24.42**
SE(Sij)	0.06	0.29	1.18	15.29	10.56	0.92	5.36
SE(Sij-Sik)	0.09	0.43	1.75	22.71	15.68	1.37	7.96
SE(Sij-Skm)	0.09	0.41	1.64	21.24	14.70	1.28	7.44

* & **: level of significance at 5 % and 1 %, respectively. ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-kw: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

Table.5 Estimates of components of variance for fourteen quantitative characters in maize

Sources	Mean squares						
	DA	**DS**	**ASI**	**DPM**	**PH**	**EH**	**EL**
σ^2 gca	1.80	3.63	0.34	6.18	73.85	46.47	0.20
σ^2 sca	13.02	16.74	0.70	10.45	496.74	136.53	4.17
σ^2 gca/ σ^2 sca	0.14	0.22	0.48	0.59	0.15	0.34	0.05

DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length.

Contd. **Table.5** Estimates of components of variance for fourteen quantitative characters in maize

Sources	Mean squares						
	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
σ^2 gca	0.01	0.70	4.73	886.12	116.31	16.11	27.18
σ^2 sca	0.29	8.56	43.64	12030.68	356.53	97.54	1037.81
σ^2 gca/ σ^2 sca	0.05	0.08	0.11	0.07	0.33	0.17	0.03

ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant

Table.6 Estimates of standard heterosis over the best check, DMRH-1308 for grain yield and its attributes

Sl. No.	F_1's	DA	DS	ASI	DPM	PH	EH	EL	ED	KRPE	KPR	GPP	1000-KW	SP	GYP
1	P1 x P2	-3.57	-9.50**	-100.00**	-1.44	11.88**	9.33	2.72	0.91	-3.23	11.43	25.87**	23.52**	1.37	52.43**
2	P1 x P3	-1.19	-7.26**	-100.00**	-2.88	-0.77	-1.77	4.6	-1.49	-0.46	5.79	17.88	20.23*	1.99	36.10**
3	P1 x P4	-5.36**	-12.85**	-127.27**	-8.63**	22.09**	35.79**	16.97**	-4.38	-7.83*	18.49*	27.49**	29.14**	1.40	62.35**
4	P1 x P5	-5.36**	-12.85**	-127.27**	-3.6	17.22**	27.98**	12.88*	-4.88	2.3	9.74	33.15**	11.75	-0.21	47.63**
5	P1 x P6	-3.57	-11.17**	-127.27**	-8.27**	16.49**	19.72**	0.67	-5.37*	-7.83*	-3.53	0.34	31.72**	2.70	27.79*
6	P1 x P7	-1.19	-7.26**	-100.00**	-2.88	12.49**	31.54**	10.87	-3.97	-14.29**	23.50**	28.29**	23.43**	3.39	54.37**
7	P2 x P3	2.98	-1.68	-72.73**	5.76	11.65**	12.45	11.57	9.01**	5.53	4.8	23.30*	42.47**	-0.09	75.83**
8	P2 x P4	2.98	-1.68	-72.73**	2.52	20.68**	23.98**	0.75	0.91	-5.53	-1.13	11.48	31.43**	1.00	42.89**
9	P2 x P5	0.00	-6.15**	-100.00**	1.08	23.30**	27.31**	6.92	0.83	0.46	8.96	21.45*	21.01*	1.20	43.78**
10	P2 x P6	-2.98	-7.26**	-72.73**	1.8	22.70**	24.12**	8.02	0.83	-8.76**	3.39	15.65	36.01**	1.73	56.04**
11	P2 x P7	2.38	-3.91*	-100.00**	3.6	16.00**	28.49**	1.54	-3.47	-10.60**	11.5	20.65*	7.39	3.10	28.70*
12	P3 x P4	2.38	-2.23	-72.73**	2.52	15.02**	14.92*	23.06**	0.17	-7.83*	9.6	14.54	41.72**	0.80	60.55**
13	P3 x P5	1.79	-1.12	-45.45**	3.24	10.19*	-2.74	14.14*	-3.06	-4.15	7.13	17.74	22.49**	-1.92	44.99**
14	P3 x P6	2.38	-3.91*	-100.00**	6.12	13.99**	5.75	18.43**	-0.33	-9.68**	3.53	6.96	50.44**	2.34	57.02**
15	P3 x P7	7.14**	2.23	-72.73**	8.63**	0.54	5.43	10.46	-5.29*	-9.68**	18.28*	30.38**	22.59**	3.94*	51.50**
16	P4 x P5	0.00	-4.47*	-72.73**	2.52	17.49**	17.92*	10.05	-6.69**	-10.60**	0.78	8.37	23.07**	-0.99	30.12*
17	P4 x P6	8.33**	1.68	-100.00**	4.32	7.33	16.25*	-10.44	-16.53**	-21.66**	-25.62**	-41.64**	32.95**	3.40	-21.82
18	P4 x P7	3.57	-1.12	-72.73**	6.47*	11.56**	28.14**	9.9	-8.43**	-15.21**	16.37	9.85	27.01**	5.57**	34.73**
19	P5 x P6	-1.19	-7.26**	-100.00**	3.6	24.24**	16.74*	7.79	-1.24	-8.76**	-6.35	-7.55	52.15**	-0.96	44.08**
20	P5 x P7	2.98	-1.68	-72.73**	7.91*	8.33	19.51**	6.45	-6.78**	-14.29**	3.6	-0.1	32.33**	1.25	35.01**
21	P6 x P7	-2.98	-8.94**	-100.00**	5.04	23.03**	42.17**	14.55*	-3.64	-9.68**	25.34**	35.38**	36.43**	7.51**	68.49**

* & **: level of significance at 5 % and 1 %, respectively. DA: Days to 50 per cent anthesis, DS: days to 50 per cent silk, ASI: anthesis-silking interval, DPM: days to 50 per cent physiological maturity, PH: plant height, EH: ear height, EL: ear length, ED: ear diameter, KRPE: kernel rows per ear, KPR: kernels per row, GPP: grains per plant, 1000-KW: 1000-kernel weight, SP: shelling per cent and GYP: grain yield per plant.

The promising cross combinations having significant to highly significant SCA effects in desirable direction could be exploited commercially after verifying their performance across environments. These results are in close conformity with the findings of Singh *et al.,* (2019), Ambikabathy *et al.,* (2019), Abhishek (2018), Dar *et al.,* (2018), Singh *et al.,* (2017), Kumar and Babu (2016), Kumar *et al.,* (2015) and Gouda *et al.,* (2013).

Standard heterosis

The estimates of standard heterosis over the check, DMRH-1308 for fourteen quantitative traits (Table 6) revealed the per cent of standard heterosis for grain yield ranged from -21.82 per cent (P4 x P6) to 75.83 per cent (P2 x P3). The top five cross combinations, P2 x P3, P6 x P7, P1 x P4, P3 x P4 and P3 x P6 had highest positive significant standard heterosis for grain yield per plant. These hybrids also exhibited significant to highly significant positive standard heterosis for one or more grain yield contributing traits. Hence, these hybrids can be exploited commercially after critical evaluation for their superiority and stability over the locations or years. Days to 50 per cent anthesis and days to 50 percent silk regulate the early flowering. The cross combinations, P1 x P4 and P1 x P5 had highly significant negative standard heterosis for days to 50 per cent anthesis. For days to 50 per cent silk, the cross combinations, namely, P1 x P2, P1 x P3, P1 x P4, P1 x P5, P1 x P6, P1 x P7, P2 x P5, P2 x P6, P2 x P7, P3 x P6, P4 x P5, P5 x P6 and P6 x P7 exhibited significant to highly negative standard heterosis, while, all the cross combinations had highly significant negative standard heterosis for anthesis-silking interval. Two cross combinations, P1 x P4 and P1 x P6 had highly significant negative standard heterosis for days to 50 per cent maturity. Hence these hybrids can be exploited earliness after critical testing over environments. Similar results were reported by Ambikabathy *et al.,* (2019), Kumar and Babu (2016), Kumar *et al.,* (2015), Ofori *et al.,* (2015), Lahane *et al.,* (2014).

Hence concluded, in the present study for grain yield per, the cross combinations, P1 x P2, P1 x P4 and P1 x P5 were identified as the best experimental hybrids on the basis of high standard heterosis, high SCA and high GCA for at least female parent. Hence, these hybrids may be exploited commercially after critical evaluation for their performance and stability over environments for this trait.

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