Plant Archives
Journal home page: www.plantarchives.org
DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.095

STUDIES ON HETEROSIS AND COMBINING ABILITY THROUGH DIALLEL METHOD IN MAIZE (*ZEA MAYS* L.)

Mahipat Singh Yadav and B. Gangwar
Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), India
Email: maahiseeds@gmail.com
(Date of Receiving-22-11-2020; Date of Acceptance-26-02-2021)

ABSTRACT

The present investigation was conducted using 28 different genotypes (seven parents and their 21 F1s) of maize under organic conditions at the Rain-fed Organic Research Farm, Narayanbag, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) India, during *kharif* 2018 and *rabi season* 2018-19. In order to determine the general and specific combining ability of parents and the crosses, the growth parameters and yield components were evaluated in a 7×7 diallel fashion in maize in a Randomized Block Design (RBD) with three replications. In this study, the GCA effects suggested that parent P1, P2 and P4 were the most desirable as they possessed high GCA effect for most of the characters. Among F_1 crosses, P4 x P3, P3 x P1, P5 x P3 and P7 x P5 having significant positive SCA were found to be desirable for yield and yield attributing characters. The maximum heterotic effects in desirable direction for yield attributes were showed by the cross combinations viz; P1 x P6, P2 x P7, P2 x P5, P1 x P2, P3 x P4, P5 x P7 and P3 x P5. The maximum heterosis was recorded in for Seed yield per plant P5 x P7 (39.32%) which ranged from -14.69 to 49.55.

Keywords: Heterosis, Combining Ability, GCA, SCA, Maize

INTRODUCTION

Maize is the country's 3rd largest cereal crop after rice and wheat and is valued as food, feed, feed and industrial raw material. In view of maize being produced in a very diverse environment in our country, the development of high yielding hybrids with built-in resistance and tolerance to diseases, pests and various climatic stresses; the development and fine tuning of production ecology are our top priorities. The concept of combining ability has become increasingly important in breeding programme not only in maize but also in other crops, which provide useful information for the parent's selection in terms of hybrid performance (Sprague, G.F. and Tatum, L.A., 1942). Diallel analysis is widely and extensively used to estimate the type of gene action. The effects of the General and Specific Combining Abilities are important indicators of potential value for inbreed lines in hybrid combinations. The main genetic parameters for the diallel analysis are GCA and SCA, which are essential for the development of breeding programme. The evaluation of crosses among inbred lines is an important step towards for development of hybrid varieties in maize. Combining ability analysis is one of the useful tools to identify better combiners that can be hybridized to utilize heterosis and to select better crosses for direct use or further breeding work (Gazal Asima, *et al.,* 2017 and Nataraj *et al.,* 2014).

MATERIALS AND METHODS

The experimental material used in the present study comprised of seven genotypes of Maize viz., V1(D2-2),V2(CML-150),V3(D-1),V4(TSK11-1), V5(POP-65), V6(Azad Kamal OFWS) and V7(DHOLI-M7) which were obtained from Chandra Shekhar Azad University, Kanpur (U.P).The trials were conducted at the Rain-fed Organic Research Farm, Narayanbag, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) India, geographically located at 25°. 27" N latitude and 78°35 E longitude at an latitude of 271 meters above the mean sea level in semi-arid tract of central India. Seven inbred lines were crossed according to a half diallel crosses mating design to obtain 21single crosses, in *kharif* season 2018 while in *rabi* season 2018-19, all 28 genotypes, which included seven parental inbred lines and 21 F_1s were cultivated. Seven parental inbred lines planted in Randomized Block Design (RBD) with each in two plots. The plots were defined as three 23.10m long replication having width of 1.0 m apart and expected stand of 240 plants in each replication. Seeds of each genotype's entry were sown at the distance of 60 cm row to row and 20cm plant tom plant. However, one healthy seedling per hill was kept after proper thinning. Fertilizers were applied @120, 60 and 40 kg/ha of N, P, K, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Data on days to 50% germination and silking were recorded on whole plot basis. Five randomly selected plants were used for recording observations on plant height and cob length (cm). Seed yield per plant (g) was recorded by weighing samples of sun-dried Kernels of total matured cobs in individual plants. The combining ability analysis was carried out in twenty-one single crosses comprise a half diallel between 7 inbred parents. Data of all 28 genotypes were analyzed as randomized blocks. General combining ability effects for the inbred parents, specific combining ability effects

Table 1. Mean values for seed yield per plant (g) and other related traits in maize genotypes .

SN	Genotype	Days to 50% germination	Days to 50% teaseling	Days to 50% silking	Days to 50% maturity	Plant height (cm)	No. of leaves per plant	Biological yield per plant (g)	No. of cobs per plant	Cob weight (g)	Cob length (cm)	No. of rows per cob	No. of seed per row	No. of seed per cob	100 Seed weight (g)	Shelling percent	Harvest index (%)	Seed yield per cob (g)	Seed yield Per Plant (g)
1	D 2-2	9.33	81.67	95.67	127.00	182.00	10.20	286.67	1.27	74.70	20.83	12.47	24.00	246.87	21.37	67.95	23.49	50.72	63.97
2	CML-150	10.00	80.33	66.67	124.33	176.00	10.07	278.33	1.20	90.76	21.53	13.13	22.27	255.53	23.21	64.12	23.45	58.55	66.27
3	D- 1	12.33	80.67	96.33	127.00	179.73	10.20	309.67	1.00	79.29	20.83	10.77	21.40	230.22	18.68	54.92	15.30	43.62	43.62
4	TSK 11-1	12.33	78.33	96.33	125.33	182.23	10.47	278.00	1.13	75.09	21.33	13.13	21.33	210.43	21.78	60.62	15.31	45.57	47.32
5	POP-65	8.67	79.33	97.00	128.33	180.73	9.40	252.33	1.13	74.92	21.90	12.92	21.39	222.67	21.66	69.99	18.29	51.44	53.27
6	Azad Kamal OFWS	8.00	83.33	95.67	127.33	195.40	10.40	344.33	1.13	74.85	20.97	13.15	21.43	219.57	19.56	60.04	19.37	44.26	51.00
7	DHOLI-M7	10.33	80.00	96.00	125.00	162.47	9.40	229.33	1.13	66.09	21.10	12.15	19.27	179.72	19.42	57.10	17.30	38.14	44.21
8	P1 x P2	9.33	80.67	98.33	123.33	192.00	10.13	403.33	1.27	103.79	21.35	11.80	22.03	247.33	24.47	69.02	16.57	55.30	63.91
9	P1 x P3	9.67	79.67	97.67	127.00	206.93	10.00	333.00	1.13	96.91	23.00	11.97	23.98	278.60	24.67	69.86	20.55	65.72	68.17
10	P1 x P4	10.33	79.00	95.67	124.67	203.13	11.20	325.00	1.20	96.37	21.30	13.00	23.23	265.77	21.65	54.99	17.85	54.13	60.18
11	P1 x P5	10.00	78.00	96.33	124.67	182.80	10.07	331.00	1.13	100.05	21.30	13.03	23.60	233.47	22.14	57.21	18.60	57.57	64.07
12	P1 x P6	8.67	79.00	94.67	126.00	189.20	9.67	297.33	1.07	77.33	21.10	12.69	20.96	246.82	22.33	70.67	19.59	54.85	55.10
13	P1 x P7	9.33	79.00	95.00	127.33	154.53	8.53	265.67	1.00	83.24	21.45	13.22	23.60	267.33	21.37	67.74	21.21	56.49	56.49
14	P2 x P3	10.67	82.33	97.00	124.67	174.80	9.47	293.67	1.00	78.34	21.07	12.50	20.40	233.75	20.20	59.34	16.04	46.86	46.87
15	P2 x P4	10.33	82.67	96.33	125.67	206.73	11.20	363.00	1.00	102.66	23.25	13.02	20.95	235.72	24.33	55.09	16.54	57.32	57.32
16	P2 x P5	9.33	82.00	96.33	127.00	187.33	9.53	289.00	1.27	83.97	21.77	12.25	22.80	254.45	22.27	64.02	18.64	54.23	54.23
17	P2 x P6	10.33	79.33	94.33	129.00	161.07	9.27	228.67	1.20	68.66	22.20	12.30	20.81	227.64	20.49	66.15	20.25	45.79	53.21
18	P2 x P7	9.00	81.33	94.00	124.67	187.53	10.47	325.33	1.20	80.52	23.08	12.55	20.68	195.25	22.50	54.55	15.29	44.12	49.84
19	P3 x P4	11.00	79.00	96.00	125.33	219.40	11.73	405.33	1.00	70.99	21.70	12.62	19.32	219.12	18.33	60.74	10.75	42.63	42.63
20	P3 x P5	9.33	84.33	96.00	123.67	206.13	11.20	318.67	1.13	83.90	21.50	14.42	25.33	301.29	20.02	73.72	19.66	59.33	62.47
21	P3 x P6	11.67	81.00	97.33	121.33	186.47	9.87	229.33	1.07	65.93	20.43	11.78	19.55	186.90	21.17	59.97	20.55	39.62	46.24
22	P3 x P7	10.00	79.00	97.00	123.67	156.93	9.60	247.33	1.33	59.16	20.00	12.57	20.37	191.85	18.63	58.42	18.80	35.35	52.90
23	P4 x P5	11.67	80.00	94.33	126.33	190.33	10.20	329.00	1.20	83.62	20.75	13.33	21.75	245.50	21.65	64.74	17.24	54.05	58.15
24	P4 x P6	10.67	81.67	95.00	127.67	194.47	11.20	326.33	1.27	77.64	20.60	13.27	24.92	263.07	19.82	70.97	18.74	54.29	67.47
25	P4 x P7	10.00	83.67	96.67	127.67	120.47	9.87	302.67	1.33	78.65	21.17	13.93	24.39	289.60	17.09	63.83	18.17	50.25	62.84
26	P5 x P6	9.67	81.33	95.33	126.67	171.80	10.53	276.00	1.40	74.91	21.20	10.67	20.20	190.27	21.31	54.32	14.40	40.65	45.98
27	P5 x P7	8.33	84.67	94.00	126.00	200.13	10.20	370.33	1.53	105.94	22.55	14.73	22.16	275.13	22.61	58.06	21.27	61.20	72.89
28	P6 x P7	10.67	79.00	96.67	128.00	162.93	10.20	268.67	1.27	80.29	22.00	12.40	21.33	262.60	19.39	63.94	19.16	51.43	60.00
29	Check 1	11.67	77.00	93.67	126.00	158.67	10.53	245.36	1.57	86.50	21.10	11.58	22.22	238.12	21.13	54.29	17.45	46.72	52.90
30	Check 2	11.00	81.33	94.67	122.00	171.35	9.36	239.50	1.33	93.10	21.20	11.72	20.40	243.95	19.24	49.95	22.73	45.76	53.39
	PM	10.14	80.52	91.95	126.33	179.80	10.02	282.67	1.14	76.53	21.21	12.53	21.58	223.57	20.81	62.11	18.93	47.47	52.81
	FM	10.00	80.79	95.90	125.73	183.58	10.20	310.89	1.19	83.47	21.56	12.76	22.02	243.40	21.26	62.73	18.09	51.48	57.19
	CM	11.33	79.17	94.17	124.00	165.01	9.95	242.43	1.45	89.80	21.15	11.65	21.31	241.03	20.19	52.12	20.09	46.24	53.14
	GM	9.78	77.96	91.67	121.59	176.04	9.83	292.10	1.16	80.07	20.75	12.23	21.23	232.63	20.44	59.97	17.84	48.93	54.42
	SE	0.66	1.57	5.46	1.04	12.02	0.36	26.55	0.13	9.24	0.76	0.58	1.92	24.23	1.77	6.07	2.74	6.75	8.03
	CD5	1.86	4.43	15.44	2.95	34.03	1.03	75.15	0.37	26.16	2.14	1.64	5.42	68.59	5.02	17.20	7.76	19.12	22.74
	CD1	2.48	5.90	20.55	3.93	45.30	1.36	100.02	0.49	34.82	2.85	2.18	7.22	91.28	6.68	22.89	10.33	25.45	30.26
	CV	11.65	3.48	10.31	1.48	11.83	6.38	15.74	19.41	19.99	6.31	8.20	15.63	18.04	15.03	17.54	26.63	23.91	25.56

Table 2. GCA and SCA effects for days to 50% germination, days to 50% teaseling, biological yield per plant (g), cobs per plant (no.), cob weight (g), seed yield per plant (g) and other traits in maize genotypes.

SN	Geno-type	Days to 50% germi-nation	Days to 50% teaseling	Days to 50% silking	Days to 50% maturity	Plant height (cm)	No. of leaves per plant	Biological yield per plant (g)	No. of cobs per plant	Cob weight (g)	Cob length (cm)	No. of rows per cob	No. of seed per row	No. of seed per cob	100 Seed weight (g)	Shelling percent	Harvest index (%)	Seed yield per cob (g)	Seed yield Per Plant (g)
1	P1	-0.48*	-0.79	1.07	-0.01	3.50	-0.14	10.89	-0.01	5.91*	-0.07	-0.11	1.13	13.94	1.13*	2.75	1.66	4.63*	5.24*
2	P2	-0.14	0.35	-5.52**	-0.45	0.05	-0.11	3.22	-0.01	5.06	0.44	-0.11	-0.34	-0.26	1.28*	-0.46	0.43	1.87	1.02
3	P3	0.75**	0.10	1.59	-0.82*	5.45	0.12	1.78	-0.08*	-4.45	-0.27	-0.47*	-0.39	-3.96	-0.98	-0.97	-1.05	-3.01	-4.69
4	P4	0.93**	-0.35	0.81	0.11	4.22	0.57**	19.63*	-0.02	0.69	-0.04	0.42*	0.22	3.56	-0.30	-1.00	-1.83*	-0.00	-0.61
5	P5	-0.51*	0.35	0.78	0.44	4.33	-0.08	-1.33	0.06	3.15	0.12	0.29	0.37	4.21	0.46	1.27	-0.00	2.90	1.73
6	P6	-0.29	0.24	0.59	0.70*	-0.48	0.03	-12.85	0.01	-6.60*	-0.26	-0.25	-0.52	-10.13	-0.62	0.61	0.56	-3.19	-2.08
7	P7	-0.25	0.10	0.67	0.03	-17.07**	-0.39**	-21.33*	0.06	-3.77	0.07	0.23	-0.47	-7.37	-0.97	-2.21	0.23	-3.19	-0.60
8	P2 x P1	-0.08	0.38	7.86	-2.09*	5.82	0.23	85.39**	0.11	11.08	-0.50	-0.69	-0.66	-4.79	0.91	4.15	-3.82	-1.69	1.56
9	P3 x P1	-0.64	-0.36	0.08	1.94*	15.34	-0.13	16.50	0.05	13.72	1.86**	-0.15	1.34	30.17	3.37*	5.49	1.64	13.62*	11.54
10	P4 x P1	-0.16	-0.58	-1.14	-1.31	12.78	0.61	-9.35	0.05	8.03	-0.06	-0.02	-0.02	9.81	-0.32	-9.34	-0.28	-0.97	-0.53
11	P5 x P1	0.95	-2.29	-0.44	-1.65	-7.66	0.13	17.61	-0.09	9.25	-0.22	0.15	0.19	-23.13	-0.60	-9.39	-1.36	-0.43	1.01
12	P6 x P1	-0.60	-1.18	-1.92	-0.57	3.54	-0.39	-4.54	-0.11	-3.72	-0.05	0.34	-1.56	4.56	0.67	4.73	-0.93	2.93	-4.15
13	P7 x P1	0.03	-1.03	-1.66	1.43	-14.54	-1.09**	-27.72	-0.22	-0.64	-0.03	0.40	1.03	22.32	0.07	4.62	1.01	4.58	-4.24
14	P3 x P2	0.03	1.16	6.01	0.06	-13.33	-0.69*	-15.17	-0.08	-4.01	-0.58	0.37	-0.78	-0.48	-1.24	-1.80	-1.63	-2.48	-5.55
15	P4 x P2	-0.49	1.94	6.12	0.13	19.84	0.59	36.31	-0.15	15.17	1.37*	-0.00	-0.84	-6.03	2.21	-6.02	-0.36	4.97	0.82
16	P5 x P2	-0.05	0.56	6.16	1.13	0.33	-0.43	-16.72	0.04	-5.98	-0.27	-0.64	0.86	12.06	-0.62	0.64	-0.09	-1.02	-4.62
17	P6 x P2	0.73	-1.99	4.34	2.87**	-21.13	-0.81*	-65.54**	0.02	-11.53	0.54	-0.05	-0.25	-0.42	-1.32	3.43	0.97	-3.38	-1.82
18	P7 x P2	-0.64	0.16	3.94	-0.80	21.92	0.82*	39.61	-0.02	-2.51	1.09	-0.28	-0.42	-35.56	1.04	-5.35	-3.67	-5.05	-6.68
19	P4 x P3	-0.71	-1.47	-1.32	0.17	27.10*	0.90**	80.09**	-0.08	-6.99	0.54	-0.04	-2.42	-18.94	-1.54	0.13	-4.67	-4.84	-8.16
20	P5 x P3	-0.94	3.16*	-1.29	-1.83	13.72	1.01**	14.39	-0.02	3.46	0.18	1.90**	3.44	62.59**	-0.61	10.84	2.41	8.97	9.33
21	P6 x P3	1.18	-0.06	0.23	-4.43**	-1.14	-0.44	-63.43*	-0.04	-4.75	-0.51	-0.20	-1.45	-37.46	1.62	-2.25	2.74	-4.66	-3.08
22	P7 x P3	-0.53	-1.92	-0.18	-1.43	-14.09	-0.27	-36.94	0.18	-14.36	-1.28	0.11	-0.68	-35.27	-0.57	-0.98	1.31	-8.93	2.10
23	P5 x P4	1.21*	-0.73	-2.18	-0.09	-0.84	-0.44	6.87	-0.02	-1.96	-0.80	-0.09	-0.75	-0.72	0.35	1.89	0.77	0.68	0.94
24	P6 x P4	-0.01	1.05	-1.32	0.98	8.10	0.44	15.72	0.09	1.82	-0.58	0.39	3.31	31.18	-0.41	8.78	1.71	7.01	14.07
25	P7 x P4	-0.71	3.19*	0.27	1.65	-49.32**	-0.46	0.54	0.12	-0.01	-0.34	0.58	2.73	54.96*	-2.78	4.46	1.47	2.96	7.96
26	P6 x P5	0.44	0.01	-0.95	-0.35	-14.68	0.42	-13.65	0.15	-3.37	-0.14	-2.08**	-1.57	-42.26	0.32	-10.14	-4.45	-9.54	-9.76
27	P7 x P5	-0.94	3.49*	-2.36	-0.35	30.24**	0.52	89.17**	0.24*	24.82**	0.88	1.51**	0.34	39.85	1.98	-3.58	2.74	11.01	15.66*
28	P7 x P6	1.18	-2.06	0.49	1.39	-2.15	0.41	-0.98	0.02	8.92	0.71	-0.29	0.41	41.65	-0.17	2.96	0.07	7.33	6.58
	Standard error																		
	Gi	0.21	0.50	1.74	0.33	3.83	0.11	8.29	0.04	2.88	0.23	0.18	0.61	7.64	0.56	1.90	0.87	2.15	2.56
	Gi-Gj	0.32	0.76	2.66	0.50	5.84	0.17	12.66	0.06	4.40	0.36	0.28	0.92	11.67	0.86	2.90	1.33	3.28	3.92
	Sii	0.51	1.23	4.31	0.80	9.47	0.28	20.51	0.10	7.12	0.58	0.45	1.50	18.91	1.39	4.69	2.15	5.32	6.34
	Sij	0.60	1.44	5.07	0.95	11.13	0.33	24.11	0.11	8.37	0.68	0.53	1.76	22.22	1.63	5.51	2.53	6.25	7.46
	Sij-ik	0.89	2.14	7.53	1.41	16.53	0.49	35.81	0.17	12.43	1.01	0.79	2.61	33.01	2.42	8.19	3.76	9.28	11.08
	Sij-Skl	0.84	2.01	7.04	1.31	15.46	0.46	33.50	0.16	11.63	0.95	0.74	2.45	30.88	2.26	7.66	3.52	8.68	10.36

*, ** Significant at 5% and 1% respectively.

Table 3. (1). Extent of heterosis for days to 50% germination, days to 50% tasseling and days to 50% sillking, days to 50% maturity, plant height (cm) and leaves per plant (no.)

SN.	Crosses	Biological yield per plant (g)			Cobs per plant(no.)			Cob weight (g)			Cob length (cm)			Rows per cob(no.)			Seed per row(no.)		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	P1 x P2	42.77**	40.70**	64.38**	2.70	0.00		25.46	14.36	11.48	0.79		0.71	-7.81		0.68	-4.76		
2.	P1 x P3	11.68	7.53	35.72*	0.00			25.87	22.23	4.10	10.40*	10.40*	8.49	3.01		2.10	5.65		7.95
3.	P1 x P4	15.11	13.37	32.46*	0.00			28.68	28.35	3.52	1.03		0.47	1.56		10.92	2.50		4.58
4.	P1 x P5	22.82	15.47	34.90*	-5.56			33.74*	33.54	7.47	-0.31		0.47	2.69	0.90	11.21	3.99		6.23
5.	P1 x P6	-5.76		21.18	-11.11			3.42	3.31		0.96	0.64		-0.92		8.28	-7.75		
6.	P1 x P7	2.97		8.28	-16.67			18.25	11.44		2.31	1.66	1.18	7.41	6.04	12.80	9.09		6.23
7.	P2 x P3	-0.11		19.69	-9.09			-7.87			-0.55			4.57		6.63	-6.56		
8.	P2 x P4	30.50*	30.42*	47.95**	-14.29			23.80	13.11	10.26	8.48	7.97	9.67	-0.89		11.06	-3.90		
9.	P2 x P5	8.92	3.83	17.79	8.57	5.56		1.36			0.23		2.67	-5.95		4.52	4.45	2.40	2.63
10.	P2 x P6	-26.55*			2.86			-17.08			4.47	3.10	4.72	-6.40		4.95	-4.77		
11.	P2 x P7	28.17*	16.89	32.59*	2.86			2.67			8.29	7.20	8.88	-0.73		7.08	-0.40		
12.	P3 x P4	37.95**	30.89*	65.20**	-6.25			-8.03			2.92	1.72	2.36	5.58		7.65	-9.59		
13.	P3 x P5	13.40	2.91	29.88	6.25	0.00		8.81	5.81		0.62		1.42	21.80**	11.66	23.07**	18.41	18.38	14.03
14.	P3 x P6	-29.87**			-0.00			-14.45			-2.23			-1.46		0.54	-8.72		
15.	P3 x P7	-8.23		0.80	25.00	17.65		-18.62			-4.61			9.67	3.43	7.22	0.16		
16.	P4 x P5	24.07	18.35	34.09*	5.88	5.88		11.48	11.36		-4.01			2.37	1.52	13.77	1.82	1.68	
17.	P4 x P6	4.87		33.00*	11.76	11.76		3.57	3.40		-2.60			0.95	0.89	13.20	16.52	16.25	12.15
18.	P4 x P7	19.32	8.87	23.36	17.65	17.65		11.43	4.75		-0.24			10.22	6.09	18.89**	20.15	14.33	9.78
19.	P5 x P6	-7.49		12.49	23.53	23.53		0.04			-1.09		0.00	-18.16**			-5.66		
20.	P5 x P7	53.77**	46.76**	50.93**	35.29*	35.29*		50.26**	41.40*	13.80	4.88	2.97	6.37	17.55**	14.06*	25.71**	8.99	3.58	
21.	P6 x P7	-6.33		9.50	11.76	11.76		13.93	7.26		4.60	4.27	3.77	-1.98		5.80	4.83		

*, ** Significant at 5% and 1% respectively.

Table 3.(2) Extent of heterosis for biological yield per plant (g), cobs per plant (no.) and cob weight (g), cob length (cm), rows per cob (no.) and seed per row(no.)

SN.	Crosses	Biological yield per plant (g)			Cobs per plant(no.)			Cob weight (g)			Cob length (cm)			Rows per cob(no.)			Seed per row(no.)		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	P1 x P2	42.77**	40.70**	64.38**	2.70	0.00		25.46	14.36	11.48	0.79		0.71	-7.81		0.68	-4.76		
2.	P1 x P3	11.68	7.53	35.72*	0.00			25.87	22.23	4.10	10.40*	10.40*	8.49	3.01		2.10	5.65		7.95
3.	P1 x P4	15.11	13.37	32.46*	0.00			28.68	28.35	3.52	1.03		0.47	1.56		10.92	2.50		4.58
4.	P1 x P5	22.82	15.47	34.90*	-5.56			33.74*	33.54	7.47	-0.31		0.47	2.69	0.90	11.21	3.99		6.23
5.	P1 x P6	-5.76		21.18	-11.11			3.42	3.31		0.96	0.64		-0.92		8.28	-7.75		
6.	P1 x P7	2.97		8.28	-16.67			18.25	11.44		2.31	1.66	1.18	7.41	6.04	12.80	9.09		6.23
7.	P2 x P3	-0.11		19.69	-9.09			-7.87			-0.55			4.57		6.63	-6.56		
8.	P2 x P4	30.50*	30.42*	47.95**	-14.29			23.80	13.11	10.26	8.48	7.97	9.67	-0.89		11.06	-3.90		
9.	P2 x P5	8.92	3.83	17.79	8.57	5.56		1.36			0.23		2.67	-5.95		4.52	4.45	2.40	2.63
10.	P2 x P6	-26.55*			2.86			-17.08			4.47	3.10	4.72	-6.40		4.95	-4.77		
11.	P2 x P7	28.17*	16.89	32.59*	2.86			2.67			8.29	7.20	8.88	-0.73		7.08	-0.40		
12.	P3 x P4	37.95**	30.89*	65.20**	-6.25			-8.03			2.92	1.72	2.36	5.58		7.65	-9.59		
13.	P3 x P5	13.40	2.91	29.88	6.25	0.00		8.81	5.81		0.62		1.42	21.80**	11.66	23.07**	18.41	18.38	14.03
14.	P3 x P6	-29.87**			-0.00			-14.45			-2.23			-1.46		0.54	-8.72		
15.	P3 x P7	-8.23		0.80	25.00	17.65		-18.62			-4.61			9.67	3.43	7.22	0.16		
16.	P4 x P5	24.07	18.35	34.09*	5.88	5.88		11.48	11.36		-4.01			2.37	1.52	13.77	1.82	1.68	
17.	P4 x P6	4.87		33.00*	11.76	11.76		3.57	3.40		-2.60			0.95	0.89	13.20	16.52	16.25	12.15
18.	P4 x P7	19.32	8.87	23.36	17.65	17.65		11.43	4.75		-0.24			10.22	6.09	18.89**	20.15	14.33	9.78
19.	P5 x P6	-7.49		12.49	23.53	23.53		0.04			-1.09		0.00	-18.16**			-5.66		
20.	P5 x P7	53.77**	46.76**	50.93**	35.29*	35.29*		50.26**	41.40*	13.80	4.88	2.97	6.37	17.55**	14.06*	25.71**	8.99	3.58	
21.	P6 x P7	-6.33		9.50	11.76	11.76		13.93	7.26		4.60	4.27	3.77	-1.98		5.80	4.83		

*, ** Significant at 5% and 1% respectively.

Table 3.(3) Extent of heterosis for seed per cob(no.), 100 seed weight (g) and shelling percent, harvest index (%),seed yield per cob (g) and seed yield per plant (g)

SN.	Crosses	Seed per cob (no.)			100 Seed weight (g)			Shelling percent			Harvest index (%)			Seed yield per cob (g)			Seed yield per plant (g)		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	P1 x P2	-1.54		1.39	9.78	5.41	15.79	4.52	1.57	27.13	-29.41*			1.21		18.37	-1.85		19.71
2.	P1 x P3	16.79	12.86	14.21	23.20*	15.44	16.72	13.71	2.81	28.67	5.98			39.32*	29.57	40.67	26.74	6.58	27.70
3.	P1 x P4	16.23	7.66	8.94	0.36		2.46	-14.45		1.30	-7.98			12.43	6.72	15.87	8.16		12.73
4.	P1 x P5	-0.55			2.90	2.20	4.75	-17.05		5.37	-10.96			12.71	11.92	23.24	9.31	0.17	20.02
5.	P1 x P6	5.83		1.18	9.11	4.51	5.66	10.43	4.00	30.17	-8.59			15.49	8.14	17.40	-4.15		3.21
6.	P1 x P7	25.34	8.29	9.59	4.81	0.03	1.14	8.35		24.78	3.98			27.15	11.38	20.93	4.45		5.82
7.	P2 x P3	-3.76			-3.54			-0.30		9.31	-17.21			-8.28		0.30	-14.69		
8.	P2 x P4	1.17			8.16	4.82	15.14	-11.67		1.47	-14.66			10.09		22.69	0.92		7.36
9.	P2 x P5	6.42		4.31	-0.76		5.36	-4.53		17.92	-10.69			-1.40		16.08	-9.27		1.57
10.	P2 x P6	-4.17			-4.18			6.55	3.16	21.84	-5.40			-10.93			-9.26		
11.	P2 x P7	-10.28			5.54		6.45	-10.00		0.48	-24.97			-8.75			-9.77		
12.	P3 x P4	-0.55			-9.41			5.14	0.20	11.89	-29.76			-4.41			-6.25		
13.	P3 x P5	33.05*	30.87*	23.51	-0.75			18.03	5.33	35.78*	17.06	7.49		24.84	15.34	27.01	28.95	17.26	17.01
14.	P3 x P6	-16.89			10.72	8.21	0.17	4.33		10.46	18.55	6.09		-9.84			-2.26		
15.	P3 x P7	-6.40			-2.21			4.31	2.32	7.61	15.33	8.65		-13.53			20.47	19.66	
16.	P4 x P5	13.37	10.25	0.64	-0.31		2.46	-0.87		19.24	2.64			11.43	5.07	15.70	15.62	9.16	8.92
17.	P4 x P6	22.36	19.81	7.84	-4.13			17.63	17.07	30.72	8.07			20.88	19.14	16.22	37.24	32.28	26.37
18.	P4 x P7	48.46**	37.62*	18.71	-17.02			8.44	5.29	17.57	11.45	5.05		20.04	10.26	7.56	37.32	32.81	17.71
19.	P5 x P6	-13.95			3.37		0.82	-16.45		0.05	-23.50			-15.04			-11.81		
20.	P5 x P7	36.75*	23.56	12.78	10.10	4.40	7.00	-8.63		6.94	19.56	16.33		36.63	18.97	31.00	49.55*	36.83	36.53
21.	P6 x P7	31.54*	19.60	7.65	-0.53			9.17	6.50	17.77	4.49			24.82	16.19	10.08	26.03	17.64	12.39

*, ** Significant at 5% and 1% respectively.

for cross combinations and their respective standard errors were computed (Griffing, D., 1956). Heritability and narrow sense heritability were computed as the ratio of genetic variance, total phenotypic variance and the ratio of additive genetic variance to the total phenotypic variance (Shull, G.H., 1914).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance for eighteen traits partitioned the total variation into the variation due to genotypes and other sources. The analysis of variance for yield and its component attributes is presented in Table 1. It indicated the presence of significant genetic variability among the genotypes for the characters studied, days to 50% germination, days to 50% maturity, plant height, and number of leaves per plant, biological yield per plant, cob weight and number of rows per cob. It indicated the presence of considerable variability among all the genotypes for all these characters under study. The analysis of variance for yield and its component traits for parents showed that days to 50% germination and days to 50% silking were significant. F_1s were found significant for days to 50% maturity, plant height, and number of leaves per plant, biological yield per plant, cob ear weight, number of rows per cob and number of seeds per cob. Mean sum of squares due to Parents v/s F_1s were found significant for biological yield per plant. Similar trends were reported by (Gazal Asima *et al.,* 2017). The days to 50 % germination varied from 8 to 12.33 with an overall mean performance of 9.78 days. A minimum day to 50 % tasseling was recorded for check 1 (77). Minimum days to 50 % silking recorded for genotype CML-150 (66.67). Days to 50 % maturity ranged from 121.33 days to 129 days with an overall mean 121.59 days. The genotype P3 x P4 (219.4cm) showed highest plant height (Bekele Atnafua and Rao T. Nageshwar, 2014).

Genotype P3 x P4 (405.33) given maximum biological yield per plant (g). The highest number of cobs per plant was reported in P1 x P3 (1.57). The variations for cob weight (g) ranged from 59.16 to 105.94 g with general mean 80.07 g. Genotype Azad Kamal OFWS (105.94) exhibited maximum cob weight (g). The maximum cob length was observed in P2 x P4 (23.25 cm). The maximum number of rows per cob observed in P5 x P7 (14.73). Number of seeds per row ranged from 19.27 to 25.33 with mean value 21.23. Genotype P3 x P5 (25.33) had shown maximum number of seeds per row. Maximum number of seeds per cob was reported in P3 x P5 (301.29.). The range of 100 Seed weight varied from 17.09 to 24.67 g with general mean 20.44 g. The shelling % ranged from 49.95 to 73.72 with mean value 59.97%. Harvest index (%) ranged from 10.75 % to 23.49 % with an overall mean 17.84%. Genotype P1 x P3 (65.72 g) had shown maximum seed yield per cob, seed yield per cob ranged from 35.35 to 65.72 g with an overall mean 48.93 g. Genotype P5 x P7 (72.89 g) had shown maximum seed yield per plant followed by P1 x P3 (68.17 g), Seed yield per plant ranged from 42.63 to 72.89 g with an overall mean (54.42 g) (Kumar Ankit, *et al.,* 2017).

Combining ability variances

The effects of general combining ability are more pronounced and appreciable progress could be achieved through conventional breeding methods (Table 2). The analysis of variance of combining ability for grain yield and its components showed that variance due to GCA were significant for days to 50% germination, plant height, number of leaves per plant, biological yield per plant, cob weight, number of rows per cob and 100 seed weight. The ratio of variances due to GCA and SCA was less than unity for all the characters other than number of cobs per plant and seed yield per cob which indicated the preponderance of non-additive components in the inheritance of these characters (Lim S.M. and White D.G., 1978).

In the present study, the GCA estimates of the parents were desirable for days to 50% germination in parent P1 (-0.48*) and parent P5 (-0.51*). GCA effects were desirable for days to 50% silking in parent P2 (-5.52**). Parent P3 (-0.82*) has desirable GCA effects for days to 50% maturity. Parents with negative GCA effects were good general combiners for this trait. Among the parents GCA effects were desirable for number of leaves per plant in parent P4 (0.57*) for biological yield per plant (g) in parent P4 (19.63*). Among the parents, GCA effects were desirable for cob weight in parent P1 (5.91*). Parent P4 showed desirable GCA effects for number of rows per cob. The parents P1 (1.13*) and P2 (1.28*) performed positive and significant GCA effects for 100 seed weight were observed. The parent P1 exhibited positive and significant GCA effects (4.63*) for seed yield per cob and for seed yield per plant (5.24*) (Matin Islam Quamrul Mohammad, *et al.,* 2017).

Out of 21 crosses, two crosses viz., P2 x P1 (-2.09*) and P6 x P3 (-4.43**) showed significant negative SCA effects for days to 50% maturity while crosses P4 x P3 (27.10*) and P7 x P5 (30.24**) performed significant positive SCA effects for plant height. Three crosses viz., P7 x P2 (0.82*), P4 x P3 (0.90**), and P5 x P3 (1.01**) showed significantly positive effects on SCA for number of leaves per plant (Nataraj, *et al.,* 2014). Three crosses viz., P3 x P1 (85.39**), P4 x P3 (80.09**), and P7 x P5 (89.17**) performed significantly positive SCA effects for biological yield per plant the cross P7x P5 (0.24*) exhibited significantly positive SCA effects for number of cobs per plant and for-cobs weight (24.82**). The crosses viz., P3x P1 (1.86**) and P4x P2 (1.37*) for Cob length, P5x P3 (1.90**) and P7x P5 (1.51*) for number of rows per cob, and P5x P3 (62.59**) and P7x P4 (54.96*) for number of seeds per row respectively showed significantly positive SCA effects. The cross P3 x P1 (3.37*) for 100 seed weight and for seed yield per cob (13.62*) performed significantly positive SCA effects. Out of 21 crosses, the cross P7x P5 (15.66*) performed significantly positive

SCA effect for seed yield per plant. In addition to this, ten cross combinations were observed with no significant positive SAC effects for the seed yield per plant (Patil SM., *et al.,* 2016).

Heterosis

Heterosis was calculated as superiority of F_1 hybrid over the mid parent. Heterobeltiosis was estimated as superiority of F_1 hybrid over the better parent. On the other hand, standard heterosis was computed as per cent increase (+) or decrease (-) of F_1's over superior check hybrid. The results obtained are presented in Table 3.1, 3.2 & 3.3. The crosses viz. P1 x P6

(-21.21*), P2x P7 (-18.18*) and P5 x P7 (-24.24**) performed significantly negative heterosis for days to 50 % germination and crosses viz., P1 x P5 (-2.35*), P3x P4 (-3.13**) and P3 x P6 (-4.59**) for days to 50% maturity. Two crosses viz., P3x P5 (-2.62*) and P3x P6 (-4.46**) showed significantly negative heterobeltiosis for days to 50 % maturity. The cross P3x P4 performed significant positive heterosis, heterobetiosis and standard heterosis for plant height with magnitude of 21.23*, 20.40* and 28.04** respectively (Rojas BA, and Sprague GF., 1952). Cross P3xP4 exhibited significant positive heterosis, heterobeltiosis and standard heterosis for number of leaves per plant with magnitude of 13.55**, 12.10* and 11.39* respectively (Sravanti K., *et al.,* 2017).

Out of 21 crosses, five crosses, four crosses and ten crosses depicted significant positive heterosis, heterobeltiosis and standard heterosis respectively for biological yield per plant. Out of these, four crosses viz P1x P2, P2x P4, P3x P4 and P5x P7 were common for heterosis, heterobeltiosis and standard heterosis which exhibited 42.77**, 30.50*, 37.95**, and 53.77% heterosis, respectively. The magnitude of heterobeltiosis in these crosses were 40.77**, 30.42*, 30.89* and 46.76** % respectively while the magnitude of standard heterosis in these crosses were 64.38**, 47.95**, 65.20** and 50.93**% respectively. Out of 21 cross combination, one cross combination i.e. P5x P7 showed significant and positive heterosis and heterobeltiosis for number of cob per plant. The magnitude of heterosis and heterobeltiosis was 35.29* and 35.29* % respectively. Cross P5x P7 performed significant and positive heterosis and heterobeltiosis for cob weight (g) with magnitude of 50.26** and 41.40* % respectively. Cross P1x P3 performed significant and positive heterosis and heterobeltiosis for cob length (cm) with magnitude of 10.40**. The range of standard heterosis varied from 0.47 to 9.67% for this trait. Four crosses viz P3 x P5 (33.05*), P4 x P7 (48.46**), P5 x P7 (36.75*) and P6 x P7 (31.54*) performed with significant and positive heterosis for number of seeds per cob. Cross P1 x P3 showed significant and positive heterosis for 100 Seed weight with magnitude of 23.20*%. The range of the standard heterosis varied from 0.17 to 16.72. The cross P3x P5 exhibited and standard heterosis for shelling % with magnitude of was 35.78*%. The cross P1 xP3 showed significant and effective heterosis for seed yield per cob with magnitude of 39.32*% similarly, cross i.e. P5 xP7 performed significant and effective heterosis for seed yield per plant with magnitude of 49.55*%. The range of the heterosis varied from -14.69 to 49.55* (Al, Naggar A. M. M., *et al.,* 2016).

CONCLUSION

In present investigation, parent P1, P2 and P4 were found to be good general combiner for yield and its contributing traits. The crosses viz., P4x P3, P3x P1, P5x P3 and P7 x P5 were found with major SCA effects for seed yield per plant and its contributing characters. In overall, the results indicated that P1, P2 and P4 were the most desirable parents as they had a high GCA effect on most of the characters. Among F_1 crosses, P4x P3, P3x P1, P5x P3 and P7 x P5 were found to be desirable for yield and yield attributes. Heterosis studies for various characters revealed that among the twenty eight crosses, maximum heterotic effects were exhibited by the cross combinations viz; P1 x P6, P2 x P7, P2x P5, P1 x P2, P3x P4, P5 x P7 and P3 x P5 which had high performance and high heterotic effects for improving the yield contributing characters along with earliness and also with significant SCA effects for yield characters. Thus, these crosses could be recommended for the commercial exploitation of heterosis for component traits and could also acquire segregates for higher grain yield in future breeding programmes.

REFERENCES

Al, Naggar A. M. M., Atta M. M. M., Ahmed M. A. and Younis A. S. M., (2016). Heterosis and combining ability of maize (*Zea mays* L.) grain protein, oil and starch content and yield as affected by water stress. *Science domain International*. 4(4): 2454-7077.

Bekele Atnafua and Rao T. Nageshwar (2014). Estimates of heritability, genetic advance and correlation study for yield and its attributes in maize (*Zea mays* L.). *Journal of Plant Sciences*. 2(1): 1-4.

Gazal Asima, Nehvi FA, Lone Ajaz Ahmad and Ahmad Dar Zahoor. (2017). Assessment of genetic variability of a set of maize inbred lines for drought tolerance under temperate conditions. *International Journal Current Microbiology Applied Sciences*. 6(12): 2380-2389.

Griffing, D. (1956). Concept of general & specific combining ability in relation to diallel crossing systems. *Austrian Journal Biological Sciences.* 9: 463-493.

Kumar Ankit, Vyas RP, Tomat Amit and Singli Makak. (2017). Selection of best germplasm on the basis of selection parameters (heritability, genetic advance & correlation) in maize (*Zea mays* L). *Journal of Pharmacognosy and Phytochemistry*. 6 (1): 479-481.

Lim S.M. and White D.G.(1978). Estimates of hetrosis

and combining ability for resistance of maize to colletotrichum graminicola. *Phytopathology*. 68:1336-1342.

Matin Islam Quamrul Mohammad, Rasol Gulam Md., Islam Amilum A.K.M., Mian Khaleque AK., Ivy Akter Nasrin, Jalal Uddin Ahmad (2017). Combining ability and heterosis in maize (*Zea mays* L.). *American Journal of Biological Science*. 4: 84-90.

Nataraj, Shahi, JP and Vandana, D. (2014). Estimates of variability, heritability and genetic advance in cerain inbreds of maize (*Zea mays* L.). *International Journal of Applied Biology and Pharmaceutical Technology*. **5**(1):257-260.

Patil SM., Kumar Kamlesh, Jhakhar Singh Dan, Rai Abhijt, Borle U.M. and Singh Pargat (2016). Studies on variahility, heritability, genetic advance and correlation in maize (*Zea mays* L.). *International Journal of Agriculture, Environment and Biotechnology*. **9**(6):1103-1108.

Rojas BA, Sprague GF (1952). A comparison of variance components in corn yield trials: III. General and specific combining ability and their interaction with locations and years. *Agronomy Journal*. 44: 462–466.

Sprague, G.F. and Tatum, L.A. (1942). General verses specific combining ability in crosses of corn. *Journal American Society Agm.* 34:923-932.

Shull, G.H.(1914), What is heterosis ?, *Genetics*. 33:439-446.

Sravanti K., Devi I. Swarnalatha, Sudarshan MR, and Supriya K.(2017). Evaluation of maize genotypes (*Zea mays* L.) for variability, heritability and genetic advance. *International Journal Current Microbiology and Applied Sciences.* 6 (1): 2227-2232.