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Combining Ability and Gene Action Analysis for Yield and Yield Attributing Traits in Kharif Maize (*Zea mays* L.)

A.A. Patel[1*], J.M. Patel[2], R.M. Patel[3], K.D. Gajjar[1], D.R. Chaudhary[4] and N.V. Soni[1]

[1]*Dept. of Genetics and Plant Breeding, C.P. College of Agriculture, SDAU, Sardarkrushinagar-385 506*

[2]*Wheat Research Station, Sardar krushinagar Dantiwada Agricultural University, Vijapur-382 870*

[3]*Maize Research Station, Sardar krushinagar Dantiwada Agricultural University, Bhiloda-383 245*

[4]*Agriculture Research Station, Sardar krushinagar Dantiwada Agricultural University, Ladol-382 840*

***Email :** aniket281298@gmail.com*

Abstract

A diallel mating design excluding reciprocal was practised among 8 diverse parents and their 28 crosses to access the gene action and combining ability in maize during *kharif* 2021. Analysis of variance revealed that, parents were found significant for all the characters under study except for leaf area, cob length, cob girth, number of kernel row per cob and 100 grain weight. This finding indicated the presence of sufficient amount of genetic variability in parents for grain weight and its component traits. The variance due to hybrids were found significant for all the traits except for cob girth and starch content indicating that genetic variation was existing in the hybrids. Further the variance due to parents *vs*. hybrids was found significant for all the characters under study except for anthesis silking interval, leaf area, starch content and protein content which suggested the existence of difference between parents and hybrids. Variance due to check vs. hybrids was found significant for days to tasseling, days to silking and grain weight per plant only, which indicates lesser difference between check and hybrid for remaining traits. Parent BLD 29 was found good general combiner for grain weight per plant and other yield attributing characters. However, the parents BLD 126 and WNC 40406 had favourable genes for flowering traits. The estimates of sca effects showed that top five hybrids viz BLD 29 × BLD 124, WNC 32867 × WNC 40449, WNC 32867 × WNC 40406, BLD 30 × WNC 32588 and BLD 29 × WNC 32867 were exhibited maximum positive significant sca effect for grain weight per plant and other contributing traits. Thus, best specific combiners should be exploited to develop commercially high yielding hybrids. The ratio of ó²gca and ó²sca was found less than unity for most the characters, which revealed prime role of non additive gene action for expression of the characters under study.

Key words : *Maize, diallel, gene action, combining ability.*

Introduction

Maize (*Zea mays* L.) is one of world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. Maize is the third most important food grain in India after wheat and rice. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons. Being a C4 plant, it is physiologically more efficient and resilient to changing climatic conditions with wider genetic variability and also able to grow successfully throughout the world over a wide range of environmental conditions covering tropical, subtropical and temperate agro-climatic conditions. Selection of appropriate breeding programme for maximum genetic improvement is based on relative values of general and specific combining abilities. Combining ability is one of the powerful tools in identifying the best combiner that may be used in crosses either to exploit heterosis for accumulate fixable genes. Variance due to GCA is an indicator for extent of additive gene action while variance due to SCA shows the extent of non additive gene action. Additive and non additive types of gene action are very important for genetic expression of yield and related traits. The given experiment was performed to study general combining ability of parents as well as specific combining ability of hybrids for different yield attributing characters and also to explore the nature with relative magnitude of gene action for different traits.

Material and Methods

Plant materials : The experimental material consisted 37 entries having 28 hybrids produced from diallel mating design excluding reciprocals which involved 8 parental lines with a standard check GDYMH 101.

Field experiments : The above presented experimental material was evaluated in Randomized Block Design with three replications in *kharif*-2021 at Maize Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhiloda. Each entry was grown in 1 row with 4 m in length.The spacing of 60 cm between the rows and 20 cm between the plant was maintained. All recommended agronomic practices were followed for raising a good maize crop. Different fifteen observations

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Table-1 : Analysis of variance (Mean square) for parents and hybrids for grain yield and its components characters in maize.

Source of variation	d.f.	DT	DS	ASI	LA	PEH	PH	CL	CG
Replications	2	0.10	0.27	0.33	14763.88	85.20	374.81	6.94	0.823
Genotypes (G)	36	3.53**	3.16**	0.41**	90361.76**	185.92**	415.83**	7.65**	0.66**
Parents (P)	7	3.31**	4.64**	0.66**	37063.26	201.79**	573.45**	4.14	0.632
Hybrids (H)	27	2.05**	1.58**	0.35*	107341.25**	167.78**	318.96**	8.51**	0.515
Parents vs. Hybrids	1	44.70**	37.46**	0.32	52203.28	671.06**	2312.76**	13.26*	5.63**
Check vs. Hybrids	1	3.66**	1.37*	0.55	43163.34	79.40	30.97	3.18	0.08
Error	72	0.18	0.27	0.18	38682.56	42.07	155.56	3.05	0.34

Table-1 Cont....

Source of variation	d.f.	NKRPC	NKPR	CWPP	GWPP	100 GW	SC	PC
Replications	2	0.03	10.63	21.41	47.27	0.87	1.41	0.005
Genotypes(G)	36	1.29**	24.70**	273.40**	175.67**	6.82**	0.82*	0.100**
Parents (P)	7	0.43	16.02**	185.73*	145.25**	0.94	1.29*	0.105*
Hybrids (H)	27	1.50**	25.19**	226.86**	125.72**	6.77**	0.75	0.102**
Parents vs. Hybrids	1	2.60*	91.62**	2229.42**	1717.33**	52.22**	0.35	0.112
Check vs. Hybrids	1	0.48	5.46	187.59	195.38*	3.91	0.008	0.001
Error	72	0.37	5.16	67.78	38.48	2.26	0.495	0.040

were recorded on days to tasseling, days to silking, anthesis-silking interval, leaf area (cm^2), primary ear height (cm), plant height (cm), cob length (cm), cob girth (cm), number of kernel row per cob, number of kernel per row, cob weight per plant (g), grain weight per plant (g), 100 grain weight (g), starch content (%), protein content (%). The data of observations were recorded from randomly selected 5 plants from each genotype in each replication.

Statistical analysis : The mean performance of each parents and hybrids was subjected to statistical analysis. Analysis of variance to test the significance for each character was carried out as per methodology given by Panse and Sukhatme (1985)[11]. Combining ability analysis for parents and their crosses (Diallel method excluding reciprocals with numerical approach) by Griffing (1956[a])[4]and Griffing (1956[b]).

Results and Discussion

The results of analysis of variance (Table-1) revealed that mean square values due to genotypes were found significant for all the characters, indicating the presence of sufficient amount of genetic variability in the material under study. The variance due to parents were found significant for the characters like; days to tasseling, days to silking, anthesis-silking interval, primary ear height, plant height, number of kernel per row, cob weight per plant, grain weight per plant, starch and protein percentages.The mean square due to hybrid indicated significant difference for all the traits under study except cob girth, starch content. Mean sum of squares due to parents vs hybrids showed significant differences for characters under study viz; day to tasseling, days to silking, primary ear height, plant height, cob length, cob girth, number of kernel row per cob, number of kernel per row, cob weight per plant, grain weight per plant, 100 grain weight. which suggested the existence of differences between parents and hybrids leading to manifestation of heterosis.

Variances for general combining ability and specific combining ability along with gene action for different traits in maize is presented in Table 2. GCA and SCA variance were found significant for all the characters under study except, 100 grain weight andstarch content. These results indicated that both additive and non additive gene effects were important for inheritance of characters under study. While for 100 grain weight, only SCA variance was significant indicating role of only non additive gene action. While in case of starch content, GCA and SCA variance were non significant therefore, there may be a role of environment in governing of this trait. The ratio of ^{2}gca / ^{2}sca for all the characters under study was found less than unity. Therefore, prime role of non-additive gene action was observed for inheritance of most the traits. So, exploitation of these traits for improvement of yield through heterosis breeding may be beneficial. The results were in accordance with the findings of Amiruzzaman et al., (2013)[1], Attia et al., (2015)[2], Talukder et al., (2016) [14], Sandesh et al., (2018) [13], Mogesse et al., (2020)[10],Matin et al., (2016)[9],Hammadi and Abed (2018)[6], Hassan et al., (2019)[7],Lahane et al., (2014)[8], Patel and Kathiriya (2016)[12], Darshan and Marker (2019)[3], Venkadeswaran et al., (2022).

Among all the parental genotypes under study, parent BLD 29 was recorded as good general combiner for grain weight per plant. BLD 29 was also found promising for other traits like anthesissilking interval (ASI), primary ear height, plant height, cob length, number of

Table-2 : Variances for general combining ability and specific combining ability along with gene action for different traits in maize.

Source of variation	d.f.	DT	DS	ASI	LA	PEH	PH	CL	CG	NKRPC	NKPR	CWPP	GWPP	100 GW	SC	PC
GCA	7	0.92**	1.18**	0.20**	30216.69*	105.69**	241.74**	3.54**	0.30*	0.37**	12.86**	107.35**	60.88**	0.59	0.32	0.056**
SCA	28	1.23**	1.04**	0.12*	30658.65**	52.31**	117.40**	2.35**	0.20*	0.45**	7.30**	88.09**	57.74**	2.72**	0.27	0.028**
Error	70	0.05	0.09	0.06	13191.65	14.14	51.71	1.04	0.11	0.12	1.76	22.46	12.89	0.76	0.16	0.013
^{2}gca		0.08**	0.10**	0.01**	1702.50*	9.15**	19.00**	0.25**	0.01*	0.02**	1.10**	8.48**	4.79**	-0.01#	0.01	0.004**
^{2}sca		1.17**	0.94**	0.06*	17467.00**	38.16**	65.69**	1.31**	0.09*	0.32**	5.54**	65.63**	44.84**	1.96**	0.10	0.015**
^{2}gca/ ^{2}sca		0.06	0.10	0.16	0.09	0.23	0.28	0.19	0.11	0.06	0.19	0.12	0.10	-0.005#	0.1	0.26

Table-3 : Estimation of general combining ability effect associated with each parent for various maize characters.

Parents	DT	DS	ASI	LA	PEH	PH	CL	CG	NKRPC	NKPR	CWPP	GWPP	100 GW	SC	PC
BLD29	0.21**	-0.02	-0.23**	14.36	-5.26**	-7.05**	0.91*	0.05	-0.02	1.51**	5.63**	4.22**	0.08	0.32*	0.15**
BLD30	-0.22**	-0.12	0.11	-26.07	-3.87**	-4.21	-0.29	0.03	-0.19	-0.07	0.40	1.16	-0.03	0.15	0.07*
WNC32588	-0.22**	-0.05	0.17*	-35.28	2.38*	8.03**	0.19	-0.25*	-0.05	0.73	2.50	1.68	-0.13	-0.11	-0.05
WNC32867	0.08	0.15	0.07	25.85	1.77	1.55	-0.16	-0.13	0.26*	0.10	-0.24	-0.28	-0.13	-0.05	-0.03
BLD124	0.58**	0.72**	0.14	-6.13	0.79	-4.38**	-0.51	0.30**	0.27*	-1.21**	-2.76	-1.91	0.01	0.01	0.01
BLD126	-0.36**	-0.48**	-0.13	-97.76**	1.86	1.15	-0.93**	-0.09	0.01	-1.89**	-5.23**	-4.04**	-0.42	0.07	-0.05
WNC40406	-0.16*	-0.22*	-0.06	40.79	-1.64	1.35	0.24	0.17	-0.29**	-0.19	-1.15	-0.76	0.24	-0.21	-0.02
WNC40449	0.11	0.02	-0.09	84.23*	3.97**	3.55	0.57	-0.09	0.01	1.03*	0.85	-0.08	0.37	-0.19	-0.08*
S.E. (gi)	0.07	0.09	0.07	33.97	1.11	2.12	0.30	0.10	0.10	0.39	1.40	1.06	0.25	0.12	0.03
Range	-0.36 to 0.58	-0.48 to 0.72	-0.23 to 0.17	-97.76 to 84.23	-5.26 to 3.97	-7.05 to 8.03	-0.93 to 0.91	-0.25 to 0.30	-0.29 to 0.27	-1.89 to 1.51	-5.23 to 5.63	-4.04 to 4.22	-0.42 to 0.37	-0.21 to 0.32	-0.08 to 0.15

Table-4 : Estimation of general combining ability effect associated with each parent for various maize characters.

Sr. No.	Hybrids	DT	DS	ASI	LA	PEH	PH	CL	CG
1.	BLD29 × BLD30	-1.20**	-1.18**	0.01	179.64*	-1.19	-5.39	0.43	0.28
2.	BLD29 × WNC32588	0.14	0.09	-0.05	99.64	0.49	-1.37	0.22	0.22
3.	BLD29 × WNC32867	0.84**	0.89**	0.05	155.28	-3.30	-1.03	2.16**	0.24
4.	BLD29 × BLD124	-1.66**	-1.35**	0.31	230.94*	5.42	4.17	1.92*	0.41
5.	BLD29 × BLD126	-1.06**	-0.48	0.58**	-172.43	4.21	8.97	-0.26	-0.10
6.	BLD29 × WNC40406	1.07**	0.92**	-0.15	-185.75*	0.05	4.71	-1.57	-0.70*
7.	BLD29 × WNC40449	0.47*	0.35	-0.12	164.36	-8.36**	-4.02	1.44	0.33
8.	BLD30 × WNC32588	-0.43*	-0.48	-0.05	150.84	14.51**	25.99**	2.68**	0.24
9.	BLD30 × WNC3867	-1.06**	-0.35	0.71**	-70.18	-0.09	1.20	-1.17	-0.10
10.	BLD30 × BLD124	-0.23	-0.58*	-0.35	-189.13*	6.50*	10.20	-1.42	0.37
11.	BLD30 × BLD126	-0.30	-0.05	0.25	-118.59	-3.24	-6.73	-0.06	0.45
12.	BLD30 × WNC40406	-0.50*	-0.65**	-0.15	-23.71	-5.27	-9.40	-1.17	-0.11
13.	BLD30 × WNC40449	1.24**	1.45**	0.21	144.54	2.72	5.54	0.24	-0.45
14.	WNC32588 × WNC32867	-0.40*	-0.75**	-0.35	91.07	0.26	1.69	0.62	0.57*
15.	WNC32588 × BLD124	-1.56**	-0.98**	0.58**	58.48	-0.55	-2.64	0.44	0.04
16.	WNC32588 × BLD126	-0.30	-0.11	0.18	-126.55	-3.96	-2.77	-2.01*	-0.24
17.	WNC32588 × WNC40406	-0.50*	-0.71**	-0.22	82.18	-3.26	0.63	-0.05	-0.17
18.	WNC32588 × WNC40449	0.57**	0.05	-0.52**	-428.28**	-9.60**	-14.23*	-2.58**	-0.24
19.	WNC32867 × BLD124	-0.53**	-0.85**	-0.32	117.09	8.92**	16.50**	0.18	0.66*
20.	WNC32867 × BLD126	-0.26	-0.31	-0.05	27.02	5.45	7.10	0.20	0.38
21.	WNC32867 × WNC40406	-0.13	-0.25	-0.12	37.64	8.95**	11.17	2.43**	0.59*
22.	WNC32867 × WNC40449	0.27	0.19	-0.09	130.23	12.47**	17.97**	1.37	-0.05
23.	BLD124 × BD126	0.57**	0.12	-0.45*	-266.36**	6.77*	4.23	-0.71	0.02
24.	BLD124 × WNC40406	-0.30	0.19	0.48*	-32.52	-2.87	-3.90	-0.28	0.02
25.	BLD124 × WNC40449	-1.56**	-1.71**	-0.15	24.40	-2.87	-0.36	-0.14	0.08
26.	BLD126 × WNC40406	-0.70**	-0.61*	0.08	37.28	-1.81	-3.30	-0.46	0.14
27.	BLD126 × WNC40449	-0.96**	-0.51*	0.45*	100.95	5.45	2.57	1.21	-0.13
28.	WNC40406 × WNC40449	-1.16**	-1.11**	0.05	110.97	1.49	1.77	1.57	0.67*
S.E.(Sij) ±		0.1	0.24	0.19	90.59	2.96	5.67	0.80	0.27
Range		-1.66 to 1.24	-1.71 to 1.45	-0.52 to 0.71	-428.28 to 230.94	-9.6 to14.51	-14.23 to 25.99	-2.58 to 2.68	-0.70 to 0.67
Positive significant		6	3	5	2	6	3	5	2
Negative significant		14	12	2	4	14	12	2	4
Total significant		20	15	7	6	20	15	7	6

Table-4 Cont…..

Table-4 Cont…..

Sr. No.	Hybrids	NKRPC	NKPR	CWPP	GWPP	100 GW	SC	PC
1.	BLD29 × BLD30	-0.19	0.93	-3.21	-3.61	-0.56	-0.87**	-0.14
2.	BLD29 × WNC32588	-0.34	-0.34	-5.98	-4.32	-1.46*	0.20	0.24**
3.	BLD29 × WNC32867	-0.11	2.16*	6.96	8.11**	1.87**	-0.12	-0.06
4.	BLD29 × BLD124	0.94**	5.01**	21.68**	16.27**	1.41*	-0.06	0.38**
5.	BLD29 × BLD126	0.27	0.69	6.55	4.79	0.51	0.67*	-0.02
6.	BLD29 × WNC40406	-1.03**	-1.75	-4.19	-3.42	-1.49*	0.98**	-0.09
7.	BLD29 × WNC40449	1.21**	2.23*	10.94**	8.03**	1.71*	-0.19	-0.02
8.	BLD30 × WNC32588	0.63*	3.65**	11.58**	8.74**	4.31**	0.06	0.13
9.	BLD30 × WNC3867	0.33	-0.65	-0.75	-0.17	-2.03**	0.20	0.08
10.	BLD30 × BLD124	-0.35	-2.01	-2.23	-1.14	-0.83	0.29	0.04
11.	BLD30 × BLD126	0.31	-1.13	0.51	2.85	0.94	0.24	-0.09
12.	BLD30 × WNC40406	-0.06	-0.30	0.10	0.84	0.61	0.60	-0.15
13.	BLD30 × WNC40449	-0.35	1.01	2.63	1.03	1.14	0.19	-0.16
14.	WNC32588 × WNC32867	0.98**	0.87	1.75	0.52	0.41	-0.23	-0.28**
15.	WNC32588 × BLD124	-1.17**	1.99	4.87	3.01	1.27	-0.05	0.05
16.	WNC32588 × BLD126	-0.23	-4.07**	-4.19	-4.39	1.04	-1.02**	-0.01
17.	WNC32588 × WNC40406	-0.47	1.09	3.60	3.33	-0.96	0.56	-0.13
18.	WNC32588 × WNC40449	-0.10	-3.79**	-13.00**	-8.82**	-2.09**	0.83*	-0.12
19.	WNC32867 × BLD124	0.39	1.55	4.68	3.64	0.27	-0.42	0.05
20.	WNC32867 × BLD126	0.26	1.83	3.62	3.30	-0.63	-0.12	0.29**
21.	WNC32867 × WNC40406	1.22**	3.46**	10.21**	9.22**	2.37**	0.22	0.13
22.	WNC32867 × WNC40449	-0.14	2.84**	11.87**	9.61**	1.57*	-0.05	0.04
23.	BLD124 × BD126	0.51	-1.59	-3.06	0.66	-1.43*	-0.32	0.00
24.	BLD124 × WNC40406	-0.13	-1.09	-1.94	-1.69	1.24	0.08	0.04
25.	BLD124 × WNC40449	0.65*	-0.51	-3.47	-2.23	1.11	-0.67*	0.05
26.	BLD126 × WNC40406	-0.26	-1.48	-5.27	-4.23	0.34	-0.06	-0.08
27.	BLD126 × WNC40449	-0.29	1.43	5.93	4.89	-0.13	0.20	-0.12
28.	WNC40406 × WNC40449	-0.13	1.79	7.79*	4.81	-0.13	-0.28	0.32**
S.E.(Sij) ±		0.28	1.04	3.73	2.83	0.68	0.32	0.09
Range		-1.17 to 1.22	-4.07 to 5.01	-13.00 to 21.68	-8.82 to 16.27	-2.09 to 4.31	-1.02 to 0.98	-0.28 to 0.38
Positive significant		6	6	6	6	6	2	4
Negative significant		2	2	1	1	5	3	1
Total significant		8	8	7	7	11	5	5

kernel per row, cob weight per plant, starch content and protein content. For days to tasseling, BLD 126, BLD 30, WNC 32588, WNC 40406 were found good general combiner. While, parents BLD 126 and WNC 40406 were found good general combiner for days to silking. Parental line WNC 40406 was found good general combiner for leaf area. For the cob girth, BLD 124 was found good general combiner. Parents BLD 124 and WNC 40406 both were found good general combiners for number of kernel row per cob (Table-3). These parents have resulted in the production of superior single cross hybrids. Hence these parental genotypes could be utilised in future breeding programmes for exploitation of hybrid vigor and also to generate a greater number of desirable segregants for grain weight and yield attributing characters.

The crosses BLD 29 × BLD 124 (16.27), WNC 32867 × WNC 40449 (9.61), WNC 32867 × WNC 40406 (9.22), BLD 30 × WNC 32588 (8.74), BLD 29 × WNC 32867 (8.11) and BLD29×WNC40449 (8.03) were reported with high and significant specific combining ability effects for grain weight per plant (Table-4).These crosses may be tested under multi locations and can be developed as commercial hybrids or advanced for the isolation of transgressive segregants or homozygous lines for use in further breeding programme.

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