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Genetic Studies of the Kernel Yield and Attributing Traits of Single Cross Hybrid in Yellow Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RAG and NVS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SMC and SDS managed the analyses of the study. Author PCP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize (*Zea mays* L.) is one of the emerging crops having its position in top three cereal crops throughout the world in area and production. In this study, six lines and five testers were crossed in Line × Tester mating design to produce 30 single cross hybrids. The hybrids, their parents along with standard check GAYMH-1 were evaluated in Randomized Block Design, with three replications for yield and attributing traits. The results indicated non-additive gene action found to be predominant for inheritance of flowering traits while, kernel yield, cob yield, cob girth and cob length showed solely non-additive gene actions. Among the parents, BLD-250, BLD-221, BLD-210 and BLD-107 reported as best combiners for yield and attributing traits. The hybrids, Z 488-4 × VL-1032 and BLD-250 × BLD-46 reported good specific combining ability, higher magnitude of heterobeltiosis and standard heterosis for kernel yield per plant. Whereas, the cross combination, WNC 18242 × VL-1032 reported desirable *SCA* and heterobeltiosis for flowering and maturity traits. The cross

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combinations found superior for kernel yield and related traits includes both parents with either good or average general combiners. These combinations could be utilized in near future for identifying superior genotypes with better kernel yield performance and/or earliness.

Keywords: Zea mays L.; combining ability; gene action; heterosis.

1. INTRODUCTION

Maize (*Zea mays* L.; 2n=2x=20) is one of the most important cereal crops as a food for human. It secured its position among one of the most versatile emerging crops with wider adaptability under varied agro-climatic conditions. Across the globe, it is known as queen of cereals because it possesses the highest genetic yield potential as compared to other cereal crops. It is one of three important cereals in India and world. It is cultivated throughout the year in many states of the country for various purposes including grain, fodder, green cobs, sweetcorn, babycorn, popcorn.

Being highly cross pollinated crop, the scope for the exploitation of hybrid vigour will depend on the magnitude and direction of heterosis and the type of gene action involved for the trait. Exploitation of hybrid vigour in maize has gained much significance in view of its tremendous yield increase. In maize, appreciable percentage of heterosis for grain yield have reported by [1]. Combining ability analysis is tool to identify potential inbred lines based on the nature of gene action and genetic architecture of quantitative traits. The concept of combining ability has been widely adopted in maize improvement [2]. The Line × Tester analysis of crosses and parents is the most important statistical genetical technique since it provides information on the general combining ability (GCA), specific combining ability (SCA) of genotypes and type of predominant gene action [3]. There is a strong possibility to develop hybrids which are having superior grain yield and better quality. Hence, the present study has been undertaken to assess gene action for flowering, grain yield and attributing traits and to identify best general combiner parents and best hybrids having high economic heterosis to use in the future breeding programme.

2. MATERIALS AND METHODS

2.1 Genotypes

Six inbred lines *viz*., BLD-250, BLD-221, BLD210, WNC 18242, Z 488-4 and BLD-188 as females and five inbred lines *viz*., BLD-107, BLD-46, IMR-70, IMR-48 and VL-1032 as males were crossed in a Line × Tester fashion to produce 30 single cross hybrids during the Rabi 2016-17.

2.2 Field Experiment

The hybrids, their parents and standard check *i.e.*, GAYMH-1 were raised in Randomized Block Design with three replications during *kharif* 2017 at Maize Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhiloda (Gujarat). The five representative plants were taken from each plot and data were recorded for kernel yield and its components traits *viz*. plant height (cm), cob height (cm), cob length (cm), cob girth (cm), number of kernel rows per cob, number of kernels per row, 100 kernels weight (gm) and shelling (%). Whereas days to tasseling, days to silking, Anthesis Silking Interval (ASI) and days to dry husk were recorded on per plot basis. The kernel yield for each entry estimated with modification of method mentioned by [4] by reducing grain moisture content to 15 percent with stepwise formula. (A) grain yield at observed grain moisture content [Ear yield gm/plant at harvest × shelling proportion (%)], (B) grain dry matter content = 1-moisture percent at harvest, (c) grain yield at 15% grain moisture content = [(grain yield at observed grain moisture content x grain dry matter content)/0.85], (d) grain yield at 15 % grain moisture content = [(grain yield at 15% grain moisture content)/100].

2.3 Statistical Analysis

The mean data were analysed statistically. The analysis of variance was carried out as per the procedure suggested by [5], combining ability variance analysis by [6], estimation of heterobeltiosis by [7] and economic heterosis as per [8].

3. RESULTS AND DISCUSSION

Analysis of variance indicated significant differences among the genotypes for all the morphological traits deliberated. It indicated that experimental genotypes had sufficient genetic

Table 1. Analysis of variance for combining ability of yield and its attributing traits in yellow maize

Source of variation	df	Days to Tasseling	Days to silking	ASI	Days to dry husk	Plant height	Cob height	Cob length	Cob girth	Number of kernel rows per cob	Number of kernels per row	100-kernal weight	Cob yield per plant	Kernel yield per plant	Shelling (%)
Replicates	2	0.30	0.74	0.14	1.24	9.01	0.03	0.80	2.40	2.06	6.28	1.11	29.42	75.95	81.26
Crosses	29	13.81*	17.13*	1.02*	18.28**	746.42**	365.13*	7.06*	2.28*	4.97*	28.03*	37.22*	1351.59*	936.35*	22.24
Female Effect	5	43.86**	50.81**	1.40	51.06**	2813.15**	1437.03*	8.70	0.06	9.55	36.51	8.12	1511.48	1025.40	35.97
Male Effect	4	8.14	7.03	1.67	10.25	356.14	44.07	2.86	3.19	2.58	29.05	100.43*	437.41	469.08	19.04
Female × male Eff.	20	7.43*	10.73*	0.79*	11.70**	307.79**	161.37*	7.49*	2.65*	4.31*	25.71*	31.85*	1494.46*	1007.54*	19.45
Error	58	0.89	0.87	0.13	0.90	2.46	1.91	0.21	0.25	0.54	2.06	4.80	120.60	92.43	18.16
δ^2 Female		2.87**	3.33**	0.08	3.35**	187.33**	95.67**	0.56	-0.02	0.60	2.29	0.20	93.35	62.71	1.32
δ^2 Male		0.41	0.34	0.08	0.52	19.61	2.34	0.15	0.16	0.11	1.50	5.29*	18.12	21.35	0.16
δ^2 GCA		1.52**	1.70**	0.08**	1.80**	95.85**	44.77**	0.34	0.08	0.33*	1.86*	2.98*	52.32	40.15	0.68*
δ^2 SCA		2.19**	3.30**	0.21**	3.61**	101.53**	53.15**	2.42**	0.78**	1.24**	7.87**	8.90**	461.09**	307.60**	1.07
δ^2 GCA / δ^2 SCA		**0.69**	**0.52**	**0.39**	**0.50**	**0.94**	**0.84**	**0.14**	**0.10**	**0.27**	**0.24**	**0.33**	**0.11**	**0.13**	**0.64**

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

Table 2. The three top ranking hybrids with respect to SCA effects and heterosis over better parent and standard check GAYMH-1

Characters	Hybrids with high SCA effects		Hybrids with highest heterobeltiosis		Hybrids with highest economic heterosis	
Days to tasselling	BLD-221 × BLD-107	-2.34**	BLD-188 × BLD-46	-9.62**	BLD-221 × BLD-107	-10.19
	WNC 18242 × VL-1032	-2.30**	BLD-188 × VL-1032	-9.62**	BLD-221 × BLD-46	-10.19
	BLD-221 × BLD-46	-2.29**	BLD-188 × IMR-48	-8.97**	BLD-188 × BLD-46	-10.19
Days to silking	WNC 18242 × VL-1032	-3.40**	BLD-188 × VL-1032	-10.91**	BLD-221 × BLD-107	-10.37
	Z 488-4 × IMR-70	-2.60**	WNC 18242 × VL-1032	-8.77**	BLD-221 × BLD-46	-10.37
	BLD-221 × BLD-46	-2.50**	BLD-188 × IMR-48	-8.64**	BLD-188 × IMR-70	-10.37
ASI	WNC 18242 × VL-1032	-1.10**	WNC 18242 × VL-1032	-66.67**	BLD-210 × VL-1032	-57.08
	Z 488-4 × BLD-107	-0.57*	BLD-210 × VL-1032	-50.00**	WNC 18242 × VL-1032	-57.08
	Z 488-4 × IMR-70	-0.51*	BLD-221 × VL-1032	-44.44**	BLD-221 × VL-1032	-28.47
Days to dry husk	WNC 18242 × VL-1032	-3.90**	BLD-188 × VL-1032	-7.32**	BLD-221 × BLD-107	-10.59
	BLD-221 × BLD-46	-2.51**	WNC 18242 × VL-1032	-6.17**	BLD-221 × BLD-46	-10.59
	Z 488-4 × IMR-70	-2.38**	BLD-221 × BLD-46	-5.95**	BLD-188 × IMR-70	-10.59
Plant height	BLD-221 × BLD-46	-15.96**	BLD-188 × BLD-107	-10.94**	BLD-188 × BLD-107	-13.52**
	BLD-221 × VL-1032	-12.50**	BLD-188 × IMR-48	-9.51**	Z 488-4 × BLD-107	-5.24**
	WNC 18242 × IMR-48	-11.93**	BLD-188 × IMR-70	-8.72**	BLD-221 × BLD-46	-5.99**

Characters	Hybrids with high SCA effects		Hybrids with highest heterobeltiosis		Hybrids with highest economic heterosis	
Cob height	BLD-221 × VL-1032	-12.36**	BLD-188 × IMR-70	-29.27**	BLD-188 × IMR-70	-26.49
	WNC 18242 × IMR-48	-10.82**	BLD-188 × BLD-46	-25.28**	BLD-188 × BLD-46	-25.03
	Z 488-4 × BLD-107	-8.90**	BLD-221 × VL-1032	-16.44**	BLD-221 × VL-1032	-24.13
Cob length	Z 488-4 × VL-1032	1.36**	Z 488-4 × IMR-48	31.65**	BLD-250 × BLD-46	12.9
	BLD-188 × IMR-70	1.35**	Z 488-4 × BLD-107	30.84**	WNC 18242 × BLD-46	12.02
	BLD-250 × BLD-46	1.31**	Z 488-4 × VL-1032	27.89**	Z 488-4 × VL-1032	11.58
Cob girth	Z 488-4 × VL-1032	1.48**	WNC 18242 × BLD-107	23.07**	BLD-250 × BLD-107	19.48
	BLD-250 × BLD-107	1.11**	Z 488-4 × BLD-107	15.14**	Z 488-4 × VL-1032	18.28
	BLD-250 × BLD-46	1.00**	Z 488-4 × VL-1032	11.82**	WNC 18242 × BLD-107	15.57
Number of kernel rows per cob	BLD-221 × IMR-48	2.28**	WNC 18242 × BLD-107	21.16**	WNC 18242 × BLD-107	10.63
	WNC 18242 × BLD-107	1.41**	BLD-188 × VL-1032	13.61**	BLD-250 × IMR-70	9.66
	Z 488-4 × VL-1032	1.33**	BLD-188 × BLD-46	12.57*	BLD-250 × BLD-107	7.73
Number of kernels per row	BLD-188 × VL-1032	5.66**	Z 488-4 × BLD-107	21.92**	BLD-250 × BLD-46	28.11**
	WNC 18242 × BLD-46	3.21**	WNC 18242 × BLD-107	16.82**	WNC 18242 × BLD-46	24.41**
	Z 488-4 × BLD-107	2.98**	BLD-250 × IMR-48	15.57**	BLD-250 × IMR-48	24.70**
100-kernal weight	BLD-221 × VL-1032	4.31**	BLD-250 × BLD-46	10.75	BLD-221 × VL-1032	17.01**
	BLD-250 × BLD-46	4.14**	BLD-221 × VL-1032	10.38	BLD-188 × BLD-107	13.01**
	BLD-221 × BLD-46	3.81**	BLD-250 × BLD-107	5.88	Z 488-4 × VL-1032	9.01**
Cob yield per plant	Z 488-4 × VL-1032	33.03**	Z 488-4 × VL-1032	56.36**	BLD-250 × BLD-46	103.03**
	BLD-188 × IMR-70	25.10**	BLD-250 × BLD-107	50.20**	BLD-250 × BLD-107	101.09**
	BLD-188 × VL-1032	24.26**	BLD-188 × VL-1032	49.83**	Z 488-4 × VL-1032	82.36**
kernel yield per plant	Z 488-4 × VL-1032	27.32**	Z 488-4 × VL-1032	58.44**	BLD-250 × BLD-46	124.63**
	BLD-250 × BLD-46	23.36**	BLD-188 × VL-1032	56.69**	BLD-250 × BLD-107	118.34**
	BLD-188 × VL-1032	19.82**	BLD-250 × BLD-46	54.84**	Z 488-4 × VL-1032	88.99**
Shelling (%)	WNC 18242 × VL-1032	4.1	WNC 18242 × VL-1032	6.2	BLD-250 × BLD-46	10.64**
	BLD-221 × IMR-48	3.36	BLD-250 × BLD-46	4.79	BLD-250 × BLD-107	8.57**
	BLD-250 × BLD-46	3.13	BLD-221 × IMR-48	4.24	BLD-210 × BLD-46	7.87**

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

Table 3. General combining ability (*GCA*) effects for various characters in yellow maize

Characters	Days to tasseling	Days to silking	ASI	Days to dry husk	Plant height	Cob height	Cob length	Cob girth	Number of kernel rows per cob	Number of kernels per row	100-kernal weight	Cob yield per plant	Kernel yield per plant	Shelling (%)
Line (Female)														
BLD-250	0.10	0.08	-0.02	0.36	23.46**	16.54**	0.33*	0.08	1.19**	2.25**	0.24	17.25**	15.94**	1.44
BLD-221	-0.77**	-1.06**	-0.29**	-1.04**	-2.50**	-3.41**	-0.77**	-0.07	-0.57**	-1.93**	-0.76	-11.26**	-8.15**	0.41
BLD-210	-0.10	-0.52*	-0.42**	-0.64*	-6.56**	-4.37**	-0.98**	0.01	-1.13**	1.41**	1.04	-6.40*	-3.34	1.21
WNC 18242	2.63**	3.01**	0.38**	2.96**	6.35**	0.76*	0.70**	0.07	0.26	-0.25	-0.82	5.04	-0.58	-2.88**
Z 488-4	0.70**	0.88**	0.18	0.82**	-3.97**	3.26**	0.86**	-0.02	-0.06	-0.43	-0.22	-3.43	-2.99	-0.16
BLD-188	-2.57**	-2.39**	0.18	-2.44**	-16.79**	-12.78**	-0.14	-0.07	0.31	-1.05**	0.51	-1.19	-0.88	-0.02
S. Em ±	**0.24**	**0.24**	**0.10**	**0.24**	**0.46**	**0.36**	**0.13**	**0.15**	**0.20**	**0.37**	**0.59**	**2.72**	**2.38**	**1.04**
Tester (Male)														
BLD-107	0.28	0.44*	0.17	0.28	-6.53**	-1.84**	-0.01	0.60**	0.56**	-0.10	1.97**	5.70*	5.70*	0.89
BLD-46	0.22	0.50*	0.28**	0.44*	-1.00*	1.21**	0.46**	-0.49**	-0.21	1.70**	-2.48**	4.59	5.34*	1.21
IMR-70	-0.44*	-0.33	0.11	-0.56*	4.34**	1.28**	-0.49**	-0.03	-0.10	-0.87*	-1.37*	-5.76*	-4.50*	-0.16
IMR-48	-0.89**	-0.94**	-0.06	-1.00**	-0.82	0.92**	0.32**	-0.27*	-0.41*	0.76*	-1.14*	-2.62	-4.18	-1.19
VL-1032	0.83**	0.33	-0.50**	0.83**	4.01**	-1.57**	-0.29*	0.19	0.16	-1.49**	3.02**	-1.91	-2.36	-0.75
S. Em ±	**0.22**	**0.21**	**0.09**	**0.22**	**0.42**	**0.33**	**0.12**	**0.13**	**0.18**	**0.34**	**0.53**	**2.48**	**2.17**	**0.95**

**, ** Significant at 5% and 1% levels, respectively* variability for the characters. The variance due to Female *vs* male found significant for all the traits except for shelling percentage which indicating the presence of high heterosis response in the material studied. Also, both the GCA and SCA variances found significant for days to tasseling, days to silking, ASI, days to dry husk, plant height, ear height, number of kernel rows per cob, number of kernels per row, 100 kernel weight.

The quadratic components associated with the SCA effect were greater than those associated with the GCA for all the traits evaluated, the ratio of σ^2_{gca} / σ^2_{sca} was also less than unity for all the characters which revealed the preponderance of non-additive gene action for the inheritance of these traits (Table 1). These results were corresponded with [9] for number of kernel rows per cob and number of kernels per row [10] and [11] for yield and its attributing traits.

The extent of heterosis and SCA effects of hybrids is important tools. Based on these parameters, hybrids with superior performance were identified for all the traits and top three performing genotypes are presented in Table 2. The superiority of the cross over the standard check i.e. GAYMH-1 considered as standard heterosis. Based on the heterobeltiosis and standard heterosis estimated the crosses, Z 488-4 × VL-1032 (58.44% and 88.99%) and BLD-250 × BLD-46 (54.84% and 124.63%) ranked among top three, respectively for kernel yield per plant. The cross, Z 488-4 × VL-1032 also found to be superior for cob yield per plant, cob length and cob girth. Similarly, another cross, BLD-250 × BLD-46 found superior for 100-kernel weight and shelling percentage for hybrid vigour. The cross, WNC 18242 × VL-1032 recorded significant better parent heterosis for days to silking, ASI and days to dry husk depicting earliness as compared to its best parent for flowering and maturity traits. Similar findings were also reported by [9,12] and [13]. The high degree of heterobeltiosis and standard heterosis over checks for kernel yield per plant indicated the presence of large-scale genetic diversity among lines as well as testers and unidirectional dominance of the allelic constitution contributing towards heterosis for this trait in material under study.

The parents and hybrids were classified into good, average and poor classes based on their significant in desired direction, non-significant and significant in undesired direction of GCA or SCA effect value, respectively. In investigation, no single parent was good general combiner for all the characters studied. Among lines, BLD-250 found to be good general combiner for kernel yield per plant, cob yield per plant, cob length, number of kernel rows per cob and number of kernels per row. The line BLD-221 and BLD-210 found significant *GCA* effect in desired direction for earliness and dwarfness. Among testers, BLD-107 found to be good general combiner for plant height, ear height, cob girth, number of kernel rows per cob, 100-kernel weight, cob yield per plant and kernel yield per plant and average general combiner for flowering and maturity traits. The combinations involving these parents might perform better for the said traits with better vigour for the respective trait, as these parents might possess favorable allele for these traits. Similarly, for specific combining ability effects, Z 488-4 × VL-1032 for cob yield per plant, kernel yield per plant, number of kernel rows per cob, cob length and cob girth and BLD-250 × BLD-46 for kernel yield per plant, 100-kernel weight, cob length and cob girth found to be good specific combiner. For flowering and maturity traits, the cross, WNC 18242 × VL-1032 found good specific combiner. The single cross hybrid, Z 488-4 × VL-1032 includes both average general combiners; BLD-250 × BLD-46 includes good × average general combiners as parents for kernel yield. While, WNC 18242 × VL-1032 includes both poor × poor combination of parents for flowering and maturity traits (Table 3).

4. CONCLUSION

The results obtained in the present investigation were hopeful and provide important information for genetic improvement of maize genotypes using hybrid breeding. From the study, it concluded that most of the characters depicted greater role of non-additive gene action for their inheritance. The best general combiners such as BLD-250, BLD-221, BLD-210 and BLD-107 and cross combinations such as Z 488-4 × VL-1032, BLD-250 × BLD-46 for kernel yield and WNC 18242 × VL-1032 for earliness could be utilized in future breeding programmes. These parents and hybrids used to generate more number of desirable segregates for improving respective traits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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