

EVALUATION OF MAIZE S₂ LINES IN TEST CROSS COMBINATIONS I: FLOWERING AND MORPHOLOGICAL TRAITS

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Abstract

This research work was conducted at N.W.F.P. Agricultural University, Peshawar to test 24 maize S₂ lines using line x tester analysis. Data were recorded on days to 50% pollen shedding and silking, anthesis silking interval (ASI), ear height and plant height. Results revealed highly significant differences among the testcrosses for all these parameters. Maximum days to silking (62) were observed for TC-13, using WD 2x8 as a tester, while SCA for day to silking was recorded 3.15. Maximum days to anthesis were observed (60) for TC-36, using WD 3x6 as a tester. Maximum value (3 days) for anthesis silking interval was observed for TC-13, using WD 2x8 as a tester, while SCA for anthesis silking interval was recorded to be 1.60 days. Maximum ear height (82cm) was observed for the TC-21, using WD 3x6 as a tester, while SCA for ear height was 1.5 cm. Maximum plant height (161 cm) was observed for TC-21, using WD 3x6 as a tester, while SCA for plant height was found to be -17.8 cm. These testcrosses are recommended to be included in further breeding programs for developing maize germplasm with earlier flowering and desirable plant and ear height attributes.

Introduction

Maize (*Zea mays* L.) is the world leading cereal crop. It does not survive in its wild form probably because of the highly cross pollinated nature (Ram & Singh, 2003). It is a short day plant, with monoecious nature of flowering. Maize being the highest yielding cereal crop in the world is of significant importance for countries like Pakistan, where rapidly increasing population has already out stripped the available food supplies. In Pakistan during the year 2005-06, maize was grown on 1024 thousand hectares, resulting in total annual production of 3109.6 thousand tones, with an average of 2984 kg per hectare (Anon., 2005-6). In NWFP it is a primary crop in majority of farming systems and staple food of the rural population in much of the province. A considerable area of approximately more than 500,000 ha in plains and high mountains of NWFP is planted with maize crop. Per hectare production of maize is considerably low in these areas compared to other countries of similar environments. The reduced yield per unit area could be attributed to several reasons. Lack of suitable maize hybrid seed is one of these limiting factors.

The ultimate goal of various breeding methods in maize is the production of improved genotypes. Hence short cut but efficient methods are needed for isolation and identification of superior genotypes which can be used in hybrid breeding programs (Arshad *et al.*, 2003). For selection of inbred lines tolerant to inbreeding depression and being superior in genetic potential, early generation testing is desirable (Barata & Carena, 2006). In early generation testing, S₁ or second generation of selfed progeny (S₂) are out crossed to a common tester for yield and general performance. Lines with poor combing abilities are discarded and only good performance lines are further selfed and selected in subsequent cycles of selection (Menkir & Charles, 2007).

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The objective of this study was to evaluate maize S₂ testcrosses derived from maize variety Azam for grain yield and morphological parameters and to identify superior maize S₂ lines for combining ability as potential source in the production of improved maize germplasm, adapted to the agro- climatic conditions of Peshawar.

Materials and Methods

This research was conducted during 2008 at the research farm of NWFP Agricultural University, Peshawar. Breeding material used in this experiment comprised 24 S₂ lines developed from maize variety Azam which is a white flint genotype with medium stature and 90-110 days maturity. It is a well adapted maize composite which is used in most parts of NWFP. Three testers were used in this experiment, comprising two single cross hybrids i.e., WD 2×8, WD 3×6 and an open pollinated variety Jalal.

During spring crop season February-June 2008, 39 S₂ lines, derived from maize variety Azam were crossed with the above three testers in three isolations. During kharif season (July-October 2008) test crosses along with check were evaluated in replicated trial using 10×10 square lattice design, with three replications. Row length was kept 4m with plant to plant spacing of 0.25m and row to row spacing of 0.75m. Fertilizer was applied in the form of diammonium phosphate (DAP) and urea @ 120 and 60kg ha⁻¹. Entire DAP was applied at the time of sowing while half of urea was applied before sowing and rest was applied when plants were at knee height stage. The crop was irrigated weekly. When more than 50% plants in a row showed pollen shedding and silks coming out, the date was recorded as the number of days needed for pollen shedding and silking accordingly. The difference between pollen shedding and silking was taken as anthesis silking interval (ASI). Data for plant and ear height was recorded as the distance from the ground level to flag leaf node and upper ear bearing node, respectively. Five plants were selected at random from each row for these two plant parameters.

All the data were subjected to ANOVA appropriate for 10×10 square lattice design using computer program "MSTATC". Analysis for GCA and SCA was carried out following Singh & Chaudhary (1985).

Results

Days to 50% anthesis: Analysis of variance indicated highly significant variations ($p>0.05$) among testcrosses for days to 50% anthesis. Maximum mean value (60 days) was observed for TC₃₆, using WD 3x6 as a tester, while minimum mean value (56 days) was recorded for TC₉, using OPV Jalal as a tester (Table 1). The overall mean for days to anthesis for the testcrosses was 58 days. It is evident that 21 out of 24 testcrosses showed positive GCA effect. The highest positive GCA effect was recorded in TC₆, while GCA effect was negative and maximum in case of testcross TC₃₈, followed by TC₃₉. Similarly positive SCA effects were recorded in 8 out of 69 testcrosses, in which maximum SCA effect was observed for TC₃₈, followed by TC₃₉, using WD 3x6 as a tester. Highest negative SCA effects were recorded for testcross TC₂₉, using Jalal as a tester, followed by TC₁₂, using WD 3x6 as a tester.

Table 1. Mean values, general combining ability (GCA) and specific combining ability (SCA) effects for days to pollen shedding of 24 test crosses.

S ₂ line	Tester						GCA
	WD2x8		WD3x6		Jalal		
	Days to shedding	SCA	Days to shedding	SCA	Days to shedding	SCA	
2	57.00	-1.00	58.00	-0.90	58.00	-2.83	3.24
6	59.00	-0.90	59.00	-2.10	59.00	-1.72	3.24
7	58.00	-0.22	57.00	-2.43	57.00	-2.06	1.60
8	57.00	-1.80	58.00	-2.32	58.00	-0.61	2.12
9	57.00	-0.55	57.00	-1.80	57.00	-2.40	0.90
10	----	-----	60.00	4.60	60.00	4.93	-2.42
11	58.00	-0.44	57.00	-2.65	57.00	-1.61	1.80
12	57.00	-1.55	58.00	-57.20	58.00	-1.72	1.60
13	59.00	0.21	57.00	-2.65	57.00	-2.30	1.80
15	57.00	-0.70	57.00	-2.21	57.00	-1.83	1.35
16	58.00	-1.55	59.00	-1.80	59.00	-1.40	2.90
19	56.00	-1.70	58.00	-1.21	58.00	-1.83	1.01
20	57.00	-1.22	58.00	-1.43	58.00	-2.10	1.60
21	58.00	-1.70	58.00	-2.90	58.00	-0.20	2.70
23	57.00	-0.90	57.00	-2.10	57.00	-1.72	1.24
25	59.00	-0.22	58.00	-2.43	58.00	-2.10	2.60
26	57.00	-0.80	57.00	-1.65	57.00	-2.30	0.80
29	58.00	-0.33	57.00	-2.54	57.00	-57.60	1.35
30	59.00	-0.80	60.00	-1.32	60.00	-2.61	3.12
34	57.00	-0.70	56.00	-2.54	56.00	-1.50	1.01
35	56.00	-1.22	57.00	-1.43	57.00	-2.10	0.60
36	57.00	-2.11	60.00	2.11	60.00	-2.61	2.12
38	----	-----	59.00	20.33	59.00	16.60	-17.10
39	----	-----	58.00	17.00	58.00	17.71	-17.20

Overall mean for testcrosses = 58 days

Mean value for check = 59 days

LSD_(0.05) = 0.51

Days to 50% silking: Analysis of variance regarding days to 50% silking indicated highly significant ($p > 0.05$) differences among testcrosses. Maximum days to silking (62) were observed for TC₁₃, using WD 2x8 as a tester, followed by TC₁₀, using OPV Jalal as a tester (61 days). Minimum days to 50% silking (57) was recorded for TC₃₅, with WD 2x8 as a tester, followed by TC₉, using OPV Jalal as a tester. The mean days to silking of all the testcrosses was 59 days. Table 2 indicates that 23 out of 24 testcrosses exhibited positive GCA effect. The highest positive GCA effect was observed for TC₆, followed by TC₃₀, while GCA effect was negative and maximum in case of testcross TC₁₀. Positive SCA effects were recorded in 8 out of 69 testcrosses, maximum SCA effect being observed for TC₃₆, using WD 2x8 as a tester, followed by TC₁₀, using OPV Jalal as a tester. The highest negative SCA effect was recorded for testcrosses TC₁₃, using WD 3x6 as a tester, followed by TC₁₃, using OPV Jalal as a tester.

Table 2. Mean values, general combining ability (GCA) and specific combining ability (SCA) effects for days to silking of the 24 testcrosses.

S ₂ line	Tester						GCA
	WD2x8		WD3x6		Jalal		
	Days to shedding	SCA	Days to shedding	SCA	Days to shedding	SCA	
2	58.00	-2.84	59.00	-1.00	57.00	-2.84	1.40
6	60.00	0.93	60.00	-2.21	60.00	-1.73	3.30
7	59.00	-0.20	57.00	-3.10	58.00	-1.95	1.50
8	57.00	-0.95	59.00	-2.21	60.00	-0.40	1.95
9	57.00	2.30	58.00	-1.66	57.00	-2.20	2.44
10	-----	-----	61.00	4.56	61.00	5.04	-2.50
11	58.00	-2.80	58.00	-1.55	58.00	-1.62	1.20
12	59.00	-1.20	60.00	-1.32	58.00	-2.50	2.40
13	62.00	3.15	58.00	-3.55	58.00	-3.06	2.62
15	58.00	-2.10	58.00	-2.21	58.00	-1.73	1.30
16	57.00	-1.20	60.00	-1.10	60.00	-0.95	2.50
19	57.00	-2.20	59.00	-1.21	57.00	-2.06	0.95
20	58.00	-2.30	59.00	-1.55	58.00	-2.06	1.62
21	59.00	-0.20	59.00	-3.00	61.00	-0.17	2.73
23	58.00	-2.40	58.00	-2.21	58.00	-1.73	1.30
25	60.00	1.70	60.00	-2.10	59.00	-2.30	2.84
26	57.00	-1.40	58.00	-1.70	57.00	-2.30	0.73
29	58.00	-2.84	58.00	-2.43	58.00	-1.62	1.17
30	60.00	1.40	61.00	-1.21	59.00	-2.73	3.30
34	58.00	-0.20	57.00	-2.70	58.00	-1.50	1.06
35	57.00	-2.73	58.00	-1.55	57.00	-2.06	0.62
36	58.00	17.60	61.00	-0.10	58.00	-2.62	2.20
38	-----	-----	60.00	-1.21	58.00	-2.73	2.30
39	-----	-----	59.00	-2.21	59.00	-1.40	2.12

Overall mean for testcrosses = 59 days

Mean value for check = 58 days

LSD_(0.05) = 1.10LSD_(0.01) = 1.50

Anthesis silking interval (ASI): The analysis of variance for anthesis-silking interval showed highly significant ($p > 0.05$) variation among the testcrosses (Table 3). Maximum mean value (3.3 days) for anthesis silking interval was observed for TC₁₃, followed by TC₁₂ (2.33 days), using WD 2x8 as a tester, while minimum mean value was observed for TC₁₆, followed by TC₁₁, using WD 2x8 as a tester. The mean anthesis-silking interval of all the testcrosses was 0.98 days. It is evident from Table 3 that 12 out of 24 testcrosses showed positive GCA effect. The highest positive GCA effect was observed for TC₁₂, followed by TC₁₃, while GCA effect was negative and maximum in case of testcross TC₁₁, followed by TC₁₆. Similarly positive SCA effect was observed for 29 out of 69 testcrosses, in which maximum SCA effect was recorded for TC₁₃, using WD 2x8 as a tester, followed by TC₁₆, using WD 3x6 as a tester. Highest negative SCA effect was observed for TC₁₀, using WD 3x6 as a tester, followed by TC₁₂, with Jalal as a tester.

Table 3. Mean values, general combining ability (GCA) and specific combining ability (SCA) effects for anthesis-silking interval of 24 testcrosses.

S ₂ line	Tester						GCA
	WD2x8		WD3x6		Jalal		
	Mean	SCA	Mean	SCA	Mean	SCA	
2	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
6	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
7	1.33	-0.51	0.33	-0.67	1.00	0.10	-0.06
8	0.33	-0.39	1.00	0.10	1.00	0.21	-0.17
9	0.33	-0.39	1.00	0.10	1.00	0.21	-0.17
10	-----	-----	1.00	-1.07	1.00	0.10	-0.06
11	-0.33	-0.62	1.00	0.55	0.33	-0.00	-0.62
12	2.33	0.60	2.00	0.10	1.00	-0.78	0.82
13	3.33	1.60	1.00	-0.89	1.00	-0.78	0.82
15	0.66	-0.17	1.00	-0.00	1.00	0.10	-0.06
16	-0.66	-1.17	1.33	0.66	1.00	0.43	-0.39
19	1.00	0.15	1.00	-0.00	0.66	-0.22	-0.06
20	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
21	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
23	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
25	1.00	-0.17	1.66	0.32	1.00	-0.22	0.26
26	0.66	-0.17	1.00	-0.00	1.00	0.10	-0.06
29	0.33	-0.39	1.00	0.10	1.00	0.21	-0.17
30	1.00	-0.06	1.33	0.10	1.00	-0.11	0.15
34	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
35	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
36	1.00	0.04	1.00	-0.11	1.00	-0.00	0.04
38	---	-----	1.00	0.21	1.00	0.32	-0.28
39	---	-----	1.00	0.21	1.00	0.21	-0.28

Overall mean for testcrosses = 0.98 days

Mean value for check = 0.98 days

LSD_(0.05) = 0.98

LSD_(0.01) = 1.3

Ear height (cm): Analysis of variance regarding ear height showed significant variations ($p>0.05$) among testcrosses. Table 4 indicates that maximum mean ear height (82.66 cm) was observed for the TC₂₁, using WD 3x6 as a tester, followed by TC₂₁ (81.33cm), using OPV Jalal as a tester. Minimum mean ear height (45.33 cm) was recorded for TC₂, using WD 2x8 as a tester. The mean ear height of all testcrosses was 68 cm while for the check it was 68 cm. It is evident from Table 4 that 15 out of 24 testcrosses showed positive GCA effect. The highest positive GCA effect was recorded in TC₂₁, followed by TC₁₅, while GCA effect was negative and maximum in case of testcross TC₁₀, followed by TC₆. Positive SCA effects were recorded in 25 out of 69 testcrosses, in which maximum SCA effect was observed for TC₁₀, using WD 3x6 as a tester, followed by TC₆, using Jalal as a tester. Highest negative SCA was recorded for TC₁₅, using OPV Jalal as a tester, followed by TC₂, with WD 2x8 as a tester.

Table 4. Mean values, general combining ability (GCA) and specific combining ability (SCA) effects for ear height of the 24 testcrosses.

S ₂ line	Tester						GCA
	WD2x8		WD3x6		Jalal		
	Mean (cm)	SCA	Mean (cm)	SCA	Mean (cm)	SCA	
2	45.33	-11.80	65.33	0.00	71.33	6.60	-5.10
6	51.33	-4.00	55.33	-8.20	70.00	7.10	-6.90
7	59.33	-2.10	70.66	1.00	65.00	-4.00	-0.80
8	63.00	-1.00	66.33	-5.90	49.33	1.70	1.70
9	65.00	0.30	71.33	-1.60	68.33	-3.90	2.40
10	----	----	73.00	11.90	69.00	8.50	-9.40
11	74.66	4.10	75.66	-3.10	72.00	-6.10	8.30
12	68.33	0.20	76.33	0.00	70.33	-5.40	5.90
13	65.00	1.70	73.66	2.20	61.66	-9.10	1.00
15	80.66	8.60	80.66	0.40	65.33	-14.30	9.70
16	62.00	-3.30	77.00	3.50	67.33	-5.50	3.00
19	65.33	4.40	63.33	-5.80	64.66	-3.80	-1.40
20	59.66	-0.50	66.66	-1.70	64.66	-3.00	-2.10
21	65.33	-7.60	82.66	1.50	81.33	0.90	10.60
23	64.33	-1.80	76.66	2.30	68.00	-5.70	3.90
25	63.33	-4.50	76.33	0.30	74.33	-1.00	5.50
26	69.33	-1.30	76.66	-2.10	76.33	-1.80	8.30
29	63.00	0.20	63.00	-8.00	73.00	2.60	0.50
30	64.66	-1.10	70.66	-3.30	72.66	-0.70	3.50
34	57.33	-0.50	63.00	-3.10	63.83	-1.60	-4.40
35	68.00	-0.50	71.33	-5.40	76.83	0.70	6.20
36	68.00	6.60	68.66	-1.00	58.20	-10.80	-0.90
38	----	----	61.66	-8.30	69.00	-0.40	-0.50
39	----	----	65.66	-11.70	79.66	3.00	6.90

Overall mean for testcrosses= 68 cm

Mean value for check = 68 cm

LSD_(0.05) = 15

LSD_(0.01) = 19

Plant height (cm): Analysis of variances showed significant differences at $p > 0.05$ level of probability for plant height among the testcrosses. Maximum value (161.60 cm) was observed for TC_21, using WD 3x6 as a tester, followed by TC_2 (154.63 cm), using OPV Jalal as a tester (Table 4). Minimum plant height (114.77 cm) was recorded for TC_7, using WD 2x8 as a tester. The grand mean plant height of all testcrosses was 135 cm 134.66 cm for the check. Table 4 indicates that 16 out of 24 testcrosses showed positive GCA effect. The highest positive GCA effect was observed for TC_21, followed by TC_11, while GCA effect was negative and maximum in case of testcross TC_38, followed by TC_39. Similarly positive SCA effects were recorded in 23 out of 69 of testcrosses, in which maximum SCA effects were observed for TC_39, using WD 3x6 as a tester, followed by TC_38, using WD 2x8 as a tester. Highest negative SCA effect was recorded for TC_2, using WD 2x8 as a tester, followed by TC_11, using WD 3x6 as a tester.

Table 5. Mean values, general combining ability (GCA) and specific combining ability (SCA) effects for plant height of 24 testcrosses.

S ₂ line	Tester						GCA
	WD2x8		WD3x6		Jalal		
	Mean (cm)	SCA	Mean (cm)	SCA	Mean (cm)	SCA	
2	120.00	-21.60	151.07	-10.30	154.63	13.30	7.20
6	120.33	6.80	123.23	-14.10	139.73	0.30	5.30
7	114.77	-3.90	136.80	-2.30	122.40	-9.50	-2.30
8	126.00	21.0	130.50	0.40	139.07	-31.20	-7.90
9	118.93	-2.70	124.20	-6.30	133.87	2.70	-3.00
10	---	-----	131.20	17.10	131.60	21.50	-24.10
11	131.23	10.20	143.27	-17.70	138.13	-10.20	14.10
12	125.93	-3.30	143.60	-7.80	131.67	-6.80	4.30
13	137.27	0.00	139.93	-5.50	123.87	-12.30	2.00
15	132.10	0.60	145.60	-11.80	135.63	-7.00	8.50
16	116.80	-2.60	147.07	-11.80	138.97	-3.50	8.30
19	131.10	-7.50	135.80	-3.00	129.73	-0.50	-3.90
20	135.40	4.50	140.63	-12.60	134.27	-8.40	8.50
21	130.47	-7.40	161.60	-17.80	152.27	0.30	17.80
23	119.83	14.20	139.73	-15.40	132.00	-11.40	9.20
25	129.87	-14.90	151.80	-7.50	142.27	3.70	4.40
26	129.67	2.70	143.40	-14.30	139.30	-5.00	10.10
29	129.10	1.80	135.27	-9.30	132.77	-4.20	2.80
30	116.03	-3.00	147.07	-8.20	131.40	-8.20	5.40
34	130.10	-13.90	133.63	-1.50	132.07	2.10	-4.20
35	122.73	3.30	138.67	-12.60	137.07	-3.90	6.80
36	----	-119.3	144.27	-5.90	130.93	-4.60	1.40
38	-----	--- --	129.10	32.80	131.53	37.40	-40.10
39	---	-----	144.27	26.90	149.17	45.30	-30.30

Overall mean for testcrosses = 135 cm.

Mean value for check= 134.66 cm.

LSD_(0.05) = 2.40

LSD_(0.01) = 3.30

Discussion

Days to 50% pollen shedding: The testcross that took minimum days to pollen shedding was TC_9 using OPV Jalal as a tester. Among all the testcrosses, 79.71% took less days to 50% pollen shedding than the check, while 13.04% testcrosses were similar to the check. Testcrosses needed less time for maturity when compared to S₂ lines. It is clear from the result that TC_6 had the highest positive GCA effects. About 91.66% showed positive GCA effects, while 8.33% were having negative GCA effects. Highest SCA effects were observed for TC_38, using WD 3x6 as a tester, followed by TC_39 using WD 2x8 as a tester. About 12.12% testcrosses showed positive SCA effects, while 87.87% were recorded with negative SCA effects. Our results are in conformity to those of Menkir & Charles (2007) who observed significant variation for days to 50% anthesis in test cross evaluation of exotic maize accessions.

Days to 50% silking: The testcross that needed minimum days to silking were TC_35, with WD 2x8 as a tester and TC_9, using OPV Jalal as a tester. About 17.39% testcrosses took minimum days to 50% silking when compared to check, while 39.13% had similar to the check. Testcrosses showed minimum days to 50% silking when compared to S₂ parental lines. About 96% testcrosses showed positive GCA effects, while 4% testcrosses were having negative GCA effects. About 14% testcrosses showed positive SCA effects, while 84% testcrosses exhibited negative SCA effects. In multiple cropping systems and for regions with short growing seasons, early maturing varieties are needed. Days required to silking along with other maturity traits are commonly used by plant breeders as basis of determining maturity of maize. Peiris & Hallauer (2005) reported significant variability among half and full sib families in a maize recurrent selection program.

Anthesis silking interval (ASI): Analysis of variance for ASI showed highly significant differences among the testcrosses. In all, 13.64% of the testcrosses had lower ASI than the mean of the check. On the other hand 78.79% testcrosses had ASI similar to the check, while 11% of testcrosses had ASI which was greater than the mean of the check. It is clear from the results that 96% testcrosses showed positive GCA effects, while 4% were having negative GCA effects. About 14% testcrosses showed positive SCA effects; while 84% testcrosses exhibited negative SCA effects. Compared to silks, pollen grains are more sensitive to environmental stresses and under high temperature and drought conditions may quickly lose their viability. If there is pollen silk asynchrony, the silk may not be receptive to pollen and may not be effectively pollinated. This will lead to low kernel setting and ultimately loss in grain yield.

Ear height: The lowest ear height (45.33 cm) was recorded for TC_2, using WD 2x8 as a tester. About 40.57% of the testcrosses had lower ear height when compared the check. Similarly 91% of the testcrosses showed higher ear height than the S₂ parental lines, while 9% testcrosses had lower ear height than the S₂ parental lines. It is clear from the results that TC_21 had the highest GCA effects. The second highest GCA effect was observed for TC_10. About 63% testcrosses showed positive GCA effects, while 37% were having negative GCA effects. In all, 39% testcrosses showed positive SCA effects, while 61% were having negative SCA effects. Gonzalez *et al.*, (2004) reported significant variability among recurrently selected S₂ families of maize. Greater ear height is undesirable because the ear placement at a greater height from the ground level exerts pressure on plant during grain filling and maturity and causes lodging and affects yield. Therefore, cultivars with optimum ear height are required.

Plant height: In all, 52.17% testcrosses had lower plant height than check, while 30.40% had plant height similar to check. About 71% of testcrosses showed greater plant height than the S₂ parental lines, while 19% testcrosses exhibited lower plant height than the S₂ parental lines. About 67% testcrosses had positive GCA effects, while 33% with negative GCA effects. About 35% testcrosses showed positive SCA effects, while 65% were having negative SCA effects. Earlier researchers (Gul *et al.*, 2007 and Carena, 2005) have also reported similar findings for yield and agronomic traits in maize populations.

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