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Line x tester analysis of maize inbred lines for grain yield and yield related traits

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ABSTRACT

A line x tester analysis involving 48 test-crosses generated by crossing 24 elite maize inbred lines with two testers and four standard checks was conducted for different agronomic traits during 2010 cropping season at Melkassa Agricultural Research Center. The objectives of the study were to estimate general and specific combining ability effects of the inbred lines and to evaluate the test cross performance of the hybrids for grain yield and yield related traits. The genotypes were evaluated in 6x9 alpha lattice design replicated twice. Analysis of variance indicated significant mean squares due to genotypes for grain yield, 1000 kernel weight, days to anthesis and silking ear and plant heights, number of ears per plant, number of rows per ear and number of kernels per row. There were significant mean square differences due to line GCA for all the traits analyzed while tester GCA was significant only for grain yield and ear height. Mean squares due to SCA were highly significant for grain yield, plant and ear heights, number of kernels per row, 1000 kernel weight and days to anthesis. Generally, mean squares due to GCA of lines, and testers and SCA of line x tester interactions were significant for grain yield and most yield related traits indicating the importance of both additive and non additive gene actions in controlling these traits.

Keywords: combining ability, inbred lines, line x tester, grain yield

INTRODUCTION

In Ethiopia, maize is one of the most important crops and is grown across 13 agro-ecological zones which together cover about 90% of the country [1]. It is the first crop in production more than any other cereal crop in the country [2]. In the drought stressed areas of Ethiopia, which covers about half (46%) total arable land [3], the areas devoted to maize production occupy 38-42% of the maize growing area but contribute only 17% to the total maize production. Unavailability of suitable maize varieties is one of the possible reasons responsible for such yield gap. Efforts are, therefore, required to be made to develop hybrids with high yield potential in order to increase production of maize.

Drought stress tolerant maize breeding program of Melkassa Agricultural Research Center (MARC) which is experimental farm of Ethiopian Institute of Agricultural Research (EIAR) in collaboration with CIMMYT has developed a large number of drought stress tolerant and/or early maturing elite maize inbred lines. This effort is aimed at identifying better combining inbred lines for the development of hybrids for drought stressed areas of the country as no hybrid maize variety has been released for this target area so far. To initiate effective hybrid breeding program, information on the combining ability of inbred lines is an essential and critical factor. In the current study, therefore, an attempt was made to generate information on 24 elite maize inbred lines crossed to two testers of known heterotic groups in line x tester mating fashion and evaluated with the objectives of estimation of the GCA and SCA effects of the inbred lines and evaluation of the test cross performance of the hybrids for grain yield and yield related traits.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out in the 2010 main cropping season at Melkassa Agricultural Research Center (MARC). The center is located at $8^{0}24'$ N latitude and $39^{0}21'$ E longitude and an altitude of 1550 m.a.s.l. The climate of the area is characterized as semi-arid with mean monthly maximum and minimum temperature of 33°C and 10.8°C, respectively. It is characterized by low and erratic rainfall with unimodal pattern of precipitation. The soil in the testing field of Melkassa is characterized by sandy clay-loam (Cambisol) with 35% sand, 44% silt, 21% clay, pH of 7.4, 1.2% organic matter, 10.32 ppm available phosphorous (P), and cation exchange capacity (CEC) of 22.34 milli-equivalents (meq/100 g) of soil.

The Experimental Materials

A total of fifty two entries including 48 test crosses produced by crossing twenty four elite inbred lines with two testers (CML312/CML442, tester A and CML202/CML395, tester B) and four standard checks (BH540, BHQPY-545, Melkassa-2, Melkassa-6Q) were used for the study. The lines were obtained from MARC, but originally introduced from CIMMYT-Kenyan breeding program. List and pedigrees of the inbred lines used in the line x tester crosses are given in Table 1. The testers used in this study were identified by CIMMYT and are widely used in Africa by CIMMYT and many national maize breeding programs to study combining ability of newly generated maize inbred lines and at the same time to discriminate the inbred lines into heterotic groups. Among the checks, BH-540 and BHQPY-545 are medium maturing single cross hybrids released by Bako National Maize Research Project (BNMRP) for mid to high potential maize growing agro-ecologies of Ethiopia. BH-540 is normal maize while BHQPY-545 is quality protein maize (QPM) hybrid. Melkassa-2 and Melkassa-6Q are drought stress tolerant and early maturing, respectively, open pollinated varieties (OPVs) released by MARC for drought prone areas of Ethiopia. Melkassa-2 is normal maize while Melkassa-6Q is a QPM OPV.

Design and Experimental managements

The experiment was planted at MARC in 6x9 alpha-lattice design [4] with two replications. Each plot comprised of 4 rows of 5.1 m long with the spacing of 0.75 m between rows and 0.30 m between plants. Two seeds were planted per hill on 26th of June 2010 and later thinned out to one plant per hill after seedlings established well. Diammonium phosphate (DAP) fertilizer was applied at planting at the rate of 100 kg/ha while urea was applied at the rate of 50 kg/ha at knee height stage of the crop. Other cultural practices like weeding and pest management has been done manually throughout the entire growing season as required.

Data Collected

Days to Anthesis (AD): Number of days from planting to when 50% of the plant in a plot shed pollen. Days to Silking (SD): Number of days from planting to when 50% of the plants in a plot produced 2-3 cm long silk. Thousand Kernel Weight (TKWT): 1000 randomly taken kernels were weighed from each plot using sensitive balance and was adjusted to 12.5 % moisture level. Grain Yield (GY): The total grain yield in kg per plot and adjusted to 12.5% moisture level. Plant Height (PH): The average height of five randomly selected plants measured in cm from base of the plant to the first tassel branch. Ear Height (EH): The average height of five randomly selected plants measured in cm from base of the plant to the node bearing the upper most ear of the same plants used to measure plant height. Number of Kernel Rows per Ear (KRE): The total number of kernel rows of the ear was counted from five randomly taken ears and the average value was used as kernel rows per ear.

Analysis of variance

The data collected for all yield and yield-related traits were analysed using PROC MIXED procedure in SAS [5]. In the analysis, entries were used as fixed factor while replications and incomplete blocks within replication were considered as random factors. Entry means adjusted for block effects as analyzed according to lattice design [6] were used to perform combining ability analysis. Further analysis was done according to the line x tester analysis to partition the mean square due to crosses into lines, tester and line by tester effects[7, 8] using SAS computer program. For traits that showed significant differences among crosses. Further genetic analyses were carried out for traits that showed significant differences among the genotypes excluding the checks according to line x tester analysis methods as suggested by [9] to partition the mean square due to crosses in to lines (GCAf), tester (GCAm) and line x tester interactions (SCAfm) using SAS software program. The significant of GCA and SCA effects were tested by dividing the corresponding GCA and SCA values by their respective standard error and comparing the obtained t with tabular t-value at error degree of freedom.

Table 1. Descriptions of the lines, testers and checks used in the Melkassa in 2010

Line Code	Pedigree	Stock ID
L1	CML505-B	M22-1
L2	CML509-B	M22-2
L3	CML507-B	M22-3
L4	ZEWAc1F2-300-2-2-B-1-B*4-1-B-B	M22-4
L5	ZEWAc1F2-134-4-1-B-1-B*4-1-B-B	M22-5
L6	ZEWAc1F2-254-2-1-B-1-BB-1-B-B	M22-6
L7	ZEWBc1F2-216-2-2-B-2-B*4-1-B-B	M22-7
L8	MAS[MSR/312]-117-2-2-1-B*3-B	M22-8
L9	CML442-BB-B	M22-9
L10	CML444-BB-B	M22-10
L11	CML443-BB-B	M22-11
L12	CML395-BB-B	M22-12
L13	CML488-BB-B	M22-13
L14	CML489-BB-B	M22-14
L15	CML440-B	M22-15
L16	CML445-B	M22-16
L17	[CML444/CML395//ZM521B-66-4-1-1-1-BB]-3-3-1-1-B-B	M22-17
L18	[CML312/CML444//[DTP2WC4H255-1-2-2-BB/LATA-F2-138-1-3-1-B]-1-3-2-3-B]-2-1-2-BB-B-B	M22-18
L19	[CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-1-1-B*4-B	M22-19
L20	[CML442/CML197//[TUXPSEQ]C1F2/P49-SR]F2-45-7-3-2-BBB]-2-1-1-2-3-B*4-B	M22-20
L21	Pool15QPMFS57-B-5-B-#-B-B-B-B-B	M22-21
L22	Pool15QPMFS440-B-4-B-#-B-B-B-B-B	M22-22
L23	Pool15QPMFS309-B-1-B-B-B-B-B-B	M22-23
L24	Pool15QPMFS51-B-8-B-B-B-B-B-B	M22-24
Testers		
T1	CML312/CML442	Tester A
T2	CML202/CML395	Tester B
Checks		
BH-540	SC-22 x 124b-(113)	Medium maturing normal maize hybrid
Melkassa-2	ZM-521	Drought tolerant normal maize OPV
Melkassa-6Q	Pool15 C7 QPM	Drought tolerant QPM OPV
BHQPY-545	CML161 x CML165	Medium maturing QPM hybrid

RESULTS AND DISCUSSION

Analysis of Variance (ANOVA)

Analysis of variance showed that mean squares were highly significant for traits such as grain yield, 1000 kernel weight, days to anthesis and silking, plant and ear height, number of kernel rows per ear and number of kernels per row. Mean squares due to crosses were highly significant for grain yield, 1000 kernel weight, days to anthesis and silking, plant and ear height and number of rows per ear. This indicates that the crosses were sufficiently different from each other for these traits and hence, selection is possible to identify the most desirable crosses. The differences among the checks were not significant for all the traits studied. The contrast cross vs check is not significant for most studied traits except for grain yield, 1000 kernel weight and ear height (Table 2). The current finding is in line with the findings of [10].

Table 2. Mean squares due to genotypes and errors for grain yield and yield related traits of maize test crosses evaluated at Melkassa in 2010

Sources of variation	Df	GY (kg/ha)	TKWT (g)	EH (cm)	PH (cm)	AD (days)	SD (days)	RPE (No)
Replication (R)	1	236409.8ns	8530.45*	192.35ns	11.14ns	0.31ns	0.15	1.64*
Incomplete block (blk/R)	16	510118.4*	4138.29**	70.14ns	68.53ns	2.41ns	2.65*	0.45ns
Genotype (G)	51	3051187.2 **	2910.55**	252.04**	456.79**	6.38**	6.31**	0.83**
Cross (C)	47	2935023.6**	3123.91**	252.69**	446.39**	5.76**	5.59**	0.88**
Check (Ch)	3	241655.5 ns	308.04ns	218.3 ns	700.0 ns	18.08 ns	18.22 ns	0.34 ns
Check vs Cross	1	16214496.7 **	705.8**	324.5**	216.4 ns	0.96 ns	4.50ns	0.20ns
Error(E)	51	129549.70	765.4	31.64	43.49	0.70	0.66	0.19

**and ** = Significant and highly significant, respectively, ns= non- significant, AD = number of days to anthesis, EH = ear height GY = grain yield, PH = plant height, RPE= number of kernel rows per ear and SD = number of days to silking and TKWT = 1000 kernel weight.*

Mean Performance of Genotypes:

High yielding crosses were L4 x T2 (10681.1 kg/ha), L10 x T2 (10076.7 kg/ha), L8 x T2 (10003.4 kg/ha), L8 x T1 (9989.2 kg/ha) and L20 x T1 (9900.9 kg/ha). Those crosses that had mean values better than the standard checks indicating the possibility of obtaining good hybrid(s), with many desirable traits. 1000 kernel weight ranged from 211.2 g (L13 x T1) to 437.7 (L17 x T1) with mean value of 346.76 g. Highest mean numbers of days to anthesis (79 days) and silking (80.5 days) were observed for L14 x T2. Furthermore, Plant height, ear height and number of rows per ear were in the range of 140.0 cm (L19 x T1) to 252.5 (L12 x T1), 90.0 cm (L8 x T1) to 155.0 (L10 x T2) and 13.60 rows (L5 x T2) to 17.40 (L7 x T1), respectively (Table 3).

Table 3. Mean values for grain yield and yield related traits in maize genotypes evaluated at Melkassa in 2010

Crosses	GY	AD	PH	SD	RPE	TKWT	EH
L1 x T1	7379.7	77.0	252.5	78.0	14.10	277.54	130.00
L1 xT2	7443.3	77.5	252.5	78.5	14.80	383.65	125.00
L2 xT1	4991.8	78.0	227.5	79.0	14.80	311.38	120.00
L2 x T2	7740.0	76.0	232.5	77.0	13.80	337.43	137.50
L3 x T1	9805.2	74.0	225.0	75.0	14.25	415.29	117.50
L3 x T2	6729.0	72.5	222.5	74.0	13.60	335.10	125.00
L4 x T1	9720.4	74.0	190.0	75.0	14.10	427.66	102.50
L4 x T2	10681.1	73.0	205.0	74.0	13.80	366.45	107.50
L5 x T1	9505.9	71.5	190.0	72.5	13.40	399.86	90.00
L5 x T2	7082.2	71.0	215.0	73.5	12.90	423.64	90.00
L6 x T1	8396.4	71.0	192.5	72.5	13.60	420.64	147.50
L6 x T2	7550.9	70.0	202.5	71.0	14.00	397.16	97.500
L7 x T1	5788.4	73.5	232.5	75.0	17.40	301.64	125.00
L7 x T2	7691.5	73.0	220.0	74.0	16.20	251.12	120.00
L8 x T1	9989.2	73.5	197.5	75.0	13.80	395.88	90.00
L8 x T2	10003.4	75.5	230.0	76.5	13.80	426.39	125.00
L9 x T1	6182.0	78.0	207.5	79.0	13.20	274.73	107.50
L9 x T2	9215.2	77.0	242.5	78.0	14.80	402.57	120.00
L10 x T1	9046.7	78.5	217.5	79.5	14.40	350.31	117.50
L10 x T2	10076.8	78.0	237.5	79.5	14.40	411.69	155.00
L11 x T1	7628.7	76.0	195.0	77.0	12.40	360.41	110.00
L11 x T2	7715.3	75.0	227.5	76.5	13.40	405.07	145.00
L12 x T1	9776.5	77.5	252.5	79.5	13.80	377.39	145.00
L12 x T2	5559.4	78.0	235.0	79.5	15.00	316.05	120.00
L13 x T1	6125.5	76.5	240.0	77.5	14.00	211.20	137.50
L13 x T2	4855.7	76.5	210.0	77.5	13.30	381.85	112.50
L14 x T1	8706.7	78.0	230.0	79.5	14.80	383.70	115.00
L14 x T2	8564.5	79.0	225.0	80.5	12.60	405.30	137.50
L15 x T1	8001.0	71.0	217.5	73.5	14.80	319.00	105.00
L15x T2	5484.6	74.0	197.5	75.5	14.40	296.56	102.50
L16 x T1	3829.2	76.0	252.5	77.5	14.20	279.23	147.50
L16 x T2	7192.6	77.5	230.0	78.0	14.00	315.64	117.50
L17 x T1	7317.3	76.5	232.5	77.5	12.90	437.70	115.00
L17 x T2	5996.1	75.0	212.5	76.5	13.60	334.80	105.00
L18 x T1	9090.0	75.0	222.5	76.5	14.20	328.10	112.50
L18 x T2	5580.0	77.0	217.5	78.0	14.00	300.42	117.50
L19 xT1	5963.7	77.0	202.5	78.0	13.80	316.06	107.50
L19 x T2	8518.9	78.5	140.0	80.0	12.80	267.18	125.00
L20 x T1	9900.9	78.0	245.0	79.5	12.80	377.39	122.50
L20 x T2	9265.4	77.5	240.0	78.5	14.60	327.56	137.50
L21 x T1	6794.3	73.5	200.0	74.5	13.80	387.11	102.50
L21 x T2	4851.5	74.0	195.0	75.0	13.70	338.92	105.00
L22 x T1	6365.9	73.0	220.0	74.0	14.20	248.57	105.00
L22 x T2	5291.4	72.5	225.0	74.0	13.30	356.91	107.50
L23 x T1	6851.8	73.5	225.0	73.50	16.40	282.63	117.50
L23 x T2	6958.4	74.0	232.5	74.50	15.00	291.55	130.00
L24 x T1	6166.9	73.5	215.0	75.0	14.00	378.69	107.50
L24 x T2	6424.0	76.5	237.5	77.5	13.90	372.5	137.50
BH-540	5618.1	75. 0	227.5	76.0	127.5	13.60	327.30
Melkassa-2	4619.9	70.5	177.5	71.0	122.0	14.40	313.00
Melkassa-6Q	5533.0	73.0	207.5	73.5	129.0	15.00	344.70
BHQPY-545	5644.3	80.5	237.5	81.0	129.5	13.75.0	352.00
G. Mean	**7330.97**	**75.2**	**219.51**	**76.38**	**124.83**	**14.09**	**346.76**
CV (%)	**6.94**	**1.58**	**4.24**	**1.50**	**1.51**	**4.38**	**11.28**
LSD (5%)	**1023.40**	**2.40**	**18.93**	**2.33**	**3.83**	**1.25**	**79.43**

Where: AD = days to anthesis (days), EH= ear height (cm), EPP= number of ears per plant (No), GY = grain yield (kg/ha), RPE = number of kernel rows per ear (No), PH = plant height (cm), SD = days to silking (days) and TKWT = 1000 kernel weight (g).

Combining Ability Analysis

Line GCA mean squares were highly significant for grain yield, 1000 kernel weight, days to anthesis and silking, plant and ear height, number of kernels per row and number of rows per ear (Table 4). For tester GCA, only grain yield, ear height and number of kernels per row showed highly significant differences. The non significant difference tester mean square observed for most the traits suggest that the testers used for the current study had comparable potential for the studied traits. Analysis of variance for SCA also showed highly significant differences for grain yield, 1000 kernel weight, plant and ear heights, number of kernels per row, number of rows per ear and days to anthesis (Table 4). The results of analysis of combining abilities obtained from this study indicated the importance of both additive and non-additive gene actions in controlling in these agronomical important traits such as grain yield, 1000 kernel weight, plant and ear heights, days to anthesis, number of kernels per row and number of rows per ear. Therefore, both additive and non-additive variances are important in determining for the exploitation breeding behavior of the genetic potential of the inbred lines in variety development program. Highly significant mean square due to top crosses entries, checks, line GCA and non-significant mean square due to check vs crosses for most traits were also reported by [11].

Table 4. Mean squares for grain yield and yield related traits in 48 test crosses evaluated at Melkassa in 2010

Sources of variation	Df	GY (kg/ha)	PH (cm)	AD (days)	TKWT (g)	EH (cm)	SD (days)	RPE (No)
Line (GCAf)	23	3791378.1**	651.7**	10.8**	3896.5**	269.8*	10.7**	1.3**
Tester (GCAm)	1	978408.5**	0.13 ns	0.4 ns	700.7ns	229.7*	0.3 ns	0.3 ns
Line x Tester (SCAfm)	23	2163739.2**	260.45**	0.9**	2456.6**	236.4*	0.8ns	0.5**
Error (E)	47	107112	40	0.5	787.7	34.24	0.59	0.1

**and ** = Significant and highly significant, respectively, ns = non significant, AD = number of days to anthesis, EH = ear height, GY = grain yield, PH = plant height, RPE = number of kernel rows per ear and SD = number of days to silking and TKWT = 1000 kernel weight.*

Estimates of general combining ability effects

Estimates of GCA effects for grain yield showed that out of the 24 inbred lines studied in line x tester cross eight exhibited positive and highly significant GCA effects while 10 lines exhibited negative and significant GCA effects (Table 5). Inbred line L4 exhibited the maximum GCA effect of 2705.02 kg/ha, whereas L13 exhibited the lowest GCA effect of -2005.13 kg/ha, indicating the existence of best and poorest general combiners in the group of inbred lines studied, respectively. Inbred lines identified for good general combining ability could be utilized in maize grain improvement programs for improvement of the traits of interest as these lines have high potential to transfer desirable traits to their cross progenies. From the tester, T2 was the best general combiner while T1 was poor general combiner for grain yield. Both positive and negative GCA effects were reported in maize by several investigators [12, 13].

Both negative and positive GCA effects were observed for days to anthesis and silking. 10 and nine of the lines showed highly negative and significant GCA effects of days to anthesis and silking, respectively. Other 10 and nine inbred lines showed positive and significant GCA effects for days to anthesis and silking, respectively. Lines L6 (-4.76 days) and L5 (-4.01 days) were good general combines while L14 (3.24 days) and L10 (2.99 days) poor general combiners for days to anthesis (Table 5). L6 (-4.73 days) and L5 (-3.48 days) were good general combiners while L14 (3.52 days) and L10 (3.02 days) poor general combiners for days to silking (Table 5). The negative value implies that the inbred lines are good combiners as it indicates the tendency of earliness and the reverse is true for those with positive GCA effects. The current results are in general agreement with the findings of researchers [14, 15].

For plant height, L19 (-48.91 cm), L21 (-22.6 cm), L4 (-22.66 cm) and L6 (-22.66 cm) were found to be good general combiners while L1 (32.34) and L12 (23.59 cm) were poor general combiners (Table 5). This indicates that L19 has a tendency to reduce whereas L1 has a tendency to increase plant height in the hybrid progenies. In maize, shorter plant height is desirable for lodging resistance. For to ear height, seven inbred lines showed negative and significant GCA effects, whereas, nine inbred lines showed positive and significant GCA effect. L5 (-28.75 cm), L15(-15.0 cm) and L21 (-15.0 cm) were good general combiners while L12 and L16 showed the highest GCA effects (13.75 cm), which indicates the tendency to increase ear height. The estimates GCA effect for the testers showed that T2 has the tendency to reduce ear height as it had negative GCA effect. In contrast, T1 showed positive GCA effect which indicates the tendency to increase ear height (Table 5). This result is in conformity with the findings of Habtamu and Hadji [16].

With respect to number of rows per ear, L7 and L23 showed positive and significant GCA effects, whereas L11 showed significant negative GCA effect (Table 5). The positive GCA effect is desired for number of rows per ear as it is the most important yield component that directly contributes to increased grain yield. Hence, inbred lines with high GCA effects for this trait can be suitable parents for hybrid formation as well as for inclusion in future breeding programs. Such parents contribute favorable alleles in the process of synthesis of new varieties. The result of this study is in conformity with the findings of [17].

Inbred lines L5, L6 and L8 were good general combiners while L7, L23 and L19 were poor combiners for 1000 kernel weight (Table 5). Inbred line L20 had positive and significant GCA effects for number of ears per plant while L12 had negative and significant GCA effects (Table 5). The positive and significant GCA effects for number of ears per plant indicates prolificacy which is desirable in increasing maize productivity while negative and significant GCA effects for the same trait indicates non-prolificacy which is undesirable. Hence, inbred lines with positive and significant GCA effect could be selected for further use in the breeding program. Similar to the current findings, positive and negative significant GCA effects for 1000 kernel weight were reported by [18, 19].

Table 5. Estimates of general combining ability effects for grain yield and yield related traits of maize inbred lines studied in line x tester crosses at Melkassa in 2010

line	GY	RPE	AD	PH	SD	TKWT	EH
L1	-84.23	0.39	1.99**	32.34**	1.77**	-17.48	8.75*
L2	-1129.83**	0.24	1.74**	9.84**	1.52**	-23.67	10.00**
L3	771.37**	-0.13	-2.01**	3.59	-1.98**	27.12	2.50
L4	2705.02**	-0.11	-1.76**	-22.66**	-1.98**	48.98**	-13.75**
L5	798.32**	-0.91	-4.01**	-17.66**	-3.48**	63.67**	-28.75**
L6	477.92**	-0.26	-4.76**	-22.66**	-4.73**	60.82**	3.75
L7	-755.78**	2.74**	-2.01**	6.09	-1.98**	-71.70**	3.75
L8	2500.57**	-0.26	-0.76*	-6.41*	-0.73	63.06**	-11.25**
L9	202.87	-0.06	2.24**	4.84	2.02**	-9.43	-5.00
L10	2065.97**	0.34	2.99**	7.34*	3.02**	32.92*	17.5**
L11	176.27	-1.16*	0.24	-8.91**	0.27	34.66*	8.75*
L12	172.22	0.34	2.49**	23.59**	3.02**	-1.36	13.75**
L13	-2005.13**	-0.41	1.24**	4.84	1.02*	-51.55**	6.25*
L14	1139.87**	-0.36	3.24**	7.34*	3.52**	46.42**	7.50*
L15	-752.93**	0.54	-2.76**	-12.66**	-1.98**	-40.30**	-15.0**
L16	-1984.83**	0.04	1.49**	21.09**	1.27**	-50.64**	13.75**
L17	-839.03**	-0.81	0.49	2.34	0.52	38.17**	-8.75*
L18	-160.73	0.04	0.74	-0.16	0.77	-33.82*	-3.75
L19	-254.43	-0.71	2.49**	-48.91**	2.52**	-56.46**	-2.50
L20	2087.42**	-0.36	2.49**	22.34**	2.52**	4.40	11.25**
L21	-1672.83**	-0.31	-1.51**	-22.66**	-1.73**	14.94	-15.0**
L22	-1667.08**	-0.31	-2.51**	2.34	-2.48**	-45.34**	-12.5**
L23	-590.63**	1.64**	-1.51**	8.59*	-2.48**	-60.99**	5.00
L24	-1200.28**	-0.11	-0.26	6.09	-0.23	27.52	3.75
SE line	163.64	0.23	0.37	3.10	0.38	14.03	2.93
Tester	GY	EH					
T1	-142.77**	2.18*					
T2	142.77**	-2.18*					
SE tester	47.24	0.84					
$SE(g_i-g_j)$ tester	66.81	1.19					

Estimation of specific combining ability

For grain yield, both negative and positive and significant estimates of SCA effects were observed among the crosses (Table 6). Cross L12 x T1 and L16 x T2 were good specific combiners, whereas, crosses L12 x T1 and L16 x T2 were poor specific combiners (Table 6). Highly significant SCA effects of the crosses indicate that significant deviation from what would have been predicted based on their parental performances. These crosses with highly positive and significant estimates of SCA effect could be selected for their specific combining ability to use in maize improvement program. The results of the current study are in agreement with the findings of [20, 21] who reported significant to highly significant level of SCA effects in most of the crosses they studied for grain yield in maize.

With respect to number of days to anthesis, crosses L15 x T1 and L24 x T1 showed the best SCA effects of -1.41 days for earliness, whereas L15 x T2 and L24 x T2 were the latest with SCA effect of 1.41 days (Table 6). For plant height, the estimates of SCA effects were found to be significant in 22 of the 48 crosses evaluated in the current study. Crosses L19 x T1 and L19 x T2 were good and poor specific combiners, respectively (Table 6). The shortened plant is advantageous in case of lodging resistance. With regard to ear height; significant estimates of

SCA effects were observed substantial number of crosses. Crosses L6 x T2, L10 x T1 and L17 x T1 were best specific combiners as they show the tendency to reduce ear height while and L6 x T1, L10 x T2 and L17 x T2 were poorest specific combiners as they show the tendency to increase ear height (Table 6). The existence of both positive and negative SCA effects in maize crosses has been also reported by [22].

Table 6. Estimates of specific combining ability effects of line x tester crosses evaluated for grain yield and yield related traits at Melkassa in 2010

Crosses	GY	AD	PH	RPE	TKWT	EH
L1 x T1	-174.57	-0.16	0.05	-0.42	-49.23*	4.69
L1 xT2	174.57	0.16	-0.05	0.42	49.23*	-4.69
L2 xT1	-1516.87**	1.09*	-2.45	0.43	-9.20	-6.56
L2 x T2	1516.87**	-1.09*	2.45	-0.43	9.20	6.56
L3 x T1	1395.33**	0.84	1.30	0.25	43.92*	-1.56
L3 x T2	-1395.33**	-0.84	-1.30	-0.25	-43.92*	1.56
L4 x T1	-623.12*	0.59	-7.45	0.08	34.43	-0.31
L4 x T2	623.12*	-0.59	7.45	-0.08	-34.43	0.31
L5 x T1	1069.08**	0.34	-12.45**	0.18	-8.07	2.19
L5 x T2	-1069.08**	-0.34	12.45**	-0.18	8.07	-2.19
L6 x T1	279.98	0.59	-4.95	-0.27	15.56	27.19**
L6 x T2	-279.98	-0.59	4.95	0.27	-15.56	-27.19**
L7 x T1	-1094.32**	0.34	6.30	0.53	29.08	4.69
L7 x T2	1094.32**	-0.34	-6.30	-0.53	-29.08	-4.69
L8 x T1	-149.87	-0.91	-16.20**	-0.07	-11.43	-15.31**
L8 x T2	149.87	0.91	16.20**	0.07	11.43	15.31**
L9 x T1	-1659.37**	0.59	-17.45**	-0.87	-60.10*	-4.06
L9 x T2	1659.37**	-0.59	17.45**	0.87	60.10*	4.06
L10 x T1	-657.77**	0.34	-9.95*	-0.07	-26.87	-16.56**
L10 x T2	657.77**	-0.34	9.95*	0.07	26.87	16.56**
L11 x T1	-186.07	0.59	-16.20**	-0.57	-18.51	-15.31**
L11 x T2	186.07	-0.59	16.20**	0.57	18.51	15.31**
L12 x T1	1965.78**	-0.16	8.80	-0.67*	34.49	14.69**
L12 x T2	-1965.78**	0.16	-8.80	0.67*	-34.49	-14.69**
L13 x T1	492.13*	0.09	15.05**	0.28	-81.50**	14.69**
L13 x T2	-492.13*	-0.09	-15.05**	-0.28	81.50**	-14.69**
L14 x T1	-71.67	-0.41	2.55	1.03**	-6.98	-9.06*
L14 x T2	71.67	0.41	-2.55	-1.03**	6.98	9.06*
L15 x T1	1115.43**	-1.41*	10.05*	0.13	15.04	3.44
L15x T2	-1115.43**	1.41*	-10.05*	-0.13	-15.04	-3.44
L16 x T1	-1824.47**	-0.66	11.30*	0.03	-14.38	17.19**
L16 x T2	1824.47**	0.66	-11.30*	-0.03	14.38	-17.19**
L17 x T1	517.83*	0.84	10.05*	-0.42	55.27*	7.19
L17 x T2	-517.83*	-0.84	-10.05*	0.42	-55.27*	-7.19
L18 x T1	1612.23**	-0.91	2.55	0.03	17.66	-0.31
L18 x T2	-1612.23**	0.91	-2.55	-0.03	-17.66	0.31
L19 xT1	-1420.3**	-0.66	31.30**	0.43	28.26	-6.56
L19 x T2	1420.37**	0.66	-31.30**	-0.43	-28.26	6.56
L20 x T1	174.98	0.34	2.55	-0.97**	28.74	-5.31
L20 x T2	-174.98	-0.34	-2.55	0.97**	-28.74	5.31
L21 x T1	828.63**	-0.16	2.55	-0.02	27.92	0.94
L21 x T2	-828.63**	0.16	-2.55	0.02	-27.92	-0.94
L22 x T1	394.48	0.34	-2.45	0.38	-50.35*	0.94*
L22 x T2	-394.48	-0.34	2.45	-0.38	50.35*	-0.94*
L23 x T1	-196.07	-0.16	-3.70	0.63	-0.64	-4.06
L23 x T 2	196.07	0.16	3.70	-0.63	0.64	4.06
L24 x T1	-271.32	-1.41*	-11.20*	-0.02	6.92	-12.81**
L24 x T2	271.32	1.41*	11.20*	0.02	-6.92	12.81**
SE SCA	231.42	0.53	4.51	0.324	19.85	4.14
SE (S_{ji}-S_{kl})	327.28	0.74	6.37	0.46	28.07	5.85

** and** = significant and highly significant, respectively, AD = days to anthesis, EH = ear height, GY= grain yield, PH= plant height, RPE = number of rows per ear and TKWT= 1000 kernel weight.*

Only six crosses were found to exhibit significant level of SCA effects for number of rows per ear (Table 6). This shows that most of the crosses evaluated in the current study did not significantly deviate from what would have been predicted based on their parental performance. Crosses L14 x T1, L20 x T2 and L12 x T2 were good specific combiners, while L14 x T2, L20 x T1 and L12 x T1 poor specific combiners for this trait, respectively (Table 6). This result is in conformity with findings of [23]

For 1000 kernel weight, 10 crosses showed significant estimates of SCA effects (Table 6). Good specific combination was observed for L13 x T2, while the poorest was L13 x T1. Crosses with positive and significant SCA effects for this trait are desirable as this trait directly contributes to grain yield of maize. In line with the present results, significant SCA effects in maize inbred lines evaluated in line x tester were reported by other researchers [24]

CONCLUSION

Generally, the results of the current study identified that inbred lines with good GCA and cross combinations with desirable SCA for the traits studied. This indicates the possibility of developing desirable cross combinations and synthetic varieties through crossing and or recombination of inbred lines with desirable traits of interest. Furthermore, promising cross combinations identified in this study could be utilized for future breeding work as well as for direct release after confirming the stability of their performances observed in the current study. Hence, the information from this study may possibly be useful for researchers who would like to develop high yielding varieties of maize.

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