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Research Article

Studying yield and yield components of Early Maturing Maize (*Zea mays L.*) Inbred Lines in Central Rift valley of Ethiopia

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The objective of the study was to evaluate yield and yield components of early maturing maize inbred lines in moisture stress areas of Ethiopia. Fifteen inbred lines were crossed in a diallel mating design; three standard checks with105 hybrids were evaluated in Alpha Lattice Design in two replications at three locations. Most studied traits showed significant for entries, hybrids, checks, checks versus hybrids, interaction of entries x location and hybrids x location. The highest grain yield was obtained from hybrids, Line7 x Line15 (8.05t/ha), L9 x L15 (6.44t/ha) andL14 x L15 (9.37t/ha) whereas, the lowest yield was recorded from hybrids, L4 x L8, L1 x L2 or L3 x L9 and L4 x L3 at Melkassa, Mieso and Zeway, in the that order. Mean of hybrids and standard checks across locations indicated that the highest grain yield of 7.2 and 7.1 (t/ha) were obtained from standard checks Melkassa hybrid-130 and BH-543 respectively. Among the hybrids, the best yield of 7.0, 6.7 and 6.6 (t/ha) were recorded for L12 x L15, L7 x L15 and L14 x L15, in that order. The lowest grain yield was obtained from hybrid, L4 x L8 (2.8 t/ha). Lines, L5 x L6 and L5 x L10 were early maturing hybrids across the locations. Hence, hybrids involving L15 as one of its parent yielded better at all locations. The study identified inbred lines and hybrid with desirable traits that will be useful for selecting high yielding and early maturing hybrids for drought areas of the country.

Keywords: *Central Rift Valley, early maturing, maize, inbred lines, yield and yield components*

INTRODUCTION

Maize (*Zea mays* L.), together with wheat (*Triticum aesivum* L.) and rice (*Oryza sativa* L.) is one of the three most important cereal crops that feed two third of the world population (Ji *et al*., 2013).It is used as a human food, livestock feed, different alcoholic and none alcohol drinks production, building material, and as fuel. It is also used to produce medicinal products such as glucose as well as an ornamental plant Abera Debelo (1982).

Ethiopia currentlyproduces more maize than any other crop (Abate *et al.*, 2015). In the country, 2,230000 hectares of land was covered with maize with an estimated production of about 6,580000 tons (CSA 2014/15). However, the national average yields 6.6 Mt/ha (CSA, 2015/16) is still far below the world average 7.0 Mt/ha (CSA, 2015/16). Such low grain yield of maize is attributable to lack of improved varieties for different agro-ecological regions, diseases and insect pests, moisture stress, poor cultural practices, excessive plant height and low soil fertility Abera Debelo (1982).

One of the important strategies plant breeders adopted to overcome the problem of getting a better yield is to select germplasms that used to identify high yielding entries that may give a reasonable yield on different soil and environmental conditions (Kaur *et al.*, 2007). The reason for selecting early maturing maize inbred lines is that no work has been done for understanding and describing yield and related traits of early maturing maize inbred lines in Central Rift valley of Ethiopia. Information on yield and yield components of locally available and introduced early maturing elite maize inbred lines is very important for future development strategies for drought stresses of Ethiopia. Therefore, the current study was designed to estimate yield and yield components of early maturing maize inbred lines in drought stresses of central Ethiopia.

MATERIALS AND METHODS

Treatments and Experimental Design

The experimental materials used for the current experiment consisted of a total of 108 entries which comprised of 105 single crosses developed from 15x 15 diallel crosses (Table 2) excluding the reciprocal crosses and parents) inbred lines, with tree standard checks; namely, Melkassa-2; BH-543 and Melkassa hybrid-130. Melkassa hybrid 130 is also check which is a double top cross hybrid. From the standard checks, BH-543 is a Single cross hybrid released by Bako National Maize Research Project and is a medium maturing three-way cross hybrid released for mid altitude, high potential maize growing agro-ecologies of Ethiopia. Whilst Melkassa-2 is an open pollinated variety (OPV) released by Melkassa Agricultiral Research Center and is an early maturing variety released for moisture stressed areas of the country. The experiment was laid out in 9 x 12 alpha-lattice designs (Patterson and Williams, 1976) with two replications. Even though the number of replication is small, efficiency of alpha lattice design increases precision of the experiment. The 105 crosses were made during the main season of 2010 at Melkassa Agricultural Research Center. The parental lines were originally obtained from CIMMYT and selected for per se performance across drought stressed environments in Central Rift Valley of Ethiopia. The checks were excluded from the genetic analysis. The net plot size was 4.25m x 0.75m i.e. 3.2$m^2$for each site. Planting was done by hand on June 24, 27 and 30, 2011 at Mieso, Melkassa and Zeway, in that order. Description of each experimental area was explained in (Table 1).

Two seeds were sown per hill which later thinned to one plant per hill after seedlings established well to get a total plant population of 53,333 per ha. 100 DAP and 50 Urea kg per hectare were applied uniformly for each location. DAP was applied at planting while whole Urea was applied at knee height stage of the crop. All other recommended crop management practices were applied uniformly.

Experimental area

Table 1. Agro climatic- description of experimental trial sites

Site	Longitude	Latitude	Elevation (m.a.s.l)	Rainfall (mm)	Temperature (^{O}C)		Soil texture
					Min	Max	
Melkassa	39.32^0 E	8.40^0 N	1540	734	14.1	28.4	sandy loam
Mieso	40.45^0 E	9.13^0 N	1327	801	14.6	30.3	Vertisoils
Zeway	38.75^0 E	8.00^0 N	1640	760	13.7	26.7	Silt to Sandy loam

Data Collection

Data were recorded on plot and single plant basis for the following parameters to represent their respective characters.

Data Collected on plot bases: days to emergence, days to anthesis, days to silking, anthesis–silking interval, ears per plant, days to maturity and thousand kernel weights.

Data recorded using random sample of 10 plants or ears from each plot.

plant height, ear height, number of ears per plant, ear length, ear diameter, number of kernel rows per row, number of kernels per row, number of kernels per.

Data Analysis

Analyses of variances (ANOVA) were computed for grain yield and related agronomic traits by using (Patterson and Williams, 1976).

RESULTS AND DISCUSSION

The objective of the present study was to evaluateyield and yield components of early maturing maize (Zea mays L.) inbred lines in drought stress areas of Ethiopia. The results of the study were presented and discussed as follows.

Analysis of Variance for each location

The results of analysis of variance for different traits studied at the three locations, namely, Melkassa, Mieso and Zeway, were presented in (Table 3). The mean squares due to Entries at the three locations were significant at ($P \leq 0.01$) for days to anthesis, days to silking, plant height and ear height while anthesis-silking interval was non-significant (Table 3). In each location, analysis of variance showed significant at ($P \leq 0.01$) among entries for number of days to anthesis, silking, plant, and ear height

Table 2. Code and pedigree of maize inbred lines used in for grain yield and related traits

NO.	code	Pedigree
1	P1	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI35-10-1/ECA-EE-POP1-B-B-2-B-B-#
2	P2	P43SR-66-n/TZEESRW-B1/EECOMP./Katumani/KATUMANI15-3-2/ECA-EE-POP1-B-B-2-B-B-#
3	P3	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI35-11-2/ECA-EE-POP1-B-B-6-B-#-#-1-#
4	P4	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI35-11-2/ECA-EE-POP1-B-B-3-4-B-# 1-#
5	P5	8721SR-34G-3-3sb-#1/TZEESRW1-B1/EECOMP./Katumani/KATUMANI58-7-1/ECA-EE-POP1-B-B-1-B-#-#-2-#
6	P6	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI4-10-1/ECA-EE-POP1-B-B-4-B-B-#
7	P7	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI35-11-2/ECA-EE-POP1-B-B-6-B-#-#-2-#
8	P8	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI35-11-2/ECA-EE-POP1-B-B-3-4-B-#-2-#
9	P9	87TZBSR-140-1-1-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI10-6-3/ECA-EE-POP1-B-B-6-B-#-#-1-#
10	P10	TZLCOMP3-168-2-5-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI4-8-1/ECA-EE-POP1-B-B-1-2-B-#-2-#
11	P11	P43SRC9FS9-2-1-1sb-#1/TZEESRW1-B1/EECOMP./Katumani/KATUMANI15-4-2/ECA-EE-POP1-B-B-2-B-B-#
12	P12	87TZBSR-140-1-1-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI10-6-3/ECA-EE-POP1-B-B-4-B-#
13	P13	87TZBSR-140-1-1-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI10-13-1/ECA-EE-POP1-B-B-2-B-B-#
14	P14	87TZBSR-140-1-1-#/TZEESRW1-B1/EECOMP./Katumani/KATUMANI10-6-3/ECA-EE-POP1-B-B-6-B-#-#-2-#
15	P15	CML395

P=parent

Table 3. Analysis of variance for each location.

Location	Melkassa		Mieso		Zeway	
	Entry	Error	Entry	Error	Entry	Error
Traits	Df=107	Df=107	Df=107	Df=107	Df=107	Df=107
GY	1.67**	0.48	1.33ns	1.19	2.22**	1.08
DA	32.97**	2.07	8.81**	4.73	30.87**	4.01
DS	30.78**	2.16	8.27**	4.37	28.81**	5.22
ASI	0.58ns	0.56	0.21ns	0.25	2.07ns	0.91
PH	533.34**	97.21	487.01**	132.87	430.07*	266.57
EH	262.81**	113.03	296.77**	125.64	365.94**	190.72
EPP	0.019ns	0.02	0.01ns	0.01	0.03**	0.02
DM	20.31**	8.88	34.43ns	32.95	9.34ns	12.13
EL	5.04**	2.80	5.8ns	5.58	3.19ns	2.31
ED	18.71**	11.08	9.63ns	10.80	12.87*	7.93
KPR	26.85*	17.16	31.7ns	31.25	17.30ns	12.97
RPE	4.15*	2.84	4.94ns	4.02	3.6**	1.69
KPE	9788.34ns	7297.70	10427.88ns	8347.04	9205.84**	4397.17
TKW	2533.61**	625.89	2319.99ns	1766.66	3292.51**	254.22

GY=grain yield (t ha^{-1}), DA=days to anthesis, DS=days to silking, ASI=anthesis-silking interval, PH=plant height (cm), EH=ear height (cm), EPP=number of ear per plant, DM=days to maturity, EL=ear length (cm), ED=ear diameter (caliper), KPR=number of kernels per row, RPE=number of kernel rows per ear, KPE=number of kernels per ear and TKW=thousand kernel weight (g). * $p \leq 0.05$,**$p \leq 0.01$, ns= non-significant (DF=107 and DF=107)=degrees of freedom for Entries and error, in that order. *, **, Significant at 0.05, and 0.01 level of probability, in that order.

for these traits computed in all locations except significantat ($P \leq 0.05$) for plant height at Zeway (Table 3). This indicated the presence of inherent variation among the entries, which makes selection possible. Entries exhibited significant in all traits at Melkassa except anthesis-silking-interval, number of ear per plant and number of kernels per ear. Entries were significant at ($p \leq 0.01$) for grain yield, days to anthesis, silking, maturity, plant height, ear height, ear length, ear diameter, and thousand kernel weights while significant at ($p \leq 0.05$) for number of kernels per row and rows per ear. At MiesoEntries were significant at ($p \leq 0.01$) for days to anthesis, days to silking, plant height and ear height. Entries weresignificant at ($p \leq 0.01$) for grain yield, days to anthesis, silking, ear height, number of ear per plant, rows per ear, kernels per row and thousand kernel weights while significant at ($p \leq 0.05$) for plant height and ear diameter at Zeway (Table 3). Significance of the traits showed that it is important to test across different locations to exploit high yielding and early maturing varieties for future maize breeding program.(Anonymous, 2017) also found similar result with the present investigation in the study of Combining ability and heterotic orientation of mid-altitude sub-humid tropical maize inbred lines for grain yield and some agronomic traits.

The significant mean squares due to Entries indicated the existence of genetic variability among the materials evaluated, which could be exploited for the improvement of respective traits for future maize breeding program.

Analysis of variance across locations

Pooled analysis of variance was made for eight traits for those that showed homogeneity of variances only. Pooled

Table 4. Analysis of variance for grain yield and yield related traits in 15 x 15 diallel crosses of maize inbred lines and the three standard checks evaluated across three locations.

Source	Df	(GY)+	DA	DS	PH	EH	(ED)+	(RPE)+	(TKW)+
Loc	2	53.71**	6358.98**	6046.93**	62652.64**	49873.50**	956.85**	0.93ns	29307.87**
Rep	1	13.26	0.50	1.68	638.04	1.58	61.63	0.04	14129.20
Bloc(Rep)	22	2.40	13.52	14.67	320.74	141.34	9.82	2.32	822.66
Rep(Loc)	2	16.87	2.84	1.46	327.15	151.33	61.07	0.00	1927.66
Entry	107	547.48 **	7168.29**	7314.88**	20533.30**	8774.36**	4637.38**	1391.71**	29007.70**
Entry*Loc	214	0.88ns	9.53**	8.91**	278.05**	201.58**	10.39ns	2.50ns	3675.78**
Hybrids	104	527.28**	6945.47**	7089.68**	19909.41**	8477.39**	4502.16**	1351.31**	28204.80**
Hyb*Loc	208	0.97**	9.44**	8.95**	289.30**	201.36**	11.11ns	2.40ns	4021.42**
Checks	2	13.57**	148.33**	150.67**	413.33**	198.33**	90.23**	26.89**	434.53**
Hyb vs. Ch	1	6.64**	74.49**	74.53**	210.55**	98.64**	44.99**	13.52**	368.37**
Error	301	0.91	4.19	4.62	185.70	148.04	9.89	2.21	477.87
Grand mean		5.46	66.99	68.36	191.89	82.00	43.69	12.98	280.92
CV (%)		17.42	3.06	3.14	7.10	14.84	7.20	11.46	7.78

*, ** Significant at $p \leq 0.05$ and $p \leq 0.01$ level of probability, in that order. Entry = Entry, Loc = location, Hyb=hybrids, Ch=checks, Vs. =versus Rep = replication, + = combined over two locations, CV = coefficient of variation.

mean squares of Entries, Entry x location and error were presented in (Table 4). Pooled analysis of variance revealed that the mean squares due to Entries were significant at ($p \leq 0.01$) for all traits across locations. Whereas Entry x location interaction were significant at ($p \leq 0.01$) for days to anthesis, days to silking, plant height, ear height and thousand kernel weights. Hybrids, hybrids x location, checks and hybrids versus checks exhibited significant at ($p \leq 0.01$) (Table 4).This indicated the presence of inherent variation among the genotypes and these sources of variations had significant interactions with the environment for grain yield, which makes selection possible.

In line with the current study, the result of the combined analysis of variance across the three environments revealed that there were significant differences among the genotypes for days to anthesis days to silking, plant height, ear height, ear aspect and grain yield (Anonymous, 2017).In addition, significant differences following combined analyses were previously reported by various researchers (Gudeta, 2007; Bayisa *et al*., 2008; Kanyamasoro *et al*., 2012) in their studies using different sets of maize inbred lines.

Mean performance of Entries at each location and across locations

Mean agronomic performance of hybrids and checks evaluated across Melkassa, Mieso and Zeway were presented and discussed as below (Table 5).

The result revealed that the highest grain yield was obtained from hybrids, Line7 x Line15 (8.05t/ha), L9 x L15 (6.44t/ha) and L14 x L15 (9.37t/ha) at Melkassa, Mieso and Zeway in that order. In contrast, the lowest yield was recorded from hybrids, L4 x L8, L1 x L2 or L3 x L9 and L4 x L3 at Melkassa, Mieso and Zeway, in the given order. Hence, hybrids involving L15 as one of its parent yielded better at all locations (data not shown).

Mean of hybrids and standard checks across locations indicated that the highest grain yield of 7.2 and 7.1 (t/ha) were obtained from standard checks Melkassa hybrid-130 and BH-543, respectively. Among the hybrids, the best yield of 7.0, 6.7 and 6.6 (t/ha) were recorded for L12 x L15, L7 x L15 and L14 x L15, in that order. The lowest grain yield was obtained from hybrid, L4 x L8 (2.8 t/ha) (Table 5). From hybrids, more than 59% yielded 5≤ t/ha while the rest gave grain yield of (4 ≤ t/ha) except four hybrids. The mean grain yield of L12 x L15 hybrid exceeded that of the average of the checksin this experiment by 20%. Therefore, the above hybrids are the best candidates for wide area production after testing their stabilityin yields across years.

The maximum number of days to anthesis was scored for the check BH-543 (80.30) followed by hybrids, L9 x L15, L8 x L15, L9 x L14, L12 x L15 and L14 x L15 with 74.5, 74, 73.8, 73.3 and 73.0 values, in that order, Whereas the minimum 61.5 days was for hybrids, L5 x L6 and L5 x L10. The maximum number of days to silking was from BH-543 (81.7) followed by hybrids, L9 x L15, L8 x L15, L9 x L14, L14 x L15 and L12 x L15 with 75.7, 75.2, 74.7, 74, in that order. The highest days of to maturity of 120, 116.8, 116.5 and 116.2 to maturity was obtained from BH-543, MH-130, L6 x L15 and L3 x L1116.5, in that order. The lowest days to maturity of 105.2 and 105.3 were obtained from hybrids, L2 x L4 and L1 x L4, in that order (Table 5). Early flowering genotypes were important for screening under moisture stress environmental conditions of the country.

The highest plant height of 231.7, 228.3, 225 and 221.7cm was obtained from L7 x L15, check 2 (BH-543), L14 x L15 and L12 x L15, in that order. Lowest plant height of 152.5, 162.5 and 165cm was recorded for hybrids, L4 x L8, L2 x L5 and L5 x L10, in that order. The highest ear height was 121.7 and 115cm for BH-543 and hybrid, L14 x L15, in that order. The lowest ear height of 59.2 and 61.7 cm was obtained from hybrids, L4 x L8 and L5 x L12 in that order (Table 5). Thus, short plant stature is vital to overcome lodging of the crops and improving productivity under different environmental conditions. The highest number of ear per plant of 2.4, 2.2 and 2.1 was exhibited from BH-543, MH-130 and hybrids, L14 x L15 and L12 x L15, in that order. In contrast, lowest number of ear per plant of 1.2 was obtained from L4 x L8 and L3 x L7 and L6 x L9. The highest ear length was 19.3 and 17.8 for MH-130 and hybrid, L12 x L15, in that order. The widest ear diameter of 50.2, 49.4 and 47.8 was recorded for hybrids, L1 x L5, L12 x L15 and check-MH-130 whereas the narrowest was 39.6 and 39.8 for hybrids, L4 x L9 and L6 x L11. The highest number of kernel per rows of 38.8, 36.3 and 36.2 was recorded for hybrid, L13 x L15, checks, MH 130 and BH-543, in that order. Hybrids, L3 x L10 and L5 x L11 had the lowest value of 27 and 27.3, in that order. Number of kernel per rows varied from 16 (L1 x L15) to 10.7 (L5 x L6). The highest thousand kernel weight of 336.6g was obtained for hybrid, L10 x L13 whereas the lowest was recorded for BH-543 (Table 5). So, maximum values for the above traits are ritual for increasing maize grain yield and thus, improve productivity of the crop for the study areas. Bullo Neda (2010) and Hadji Tuna (2004) also found similar results in their study.

In line with the current study, Vasal *et al.* (1993a) and Vasal *et al.* (1993b) also found significant mean squares due to crosses for days to silking, plant height and grain yield in CIMMYT's QPM germplasms. In agreement with the current investigation, Bullo Neda (2010) found significant mean squares due to ear diameter and highly significant mean squares due to days to grain yield, silking, days to anthesis, plant height and ear height while non-significant means squares for anthesis silking interval.

CONCLUSION

In this study, high yielding and early maturing maize hybrids at all locations were identified and hence, will be useful for the selection of high yielding and early maturing hybrids for drought areas of the country for the future maize breeding program.

Table 5. Mean grain yield and related agronomic traits of 105 single cross hybrids and three checks evaluated across three locations in Ethiopia during 2011.

Crosses	Entry	GY	DA	DS	PH	EH	ED	RPE	TKW
L1XL2	1	4.0	65.3	66.7	175.0	67.5	42.2	14.7	258.9
L1XL3	2	5.0	66.5	68.0	190.0	77.5	42.8	13.7	292.4
L1XL4	3	4.7	65.0	66.3	180.0	75.0	41.5	12.7	246.1
L1XL5	4	4.3	62.5	64.2	177.5	63.3	50.2	14.0	255.5
L1XL6	5	5.4	63.0	64.7	195.8	70.0	41.7	12.3	283.3
L1XL7	6	5.4	66.5	67.8	187.5	80.0	43.4	14.0	233.5
L1XL8	7	4.5	68.8	72.3	188.3	67.5	40.2	13.7	240.6
L1XL9	8	5.6	66.5	67.8	190.8	76.7	42.8	12.3	284.8
L1XL10	9	5.8	65.5	66.7	177.5	77.5	43.2	14.0	249.7
L1XL11	10	4.7	64.8	66.5	190.0	80.8	45.6	14.7	263.0
L1XL12	11	5.4	67.7	69.3	200.0	83.3	44.1	14.3	240.9
L1XL13	12	5.5	67.0	68.2	201.7	80.8	44.9	14.7	275.3
L1XL14	13	5.8	66.3	67.3	195.0	82.5	45.2	14.7	310.1
L1XL15	14	5.2	72.8	74.0	197.7	74.2	46.8	16.0	248.3
L2XL3	15	4.8	65.2	66.8	179.2	80.0	45.2	13.7	248.7
L2XL4	16	5.5	67.0	67.7	174.2	77.5	43.3	13.3	248.3
L2XL5	17	4.4	63.3	65.2	162.5	70.0	42.7	12.0	279.8
L2XL6	18	5.6	65.0	66.3	176.7	74.2	44.1	12.0	248.7
L2XL7	19	5.7	65.8	67.0	180.0	79.2	43.7	13.7	266.8
L2XL8	20	4.7	67.7	69.3	176.7	76.7	43.1	13.3	261.1
L2XL9	21	5.6	65.0	66.2	185.8	80.8	41.6	11.7	283.9
L2XL10	22	5.3	64.2	65.2	182.5	80.8	43.9	12.7	278.4
L2XL11	23	4.7	64.7	66.3	170.0	78.3	45.7	13.7	323.2
L2XL12	24	5.4	67.2	69.0	183.3	77.5	45.9	13.3	288.6
L2XL13	25	5.4	69.5	71.2	186.7	83.3	44.6	13.3	292.5
L2XL14	26	4.4	67.2	68.3	178.3	81.7	41.0	12.3	270.0
L2XL15	27	5.2	72.7	73.7	194.2	85.0	44.7	13.3	275.6
L3XL4	28	4.4	68.3	69.5	178.3	72.5	43.2	14.0	266.2
L3XL5	29	5.5	62.2	64.0	190.0	80.0	43.1	11.7	276.2
L3XL6	30	5.2	63.8	65.7	176.7	74.2	40.1	12.3	277.4
L3XL7	31	3.4	69.3	70.7	170.0	67.5	41.5	12.3	275.2
L3XL8	32	5.4	67.3	68.0	193.3	75.0	43.7	14.3	258.2
L3XL9	33	4.6	68.2	69.3	207.5	93.3	42.2	12.0	273.3
L3XL10	34	4.9	67.3	68.8	180.8	78.3	41.5	12.3	251.4
L3XL11	35	5.1	66.0	67.0	190.8	80.8	42.3	13.7	241.3

Table 5. Continue: Mean grain yield and related agronomic traits of 105 single cross hybrids and three checks evaluated across three locations in Ethiopia during 2011.

Crosses	Entry	GY	DA	DS	PH	EH	ED	RPE	TKW
L3XL12	36	4.6	67.2	69.2	202.5	78.3	43.7	13.0	285.4
L3XL13	37	6.4	67.2	68.2	201.7	75.0	44.6	12.7	279.7
L3XL14	38	5.0	68.0	69.8	205.8	91.7	40.7	11.7	287.4
L3XL15	39	5.4	72.5	73.7	216.7	88.3	46.7	14.3	258.2
L4XL5	40	4.8	64.3	66.0	175.0	66.7	44.1	14.3	288.7
L4XL6	41	5.1	66.3	68.5	195.8	77.5	40.8	13.3	272.0
L4XL7	42	4.3	68.0	69.7	186.7	78.3	42.4	13.3	261.8
L4XL8	43	2.8	72.0	73.5	152.5	59.2	40.5	14.0	267.8
L4XL9	44	5.1	67.0	68.3	198.3	91.7	39.6	12.3	264.2
L4XL10	45	5.3	67.2	67.7	184.2	77.5	42.9	12.3	254.1
L4XL11	46	5.1	64.7	66.0	197.5	85.8	45.5	12.7	223.9
L4XL12	47	5.4	65.3	66.5	199.2	76.7	45.2	14.0	265.6
L4XL13	48	4.3	68.7	70.8	200.0	85.0	42.6	13.0	211.9
L4XL14	49	4.8	65.7	66.5	194.2	88.3	40.9	12.0	272.6
L4XL15	50	4.9	72.8	73.7	200.8	86.7	43.5	14.7	243.5
L5XL6	51	5.0	61.5	62.8	181.7	66.7	40.1	10.7	286.5
L5XL7	52	4.7	65.2	66.3	173.3	65.8	43.5	12.0	284.3
L5XL8	53	5.5	64.5	66.0	175.0	66.7	43.7	12.0	303.8
L5XL9	54	4.6	63.5	65.0	190.0	81.7	42.7	12.3	316.9
L5XL10	55	4.4	61.5	62.5	165.0	67.5	44.0	13.0	242.2
L5XL11	56	5.3	63.2	64.8	174.2	63.3	43.3	11.3	290.6
L5XL12	57	4.6	62.7	64.7	168.3	61.7	43.7	11.7	301.6
L5XL13	58	4.9	62.5	64.3	190.2	65.0	41.5	12.7	277.7
L5XL14	59	5.3	63.5	65.2	185.8	76.7	43.6	12.3	264.0
L5XL15	60	5.9	71.5	72.3	204.2	77.5	46.1	13.3	260.4
L6XL7	61	5.0	65.3	66.5	201.7	84.2	40.8	12.7	247.3
L6XL8	62	5.0	67.5	68.7	190.8	80.8	42.7	12.3	228.0
L6XL9	63	3.9	66.2	67.8	204.2	91.7	40.6	10.7	276.4
L6XL10	64	5.0	62.5	63.8	182.5	70.8	41.4	11.7	293.2
L6XL11	65	4.0	64.2	65.5	181.7	77.5	39.8	11.0	299.8
L6XL12	66	4.2	65.0	66.7	197.5	84.2	42.6	12.7	257.7
L6XL13	67	5.1	64.3	65.7	194.2	79.2	41.8	11.3	252.5
L6XL14	68	5.2	64.7	66.3	200.0	90.8	40.1	11.3	246.3
L6XL15	69	6.4	72.7	73.3	211.7	100.8	43.9	14.3	246.6
L7XL8	70	5.6	68.0	69.0	189.2	80.8	42.2	14.0	246.6
L7XL9	71	5.2	66.8	68.5	197.5	86.7	41.1	12.7	264.5
L7XL10	72	4.7	63.5	64.5	180.8	78.3	42.1	14.0	264.0
L7XL11	73	4.1	67.0	68.8	193.3	92.5	41.9	14.0	264.8
L7XL12	74	5.0	67.8	69.5	205.8	85.8	44.2	14.7	287.4
L7XL13	75	4.8	66.7	68.0	187.5	75.8	44.8	14.7	267.3
L7XL14	76	5.3	66.0	67.5	204.2	90.8	43.0	13.3	299.9
L7XL15	77	6.7	70.8	71.8	231.7	99.2	46.2	14.7	260.2
L8XL9	78	5.4	67.5	69.0	196.7	87.5	41.0	12.3	296.4
L8XL10	79	5.5	65.8	67.3	185.8	89.2	43.2	13.0	276.6
L8XL11	80	5.5	65.8	66.8	192.5	91.7	42.2	13.0	279.5
L8XL12	81	5.8	66.3	67.5	200.8	82.5	46.4	15.3	285.0
L8XL13	82	5.0	67.5	69.2	203.3	89.2	43.6	13.3	305.1
L8XL14	83	4.9	68.7	70.2	192.5	79.2	42.2	13.0	243.0
L8XL15	84	5.4	74.0	75.2	201.5	88.8	42.4	12.7	259.5
L9XL10	85	4.8	65.8	66.5	193.3	90.0	43.2	12.3	291.3
L9XL11	86	5.3	67.3	68.3	209.2	106.7	42.8	11.3	284.7
L9XL12	87	4.9	67.3	68.5	195.0	84.2	47.0	13.0	311.0
L9XL13	88	4.9	67.5	68.2	198.8	90.8	42.5	13.0	284.3
L9XL14	89	3.5	73.8	74.7	184.2	91.7	43.3	12.0	309.4
L9XL15	90	5.8	74.5	75.7	211.7	95.0	45.3	14.0	301.7
L10XL11	91	5.4	64.0	65.5	175.8	75.8	42.8	12.3	281.8
L10XL12	92	5.7	62.5	63.7	194.0	87.5	47.5	14.0	273.2
L10XL13	93	4.7	66.7	68.0	190.8	75.0	42.7	11.7	336.6
L10XL14	94	5.3	64.8	66.2	185.8	85.0	42.0	11.3	321.0
L10XL15	95	5.9	71.0	72.0	210.8	100.8	43.7	13.0	260.7
L11XL12	96	5.0	64.0	66.0	185.8	76.7	42.7	13.3	289.6
L11XL13	97	4.7	65.0	66.5	194.2	90.0	44.1	13.3	267.4

Table 5. Continue: Mean grain yield and related agronomic traits of 105 single cross hybrids and three checks evaluated across three locations in Ethiopia during 2011.

Crosses	Entry	GY	DA	DS	PH	EH	ED	RPE	TKW
L11XL14	98	4.4	67.2	68.3	196.7	94.2	41.4	10.7	272.4
L11XL15	99	5.9	69.2	70.7	209.2	100.8	44.2	14.0	298.0
L12XL13	100	5.3	65.3	67.3	202.5	84.2	43.8	14.3	275.5
L12XL14	101	5.2	66.5	68.5	196.7	83.3	44.7	13.7	284.9
L12XL15	102	7.0	73.3	74.0	221.7	90.8	49.4	14.7	280.3
L13XL14	103	4.5	67.3	68.2	196.7	87.5	44.6	12.7	270.5
L13XL15	104	5.8	71.2	72.2	216.2	93.3	44.8	12.3	265.0
L14XL15	105	6.6	73.0	74.2	225.0	115.0	46.0	12.7	297.3
Check 1	106	7.1	70.8	72.0	193.3	83.3	47.8	12.7	259.5
check 2	107	7.2	80.3	81.7	228.3	121.7	44.4	14.7	211.6
Check 3	108	6.1	71.3	72.3	198.3	92.5	43.2	13.0	233.6
Mean		5.46	66.99	68.36	191.89	82.00	43.69	12.98	280.92
CV (%)		17.42	3.06	3.14	7.10	14.84	7.20	11.46	7.78
LSD		1.25	2.87	2.87	90.85	14.80	3.61	1.89	50.35

*, ** and ***, Level of significance at 5%, 1% and 0.1% respectively; †GY, grain yield (t ha-1); L=line; AD, number of days to anthesis; DS=number of days to silking; ASI, anthesissilking interval; PH, plant height (cm); EH, ear height (cm); EPP=number of ear per plant; DM=number of days to maturity; EL=ear length; ED=ear diameter; KPR=number of kernels per row; RPE=number of row per ear; KPE=number of kernels per ear; TKW=thousand seed weight.
Key: Check 1 = Melkassa hybrid-130
Check 2 = BH-543
Check 3= Melkassa 2

CONFLICT OF INTERESTS

There is no conflict of interest for this paper

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