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RESEARCH ARTICLE

Evaluating released Maize hybrids' parents for yield producibility and nicking time in mid altitude of western and north western Ethiopia

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Abstract

In maize (*Zea mays* L.) hybrid seed production, parent seed producibility is the primary criteria to be considered. Experiments which comprised 33 maize genotypes (nine crosses and 24 lines) planted in randomized complete block design with three replications at Bako and Pawe agricultural research center in 2019 to evaluate seed producibility of the parents. Combined analysis of variance showed highly significant difference among genotypes for all traits including grain yield (GY). Highly significant difference of the genotypes with environment interactions for GY and flowering characters (50% days to anthesis and silking) indicated inconsistence performance and flowering. In both location, single cross female parents flowered more than five days (-5) earlier than the male parent inbred lines during certified seed production in all three-way-cross hybrids. This suggested separate planting days would be needed for the male inbred line and the single cross female parent at each location. Hybrid varieties, BHQPY545, BH549 (Ilu), and BH520 (Nada) showed closer flowering synchronization between their parents (ranged from -3 to +4 days), and GY ranged from 3.07t/ha to 4.54t/ha with the desired male plant height to female ear height ratio. Generally, in hybrid seed production, seed yield and flower synchronization extent depends on varietal parents, environmental factors and their interactions. Therefore, it is concluded that before a variety release, knowing flower nicking period and seed producibility are important factors to be considered, and utilizing growing degree days based on heat unit allowing more precise and calibrate staggering date decision in different maize seed producing agro ecologies.

Keywords: Inbred lines; pollen parent; Producibility; seed parent; synchronization.

1. Introduction

Maize (*Zea mays* L., 2n=20) is considered as one of the most important food and feed crop in worldwide and Africa including Ethiopia. In terms of its wide adaptation, productivity and total production, maize is an essential crop for ensuring food security for increasing population. According to (FAO, 2022), globally maize was annually cultivated on an estimated area of 197 million hectares, which making it the second most widely grown crop in the world after wheat. In comparison, wheat and rice was annually cultivated on 216 million hectares and 165 million hectares, respectively. The total production of maize surpasses both wheat and rice in worldwide. In 2020, maize production was 1,162 million tones which is markedly higher 52.9% and 53.6% than both rice (760.9 million tons) and wheat (756.7 million tons), respectively (FAO, 2022).

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In 2021/22, cereal crops in Ethiopia covered 81.97% (9.99 mil. ha) out of the total crop area, maize took up (21.02%) which is the second position after Teff (24.05%). In terms of production, maize made up 32.79% (about 107,513,689.44 qt) followed by wheat (17.71%) and Teff (17.1%) with average yield 4.2 t/ha which represent an increment of 177.8% from 1.51 t/ha in 1995 to 4.2 t/ha in 2022 (CSA, 2022). This indicating that Maize breeders' have been very fruitful in developing or releasing an improved technologies/ varieties with full packages. The other reason for this production increment may emanated from widely using of seed quality. Use of quality seeds alone could increase productivity by 15-20 % (Kushmaur, 2015).

The knowledge of maize traits particularly growth characters, yield and flowering period of male and female parents are the most important and critical traits for the success of good quality hybrid seed production. In Ethiopia, the total quantity of improved seeds of cereal crops used in 2021/22 was 1.12 million quintal. Out of this, maize accounted for 52.2% (585,801) of the total improved seed used, with wheat accounting for 36.3%. Additionally, maize and wheat accounted for the largest crop area to which enhanced seeds were applied, with estimates of 1.7 mil ha and 0.41 mil ha, respectively (CSA, 2022).

Knowing of parental inbred lines and single cross characteristics for early generation seed (EGS) and certified seed production across different environments enables seed producers to produce seed uniformly in robust. Information on parental inbred line and single-cross seed yield under different environments and flowering synchrony between parents is important for successful seed production (Worku *et al.,* 2016). In Ethiopia, many high yielding and disease resistant maize varieties have been developed and released by different research centers under Ethiopian Institute of Agricultural Research (EIAR) for commercial cultivation under different agro ecologies of Ethiopia. In maize hybrid seed production, the objective is to maximize seed yield of desirable seed grade that is saleable and genetically pure. To achieve this, the timing of pollen shed of the male and silking of the female should be well synchronized. However, with regard to the matching of females and males parental lines, understanding among different seed producers/companies varies from place to place/erratic information. Hence, the current study was aimed as an imperative to evaluate the parents of released maize hybrids for seed producibility and nicking time at different mid altitude of Ethiopia.

2. Materials and Methods

2.1. Description of study areas

The experiment was conducted during 2019 main season at two locations namely Bako national maize research center (BNMRC) and Pawe agricultural research center (PARC). The agro ecological description of each site summarized in Table below.

Table 1. Summary of ecological description of the study sites

Locations	Altitude (m.a.s.l)	Coordinate		Temperature(^{0}C)		Rain fall (mm)	RH (%)	Soil Type
		Latitude	Longitude	Min.	Max.			
BNMRC	1650m	09^{0}06'00"N	37^{0}09' E	14.36^{0}c	27.1^{0}c	1245	63.55	Nitosol
PARC	1120m	11^{0}09'03"N	36^0 03'E	17.1^{0}c	33.2^{0}c	1400	74.5	Nitosol

Source: *Metrological data at BNMRC and PARC, 2019.*

2.2. Experimental materials

The experimental materials consisted of thirty five entries (twenty three inbred lines and 9 single crosses) described in table 2.The inbred lines were parents of released hybrids which used as either male or female parent during seed production. Some single crosses were used as female parent for three way cross hybrid seed production. All entries used for this study were taken from Bako national maize research center (BNMRC), maize breeding section.

2.3. Experimental Design and Procedure

A total of 33 maize genotypes (9 single crosses and 24 inbred lines) were planted in Randomized complete block design (RCBD)with three replications at Bako national maize research center (BNMRC) and Pawe agricultural research center (PARC) during 2019.In addition to the parents of released hybrids, parents of hybrids tested at verification variety trials were also included. The other three crosses were single cross hybrid which were evaluated for certified seed (F1) production. Each genotype was sown in two rows per plot with row length 5.1m by 0.75m space apart. The number of plants per row was 21 and the space between plants to plants was 0.25m. Inorganic fertilizer, 100 kg P2O5 ha^{-1} in the form of NPS and 150 kg N ha^{-1} in the form of UREA was applied. NPS was applied at planting time and UREA was applied in two splits, one-third applied after 20 days of planting and the remaining two-third after 40 days of planting.

2.4. Data collection

Yield and related characters

- Anthesis date (DA): The date when 50% of the plants in the plot started shedding pollen.
- Silking date (DS): The date when 50% of the plants in the Plot showed silks.
- Plant height (PH in cm): The average height of five plants within a plot measured in centimeter from the ground to the first tassel branch.
- Ear height (EH in cm): The average height of five plants within a plot measured in centimeter from the ground to insertion of the top ear.
- Grain yield (ton/ha): grain yield (tonnes per hectare) was recorded the weight of the ears per plot and this was adjusted to 12.5% moisture content to estimate grain yield per hectare.

2.5. Statistical analysis

The data collected for each character were subjected to analysis of variance (ANOVA) using statistical software, SAS version 9.3. The statistical analysis contained treatments (inbred lines and single crosses) as a fixed factor while block and location as random factors. ANOVA was carried out according to the procedure recommended for randomized complete block design (RCBD) to determine the existence of significant difference among the genotypes. The analyses of variance was performed on the data from individual location and then combined across location after homogeneity test. Least significant difference method (LSD) was used for mean separation and mean comparisons among treatments.

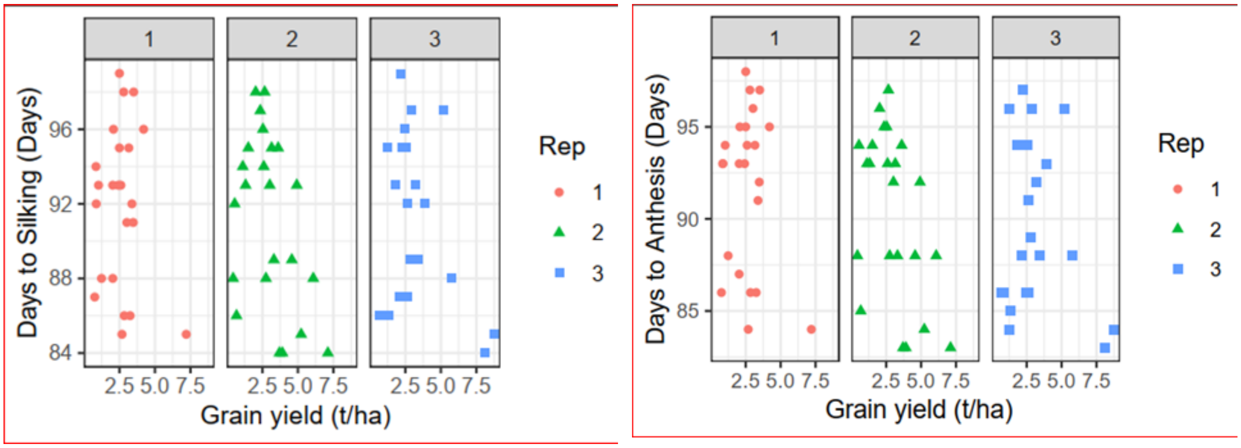
3. Results and Discussion

3.1. Data Visualization

The relation between grain yield and flowering characteristics within replication at individual location indicated below on the scatter plot. Most inbred lines distribution showed days to silking between 92 and 96 days equal to 2.5t/ha yield in all replications at Bako (Plot A) whereas between 72 and 77 days with $\leq$ 4 t/ha at Pawe (Plot C). Inbredlines showed longer days to silking than days to anthesis in both locations (Plot B and Plot D).

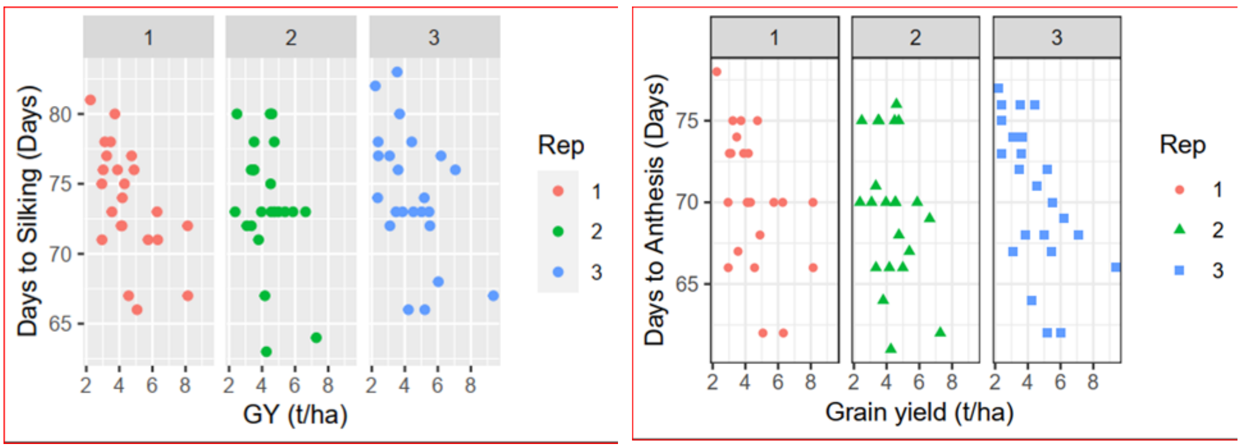
Table 2. Summary of experimental materials.

S.No	Hybrid variety	Pedigree(Parents of hybrids)	Year of Release	Single Crosses female parent of Three way cross hybrid	Inbred lines
1	BH540	SC22/124-b(113)	1995	CML144/CML159	124-b(113)
2	BHQP542	CML144/CML159//CML176	2002	SC22/124-b(109)	142-1-e
3	BH543	SC22/124-b(109))//CML197	2005	CUBA/GUADC1F27-4-3-3-B-1 BX(KILMAST94A)-30MSV-03-2-10-B-2-B-B-)-306-1-B-2-B-B-B/CML-204	A7033
4	BHQPY545	CML161/CML165	2008	CML334/ MBRC5BCF108-2-3-1-B-5-2-B-B	CUBA/GUADC1F27-4-3-3-B-1 BX(KILMAST94A)-30MSV-03-2-10-B-2-B-B-)-306-1-B-2-B-B-B
5	BH546	CML395/CML202//BKL001	2013	A7033/F7215	F7215
6	BH547	BKL002/CML312BK//BKL003	2013	CML395/CML202	124-b(109)
7	BHQP548	CML144/CML159//CML176X KULENI (F2)-4-3-1-1)	2015	BKL002/CML312BK	CML197
8	SPRH1	CUBA/GUADC1F27-4-3-3-B-1-BX(KILMAST94A)-30MSV-03-2-10-B-2-B-B-)-306-1-B-2-B-B-B/CML-204//CML-202)	2015	BKL004/BKL002	CML334
9	SBRH1	CML334/ MBRC5BCF108-2-3-1-B-5-2-B-B //CML312	2015	BKL004/CML202	MBRC5BCF10-8-2-3-1
10	BH660	A7033/F7215//142-1-e	1993		CML161
11	BH661	CML395/CML202//BKL001	2011		CML165
12	ILU (BH549)	BKL004/BKL003	2017		CML144
13	Nada(BH520)	CML536/CML444	2020		CML202
14					CML159
15					SC22
16					CML395
17					CML204
18					CML312BK
19					BKL002
20					BKL001
21					BKL003
22					BKL004
23					CML536
24					CML444
Total	13			9	24



Plot A Plot B

Figure 1. Grain yield vs days to flowering characters at Bako



Plot C Plot D

Figure 2. Grain yield vs Days to flowering characters at Pawe

3.2. Analysis of Variance

The combined analysis of variance (ANOVA) indicated there were highly significant differences (from P< 0.01 to P< 0.001) among environments (E), genotypes(G), and interactions (GEI) for maize grain yield (GY) and flowering characters 50% days to anthesis (DA) and silking (DS) in both inbred lines and crosses (**Table 3** and **Table 4**). The statistical difference in GY and 50% flowering days in both parental inbred lines and crosses may be attributed to the genetic characteristics of the genotypes (parents and crosses).

The presence of significant to highly significant difference of 24 inbred lines and 9 crosses with the environment interactions (GEI) for GY, DA and DS indicates inconsistence performance and flowering characters of both inbred lines and crosses across the two locations. The two environment significantly differed for all traits which is due to difference in temperature, altitude and rainfall between Bako and Pawe. Similarly, previous study reported the presence of significant G x E interactions for grain yield in maize (Abakemal *et al.*, 2016; Mengesha *et al.*, 2019; Wolde *et al.*, 2019). Inline to this result, (Kamutando *et al.*, 2013) reported in their study the presence significant GEI for GY, DA and DS. Setimela (1997) reported significant genotype by environment interaction for 50% silking, 50% anthesis and plant height implies that varieties are not consistent in the response of anthesis silking interval (ASI) to various environments.

Table 3. Combined analysis of variance (ANOVA) of GY and related traits for inbred lines.

Source of variation	DF	Mean square of GY and other related traits				
		GY	DA	DS	PH	EH
Replication	2	0.49^{ns}	11.44^{ns}	3.22^{ns}	752.40^{ns}	79.14^{ns}
Location	1	77.70^{***}	14570.46^{***}	10400.03^{***}	29538.85^{***}	10400.03^{***}
Genotypes	23	9.69^{***}	92.70^{***}	94.45^{***}	5078.40^{***}	2597.25^{***}
Geno*Loc	23	2.15^{**}	8.28^{**}	7.64^{*}	462.54^{ns}	227.42^{ns}
Error	92	1.08	4.30	4.37	342.01	154.00
CV (%)		28.5	2.58	2.53	10.67	15.57
LSD (5%)		0.35	2.38	2.40	21.21	14.23

Note: ***, **, ***** = significant at 0.05, 0.01 and 0.001 probability level respectively, ns = non-significant, DF = degree of freedom, GY = Grain yield, DA = Anthesis date, DS = Silking date, PH = plant height, EH = Ear height, LSD = least significance difference, CV = coefficient of variation.

Table 4. Combined ANOVA of GY and other related traits for single crosses

Source of variation	DF	Mean square of GY and other related traits of crosses				
		GY	DA	DS	PH	EH
Replication	2	7.45^{*}	9.22^{*}	7.55^{ns}	1221.32^{ns}	700.07^{ns}
Location	1	17.24^{**}	6120.60^{***}	4681.67^{***}	2884.27^{**}	400.42^{ns}
Genotypes	8	22.27^{***}	19.01^{***}	14.90^{***}	1036.41^{**}	626.23^{**}
Geno*Loc	8	3.99^{**}	6.60^{**}	9.22^{**}	369.30^{ns}	279.19^{ns}
Error	32	1.46	1.95	2.46	260.61	229.40
CV (%)		14.05	1.92	2.12	6.87	13.39
LSD (5%)		1.41	1.63	1.83	18.87	17.70

Note: ***, **, ***** = significant at 0.05, 0.01 and 0.001 probability level respectively, ns = non-significant, DF = degree of freedom, GY = Grain yield, DA = Anthesis date, DS = Silking date, PH = plant height, EH = Ear height, LSD = least significance difference, CV = coefficient of variation.

3.3. Mean performance of inbred lines and crosses

3.3.1. Grain yield

Highly productive inbred lines are desirable for yield improvement through designing crossing method. The overall average grain yield of an inbredlines was higher at Pawe than Bako (in **Table 5**). Among maize parental inbred lines about 37.5% and 41.7% gave the grain yield greater than overall mean 2.90 t/ha and 4.32 t/ha, at Bako and Pawe, respectively. Some genotypes for example, A7033, 124-b (109) and SC22 gave the grain yield 3.16 t/ha and 1.94 t/ha, 3.26 and 0.98 t/ha, and 2.17 and 0.40t/ha greater than the mean at Bako and Pawe, respectively. As compared to other inbred lines these genotypes gave highest grain yield due to early generation back ground. The common parents of BH661 and BH546 namely CML395 and CML202 parental lines gave grain yield 3.0t/ha and 3.75t/ha at Bako and 4.61 and 5.54t/ha at Pawe, respectively. These lines out yielded 0.10 and 0.20t/ha, 0.84 and 1.13 t/ha greater than the mean at Bako (2.90t/ha) and at Pawe (4.32t/ha), respectively.

Among the crosses, at Bako BKL004/BKL002 gave the highest grain yield followed by BKL004/CML202 and BKL002/CML312BK which was 10.53, 9.28 and 9.15t/ha, respectively **Table 6**. Single cross female parent of commercial hybrid variety BH547, BKL002/CML312BK gave the highest grain yield 9.15 and 11.51 with an average of 10.3t/ha at Bako and Pawe, respectively. The common single cross female parent of the commercial hybrids BH661 and BH546 which was CML395/CML202 gave the grain yield 8.39t/ha and 8.70t/ha, with an average grain yield 8.55t/ha during three way cross hybrid formation at Bako and Pawe, respectively.

3.3.2. Flowering characters

Duration of anthesis and silk receptivity of inbred lines and single crosses was longer at Bako than Pawe (**Table 5** and **Table 6**). The highest number of days at 50% male and female flowering mean was observed in Bako than Pawe.At Bako the overall mean of inbred lines and single crosses for both days to anthesis (DA) and silking (DS) was 91days and 83 days, respectively. At Pawe, DA ranged from 62 to 76 days and DS ranged from 65 to 80 days with average of 70 and 74 days, respectively. The shorter duration of flowering (days to anthesis and silking) at pawe may emanated due to predominance of environmental factors.

Table 5. Summary of mean performance of maize inbred lines at individual locations in 2019

Genotypes	Bako					Pawe				
	GY (t/ha)	DA (days)	DS (days)	EH (cm)	PH (cm)	GY (t/ha)	DA (days)	DS (days)	EH (cm)	PH (cm)
124-b(113)	2.54	84	85	55.67	157.33	4.85	62	65	81.7	185.00
142-1-e	3.97	95	96	129.33	235.67	4.25	76	79	146.7	256.67
A7033	6.06	84	85	101.33	201.33	6.26	65	66	128.3	228.33
BKL002	3.13	85	86	61.00	129.67	4.04	71	73	75.0	158.33
BKL001	2.55	94	95	79.00	176.33	3.72	75	80	90.0	188.33
BKL003	2.70	89	90	76.00	134.00	3.85	70	74	90.0	161.67
BKL004	3.33	91	92	66.67	153.33	4.20	73	74	71.7	171.67
CML161	3.07	89	90	54.00	123.67	4.54	71	74	63.3	153.33
CML165	2.01	92	93	69.33	153.00	2.92	73	76	75.0	158.33
CML312BK	2.24	92	91	73.00	151.67	3.89	75	78	95.0	183.33
CML144	1.18	92	90	44.00	132.33	3.84	71	74	83.3	171.67
CML202	3.75	91	91	60.67	150.00	5.54	70	73	73.3	176.67
CML159	2.29	89	90	54.33	141.00	4.73	70	72	68.3	191.67
SC22	5.07	89	89	94.67	194.33	4.80	67	73	91.7	195.00
CML395	3.00	92	92	70.00	140.67	4.61	69	72	80.0	156.67
CML204	1.73	94	94	56.00	138.67	2.72	75	80	80.0	176.67
CUBA/GUAD..	0.64	87	87	27.67	114.33	4.32	65	67	53.3	161.67
124-b(109)	6.17	84	85	89.33	185.67	5.38	63	70	101.7	198.33
CML197	1.60	91	91	76.33	156.00	6.00	69	75	125.0	236.67
CML334	1.08	94	94	63.33	167.33	2.71	76	78	98.3	215.00
MBRC5BCF10-8-2-3-1	1.36	88	89	61.67	132.67	3.13	66	72	68.3	143.33
CML536	3.78	93	94	80.00	183.67	3.78	75	77	83.3	216.67
F-7215	2.49	94	94	90.67	197.67	5.20	69	76	110.0	238.33
CML444	2.8	92	91	80	147.66	2.38	76	79	55	106.66
Mean	2.90	91	91	71.42	158.25	4.32	70	74	87.01	184.58
F-test	***	***	***	***	***	***	***	***	***	***
CV (%)	33.5	2.1	11.0	14.1	9.3	25.1	2.1	1.9	16.2	11.6
LSD (5%)	1.6	4.1	4.2	16.5	24.3	1.8	2.4	2.3	23.6	36.0
Ave. Std Dev	0.8	2.1	2.1	12.6	8.1	1.0	1.2	1.2	19.3	13.1

Note**: *, **, ***** = significant at 0.05, 0.01 and 0.001 probability level respectively, GY = Grain yield, DA= Anthesis date (50%), DS = Silking date (50%), EH= Ear height, PH= Plant height, LSD = least significance difference, CV = coefficient of variation, Ave. Std Dev = average standard deviation

Pawe is characterized by high temperature and lower altitude as compared to Bako. The variation in flowering days in maize parental lines or genotypes may be attributed to the genetic characteristics of the parents and agro ecological condition of the production area.

The agro-ecological conditions of the producing area and the genetic traits of the parents may be responsible for the variance in flowering days observed in maize parental lines or genotypes. Temperature, moisture, and photoperiod are three environmental variables that have a significant impact on a plant's phenology during flowering and fruiting. According to Kudo *et al.* (2004), high temperatures can alter a plant's phenology, which includes things like flowering, seed production, and other aspects of seasonal climate change. Temperature affects the rate of the physiological processes, for example, high temperatures during two weeks prior to flowering increase the rate of foliar senescence (Zaidi *et al.*, 2016). Molla *et al.* (2014) reported anthesis-silking and kernel setting may vary with the plant growth rate and environment. Otegui and Melón (1997) reported that planting dates affected the seed set and flower synchrony within the cob of maize. High temperatures are likely to shorten the growing cycle of many crop species and, during some developmental stages such as the reproductive phase, most crops are only able to tolerate narrow temperature changes, which, if exceeded, can reduce seed set and thus yield (Porter, 2005).

Table 6. Summary of mean performance of maize genotypes at individual locations in 2019

Genotype	Bako					Pawe				
	GY (t/ha)	DA (days)	DS (days)	EH (cm)	PH (cm)	GY (t/ha)	DA (days)	DS (days)	EH (cm)	PH (cm)
A7033/ F-7215	6.69	84	84	138.67	257.67	9.53	61	64	133.33	260.00
CML395/CML202	8.39	86	85	105.00	215.67	8.70	62	64	108.33	223.33
BKL002/CML312BK	9.15	82	82	110.67	242.00	11.51	63	66	105.00	230.00
CML334/MBRC5BCF108-2-3-1-B-5-2-B-B	4.82	82	83	107.67	219.67	6.77	62	65	111.67	231.67
CUBA/GUADDC1... /CML204	4.66	80	80	90.00	209.00	7.34	61	64	116.67	250.00
CML144/CML159	8.85	85	85	103.33	222.67	10.83	65	66	120.00	253.33
BKL004/BKL002	10.53	80	79	98.33	213.00	9.88	62	65	110.00	235.00
BKL004/CML202	9.28	85	86	122.67	234.67	8.82	64	65	125.00	256.67
LY1312-4	5.96	80	79	100.33	216.00	7.57	61	64	118.33	230.00
Mean	8.07	83	83	110.50	228.13	9.14	63	65	115.67	242.00
F-test	***	***	***	*	**	***	***	***	**	**
LSD (5%)	2.0	2.8	3.2	20.6	26.8	1.6	1.7	1.2	29.1	27.5
CV (%)	14.1	2.0	2.3	10.9	6.9	10.0	1.6	1.6	14.7	6.6
Ave. Std Dev	1.35	1.69	1.67	16.56	13.65	0.89	0.96	0.83	14.25	14.75

Note**: *, **, ***** = significant at 0.05, 0.01 and 0.001 probability level respectively, GY = Grain yield, DA= Anthesis date (50%), DS = Silking date (50%), EH= Ear height, PH= Plant height, LSD = least significance difference, CV = coefficient of variation, Ave. Std Dev = average standard deviation

3.4. Grain yield performance and floral synchronization

Synchronization of flowering which means shedding of pollen in male parent coinciding with the silk receptivity of female parent is a pre-requisite for successful hybrid maize seed production. The difference between 50% plants silking of single cross female parent and 50%plants shedding pollen of male parent inbred line used in identifying parents that nick or for synchronizing parents for three way cross formation. The difference between 50% plants silking of female and 50% plants shedding pollen of male parent inbred line used in identifying parents that nick or for synchronizing parents for single cross formation.

3.4.1. Grain yield and floral synchronization for certified seed production

Summary of grain yield and actual flowering of parents for three way cross and single cross hybrid variety formation indicated in **Table 7 .**

Grain filling and yield ultimately depend on the time interval between male and female flowering for pollination and fertilization (Bolaños *et al.*, 1993).The difference between DS of single cross female parent and DA of male parent inbred lines for three way cross hybrid (TWCH) formation ranged from -11 to -9 days and -12 to -3 days at Bako and Pawe, respectively. This indicated that the single cross female parents attain 50 percent flowering earlier than the male parent inbred line. In line to this, Musundire *et al.* (2018) reported 7 to -15 days between male parent inbred line and female single cross in their study.

Common single cross female parent of hybrid variety BH661 and BH546, CML395/CML202 gave 8.39t/ha at Bako and 8.70t/ha at Pawe using the male parent inbred line 142-1-e and BKL001, respectively. For BH661 production, female parent CML395/CML202 reached 50% of silking (DS) at 85 days and 64 days at Bako and Pawe, respectively. The 3rdmale parent inbred line which was 142-1-e reached 50% of anthesis (DA) at 95 days and 76 days after sowing at Bako and 76days at Pawe, respectively. This resulted, the difference between DS and DA was -10 days at Bako and -12days at Pawe, which indicated that the single cross female parent (CML395/CML202) flowered 10 days and 12 days earlier than the male parent inbred line (142-1-e) at Bako and Pawe, respectively. BKL001 which was the 3rd parent for BH546 hybrid variety reached 50% DA at 94 days at Bako and 75 days at Pawe. The difference between DS of CML395/CML202 and DA of male parent inbred line BKL001 for BH546 formation was -9 days and -11 days at Bako and Pawe, respectively. This revealed the single cross female parent (seed parent) flowered 9 days and 11 days earlier than male parent (pollen parent) at Bako and Pawe, respectively Table. Floral synchrony depend on the time from planting to pollen shed of male parent and silking of the respective female parents. In this study, silks are emerged earlier than pollen shed parent in certified seed production. So, early planting of male parental line (pollen shed) should be done to maximize pollination. Bassetti and Westgate (1993) reported in their study silks receptive to pollen for 7 days with greater than 95% kernel set and upto14 days in green house but, further delay in pollination resulted kernel reduction 28 and 20% per day in Hybrid 1 and 2, respectively. Significant increase in days between female and male parent when plants were exposed to drought during the time bracketing flowering and consequently causing reduction in grain yield (Bolaños *et al.*, 1993; Edmeades *et al.*, 2000; Musundire *et al.*, 2018).

For good seed producibility, split planting date is an important strategy in matching of flowering synchrony and increasing productivity. Musundire *et al.* (2018) reported in their study female seed yield affected by time of male parent pollen shed. Therefore; to match the flowering synchrony of both single cross female parent (seed parent) and male parent inbred line (pollen parent), the pollen parent should be planted 10 days before the seed parent (CML395/CML202) for both BH661 and BH546 production. In line to this result, Tolera et al. (2011) reported the planting date recommendation for BH660 variety as the male parent (142-1-e) should be planted ten days before female parent (A7033/F-7215).

Among single cross hybrid variety, BHQPY545, BH549 and BH520 showed -3 to +4 days interval of the difference between female and male parent inbred line at Bako and Pawe indicating almost matching of both inbred line in terms of flowering. The female parent inbred line of these hybrids namely CML161, BKL004 and CML536 gave grain yield ranged from 3.07 t/ha to 3.78t/ha and 3.78 to 4.54t/ha at Bako and Pawe, respectively. In line to this, Musundire *et al.*

(2018) reported close synchrony between pollen parent and silk female parent (+/-3 days) associated with highest yields. However in contrast to this, the difference between female and male parent +2 days would increase the kernel production potential by 38% but, perfect synchrony or silking and anthesis on the same date doesn’t correspond to optimum potential (Musundire *et al.,* 2018).

3.4.2. Grain yield and floral synchronization for basic seed production

Summary of grain yield and actual flowering parents for single cross female parent formation (basic seed production) in ***Error! Reference source not found.*** . In three way cross hybrid, the difference between female and male parent inbred lines for basic seed production ranged from -9 days to + 6 days and -9 days to +12 days at Bako and Pawe, respectively. In hybrid BH661 and BH546, the difference between seed and pollen parental lines at Bako and Pawe was +2 days indicating female parent flowed 2 days later than male parent which indicated close synchrony for basic seed production. The female parent gave 3.0t/ha and 4.6t/ha at Bako and Pawe, respectively.

In hybrid seed production, good seed set occurred when the pollen from male parent distributed uniformly across all female parents. Smaller ratio of male plant height (MPH) and female ear height (FEH) cause a poor seed set due to insufficient spread of pollen at the silk receptivity in female parent. In both combined and individual locations the proportion of MPH and FEH was greater than 1.0 which is desirable for both certified and basic seed production.

Table 7. Summary of grain yield and actual flowering of parents for three way cross and single cross hybrid variety formation (certified seed)

Variety	SX/inbred line female parent for TWCH / SC hybrid variety	Bako		Pawe		Inbred line	Bako		Pawe		Split (DS-DA) d		Combined			Seed class
		GY	DS	GY	DS		GY	DA	GY	DA	BK	PW	PH	EH	MPH:FEH	
BH660	A7033/F-7215	6.69	84	9.53	64	142-1-e	3.97	95	4.25	76	-11	-12	246.2	136.0	1.8	Certified
BH661	CML395/CML202	8.39	85	8.70	64	142-1-e	3.97	95	4.25	76	-10	-12	246.2	106.7	2.3	Certified
BH546	CML395/CML202	8.39	85	8.70	64	BKL001	2.55	94	3.72	75	-9	-11	182.3	106.7	1.7	Certified
BH547	BKL002/CML312BK	9.15	82	11.51	66	BKL003	2.70	89	3.85	70	-7	-4	147.8	107.8	1.4	Certified
SPRH1	CUBA/GUADDC1../CML204	4.66	80	7.34	64	CML202	3.75	91	5.54	70	-11	-6	163.3	103.3	1.6	Certified
BHQPY545	CML161	3.07	90	4.54	74	CML165	2.01	92	2.92	73	-3	1	155.7	58.7	2.7	Certified
BH540	SC22	5.07	89	4.80	73	124-b(113)	2.54	84	4.85	62	6	11	171.2	93.2	1.8	Certified
BH549(Ilu)	BKL004	3.33	92	4.20	74	BKL003	2.70	89	3.85	70	3	4	147.8	69.2	2.1	Certified
BH520(Nada)	CML536	3.78	94	3.78	77	CML444	2.80	92	2.38	76	2	1	127.2	81.7	1.6	Certified

GY = Grain yield (t/ha), DS = Anthesis date (days), DS = Silking date (days), EH = Ear height (cm), PH = Plant height (cm), MPH: FEH = Male parent plant height to female parent ear height ratio.

Table 1. Summary of seed producibility and actual flowering parents for single cross female parent formation (basic seed production)

Variety	Single cross female parent	Female parent line	GY	DS	EH	Male inbred line	GY	DA	PH	Split (DS-DA) d	MP:FEH	Classclass
Bako												
BH660	A7033/F-7215	A7033	6.06	85	101.33	F-7215	2.49	94	197.67	-9	2.0	Basic
BH661	CML395 /CML202	CML395	3.00	92	70.00	CML202	3.75	91	150.00	2	2.1	Basic
BH546	CML395/CML202	CML395	3.00	92	70.00	CML202	3.75	91	150.00	2	2.1	Basic
BH547	BKL002/CML312BK	BKL002	3.13	86	61.00	CML312BK	2.24	92	151.67	-6	2.5	Basic
SPRH1	CUBA/GUADDC1../CML204	CUBA/GUADDC1..	0.64	87	27.67	CML204	1.73	94	138.67	-7	5.0	Basic
SBRH1	CML334/MBRC5BCF108-2-3-1-B-5-2-	CML334	1.08	94	63.33	MBRC5BCF108-2-3-1-B-5-2-	1.36	88	132.67	6	2.1	Basic
BHQP542	CML144/CML159	CML144	1.18	90	44.00	CML159	2.29	89	141.00	1	3.2	Basic

Pawe

Variety	Single cross female parent	Female parent line	GY	DS	EH	Male inbred line	GY	DA	PH	Split (DS-DA) d	MPH: FEH	Class
BH660	A7033/F-7215	A7033	6.3	66	128.33	F-7215	5.2	69	238.33	-3	1.9	Basic
BH661	CML395 /CML202	CML395	4.6	72	80.00	CML202	5.54	70	176.67	2	2.2	Basic
BH546	CML395/CML202	CML395	4.6	72	80.00	CML202	5.54	70	176.67	2	2.2	Basic
BH547	BKL002/CML312BK	BKL002	4	73	75.00	CML312BK	3.89	75	183.33	-2	2.4	Basic
SPRH1	CUBA/GUADDC1../CML204	CUBA/GUADDC1..	4.3	67	53.33	CML204	2.72	75	176.67	-9	3.3	Basic
SBRH1	CML334/MBRC5BCF108-2-3-1-B-5-2-	CML334	2.7	78	98.33	MBRC5BCF108-2-3-1-B-5-2-	3.1	66	143.33	12	1.5	Basic
BHQP542	CML144/CML159	CML144	3.8	74	83.33	CML159	4.73	70	191.67	4	2.3	Basic

GY = Grain yield (t/ha), DS = Anthesis date (days), DS = Silking date (days), EH = Ear height (cm), PH = Plant height (cm), MPH: FEH = Male parent plant height to female parent ear height ratio

4. Conclusion

Maize inbred lines and single crosses were evaluated at Bako and Pawe for the objective of yield producibility and yield related characteristics in 2019.In hybrid maize production, the major factors to be considered is proper nicking between female (seed parent) and male (pollen parent) which results good seed set. During certified seed production from all three way cross hybrid (TWCH), the single cross female parents showed greater than five days (-5) early flowering than male parent inbred in both individual locations indicating split planting day would be required between male inbred line and single cross female parent at each location. Closer synchronization of flowering between parents of hybrid variety BHQPY545, BH549 and BH520 could be obtained -3 to +4 days interval of the difference between male and female parent inbredline along the grain yield ranged from 3.07t/ha to 4.54t/ha across locations with desirable male plant height to female ear height ratio.

The difference between female and male parent inbred lines for basic seed production ranged -9 days to + 6 days and -9 days to +12 days at Bako and Pawe, respectively. Among hybrids, parents of BH660, BH547 and SPRH1 showed female (seed parent) was flowered earlier than male (pollen) parent in both locations indicating that sowing of male parent before female parent for synchronization.

The extent of synchronization of flowering was dependent on the interaction between the varieties (single cross and inbred line parents) and the environmental factors. In hybrid seed production, flowering date of parents' was different from one to another location and within a location which cause location based recommendation of staggering date. Therefore, to conclude more concrete staggering date of the parents, using growing degree days is the most important parameter to determine flowering characters based on heat unit.

Generally, based on the above flowering data it can be concluded that smaller difference date in flowering between female (seed parent) and male (pollen parent) resulted good synchronization of flowering in single cross hybrid than three way cross hybrid variety in each environments. Hence, to achieve perfect nicking time of male and female flowering parents during hybrid seed production, the method like staggered planting is should be followed based on growing degree days to schedule planting time and estimating maturity dates.

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All authors are contributed in this research

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Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest.

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