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Research Article

Calculating Growing Degree Days for Different Inbridlines of Maize (*Zea mays.* L) at Mid Altitude of Ethiopia, Bako

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Abstract

Comparing hybrid maize to open-pollinated varieties, the former is widely recognized for its higher producing capacity. However, the production potential of hybrids varies depending on the region and the season. Maize inbreed lines are relatively week and low in yield when compared to hybrid formed from them and open pollinated variety. Hence their seed production is challenged by weather condition like rain fall and temperature. This experiment was conducted on thirteen released inbridlines to calculate the Amount of growing degree days and production potential using a randomized complete block design with 3 replications. The mean GY for inbred lines was 4.08t/. L_{10} had the highest yield (5.53 t/ha), followed by L_{13} (5.18 t/ha) and L_4 (5.13t/ha). L_{12}, L_7 and L_3 had grain yield above the mean with the mean values of 5.03, 4.14, and 4.10 (t/ha). The ANOVA for Anthesis-Silking Intervals (ASI) showed highly significant differences ($p< 0.01$). Among inbred parents, L_7, with an average of (6.66 days) had the longest ASI followed by L_5, and L_{12} with five days of ASI. And The mean of ASI was four days for L_1, L_3, L_4 and L_{10}. The mean of ASI was 3.58 days, which has highly significant effect on yield. The shortest ASI was observed for L_9 with (1day) followed by L_6 (1.33 days), L_2 (2days) and L_8, L_{11}, L_{13} with 3days. L_{10} had the highest score of Growing Degree Days (GDD) (℃) for DA and DS with 957.3 and 998, respectively. Whereas the lowest scores of GDD (℃) for DA and DS, observed on for L_2, Were 815 ℃ and 835 ℃), respectively.

Keywords

Maize, Growing Degree Days, Inbridlines, Hybrid

1. Introduction

Maize (Zea mays L.) belongs to the family Poaceae, is one of the primary cereal grains farmed globally. Global temperature change may result in a decrease in maize productivity and grain quality. The maize crop needs to reach a certain temperature in order to give the best harvest. Growing and yield formation processes might be adversely affected by a temperature that is below ideal at any crucial stage for an extended period of time. [1]. Climate change is threatening food security across the globe [2]. Crop yield must increase by 25–70% by the year 2050 without putting pressure on ecosystem functioning [3]. Since the 1960s, the yield improvement rate of major food crops (rice, wheat, and maize) has slowed down [4], and current yield trends are not sufficient to meet future requirements [5]. Moreover, improvements in crop productivity must be attainable in a highly inconstant climate. More and intensified extreme climate change

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(drought, heatwave, frost, heavy rainfall, storms, etc.) are anticipated in the future [6]. These unprecedented climatic extremes will negatively influence plant growth and development, ecosystem services, and human comfort [7].

Maize (Zea mays L.) crop provides 19.5% of global caloric intake from all sources [8]. Furthermore, it has also become an important industrial commodity. However, temperature extremes (occurrence of high and low temperatures during the growth period) are threatening the yield sustainability of maize. Maize plants are sensitive to heat stress (>30 ℃) and there is a strong decline in grain yield as plants face heat stress above this threshold for a prolonged duration [9]. The optimal growth of maize crop needs different temperatures during day and night and over the whole growing season. During daylight, the optimal temperature varies from 25 to 33 ℃, whereas during the night, optimal temperature varies from 17 to 23 ℃; the mean optimal temperature for the whole growing season is 20–22 ℃ [10]. Maize plants germinate best at 25–28 ℃ [11]. It is projected that until 2050, 45% of the global maize production area is likely to face a mean episode of five days of the maximum temperature >35 ℃ during the reproductive stage annually [12]. This is important to note as a mere 1 ℃ rise in mean seasonal temperature can cut the economic yield of maize crop by 3–13% [13]. A high temperature at critical development stages may also deteriorate the quality of maize grains [14]. Maize seed production can be affected by long term climate and short-term weather condition. Particularly Temperature can affect the seed production potential of maize parents. Hence this study was conducted on 13 inbridlines with the objective of calculating growing degree days at different stage of the crop to generate information for different seed producers.

2. Materials and Method

The trial was conducted at Bako National Maize Research Center (BNMRC) during 2019 rainy season. The station is in East Wollega Zone of the Oromia Regional State, Western Ethiopia. The center is 250 km far from Addis Ababa, the capital city of the country, and lies between $9^0 6'$ North latitude and $37^0 09'$ east longitude in the sub-humid Agro-ecology, at average altitude of 1,650 meters above sea level. The mean annual rainfall of the previous 56 years was 1239.4 mm and the mean annual rain fall during the season 2019 was 1,414.1 mm; based on Bako Agricultural Research Center metrological data. The rainy season covers April to October and maximum rain was received in the months of June and August. The Mean minimum, mean maximum and average air temperature is 14.19 ℃, 28.9575 ℃, and 21.6358 ℃, respectively; and the relative humidity is 51.3483%. The soil is reddish brown in color and clay loam in texture. According to USDA soil classification, the soil is Alfisols developed from basalt parent materials, and is deeply weathered and slightly acidic in reaction [15].

2.1. Materials Used for the Study

The experimental material includes a total of thirteen (13) Parents serving for crossing different hybrid maize variety.

Table 1. *List of inbridlines used for the experiment.*

S/No	I/lines Code	Name	Parental type (M/F)	Seed source
1	L1	BKL001	Male	BNMRC
2	L2	BKL002	Female	>>
3	L3	BKL003	Male	>>
4	L4	BKL004	Female	>>
5	L5	CML 161	Female	>>
6	L6	CML 165	Male	>>
7	L7	CML 395	Female	>>
8	L8	CML 312	Male	>>
9	L9	CML 202	Male	>>
10	L10	142-1-e	Male	>>
11	L11	CML 444	Male	>>
12	L12	CML 536	Female	>>
13	L13	124-b (109)	Male	>>

BNMRC=Bako National Maize Research Center=Female=Male.

2.2. Experimental Design and Trial Management

This experiment was plotted in a Randomized Complete Block Design (RCBD) with three replications at Bako National Maize Research Center. Each entry was planted in a two-row plot of 5.1 m long with spacing of 0.75 m between rows and 0.25 m between plants within a row. Planting was done on 5 June 2019 by hand by sowing two seeds per hill, which was later thinned to one plant per hill. Nitrogen and phosphorus fertilizer were applied at the rate of 200 kg ha^{-1} and 200 kg ha^{-1} in the form of Urea and NPS, respectively as per the recommendation for the area. All DAP was applied at the time of planting and Urea was applied in two splits, the first half at planting and the second half at knee height. Pre-emergence herbicides, “Atrazine” at the rate of 4 liters ha^{-1} for broad-leaved weeds were and “Prima gram gold” at the rate of 4 liters ha^{-1} for grass weeds was used by mixing with 200 liters of water. Hand weeding was done twice at 25 and 45 days after emergence; and weed slashing was done once at flowering stage.

2.3. Data Collected

Days to anthesis: The number of days from emergence to the date when 50% of the plants in a plot started shedding pollens.

Days to silking: The number of days from plant emergence to the date when 50% of the plants in a plot have produce 2-3 cm long silks.

Anthesis- silking interval (ASI): Recorded as the number of days between days to silking and days to anthesis.

Days to physiological maturity: The number of days from planting to when 50% of the plants in a plot form black layer at the tip where the kernel attaches to the cob.

Grain yield (t/ha): At harvest, the weight of the ears per plot was recorded and this was adjusted to 12.5% moisture level and 80% shelling percentage to estimate grain yield in tons (t ha^{-1}) for each.

Growing degree days (GDD) at different growth stages.

Under normal planting date situations, maize growth and development is largely temperature driven. To describe the environment more accurately, agronomists often use Growing Degree Days (GDD) to describe the amount of heat that drives the metabolic reactions for growth and development in the maize plant [16]. The formula for calculating GDD is: GDD = $\sum$ d [$(Tmax + Tmin)$ /2-Tb] Where GDD is growing degree days, T_{max}, is maximum temperature, T_{min}, is minimum temperature and Tb is base temperature (Tb for maize is $10°C$). GDD is cumulative and is measured per day.

2.4. Statistical Analysis

Analyses of variance (ANOVA) for all Parents were done by RCBD model of the PROC ANOVA procedure in SAS computer program (SAS Institute, 2014). Significant differences were further subjected to Least Significant Difference (LSD) for mean separation.

3. Results and Discussion

The data collected were analyzed and significance tests were performed for each trait at 5% and 1% probability levels. The results are presented and discussed below. The analysis of variance showed highly significant and significant differences among the inbridlines mean squares. Significant differences were observed among the material and response to temperature.

Table 2. *ANOVA results for maize inbridlines.*

Quality parameters	Mean squares for Source of Variation				
	Rep (df=2)	Treatments (df=12)	Error (df=24)	Coff. Var. 5%	F<P
Days to silking	1.2308	62.291*	0.8697	1.02	0.9572
Anthesis date	1.641	61.254*	1.0577	1.17	0.4066
Anthesis silking interval	0.41026	7.2863*	0.63248	22.15	0.0653
Days to Maturity	19.7179	65.53**	3.4124	1.2	0.8172
Grain yield (t/ha)	0.36082	2.431*	0.74572	21.14	0.0066
GDD at planting	5.32E-29	1.36E-29ns	6.24E-62	1.25	0
GDD at Anthesis	766.4	20882.1**	413.9	1.25	0.4969
GDD at silking	422.1	20676.2**	329.6	1.07	0.9542
GDD at maturity	8637.4	27114.6**	1472.7	1.34	0.7434

**=significant at 1%, *=Signiant at 5%.

There was no significant variation for GDD for days to planting and days to harvesting on accumulation of heat in degree Celsius while Analysis of Variance of mean for GDDDA, GDDDS and GDDDM were highly significant at ($p < 0.01$) for inbred lines. The highest and lowest growing degree days were recorded on L_{10} (957.3 ℃) and L_2 (815 ℃) with the mean value of (898.42 ℃) for 50% days to anthesis; On L_{10} (998.16 ℃) and L_2 (835 ℃) with the mean value of (934.95 ℃) for 50% days to silking; On L_7 (68.83 ℃); on L_9 (9.93) ℃ with the mean of (36.53 ℃) for anthesis silking interval and on L_{10} (1689.7 ℃), L_2 (1473.9 ℃) with the mean of 1581.9 ℃ for growing degree days at maturity, respectively. Similarly (CML444/CML536) flowered five days earlier than the average flowering time of the two parents, CML444 (65 days) and CML536 (69 days) [17].

There were differences in heat accumulation in (℃) for DA, DS and DM for parental lines while it is similar for all parental materials on days to harvesting due to heat requirement of the materials were maintained. The accumulation of heat in after days to maturity was declined and approached to similar degrees Celsius for all parental lines as the physiological development of the crop ceases.

Increment in temperature and low humidity can similarly desiccate pollen grains once they are released from the anthers of the tassel. Temperatures over 86 ℉ degrees may literally kill pollen. Temperatures in excess of 95 ℉ degrees, especially when accompanied by low relative humidity, can desiccate exposed silks, but has little direct effect on silk elongation [18].

Table 3. *The mean value of Growing degree days in (℃) for different maize inbridlines.*

Inbred lines	**GDDDA (℃)**	**GDDDS (℃)**	**GDDASI (℃)**	**GDDDM (℃)**
L1	947.2^{a}	987.93^{a}	40.73^{b-d}	1610^{b}
L2	815.6^{f}	835.05^{g}	19.45^{ef}	1473.9^{e}
L3	917.4^{bc}	957.28^{b}	39.88^{b-d}	1594.8^{b-d}
L4	917.4^{bc}	957.28^{b}	39.88^{b-d}	1598.6^{bc}
L5	844.9^{e}	897.4^{e}	52.5^{b}	1587.4^{b-d}
L6	927.3^{b}	940.5^{c}	13.2^{f}	1580^{b-d}
L7	855.23^{e}	924.06^{d}	68.83^{a}	1594.8^{b-d}
L8	907.4^{c}	937.2^{cd}	29.86^{de}	1560.7^{d}
L9	917.4^{bc}	927.33^{cd}	9.93^{f}	1568.2^{cd}
L10	957.3^{a}	998.16^{a}	40.8^{b-d}	1689.7^{a}
L11	950.6^{a}	987.9^{a}	37.31^{cd}	1594.8^{b-d}
L12	876.73^{d}	927.33^{cd}	50.6^{bc}	1610^{b}
L13	844.9^{e}	876.73^{f}	31.83^{de}	1502.4^{e}
Mean	898.42	934.94	36.53	1581.97
CV (%)	1.15	1	21.92	1.31
LSD	17.45	15.87	13.49	35.03

*Means with the same letter are not significantly different.
GDDDS=Growing degree-days at days to anthesis, GDDDS=Growing degree days at days to silking, GDDDM=Growing degree days at days to maturity.

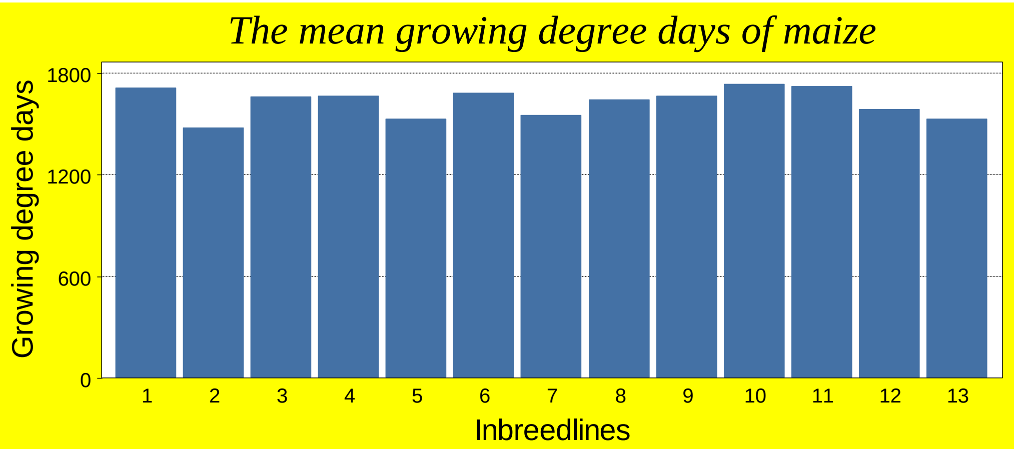

Figure 1. *Bar graph showing Growing degree days of maize inbridlines at different stages of growth.*

From figure 1 above L 10 and 11 followed by L_1 need high temperature to reach the maturity at different growth stages while L_2, L_5 and L_7 relatively need low temperature for their production.

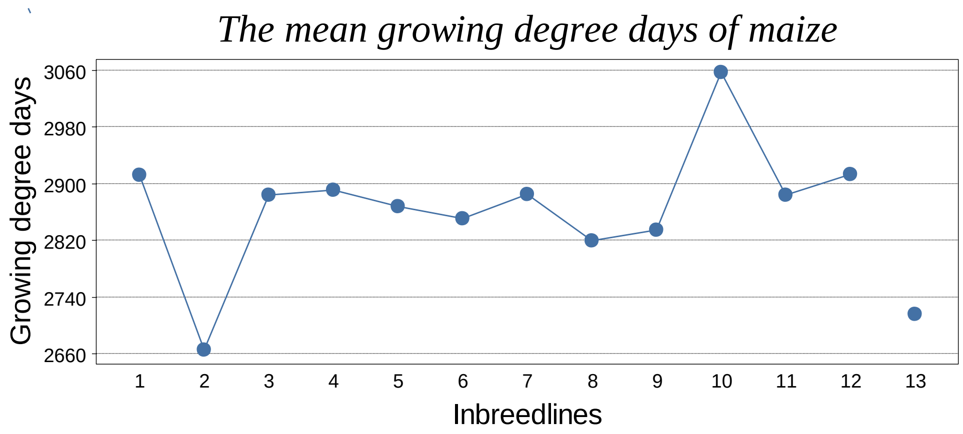

Figure 2. *Line graph showing the mean growing degree days of Maize inbridlines until maturity.*

From figure 2 above L 10 needs highest temperature to reach the physiological maturity while L_2 and L_{13} need low temperature to reach the physiological maturity.

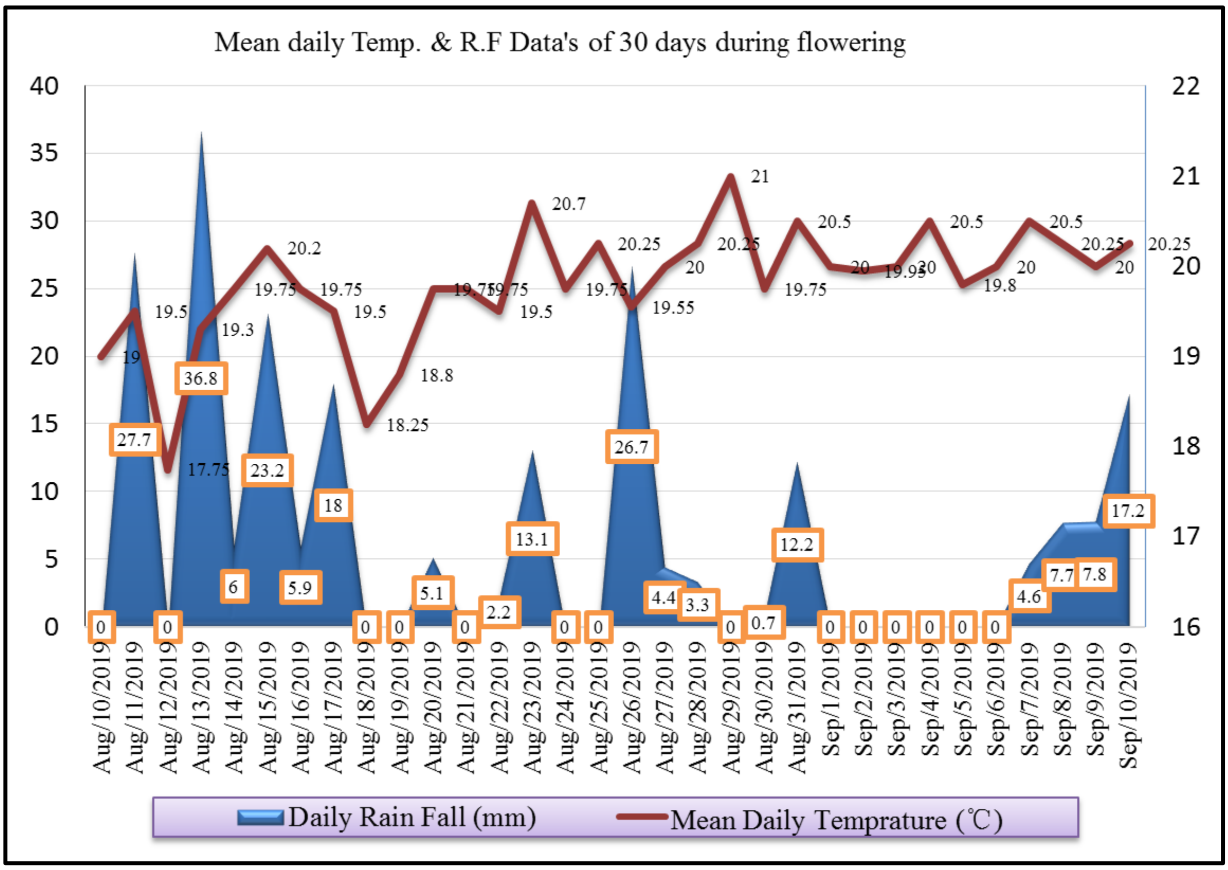

Figure 3. *Mean Daily Temperature and Rain Fall Data of the Center.*

The mean, maximum and minimum temperatures of the station during 30 days of flowering (15 days before flowering and 15 days after flowering) is displayed on the above graph from 10th month of August to 10th September 2019. The mean maximum daily Temperature 21 ℃ was recorded on 29 August whiles the mean minimum temperature 17.75 ℃ was recorded on 12th August 2019 and the mean daily temperature of each 32 days was 19.86.

The maximum and minimum daily Rainfall in (mm) of the station during 30 days of flowering (15 days before and 15 days after flowering) is displayed above from 10th of August 2019 to 10th September 2019. The maximum daily rainfall 36.8 mm was recorded on 13th August 2019 while the minimum daily rainfall 0.7mm was recorded on 30th August 2019. There is no R. F at all on 10th, 12th, 18th, 19th, 21th, 24th, 25th, 29th of the August and September 1-6th of 2019 during 32 days of flowering period.

4. Summary and Conclusion

To achieve higher productivity of maize hybrids, identifying the effect of climate condition and reaction of inbred lines to weather condition have remarkable importance. Some phenological data and growing degree days of thirteen maize parents were calculated to generate information. The analysis of variance was carried and mean squares tells that there were highly significant differences and significant among the materials. significant result observed for 50% Days to anthesis, 50% Days to silking, Days to maturity. This study also addresses the amount of heat required to reach Days to flowering, Days to maturity for each parental material adapted to the mid altitude sub-humid Agro-ecologies of Ethiopia. The result of the experiment showed that L_{10} had the highest yield (5.53 t/ha), followed by L_{13} (5.18 t/ha) and L_4 (5.13t/ha). L_{12}, L_7 and L_3 has grain yield above the mean with the mean value of 5.03, 4.14, and 4.10 t/ha respectively. These inbred lines likely produce maximum seed. while L_2, L_5, L_1, L_6, and L_8 has grain yield below the mean with the mean value of 3.62, 3.26, 3.31, 2.8 and 2.94 t/ha, respectively. The overall performance of parental lines to specific Agro ecology deals with climatic condition like temperature and rainfall are the determinant factors that influence production of seed parent, pollen shedders and hybrid maize. This study could be helpful to design appropriate knowledge to the panting information and to know the production potential of each parent.

Abbreviations

USDA: United States Department of Agriculture
BNMRC: Bako National Maize Research Center
DAP: Diammonium Phosphate
GDD: Growing Degree Days

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Conflicts of Interest

The author declares no conflict of interest.

Appendix

Some photos captured during the work.

Figure A1. *Pictorial view of maize at different growth stage.*

Figure A2. *Monitoring and evaluation at pre-flowering stage.*

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