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Performance Evaluation and Trait Association of Maize (*Zea mays* L.) Genotypes at Assosa District, Western Ethiopia

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Abstract: Maize (*Zea mays* L.), one of the most significant and important strategic food crops among cereals, ranks second in productivity but first in production area in Ethiopia. The average yield of the nation and region has grown over time, and hybrid maize varieties have played a significant role. The study's goals are to find high-yielding improved hybrid maize varieties and ascertain the relationship between agronomic traits and grain yield, both directly and indirectly. In the Assosa region of western Ethiopia, thirteen genotypes of maize and two standard checks were assessed in a randomized complete block design with three replications during the 2021 main season. Significant differences ($p \leq 0.01$) were found between genotypes for the majority of tested traits, according to analysis of variance. According to these, there was enough genetic variability for the traits under test. Grain yield and yield advantage over the standard check were highest for maize genotypes-13, 10, and genotye-12. The number of ear, days to maturity, number of ears, and number of plants per plot were all found to positively and significantly correlate with grain yield. Days to anthesis and days to siliking showed a negative significant correlation with yield. Selection for maximum number of ear, plant and late maturity day's parallel could result yield improvement in maize. Genotype-13 (8.49 t ha^{-1}), genotype-10 (8.01 t ha^{-1}) and genotype-12 (7.97 t ha^{-1}) had the uppermost grain yields and could be used in future crop maize improvement creativities.

Keywords: Genotype, Maize, Varietal Screening, Yield, Correlation

1. Introduction

Due to its higher productive potential than other members of the Gramineae family, maize (*Zea mays L.)* is universally referred to as the "Queen of the Cereals." Together with rice and wheat, it contributes to the majority of developing nations' staple diets and supplies more than 60% of all human calories [3, 10]. According to [11] 70% of Africans rely on maize as a staple grain, and the majority of smallholder farmers rely on it for both their livelihood and food supply [15]. The output of maize is expected to quadruple by 2050 in order to fulfil the growing demands of both animal and human consumption as well as the production of biofuel, especially in emerging nations [16]. Moreover, maize products play a major role in African nutrition, directly providing 31% of protein, 15% of fat, and 25% of carbohydrates for the average African diet.

With a national average yield of 4.2 t/ha t/ha, maize is one of Ethiopia's most important and strategically important food crops. It ranks first in production and productivity and second in area coverage, after teff [4, 5]. Ethiopia has a variety of agro-ecologies that are good for producing maize, with the Benshangul Gumuz region having one of the highest potentials [13]. With an average yield of roughly 3.84 t/ha, maize is the most produced crop and the second most farmed crop in the Benshangul Gumuz region [4]. Although the region has the highest potential for growing maize, the average yield is still below the global average of 5.75 t/ha [5] and needs to be raised by using the right variety of maize for the region. Numerous OPVs and hybrid maize varieties have been released since Ethiopian maize research began in 1950. But after the 1990s, Ethiopia switched to hybrid seeds for commercial maize production, which greatly raised average yield and expanded employment opportunities for communities [17]. In general, increasing maize productivity in the study area may be aided by yield improvement achieved by simultaneously selecting two or more traits and determining which hybrid varieties of maize are best suited for commercial use. The complex trait of yield is influenced by numerous genes and is both directly and indirectly subjective due to its various components. Therefore, using straightforward genotypic and phenotypic correlation coefficients to measure the true and observed association is crucial. In contrast to conventional varieties of maize, the adoption of suitable high yielding cultivars will enhance grain yield and increase income per hectare [6]. The best varieties with high prospects and wide range of acceptability should be chosen because some locally grown open pollinated varieties have declining yield potential. Due to socioeconomic factors, such as limited access to credit and farm inputs, poor agronomic management (especially low fertiliser application, weeding at the wrong time, late planting, and low plant population), and low plant population, small-scale farmers in the study region adopt improved maize varieties at varying rates. The goal of the current study is to evaluate the performance of various genotypes of maize and determine which hybrid is most suitable for producing a high yield in the study area.

2. Materials and Methods

2.1. Study Area

During the 2021 main cropping seasons, this study was conducted at Assosa Agricultural Research Centre. In western Ethiopia, the center is located at latitude 10° 2' 35.9" N and longitude 34°34' 2.5" E. It is distinguished by mean annual rainfall of 1275 mm and altitudes ranging from 1537 m.a.s.l. The months of June through August see the most rain during the rainy season, which lasts from April to October. With a mean maximum temperature of 32.0°C and a minimum temperature of 17.0°C, it has a warm, humid climate. The region's soil has a distinctive reddish-brown Nitosol colour.

2.2. Experimental Design and Materials

Thirteen maize genotypes and two standard checks were tested in RCBD with three replications following appropriate statistical procedures (Table 1). Plotting for each genotype involved using two rows that were five meters long and 75 by 25 centimeters apart between and within rows, respectively. To lessen the boundary effect, there were two border rows used in each direction. After 21 days of emergence, recommended planting density was reached by thinning two seeds of each variety per hill. Following the recommended agronomic practices for the area, the experimental field preparation, seed rate, and other agronomic tasks were carried out. Inorganic fertilizers NPS (182 kg ha-1) and UREA (125 kg ha-1) were utilized, along with a seed rate of 25 kg ha^{-1}.

2.3. Data Collection and Statistical Analysis

For ten quantitative traits, all agro-morphological, yield, and yield-attributing traits were collected from plants and plots. Five plants that were chosen at random were measured for plant height (cm) and ear height (cm). As the number of days from sowing to 50% of the plot reaches, phonological data such as days to anthesis (DA), days to silking (DS), and days to maturity (DM) were gathered on a plot basis. According to [2], disease data such as grey leaf spot (GLS) and phaeosphaeria leaf spot (PLS) were gathered on a 1–5 scale. From the entire plot, the fresh weight of each ear was measured and converted to kilogrammes per hectare. A formula developed by CIMMYT (1988) that was standardized to 15% moisture was used to calculate grain yield. Using the R (version 3.4.3) computer package, statistical analysis was performed in accordance with the randomized complete block design procedure. All recorded data were subjected to analysis of variance (ANOVA), and the mean separation was tested using Least Significant Difference (LSD) at the probability level of 5%, in accordance with the method of Gomez and Gomez (1984).

$$\text{Grain yield t/ha} = \frac{\text{F.W.(kg/plot)} * (100 - \text{GMC}) * (0.8 * 10{,}000)}{1000 * (100 - 15) * (\text{HPA})}$$

Where, GMC = Grain Moisture Content at Harvesting,
HPA = harvested net plot area (m^2),
0.8 = Shelling Coefficient and
85% = Standard Value of Grain Moisture at 15%.

Table 1. *List of the genotypes of maize that were used in the 2021 main season experiment.*

Genotype	Pedigree	Source
1	ILOO'E-1-9-1-1-1-1-1/124-b(109)	
2	Gibe-1-91-1-1-1-1/ILOO'E-1-9-1	
3	Gibe-1-91-1-1-1-1/ILOO'E-1-9-2	
4	CML395/30V53F2-20-2-1-2//142	
5	CML395/30V53F2-20-2-1-2//144	
6	CML395/30V53F2-20-2-1-2//143	
7	IL'OOE-1-9-1-1-1-1-1/DE-78-Z-12	
8	IL'OOE-1-9-1-1-1-1-1 X DE-78-Z-1	Bako NM
9	CML444/CML536//142-1-e	
10	CML444/CML536//144-7b	
11	CML444/CML536//143-5-i	
12	IL'OOE-1-9-1-1-1-1-1/CML536/	
13	IL'OOE-1-9-1-1-1-1-1/CML536/	
14	A7033/F7215//142-1-e	
15	CML395/CML202/142-1-e	

3. Results and Discussion

3.1. Analysis of Variance in Performance of Maize

Table 2 displays the ANOVA results. The phonological traits (days to anthesis, days to silking, and days to maturity), growth traits (plant height, ear height), and yield and yield traits showed a significant difference, according to the table. Given the variety of parental lines from which the hybrids originated, it is likely that these characters differed significantly from one another [12].

3.2. Phenological Traits

Traits of flowering date like anthesis days, silking days and maturity days showed significant difference. Anthesis days of the genotypes varied from 75.7 days to 83 days (Table 2). While the silking days varied from 78.3 to 86 days. Anthesis-silking intervals (ASI) reached from 1.7 to 4 days. Genotypes with lowest anthesis silking interval are genotypes 3 and 13, and the highest ASI is registered from genotypes 1 and BH661, respectively. Anthesis silking interval which is less than three days was within an acceptable range. Short anthesis silking interval is a desired trait for good seed setting. Maize plant anthesis normally begins one to three days before the emergence of silks and ends three to four days after the silks emergences are ready to be pollinated [14]. If, the gap between days to anthesis and silking is too big, the viability of pollen would be reduced and fertilization may be abnormal or may fail. Long maturity days was registered from genotype 1, and BH660, it takes more than five months at the testing site of Assosa district (Table 2). Previous findings have also reported differences for days to anthesis and silking in genotypes [8].

3.3. Growth Traits

Plant height showed non-significant between genotypes and only ear height was found to be significantly different in the tasted genotypes (Table 2). Genotype-13 and BH-660 had the highest ear height than their mean value of 158.3 cm, and shortest ear eight was registered from genotype-7 (139.5 cm) and genotype-5 (140 cm). The result is in line with [7] who reported that plant height difference of maize was among genotypic variability.

Table 2. *Analysis of genotypes of maize for yield and yield traits at Assosa, including variance and mean performance.*

Genotypes	Pedigree	DA	DS	MD	PH	EH	GLS	PLS	NP	NE	GY (t/ha)
1	ILOO'E-1-9-/144-7b	77.7^{bcd}	81.7^{a-d}	153^{d}	288.6	158.7^{a-d}	1.5^{a}	1.5^{bc}	15.7^{ab}	16.7^{abc}	7.23^{a-d}
2	Gibe-1-91-1/ILOO'E-11//144-7b	79.3^{bc}	83^{abc}	154.3^{bcd}	287.7	165.2^{abc}	1^{c}	1.5^{bc}	15^{ab}	14^{abc}	6.13^{de}
3	Gibe-1-91-1/ILOO'E--1//143-5-i	76.7^{cd}	78.3^{d}	154.7^{bcd}	289.2	167.2^{abc}	1^{c}	1.5^{bc}	16^{a}	15.3^{abc}	6.49^{cde}
4	CML395/30V53F2-20-2-1-2//142-1-e	78 ^{bcd}	81.3^{bcd}	156^{ab}	294.7	164.3^{abc}	1.2^{bc}	1.3^{c}	16^{a}	14.7^{abc}	6.89^{bcd}
5	CML395/30V53F2-20-2-1-2//144-7b	78 ^{bcd}	83.3^{abc}	155^{bcd}	265.0	140^{d}	1^{c}	1.5^{bc}	15.3^{ab}	15.7^{abc}	7.15^{bcd}
6	CML395/30V53F2-20-2-1-2//143-5-i	75.7^{d}	79^{cd}	154.7^{bcd}	283.7	153.5^{bcd}	1.2^{bc}	1.5^{bc}	17^{a}	15.3^{abc}	5.99^{def}
7	IL'OOE-1-9-1/DE-78-Z	78.3^{bcd}	81.3^{bcd}	154.7^{bcd}	256.7	139.5^{d}	1^{c}	1.67^{bc}	15.7^{ab}	13.7^{abc}	4.53^{g}
8	IL'OOE-1-1 X DE-78-Z-12	76 ^{cd}	78.3^{d}	154.6^{bcd}	275.0	149.7^{cd}	1.3^{ab}	1.83^{b}	15.7^{ab}	14^{abc}	5.92^{def}
9	CML444/CML536//142-1-e	80.7^{ab}	83^{abc}	155.7^{bc}	243.3	164.7^{abc}	1^{c}	2.33^{a}	16^{a}	17.7^{a}	7.51^{abc}
10	CML444/CML536//144-7b	80.7^{ab}	83^{abc}	156.3^{ab}	280.9	158.4^{a-d}	1^{c}	2.5^{a}	17^{a}	16.6^{abc}	8.01^{ab}
11	CML444/CML536//143-5-i	83^{a}	86^{a}	158^{a}	270.0	153.7^{bcd}	1^{c}	2.33^{a}	15.7^{ab}	16.3^{abc}	7.95^{ab}
12	IL'OOE-1-9 -1/CML536//142-1-e	79.3^{bc}	82^{a-d}	156^{ab}	278.0	151.3^{cd}	1^{c}	1.67^{bc}	16.3^{a}	17.3^{ab}	7.97^{ab}
13	IL'OOE-1-9 -1/CML536//143-5-i	79^{bcd}	81^{bcd}	155.3^{bc}	298.9	174.2^{ab}	1.3^{ab}	1.83^{b}	16^{a}	17.3^{ab}	8.49^{a}
14	A7033/F7215//142-1-e (BH660)	80.7^{ab}	84.3^{ab}	153.7^{cd}	287.7	175.3^{a}	1^{c}	1.5^{bc}	13.7^{b}	12.6^{c}	4.69^{fg}
15	CML395/CML202/142-1-e(BH661)	77.7^{bcd}	81.7^{a-d}	154.6^{bcd}	274.9	163.5^{abc}	1^{c}	1.5^{bc}	16^{a}	13.3^{bc}	5.18^{efg}
Mean		78.7	81.8	155.1	278.3	158.6	1.1	1.7	15.8	15.4	6.68
CV (%)		2.8	3.3	0.9	7.9	8.2	13.7	15.5	8.4	15.9	11.9
LSD -value		3.7	4.5	2.3	37.2	21.6	0.25	0.45	2.2	4.1	1.33
P- value		0.021	0.072	0.03	NS	0.048	0.002	<.0001	0.411	0.275	<0.0001

A column's mean value with a different letter designating a significant difference at the 0.05 and 0.01 levels (* and **, respectively) ns stands for non-significant, DS= 50% silking days, MD= maturity days, and AD= 50% anthesis days GLS stands for grey leaf spot, PLS for Phaeosphaeria leaf spot, PH for plant height (cm), EH for ear height (cm), NP for number of plants/plot, NE for number of eras per plot, and t ha^{-1} for grain yield.

Table 3. *Correlation coefficients between phenotypic pairs of traits among agronomic parameters, examined in fifteen genotypes of maize.*

	DA	DS	DM	PH	EH	GLS	PLS	NP	NE	yld
DA	1									
DS	0.91**	1								
DM	0.26	0.17	1							
PH	-0.39	-0.41	-0.17	1						
EH	-0.04	-0.20	-0.15	0.53**	1					
GLS	-0.28	-0.25	-0.10	0.25	0.09	1				
PLS	0.41*	0.24	0.36*	-0.23	-0.14	-0.15	1			
NP	-0.37	-0.40	0.14	0.11	0.03	0.11	0.08	1		
NE	-0.12	-0.22	0.31*	0.06	0.18	0.17	0.23	0.64**	1	
yld	-0.12	-0.24	0.41**	0.22	0.30*	0.22	0.21	0.49**	0.83**	1

Significant (P < 0.05) and highly significant (P < 0.01), respectively, PH stands for plant height (cm), EH for ear height (cm), GLS for grey leaf spot, PLS for Phaeosphaeria leaf spot, NE for number of eras per plot, yld for grain yield (t ha-1) and AD for 50% anthesis days, DS for 50% silking days, MD for maturity days.

3.4. Yield and Yield Related Traits

A significant difference was showed on grain yield and number of ear per plot (NEPP). Genotype-9 (17.7) showed the highest number of ear/plot followed by genotype-12 and 13(17.3) number of ear/plot were significantly at par with these top performers. The maize grain yield mean value showed significant difference, comparison presented in (Table 2) indicated that the genotype-13 is superior compared to others with 8.49 t/ha grain yield followed by genotype-10 with 8.01 t/ha grain yield per value. Low yield would be recorded from genotype-7 (4.53 t/ha) and standard check of BH-660 (4.69 t/ha). The variation in the yield potential is probably due to the various backgrounds of parental lines, from which the hybrids were developed [12]. Similar result confirmed with result reported by [1] that evaluated and identified high yielding maize varieties among different varieties tested.

3.5. Grain Yield and Yield Attributing Traits Correlation

The findings indicate that there is a positive and highly significant correlation between grain yield and the following traits: days to maturity (r=0.41), ear height (r=0.31), number of plants/ha (r=0.49), and number of ears per plot (r=0.83). No significant relationship was found between the other traits and yield traits (Table 2). Anthesis days and silking days indicated a negative correlation with yield, whereas plant height, grey leaf spot, and Phaeosphaeria leaf spot indicated a positive correlation. In maize hybrids, similar results reported a comparable negative correlation [9]. Grain yields to anthesis and siliking days do not significantly correlate, but a negative association indicates that genotypes with longer days to siliking and anthesis yield less grain; therefore, if selection is needed, it is better to select a hybrid with a shorter day to anthesis. The highest numbers of plants and ears per plot were found in top-yielding hybrids; there is a significant and positive correlation between the two variables. Increased grain yield is correlated with positive and significant numbers of mature days, plants per plot, and ears per plot. The strong positive relationship found between grain yield and maturity days, number of plants per plot, and number of ears suggests that selecting for these characteristics is crucial to raising hybrid maize's grain yield.

4. Conclusion

Among Ethiopia's cereal crops, maize is one of the most important and strategically important ones. With the switch to hybrid seeds in commercial maize production, notable yield increases have been noted. Selection for yield and significant yield components should be done concurrently in order to maintain the yield advances. In addition, recently released hybrids of maize and their breeding line should be evaluated for their adaptability and yield; selection enactments should be made to further popularise the variety. For the tested traits, there was enough variation among genotypes, according to analysis of variance.

The maize genotypes with the highest yield performance were genotypes-13, 10, and 12, which demonstrated a notable yield advantage over the standard check. In order to increase maize yield, these three genotypes of maize should be encouraged to participate in farmer field trials for testing before being suggested to the study areas' maize growers. Grain yield and days to anthesis and siliking date have a negative, non-significant correlation, according to correlation analysis. Grain yield showed a significant positive correlation with days to maturity, ear height, number of plants, and number of ears per plot. These strong and significant relationships between the characters suggested that they may be chosen as a foundation for a maize breeding effort to increase output.

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Conflicts of Interest

The authors declare no conflicts of interest.

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