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Evaluation of Maize (*Zea mays* L.) Varieties for Irrigation Season at Fogera District of South Gondar Zone, Northwestern Ethiopia

Dejen Bekis Fentie* and Alamir Ayenew Worku

Ethiopian Institute of Agricultural Research, Fogera National Rice Research and Training Center at Woreta, Ethiopia

Abstract

Production and productivity of maize at irrigation season of Fogera plain is limited mainly due to lack of recommended high-yielding varieties. Hence, five improved maize varieties were evaluated at Fogera during the irrigation season of 2021/22 with the aim of identifying the best performed high yielder maize variety/varieties in the study area. The experiment was carried out in a randomized complete block design with three replications. The data were recorded on days to maturity, plant height, ears per plant, cob length, cob diameter, cob weight, grains per cob, straw yield, 1000 kernel weight and grain yield. Significant differences were obtained between the varieties on days to maturity, plant height, cob width, cob weight, number of grains per cob and grain yield. The correlation coefficient analysis showed a significant and very strong positive association of grain yield with cob diameter (r=0.90*). Cob diameter also had highly significant and very strongly positive association (r=0.98**) with cob weight. The maximum cob length (20.47cm), cob width (5.447cm), cob weight (350.4g) and 1000 kernel weight (410.3g) were recorded from BH-549. Variety BH-549 had also showed the highest grain yield of 6083kg/ha followed by BH-546(4721kg/ha). These two varieties provided 45.56% and 12.97% yield advantages over the national (4179kg/ha) average productivity of maize in the country, respectively. Hence, BH-549 and BH-546 was found to be the most promising potential varieties to increase the average yield of maize at the irrigation season of Fogera. Therefore, these two varieties could be recommended to demonstrate in the large areas with production packages at the irrigation season of Fogera district and similar agro ecologies.

Keywords: Evaluation; Irrigation season; Maize; Varieties; Yield

Introduction

Maize (Zea mays L.) is a monoecious species that belongs to the grass family Graminae or Poaceae in the tribe Maydeae with a chromosome number of 2n=2x=20 and a male flower part (tassel) located at the top of the stem whereas female flower's part (ears) located about midway down on the same plant [1]. Maize is the most important and broadly adapted cereals worldwide [2]. In most part of the world, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals [3,4]. Globally, maize covered 197 million hectares area with a production of 1148 million metric tons [5]. Maize is an important cereal crop for around 169 countries across North America, South America, Africa, Asia and Europe [6]. Maize is preferable staple food crop in sub-Saharan Africa (SSA), which serving for more than 900 million people [3,7]. However, the demand of maize in SSA is far beyond the level of production suggesting further production and productivity of this crop.

Maize also one of the dominant cereal crops in terms of area coverage, production and utilization in Ethiopia [8]. In Ethiopia, maize ranks second next to tef in area coverage and first in total production [9]. Among cultivated cereal crops in Ethiopia, maize covered 23.97% of land with 34.95% of grain production in 2020/21 [10]. In Ethiopia, maize covered about 2,526,212.36 hectares of land and 10,557,093.59 tons of grain was produced per annum in 2020/21 with average productivity of 4.18 tons per hectare [9]. As the demand of maize production is increasing in alarming rate, the cultivated area and its production increasing from 2,271,442.47ha and 9,628,336.623 tons in 2019/20 to 2,526,212.36 ha and 10,557,093.592 tons in 2020/2021 [9,10].

Maize is an important source of carbohydrate, protein, lipids, minerals and certain vitamins [6]. Several genes involved in starch biosynthesis in maize endosperm have been mapped and cloned using well-known starch mutants [6,11]. Maize, together with rice and wheat, provides at least 30% of the food calories to more than 4.5 billion people in 94 developing countries [12]. Maize grains are consumed in various forms such as flat bread, porridge, boiled and roasted grains/cobs. Besides, maize possesses diverse usage as food in the form of sweet corn, baby corn, popcorn, waxy corn, high amylose maize and high oil maize [6-13].

In irrigation maize farming system of South Gondar, Ethiopia, especially Fogera farmers produce maize year to year at irrigation season for home consumption and market cash value. However, there are no enough investigations that have been done so far to improve production and productivity of maize at irrigation condition in the study areas. In this area, farmers need optional adaptable and high yielder maize variety/ies for irrigation cropping season. Testing of released varieties for their environmental reaction is crucial to increase productivity and avoid risks of various environmental factors (biological, physical and chemical). Therefore, the major objective of this study was to identify adaptable high yielder improved maize variety/ies and recommended a suitable one for farmers of Fogera and surrounding districts in Northwestern Ethiopia and areas of similar agro-ecologies.

***Corresponding author:** Dejen Bekis, Ethiopian Institute of Agricultural Research, Fogera National Rice Research and Training Center at Woreta, Ethiopia, Email: djbks21@gmail.com

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Materials and Methods

Experimental site description

The experiment was conducted in the Northwestern part of Ethiopia at Fogera National Rice Research and Training Center (FNRRTC) during 2021/22 in the irrigation cropping season. FNRRTC is located in Amhara Regional state, in the Northwestern part of Ethiopia, 607 km far from Addis Ababa. The experimental site is found at Woreta and located 11058' N latitude, 37° 41' E longitude and at an elevation of 1810m above sea level. Based on ten years' average meteorological data, the annual rainfall, and mean annual minimum, maximum and average air temperatures are 1300mm, 11.5°C, 27.9°C and 18.3°C, respectively. The soil type is black Vertisol with pH of 5.90. The main water source for rain-fed crop production in the study area is rain-fall. Irrigation water from underground, rivers Rib and Gumara were also used in the off season for production of maize, tef, wheat, oat and vegetables as second crop after rice.

Experimental materials and design

The treatments were consisted five improved maize varieties that obtained from Bako Agriculture Research Center and Amhara Seed Enterprise. Released maize varieties used for this study were BH-549, BH-540, BH-546, BH-660 and BH-661. The experiment was laid out in a randomized complete block design with three replications. The gross plot size of 20.25m^2 (4.5m×4.5 m) having six rows with inter row spacing of 75cm and 30cm spacing between plant was used. The net plot size was 4.5 m × 3m (13.5 m^2). Two seeds were planted per hill on the prepared plot and seedlings were thinned into one plant per hill after three weeks from emergence to obtain 90 plants per plot. Fertilizers were applied at the rate of NPS 100 kg/ha at planting and 200 kg/ha urea applied in split, half at planting and the other half was applied after weeding at knee stage. All other agronomic practices were applied as recommended for maize production in the study area.

Data collection

Ten quantitative traits were recorded at appropriate growth stage on plot and plant basis. Data of plant height, number of ears per plant, cob length, cob diameter, cob weight, number of grains per cob were recorded from pre-tagged five randomly sampled plants in the four central harvestable rows of each experimental unit/plot. However, yield per plot and phenological traits were taken on plot basis.

Data analysis

The data was subjected to analysis of variance as the procedure for randomized complete block design as stated by F and Gomez (1984) [14] using proc GLM of SAS computer Software program (SAS, 2002, Version 9.4) to assess the significance of the difference between the varieties (the F-test). For traits that have found a significant difference among the varieties, mean comparisons were carried out using least significance difference test (LSD) at p=0.05.

Results and Discussion

Analysis of variance

Analysis of variance revealed a significant difference between the varieties on day to maturity, plant height, cob diameter, cob weight, number of grains per cob, thousand kernel weight, straw yield and grain yield (Table 1). Whereas, number of ears per plant and cob length showed a non-significant difference between the varieties. Similarly, Tolessa et al. (2016) studied on maize varieties at Hora district of Southern Oromiya and found that the studied varieties differ significantly for their plant height [15], thousand seed weight and grain yield.

Mean performance and comparison of maize varieties for grain yield and other traits

Days to Maturity (DM)

Analysis of variance revealed the presence of a highly significant difference between the varieties for days to maturity (Table 1). The earliest days to maturity was recorded on the variety BH540 (135.7days) succeeded by variety BH549 (136.3days). Whereas the longest days to maturity was recorded from variety BH660 (146.7days). Similarly, Fuad et al. (2017) and Tolessa et al. (2016) confirmed the significance variability of maize varieties for days to maturity, plant height and grain yield.

Plant Height (PH)

All the varieties showed a highly significant difference for plant height (Table 1). Among the tested varieties, BH660 had the highest plant height (279.8cm) followed by BH661 (273.5cm), while short statured plants of 237.5 cm were recorded from BH549. BH660 had showed the highest height and easily exposed for weed that caused lodging of some stands before maturity [16]. This may be also reduced the yield of the variety which indicates highest height in this case is not advisable for future production of the crop at the study area. Tolessa et al. (2016) reported differential pattern of maize varieties for plant height. Tariku et al. (2022) conducted study with eight maize varieties at the lowlands of Southern Ethiopia and found mean values of plant height ranged from 180.1cm (BH140) to 209.9cm (Malkasa-7).

Number of Ears per Plant (EPP)

Statistical differences were not recorded between evaluated varieties for their ear number per plant (Table 1). But numerically, the variety BH546 gives the maximum number of ears per plant (1.583), while the minimum number of ears per plant was recorded from BH549 (1.167). This finding in line with Kusa et al. (2022) who reported a non-

Table 1: Mean squares for different sources of variation and the corresponding CV (%) for 10 characters studied at Fogera during 2021/2022 at irrigation condition.

		Mean Squares									
S.V	**Df**	**DM**	**PH**	**EPP**	**COL**	**COD**	**CW**	**NGPC**	**SY**	**TKW**	**GY**
Rep	2	11.67	1079	0.017	1.299	0.002	845.8	796.9	8.678	29.27	25.43
Variety	4	59.1**	945.3**	0.09ns	0.47ns	0.31**	2930*	2941**	10.46*	2221**	413.7**
Error	8	5.5	72.28	0.043	0.962	0.019	564.1	405.8	2.67	203	24.55
CV		1.68	3.29	15.12	4.72	2.79	7.90	3.47	10.4	3.71	11.35
R-Square		0.86	0.91	0.53	0.37	0.89	0.75	0.81	0.74	0.85	0.90

* and **= significance levels of p-value at 5% and 1%, respectively, ns: non-significant difference, S.V: Source of variation; Df: Degree of freedom, DM: Days to maturity, PH: Plant height (cm), EPP: Number of ears per plant, COL=Cob length (cm), COD: Cob diameter (cm), CW: Cob weight (g), NGPC: Number of grains per cob, SY: Straw yield (t/ha), TKW: 1000 kernel weight (g), GY: Grain yield (qt/ha)

significant difference among maize varieties. In Contrary, Tolessa et al. (2016) found significant differences among evaluated maize varieties for their ear number per plant.

Cob Length (CL)

Analysis of variance showed that non-statistical difference was observed between the varieties for cob length. Though, numerical difference was recorded with range of 20.43cm (BH660) to 21.27cm (BH549). Similarly, Tolessa et al. (2016) evaluated the improved maize varieties for their adaptability at bule hora district of Southern Oromia Ethiopia and obtained a non-significant difference with cob length as ranged from 13.9cm to 12.2cm [17]. In Contrary, Tariku et al. (2022) found a highly significant difference among studied maize varieties for cob length value that ranged from 24.90 to 29.63cm.

Cob Diameter (COD)

Analysis of variance showed a highly significant difference between the varieties for cob diameter (Table 1). The highest cob diameter was recorded from the variety BH549 with the value of 5.447cm followed by the variety BH546 (4.88cm) (Table 2). Whereas, the lowest cob diameter was recorded with BH661 (4.60cm) succeeding by BH660 (4.76cm) with overall mean value of 4.90cm (Table 2). In contrary, Tolessa et al. (2016) found a non-significant difference for cob diameter of five maize varieties with the overall mean value of 4.2cm and ranged from 4.2 to 4.4 cm.

Cob Weight (CW)

Analysis of variance showed a highly significant difference between the varieties for cob weight (Table 1). The highest cob weight was recorded from the variety BH549 with the value of 350.4g followed by the variety BH546 (300.5g) (Table 2). While, the lowest cob weight found from the variety BH661 (264.6g) succeeded by BH540 (289.4g) [18]. Similar findings were recorded by Kusa et al. (2022) that the main effect of variety significantly ($P<0.01$) affected cob weight of maize and with range of 92 to 152g.

Number of Grains per Cob (NGPC)

A highly significant difference between the varieties was found for number of grains per cob (Table1). The highest number of grains per cob recorded from the variety BH549 with the value of 617.2 followed by the variety BH661 (594.7) (Table 2). While, the lowest number of grains per cob found from the variety BH660 (531.9). Kusa et al. (2022) also found a highly significant difference on number of grains per cob from eight maize varieties with the minimum and maximum value of 329.4 and 441.8, respectively.

Thousand Kernel Weight (TKW)

The analysis showed a highly significant difference between the studied maize varieties for thousand kernel weight [19]. Thousand kernel weight ranged from 360.3g (BH661) to 416.3g (BH660) with the mean value 383.92g. Similarly, Kusa et al. (2022) found a highly significant difference on thousand kernel weight of maize varieties with the range of 223.1 to 277.5g. Tolessa et al. (2016) also obtained maximum value for 1000-grain weight from AMH851 (405.00 g), while the minimum value recorded with cultivar BH660 (295g).

Grain Yield (GY)

Analysis of variance showed a highly significant difference between the varieties for grain yield (Table 1). The highest grain yield was recorded from the variety BH549 with the value of 6083kgha-1 followed by the variety BH546 (4721kgha-1) and BH540 (4464kgha-1) (Table 2) [18]. These three varieties provided 45.56% and 12.97% yield advantages over the national (4179kgha-1) average productivity of maize in the country, respectively (Table 3). While, the lowest grain yield was found from the variety BH660 (3101kgha-1) succeeded by BH661 (3454kgha-1). A significant difference also observed between the varieties for straw yield as ranged from 14.34 tha-1(BH549) to 18.94 tha-1(BH661) (Table 1 and Table 4). The presence of such a range of variations in grain yield indicated the presence of genetic variation among the varieties which is the source of variability in genetic materials [20]. Similarly, Tariku et al. (2022) found a highly significant difference among studied maize varieties for grain yield that ranged from 1509kg (Melkasa-1Q) to 3284kg (Melkasa-6Q). Fuad et al. (2017) conducted study for evaluation of ten maize varieties in the midlands of Fedis district of Eastern Hararghe that found a significant grain yield difference at Umerkule location but not obtained a statistical difference on grain yield at Debine location.

Associations of studied traits with grain yield of maize

Cob diameter showed positive and highly significant association with grain yield of maize varieties (Table 5). Whereas, plant height also showed a highly significant negative association with grain yield of studied maize varieties at irrigation season of Fogera plain. These association, indicates that varieties named BH660 and BH661 had a highest height but not given a higher yield as much as BH 549 which is shorter than the two varieties. Cob weight has a strong association($r=0.98^{**}$) with cob diameter that indirectly associated with grain yield of maize. These results agreed with the findings of Bigul et al. (2021) that grain yield showed positive and significant phenotypic correlation with cob diameter, cob length and number of rows per cob.

Table 2: Mean performance days to maturity, plant height, ears per plant, cob length and cob diameter of tested maize varieties at Fogera in 2021/2022 irrigation season.

Varieties	DM	PH (cm)	EPP	COL (cm)	COD (cm)
BH-540	135.7c	253.3b	1.5ab	20.63a	4.802bc
BH546	138.3bc	247.8b	1.58a	21.27a	4.88b
BH549	136.3bc	237.5b	1.17b	20.47a	5.45a
BH660	146.7a	279.8a	1.25ab	21.17a	4.76bc
BH661	140.7b	273.5a	1.33ab	20.43a	4.60c
Minimum	135.7	237.5	1.167	20.43	4.604
Maximum	146.7	279.8	1.583	21.27	5.447
Mean	139.54	258.38	1.3666	20.79	4.90
CV	1.68	3.29	15.12	4.72	2.79
LSD (0.05)	4.42**	16.01**	0.39^{ns}	1.85^{ns}	0.26**

DM: days to maturity, PH: Plant height (cm), EPP: Number of ears per plant, COL=Cob length (cm), COD: Cob diameter (cm)

Table 3: Grain yield mean comparison.

Varieties	Grain yield qt/ha	Yield advantage over national average (41.79qt/ha)	Yield advantage in %
BH-540	**44.64b**	2.85	6.82%
BH546	**47.21b**	5.42	12.97%
BH549	**60.83a**	19.04	45.56%
BH660	**31.01c**	-ve	
BH661	**34.54c**	-ve	
Variety BH-549 had also showed the highest grain yield of 6083kg/ha followed by BH-546(4721kg/ha) and BH-540(4464kg/ha)			

Table 4: Mean performance cob weight, number of grains per cob, straw yield, thousand kernel weight and grain yield of tested maize varieties at Fogera in 2021/2022 irrigation season.

Varieties	CW(g)	NGPC	SY(t/ha)	TKW(g)	GY (qt/ha)
BH-540	289.4b	577.7b	14.75b	362b	44.64b
BH546	300.5b	579b	14.84b	370.7b	47.21b
BH549	350.4a	617.2a	14.34b	410.3a	60.83a
BH660	297.8b	531.9c	15.72b	416.3a	31.01c
BH661	264.6b	594.7ab	18.94a	360.3b	34.54c
Minimum	264.6	531.9	14.34	360.3	31.01
Maximum	350.4	617.2	18.94	416.3	60.83
Mean	300.54	580.1	15.72	383.92	43.65
CV	7.90	3.47	10.4	3.71	11.35
LSD (0.05)	44.72*	37.93**	3.08*	26.83**	9.33**
CW: Cob weight (g), NGPC: Number of grains per cob, SY: Straw yield (t/ha), TKW: 1000 kernel weight (g), GY: Grain yield (qt/ha)					

Table 5: Correlation coefficients (r) of maize varieties for yield and other agronomic traits during 2021/22 at Fogera.

	DM	PH	EPP	COL	COD	CW	NGPC	SY	TKW	GY
DM	1									
PH	0.857	1								
EPP	-0.328	-0.15	1							
COL	0.474	0.18	0.416	1						
COD	-0.468	-0.79	-0.453	-0.223	1					
CW	-0.323	-0.71	-0.46	-0.046	0.98**	1				
NGPC	-0.785	-0.7	-0.131	-0.715	0.57	0.38	1			
SY	0.391	0.69	-0.118	-0.331	-0.66	-0.743	-0	1		
TKW	0.453	0.02	-0.747	0.22	0.55	0.682	-0.25	-0.39	1	
GY	-0.788	-0.97**	-0.092	-0.293	0.90*	0.822	0.75	-0.65	0.15	1
DM: days to maturity, PH: Plant height (cm), EPP: Number of ears per plant, COL=Cob length (cm), COD: Cob diameter (cm), CW: Cob weight (g), NGPC: Number of grains per cob, SY: Straw yield (t/ha), TKW: 1000 kernel weight (g), GY: Grain yield (qt/ha)										

In contrary, Firezer (2019) found a positive significant correlation of grain yield with days to maturity, plant height and ear height.

Conclusion and Recommendations

Maize is one of crucially important potential crops at irrigation season of Fogera plain. The analysis of variance revealed a significant difference ($p < 0.05$) between the studied maize varieties on days to maturity, plant height, cob diameter, cob weight, number of grains per cob, straw yield, thousand kernel weight and grain yield. The present study indicated the presence of variability among varieties on most studied yield and yield-related traits. The mean of grain yield of BH 549 (6083 $kgha^{-1}$) and BH 546 (4721$kgha^{-1}$) were superior varieties as compared to other varieties. Based on the average national maize productivity, these two varieties give additional 45.56% and 12.97% yield advantages over the national maize average productivity. Therefore, these two varieties could be recommended for irrigation season of Fogera district and similar agro ecologies. Additional demonstration works considering production packages at farmers' fields with a larger plot size is crucially important to convince the superiority of the varieties as compared to locally available cultivar.

Conflict of Interests

The authors have not declared any conflict of interests.

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