Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.11, No.17, 2021

Evaluation of Maize (Zea mays L.) Varieties for Moisture Stress Areas

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Abstract
Maize is priority crop to farmers because it is a stable food in many rural communities of southern region. It is widely grown in the various parts of southern region from lowland to mid-highlands. On other hand, moisture stress is one the most critical production constraints of maize in low to intermediate agro-ecology. Thus, developing maize varieties tolerant to moisture is of paramount important in order to sustain maize production in moisture areas. In this content, field experiments were conducted during 201617 cropping at Kindo Koyisha and Humbo with objective to select adaptable maize varieties for moisture stress with reasonable grain yield. Treatments used in this study were eight maize varieties (BH546, BH547, Gibe II, MH130, Melkasa IV, MH140, Melkasa II and Melkasa 6Q) and three local cultivars (Local red, Local mixed and Local white) of total of eleven maize genotypes were evaluated at two moisture prone areas in southern Ethiopia. Treatments were laid out in a randomized complete block design (RCBD) with three replications. Maize varieties exhibited difference performance at two tested locations. Varieties had relatively superiority of performance Kindo Koyisha as compared to Humbo. At Humbo varieties MH140, MH130 BH546 and Melkasa IV gave relatively higher grain yield. At Kindo Koyisha maize varieties expressed relatively better performance with respect to grain yield. At this location varieties with superior performance with sounding grain yield were BH546, MH140, BH547 and MH130. Based on this result BH546, MH140 and MH130 could be used at both locations. Moreover, BH547 at Bale and Melkasa IV at Humbo also could used to respective locations for production.
Keywords: Maize varieties and moisture stress
DOI: 10.7176/JBAH/11-17-03
Publication date: September 30th 2021

1. Introduction

Maize (*Zea mays* L.) has become the third most important cereal crop in the world, because of its high adaptability and productivity (Mosisa *et al.*, 2002). Globally maize is cultivated under diverse climatic conditions but yields best under moderate temperatures with sufficient water. However, on the African continent, it is the most important food crop and mainstay of rural diets in the eastern and southern regions (FAO, 2003; Maredia, *et al.*, 2000; Pingali, & Pandey, 2001). Maize has a higher carbohydrate production potential per unit land than other cereals and was the first major cereal to undergo rapid and widespread technological transformation in its cultivation (Palwal, 2000). In developed countries, maize is grown mainly for animal feed and as raw materials for industrial products, such as starch, glucose, and dextrose and bio fuel. Therefore, maize occupies an important position in Africa and on the global economy where it is traded as a food, feed and industrial grain crop (Vasal, 2000).

In Ethiopia, cereals account for about 82.34% of the annual national crop production. Maize ranks first in total production and yield per unit area and second in area coverage among all the cereals. It is largely produced in western, central, southern and eastern regions (CSA, 2010). Maize research has advanced from landraces to varieties, to maize hybrids: double cross, three-way cross and single cross, and recently transgenic maize hybrids. The optimized use of adapted and exotic germplasm in various production environments is a key to the continued success in increasing grain yield and other trait-specific products: green ear, forage, oil, protein, starch. Moreover, maize is priority crop to farmers because it is a stable food in many rural communities of southern region. It is widely grown in the various parts of southern region from lowland to mid-highlands. On other hand, moisture stress is one the most critical production constraints of maize in low to intermediate agro-ecology. However, the extent of yield reduction due to moisture stress varies with genotypes. Developing maize varieties tolerant to moisture is of paramount important in order to sustain maize production in moisture areas. Hence, the objective of this study was to select adaptable maize varieties for moisture stress with reasonable grain yield.

2. MATERIALS AND METHODS

2.1 Experimental site

Field experiments were conducted during 2016/17 cropping at Kindo Koyisha (Altitude 1170 masl, annual rainfall 924 mm, 2100, major crops cultivated in the study area include maize, sorghum and sweet potato) and Humbo (Altitude 1800, annual rainfall 1295 with bimodal rainfall patterns, average temperature of 20^0c).

2.2 Treatments and experimental design

Treatments used in this study were eight maize varieties (BH546, BH547, Gibe II, MH130, Melkasa IV, MH140, Melkasa II and Melkasa 6Q) and three local cultivars (Local red, Local mixed and Local white) of total of eleven maize genotypes were evaluated at two moisture prone areas in southern Ethiopia. Treatments were laid out in a randomized complete block design (RCBD) with three replications. The plot size was 4 x 4 m with 1.5 m between replications and 1.0 m between plots. Planting was carried out as per planting time of respective area following the onset of rainfall. Maize was hand planted by placing two seeds per hill and thinned after emergence to maintain the proposed plant density per plot. Weed control was carried out by hand or hand hoeing, while diseases and insect damage were visually monitored during crop growing season. Phosphorus fertilizer in the form of DAP and N in the form urea were applied as per recommendation for maize production. Moreover, other crop management practices carried out as desired.

2.3 Data collection and measurements

Data recorded on yield components included ear length, ear diameter, number of seeds per row, kernels per ear, thousand seed weight and prolificacy (ears per plant). Ear length and diameter were measured for five randomly selected plants from the base to the tip and at approximately the middle of the ear at harvesting, respectively. Number of seeds per row was counted for five randomly selected plants. Seed number per ear was determined multiplying the number of rows by the number of seeds per row. Thousand seed weight (TSW) was measured by counting a thousand seeds with a seed counter and weighing it with sensitive balance. Prolificacy is the property of producing more ears per plant and estimated by dividing the number of ears by number of plants per plot. Grain was manually harvested from net plot and converted to kg/ha after adjusting the moisture content to 12.5%. Biomass yield was estimated as the sum of stover weighed and grain yield. Harvest index (HI) is the ratio of grain yield to the total biomass yield which was estimated by dividing grain yield by total biomass. Data were subjected to analysis of variance using the general linear model SAS version 9.1 (SAS Inst., 2003). Treatments means were compared using the least significant difference (LSD) at 5% probability level.

3. Results

3.2. Plant and ear heights

The data for plant and ear heights as affected by location and varieties are depicted in Table 1. Analysis o variance indicated that location had significant effect on plant and ear height. Both parameters were higher at Kindo Koyisha as compared to Humbo. Similarly, maize varieties were significantly differed for plant height and ear height. The tallest plant height (235 cm) was recorded for variety BH547 followed by variety BH547 with mean plant height of 229 cm. The shortest plant height (156 cm) was seen for variety Melkasa 6Q. In line with this, the tallest ear heights (117 cm) was observed for BH547 followed by variety Local mixed with mean ear height of 58 cm. On the other hand, location by variety interactions resulted in significant differences on ear heights (Table 1). Generally, all varieties exhibited taller ear heights at Kindo Koyisha as compared to Humbo. The tallest ear height (148 cm) was observed for variety Local white at Humbo followed by variety BH547 at Kindo Koyisha with mean ear height of 147 cm. The shortest ear height (34 cm) was seen for variety Melkasa 6Q at Humbo. In contrast, location by varieties interaction did not have significant effect plant heights.

3.3. Ear length and ear diameter

The data for ear length and ear diameter as affected by location and varieties are presented in Table 2. Analysis of variance showed that main effect of location and varieties had significant differences on length. The ear length of maize varieties was higher at Kindo Koyisha than that of Humbo. Regarding varieties, averaged over locations, the longest cob length (15.13 cm) was obtained from variety BH546 followed by variety BH547 with mean ear length of 13.74 cm. The shortest ear diameter (11.62 cm) was seen for variety Melkasa 6Q. In line with this, interaction of location by varieties resulted in significant differences on ear length (Table 2). The longest ear length (15.83 cm) was recorded for variety BH546 at Kindo Koyisha followed by variety BH547 with mean cob length of 14.45 cm at the same location. The shortest ear length (9.69 cm) was seen for local white at Humbo. On the other hand, only main effect of varieties exhibited significant differences on ear length. The longest cob diameter (4.75 cm) was measured for variety BH546 followed by variety BH547 with mean ear diameter of 4.34 cm. the shortest ear diameter (4.03 cm) was observed for local white. However, main effect of location and its interactions with varieties did not have significant effect on ear diameter.

3.4. Rows per ear, seeds per row, seeds per ear and thousand seed weight

Number of rows per ear seeds per row, seeds per ear and TSW as affected by location and varieties are shown in Table 3. Analysis of variance indicated that the main effect of location had significant effect on number of seeds per row and seeds per ear. Both parameters were higher at Kindo Koyisha as compared to that of Humbo. Similarly, varieties exhibited significant differences number of rows per ear, seeds per row, seeds per ear and

TSW (Table 3). Variety BH547 produced the highest number of per ear (15.1) followed by variety Melkasa 6Q with mean number of rows per ear of 14.8. The least number of rows per cob (12.4) was seen for Local white. In line with this, the greatest number of seeds per row (34) and seeds per cob (469) were recorded for variety BH546 followed by variety BH547 with mean number of seeds per row and seeds per ear of 30 and 445, respectively. Local white yielded the lowest number of seeds per row (26) and seeds per ear (295). Moreover, location by variety interactions resulted in significant on number of seeds per row. The greatest number of seeds per row (36) was recorded that Kindo Koyisha for variety BH546 followed by the same location for variety BH547 with mean number of seeds per row of 34. The lowest number of seeds per row (22) was seen for Local white. In contrast, main effect of location, variety and their interactions did not have significant effect on TSW, seeds per row and rows per ear (Table 3).

3.5. Biomass, grain yield and harvest index

The data for biomass, grain yield and HI as affected by location and variety are depicted in Table 4. Location did not have significant effect on biomass yield of maize varieties. However, varieties exhibited significant differences on biomass yield. Biomass yield for maize varieties ranged from 7083 to 14792 kg/ha with the highest biomass yield recorded (14792 kg/ha) for variety BH546 followed by variety BH547 with biomass yield of 14688 kg/ha. The lowest biomass yield (7083 kg/ha) was obtained from variety Melkasa 6Q. In line with this, location by varieties interactions resulted in significant differences on biomass yield. The greatest biomass yield (17188 kg/ha) was recorded at Kindo Koyisha for variety BH547 followed by variety BH546 at the same location with mean biomass yield of 15938 kg/ha. The lowest biomass yield (6979 kg/ha) was seen for variety Melkasa 6Q at Kindo Koyisha.

Grain yield was significantly differed in response to location where higher grain yield was obtained from Kindo Koyisha as compared to Humbo (Table 3). Similarly, maize varieties exhibited significant differences on grain yield. The highest grain yield (5208 kg/ha) was recorded at Kindo Koyisha for variety BH546 followed by MH140 with mean grain yield of 5000 kg/ha at the same location. The lowest grain yield (2396 kg/ha) was achieved from Local red at Humbo. In general maize varieties tested for moisture responded differently to respective environments. At Kindo Koyisha varieties BH546, MH140 and BH547 showed reasonable performance in a such moisture stress prone environment. On other hand, MH140 and MH130 relatively exhibited superiority over others at Humbo.

4. Discussion

Maize varieties exhibited differently for agronomic traits measured in response to location with respect of their genetic variability (Table 1, 2, 3 and 4). Generally almost all maize varieties showed superior performance at Kindo Koyisha as compared to Humbo for agronomic traits. The grain yield differences recorded was 730 kg/ha between Kindo Koyisha and Humbo. Thus, relatively the performances of varieties were poor at Humbo which probably suggests that Kindo Koyisha was relatively better environment with plant growth conditions. Moreover, this illustrated that subjecting plants to favorable growing conditions increased the ability of varieties for capturing resources which was reflected as evident in their increased agronomic performance. The significant effects of environments indicated that the genotypes performed differently across locations. Thus, the mean yield of genotypes differed from location to location. Similarly, maize varieties, averaged over locations, showed significant differences on plant height, ear height, rows per cob, seeds per row, seeds per cob, ear length and ear diameter (Table 1, 2 and 3). Relatively higher plant height (≥ 200 cm) was recorded for varieties BH546, BH547 and MH140 whereas ear heights (≥ 100 cm) were recorded for varieties BH547, Local mixed and Local white. Variety BH546 gave the longest cob length while BH547 produced the highest cob diameter. Variety BH547 gave the highest number of rows per cob while variety BH547 produced the greatest number of seeds per row and seeds per cob. Maize varieties, averaged over locations, tended to express a wide range of their genetic variability for grain yield. Grain yield variations ranged from 2396 to 4063 kg/ha. Variety BH 546 out yielded which was followed by MH140. Local red was least with respect to grain yield performance. The significant difference among the genotypes showed variations in their response (yield potential) to different locations.

Location by variety interactions resulted in significant differences on ear height, cob length, seeds per row, biomass and grain yield (Table 1, 2 & 3). For aforementioned parameters, varieties had relatively superiority at Kindo Koyisha as compared to Humbo. In general the performance of varieties was poor at Humbo with the grain yield variability ranged from 2396 to 3021 kg/ha. At Humbo varieties MH140, MH130, BH546 and Melkasa IV gave relatively higher grain yield with HI (Physiological efficiency and ability of converting total dry matter into economic yield) values were 0.30, 0.40, 0.28 and 0.36, respectively. This variability might be attributed to varietal differences in maize genotypes in response to the prevailing environmental conditions. Hence, Humbo location could be considered as a stressful environment with profound limitation in potential performance of maize varieties. At Kindo Koyisha maize varieties expressed relatively better performance with respect to grain yield. Grain yield variability ranged from 2604 to 5208 kg/ha from lowest to the highest. At this location varieties with superior performance with sounding grain yield were BH546, MH140, BH547 and MH130. This probably indicates that genotypes describe the complete set of genes inherited by an individual that is important for the expression of a trait under consideration in a particular environment. In general maize varieties at Kindo Koyisha performed best to their potential as compared to Humbo. Maize varieties BH546, MH130 and MH140 showed relatively stability across location with superiority of grain yield. Abay and Bjornstad (2009) indicated that genotype by environment (G x E) interactions is a differential genotypic expression across environments which affect the genotypes rankings within each environment and hence relevant for identifying mega environments and targeting genotypes. Moreover, the significant of G X E indicates the presence of fluctuation of genotypes performance across environments or testing sites with inconsistency performance. Similar results were recorded by Akcura *et al*. (2005), Acura and Kaya (2008) Asfaw (2008) Dagne (2008) Solomon *et al.* (2008) Abdurhaman (2009) and Muluken (2009). The relationship between selected agronomic traits with grain is depicted in Table 5. The correlation coefficient (r) values of selected agronomic traits with grain yield ranged from -0.05 to 0.82. Plant and ear height were positively significantly ($P \leq 0.05$) correlated which might suggest that the traits are closely associated with grain yield. Similarly, number seeds per row, seeds per cob, ear length, ear diameter, biomass and TSW had positively significantly associated with yield. In contrast, number of rows per cob with grain yield correlation was not significant. In general the correlation of almost all agronomic traits with grain yield was relatively strong indicating that their contribution towards grain yield was considerable.

5. Conclusion

Maize varieties reacted differently for agronomic traits measured in response to location with respect of their genetic variability. Generally almost all maize varieties exhibited superior performance at Kindo Koyisha than that of Humbo. Based on this result, varieties BH546, MH140 and MH130 could be used at both locations. Moreover, varieties BH546 and MH 140 at Kindo Koyisha whereas varieties MH 140, MH 130 and Melkasa IV at Humbo showed relatively better adaptation to their respective locations.

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Table 1. Plant and ear heights as affected by location and varieties

Location	Variety	Plant height	Ear height
Kindo Koyisha	BH546	291	124bc
	BH547	268	147a
	Gibe II	228	103de
	MH130	204	82fg
	Melkasa IV	201	88ef
	MH140	259	121cd
	Melkasa II	217	88ef
	Melkasa 6Q	202	82fg
	Local red	244	141ab
	Local mixed	245	144a
	Local white	255	148a
Humbo	BH546	178	72f-g
	BH547	189	86ef
	Gibe II	155	57hi
	MH130	117	40ij
	Melkasa IV	135	54hi
	MH140	150	58hi
	Melkasa II	136	54hi
	Melkasa 6Q	110	34j
	Local red	148	57hi
	Local mixed	153	65gh
	Local white	122	55hi
	LSD	NS	18
Variety mean	BH546	235a	98bc
	BH547	229a	117a
	Gibe II	191bc	80de
	MH130	161ef	61f
	Melkasa IV	168d-f	71ef
	MH140	205b	90cd
	Melkasa II	177c-e	71ef
	Melkasa 6Q	156f	58f
	Local red	196bc	99bc
	Local mixed	199b	105ab
	Local white	188b-d	101bc
	LSD	21	13
Location mean	Kindo Koyisha	238a	115a
	Humbo	145b	58b
	LSD	9	5
	CV (%)	9.2	13.3

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

Table 2. Cob length and diameter as affected by location and varieties

Location	Variety	Cob length (cm)	Cob diameter (cm)
Kindo Koyisha	BH546	15.83a	4.37
	BH547	14.45a-c	4.79
	Gibe II	12.71c-f	4.19
	MH130	13.09c-f	4.31
	Melkasa IV	14.15a-d	4.26
	MH140	13.64b-e	4.39
	Melkasa II	12.91c-f	4.03
	Melkasa 6Q	11.97ef	4.34
	Local red	12.29d-f	4.27
	Local mixed	12.96c-f	4.45
	Local white	12.10ef	4.17
Humbo	BH546	14.43a-c	4.32
	BH547	13.03c-f	4.71
	Gibe II	12.69c-f	4.33
	MH130	11.96ef	3.95
	Melkasa IV	12.24ef	3.99
	MH140	12.77c-f	4.16
	Melkasa II	11.89ef	4.13
	Melkasa 6Q	11.27fg	4.19
	Local red	12.66c-f	4.25
	Local mixed	12.62c-f	4.25
	Local white	9.69g	3.89
	LSD	1.90	NS
Variety mean	BH546	15.13a	4.75a
	BH547	13.74b	4.34b
	Gibe II	12.70bc	4.26bc
	MH130	12.53bc	4.13bc
	Melkasa IV	13.19b	4.13bc
	MH140	13.20b	4.27bc
	Melkasa II	12.40bc	4.08c
	Melkasa 6Q	11.62c	4.27bc
	Local red	12.48bc	4.26bc
	Local mixed	12.79bc	4.35b
	Local white	12.39bc	4.03c
	LSD	1.34	0.24
Location mean	Kindo Koyisha	13.55a	4.32
	Humbo	12.29b	4.19
	LSD	0.57	NS
	CV (%)	8.9	4.9

Means followed by the same letters within a column are not significantly different at 5% probability level, NS=not significant

Table 3. Number of rows per cob, seeds per row, seeds per cob and TSW as affected by location and varieties

Location	Variety	Rows per ear	Seeds per row	Seeds per ear	TSW (g)
Kindo Koyisha	BH546	13.6	36a	531	295
	BH547	14.8	34ab	481	329
	Gibe II	13.2	29c-g	387	281
	MH130	13.6	33a-c	402	311
	Melkasa IV	13.6	31b-e	408	296
	MH140	14.8	30b-f	441	322
	Melkasa II	13.3	30b-e	407	285
	Melkasa 6Q	15.3	27d-h	444	278
	Local red	13.8	26e-h	357	341
	Local mixed	13.2	27d-h	373	356
	Local white	12.8	29c-f	327	369
Humbo	BH546	13.0	31b-d	407	376
	BH547	15.3	27e-h	410	347
	Gibe II	14.3	27e-h	382	320
	MH130	13.0	24hi	314	309
	Melkasa IV	13.0	26f-i	334	344
	MH140	14.3	24g-i	348	368
	Melkasa II	14.3	24hi	339	315
	Melkasa 6Q	14.3	26f-i	369	285
	Local red	13.0	29c-f	374	315
	Local mixed	12.7	28d-g	360	338
	Local white	12.0	22i	262	332
	LSD	NS	4	NS	NS
Variety mean	BH546	13.3c-e	34a	469a	336a-c
	BH547	15.1a	30b	445ab	338ab
	Gibe II	13.8a-e	28bc	384c	301cd
	MH130	13.3c-e	28bc	358c	310b-d
	Melkasa IV	13.3c-e	28bc	371c	320a-c
	MH140	14.6a-c	27bc	394bc	345ab
	Melkasa II	13.8a-d	27bc	373c	299cd
	Melkasa 6Q	14.8ab	27bc	406bc	282d
	Local red	13.4b-e	28bc	366c	328a-c
	Local mixed	12.9de	28bc	367c	347a
	Local white	12.4e	26c	295d	351a
	LSD	1.4	3	53	36
Location mean	Kindo Koyisha	13.8	30a	414a	314
	Humbo	13.6	26b	355b	332
	LSD	NS	1	22	NS
	CV (%)	8.8	9.2	12.0	9.7

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

Table 4. Biomass, grain yield and harvest index as affected by location and varieties

Location	Variety	Biomass (kg/ha)	Grain yield (kg/ha)	HI
Kindo Koyisha	BH546	15938ab	5208a	0.28
	BH547	17188a	4479ab	0.26
	Gibe II	10729b-e	3438a-c	0.30
	MH130	10417b-e	3958a-c	0.35
	Melkasa IV	8542de	2917bc	0.33
	MH140	14896a-c	5000a	0.32
	Melkasa II	8646de	2604c	0.27
	Melkasa 6Q	6979e	2708bc	0.38
	Local red	9583c-e	2708bc	0.18
	Local mixed	10729b-e	3021bc	0.24
	Local white	10104b-e	2917bc	0.14
Humbo	BH546	13542a-d	2917bc	0.28
	BH547	12188a-e	2500c	0.29
	Gibe II	9375c-e	2604bc	0.33
	MH130	10104b-e	3021bc	0.30
	Melkasa IV	9375c-e	2917bc	0.36
	MH140	9375c-e	3021bc	0.40
	Melkasa II	10104b-e	2708bc	0.25
	Melkasa 6Q	7292e	2708bc	0.37
	Local red	11458a-e	2396c	0.38
	Local mixed	11458a-e	2604c	0.34
	Local white	7604de	2396c	0.27
	LSD	5943	1860	NS
Variety mean	BH546	14792a	4063a	0.28
	BH547	14688ab	3438a-c	0.27
	Gibe II	10104cd	3021a-c	0.32
	MH130	10208cd	2500c	0.33
	Melkasa IV	8958cd	2917a-c	0.35
	MH140	12188a-c	3958ab	0.36
	Melkasa II	9375cd	2604c	0.27
	Melkasa 6Q	7083d	2706bc	0.38
	Local red	10521b-d	2396c	0.28
	Local mixed	11146a-d	2813a-c	0.29
	Local white	8854cd	2604c	0.20
	LSD	4202	1316	NS
Location mean	Kindo Koyisha	11250	3438a	0.28
	Humbo	10208	2708b	0.33
	LSD	NS	673	NS
	CV (%)	13.6	1.3.2	32.4

Means followed by the same letters within a column are not significantly different at 5% probability level, NS= not significant

Table 5. Correlation of growth and yield components with grain yield

Parameter	Grain yield
Plant height	0.82*
Ear height	0.68*
Number of rows per cob	-0.05^{NS}
Number of seeds per row	0.72*
Number of seeds per cob	0.60*
Ear length	0.72*
Ear diameter	0.56*
Biomass	0.78*
Thousand seed weight	0.77*