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Research Article

Evaluation of Maize (*Zea mays* L.) Varieties in Selected Lowland Areas of Southern Ethiopia

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Drought and high temperature are among the major factors limiting maize productivity in Sub-Saharan Africa. An increase in temperature above 30°C reduces yield by 1% under optimal rain-fed conditions. Approaches that improve performance under drought and high temperatures are essential to sustain productivity. The objectives of this study were to evaluate the performance of improved maize varieties released for lowland areas and to select better-performing varieties to address climate-crosscutting issues. Eight lowland maize varieties at two locations for two years were tested by using a randomized complete block design during the 2017 and 2018 cropping seasons. Analysis of variance revealed significant differences ($p < 0.05$) between varieties for all the studied variables over years across locations. The interaction of locations with varieties was nonsignificant for grain yield, cob length, and cob number. The mean grain yield indicated that the variety Melkassa-6Q is a high yielder compared to others with 3284 kg grain yield per hectare. This variety had a 35% yield advantage over the check. The variety is, therefore, highly recommended in the study areas.

1. Introduction

Maize occupies an important position in the world economy and trade as a portion of food, feed, and industrial grain crop. Maize consumption is projected to be increased by 50% globally and by 93% in Sub-Saharan Africa from 1995 to 2020 (IFPRI). Though much of the global increase in maize use is for animal feed, human consumption is increasing and accounts for about 70% of maize consumption in Sub-Saharan Africa (Shiferaw et al. [1] and Smale et al.) [2]. It is also one of the major crops grown by small farmers in the semiarid low-rainfall areas of Ethiopia. Some reports of diagnostic surveys indicated that 93% of the farmers in the lowlands of Ethiopia are maize growers. Drought and heat stress are the major limiting factors affecting maize productivity in the tropical lowlands, where erratic rains and increased temperatures are becoming a frequent occurrence. Likely, high temperatures occur more often and last longer, and extreme precipitation events are more intense and frequent in all regions. High temperatures and changes in rainfall patterns can cause a significant decline in maize yields under rain-fed conditions in the tropical region (Cairn et al., 2013). An increase in temperature over 30°C reduces grain yield by 1% under optimal rain-fed conditions, by 1.7% under drought stress (https://www.ipcc.ch/pdf/assessmentreport/ar4/syr/ar4_syr.pdf) and up to 40% under combined drought and heat stress [3]. It is projected that by 2030, the drought and higher temperatures may render 40% of the current maize growing areas in Africa [4]. Unless strong adaptation measures are taken, these changes are expected to reduce yields of maize and other food crops by 10%–20%, causing a marked decline in human welfare [5]. Adaptation to climate change may involve the use of crop varieties that are endowed with tolerance to higher temperatures and drought, and resistance to emerging pests and diseases [6]. Approaches that improve the performance of maize varieties under combined drought and heat stress are therefore essential to sustain productivity and avoid widespread famine in Africa. Large numbers of breeding lines have been developed at various research stations and their

Table 1: Description of experimental sites.

Locations	Altitude (masl)	Geographical location		Soil type	Ave. temp (OC)	Ave. rainfall (mm)
		Latitude (N)	Longitude (E)			
Mender-1	818	06°25.9′	36°28.1″	Clay loam	22.3	1123
Mender-2	817	06°25.9′	36°27.3″			
Angla-3	883	06°15.5′	36°33.1″	Clay loam	23.5	1995
Angla-4	916	06°17.35′	36°33.12″			

Source. Basketo special and Melokoza districts, 2019.

performance evaluated across multilocation tests over several years leading to the identification of a few varieties. Maize is more sensitive than other cereals to drought at flowering because anthers and silks are separated by about 1 m, and pollen and stigma are exposed to the environmental condition [7]. The crop is particularly sensitive to drought one week before and two weeks after flowering [8] resulting in an average yield loss of 20–50% [9].

Maize (*Zea mays* L.) is the second most important cereal crop in Ethiopia, with a coverage of 2.12 million hectares, and first in total production [10]. In southern Ethiopia, maize is the most extensively cultivated food crop and the main source of calories in the area [11]. Despite its production potential, its productivity is below its potential. The availability of a limited number of drought-tolerant maize varieties and a lack of knowledge and awareness of farmers on the production of drought-tolerant genotypes as well as their benefits are leading constraints for low productivity in the lowland areas of the country in general and in southern Ethiopia in particular. The low yield in that area is not only attributed to the lack of improved varieties but also to current drought occurrence. With the introduction of high-yielding varieties, we can improve the production of maize even further. Hence, it is important to introduce early maturing and better yielding maize varieties in the area to improve maize production and productivity. Thus, the main objective of the current study is to test and evaluate the performance of improved lowland maize varieties in Ethiopia to solve the problem of maize productivity in quantity and quality.

2. Material and Methods

2.1. Description of the Experimental Sites. An experiment was conducted in the Basketo special district (Angla-3 and Angla-4 in 2017) and Melokoza district (Mender-1 and Mender-2 in 2018) during the main cropping season (March–July) (Table 1).

2.2. Plant Materials and Experimental Design. Seven released low-land maize varieties from the Melkassa agricultural research center with a standard check were used for the evaluation. The experiment was set up in a randomized complete block design with three replications. The seeds were manually planted using a seed rate of 25 kg/ha. A plot five meters long and three meters in width was used. Four rows with interrow spacing of 75 cm and intrarow spacing of 25 cm were used. The basal application made of 100 kg/ha of NPS and 25 kg/ha of urea was used at planting. Then, 25 kg/ha of urea was applied in the form of split application 40 days after planting. The fertilizer amount mentioned is a hectare base recommendation and is calculated for the experimental area. Plots and blocks were arranged at distances of 1 m and 1.5 m apart, respectively.

2.3. Data Collection. Individual plant-based data as well as whole plot base data were collected for different traits. Data collected on an individual plant from five randomly selected plants were as follows: plant height, cob number, ear height, and cob length. The middle two rows were harvested for grain yield data at maturity.

2.4. Data Analysis. Analysis of variance was conducted by using Genstat (16th edition) software for the parameters studied following the standard procedures. The combined analysis of variance (ANOVA) across locations was conducted to measure the response of varieties to the tested environments. Mean separation was conducted by using the least significant difference.

3. Results and Discussion

A combined analysis of variance indicated the responses of varieties in the tested environments (Table 2). The presence of nonsignificant differences across locations among the varieties was noted for grain yield, cob length, and cob number, which indicated less fluctuation of varieties in a response to the environmental conditions (Table 2). Analysis of variance over locations revealed significant ($P < 0.05$) differences for the parameters studied except for cob number and grain yield. The results indicated that these traits were significantly affected by the environmental variations and the varieties had inconsistent performance over the tested environments for the studied traits (Table 2).

3.1. Mean Performance of Varieties for Grain Yield and Other Traits. Based on the combined mean values of varieties over the years across environments, the highest mean grain yield was obtained from the variety Melkasa-6Q (3284 kg/ha) (Table 3). The variety Melkasa-6Q is not only a better yielder but also has a nutritional value of quality protein. The average grand mean of cob length, plant height, and cob numbers of the varieties were 24.1 cm, 1.3 cm, and 197.5 cm, respectively, without statistical variations among varieties (Table 3). Ear height ranges from 57.07 cm for the variety

Table 2: Analysis of variance for agronomic traits of maize varieties across locations during 2017 and 2018 in Basketo special and Melokoza districts, Southern Ethiopia.

Source of variation	Variables					
	DF	GY	PH	EH	CL	CN
Replication	2	49415	1211.3	0.021	11.78	20.01
Locations	3	130734**	13209.1**	1.668*	90.29**	50.04**
Varieties	7	3608717**	8224.5**	0.494**	58.87**	48.80**
Year	1	1530731**	13019.1**	2.862*	90.27**	58.82**
Location x varieties	21	385938 ns	1329.5*	0.304**	18.81 ns	23.00 ns
Location x varieties x year	21	265939**	1329.8*	0.104**	20.86*	10.50*
Residual	56	2365571	680.1	0.053	12.40	9.40

DF = degree of freedom, GY = grain yield, PH = plant height, EH = ear height, CL = cob length, CN = cob number.

Table 3: Combined mean values of agronomic traits for maize varieties at Salayish and Angila-4 locations during 2017 and 2018 in Basketo special and Melokoza districts, Southern Ethiopia.

Varieties	Variables					
	CL (cm)	CN (count)	PH (cm)	EH (cm)	GY (kg/ha)	Rank (GY (kg/ha)
Melkasa-1	23.1	1.4	190.2	69.10bc	1915c	7
Melkasa-1Q	24.3	1.4	202.0	77.23bc	1509 cd	8
Melkasa-2	25.4	1.5	193.9	78.43abc	2218bc	6
Melkasa-3	23.0	1.1	194.7	74.17bc	2361bc	4
Melkasa-4	23.7	1.3	207.0	83.20ab	2285bc	5
Melkasa-6Q	24.5	1.2	202.2	81.87ab	3284a	1
Melkasa-7	25.2	1.2	209.9	93.65a	2365bc	3
Check (BH 140)	23.7	1.3	180.1	64.93c	2415bc	2
Grand mean	24.1	1.3	197.5	77.8	2290	
$LSD_{(0.05)}$	NS	NS	NS	15.3	430	
$CV_{(\%)}$	13.8	21.7	12.5	24.2	23.0	

GY = grain yield, PH = plant height, EH = ear height, CL = cob length, CN = cob number.

BH-140 to 94.77 cm for Melkasa-7 during the 2017 cropping season at Salayish and Angil-4 (Table 4). Whereas, it varies from 64.50 cm (Melkasa-1) to 92.53 cm (Melkasa-7) for 2018 cropping seasons for the same traits at Salayish and Angil-4 (Table 4). Several authors reported the differential performance of genotypes in different environments for different traits for various crops (Nelia, 2013) [12–16]. These variations may be due to environmental effects on the performance of the traits. The genotypes also performed differently at the same location, which is an indication of the genetic variation of test varieties (Table 5).

As presented in Table 3, the mean values of genotypes for the plant height varied from 180.1 cm (BH 140) to 209.9 cm (Melkasa-7). All genotypes are statistically similar for plant height. The mean cob length ranged from 23.1 cm (Melkasa-1) to 25.2 cm (Melkasa-7). However, all genotypes are statistically similar for cob length across environments. The mean grain yield varied from 1509 kg/ha (Melkasa-1Q) to 3284 kg/ha (Melkasa-6Q). Genotypes Melkasa-1 and Melkasa-1Q are statistically similar for grain yield. The highest mean grain yield was recorded for the variety Melkasa-6Q (3284 kg/ha kg/ha), while the lowest was recorded for Melkasa-1 with 1915 kg/ha. Genotypes Melkasa-2, Melkasa-3, Melkasa-4, Melkasa-, and Check (BH 140) had statistically similar performance for grain yield across the locations. These results indicated these genotypes were similar in their performance

Table 4: Mean values of agronomic traits for maize varieties at Salayish and Angila-4 locations during 2018 in Basketo special and Melokoza districts, Southern Ethiopia.

Varieties	Variables				
	CL (cm)	CN (count)	PH (cm)	EH (cm)	GY (kg/ha)
Melkasa-1	20.00	1.4ab	166.2	64.50b	2290cd
Melkasa-1Q	20.13	1.4ab	181.5	75.90ab	1669d
Melkasa-2	22.70	1.5a	167.7	80.50ab	2415c
Melkasa-3	18.93	1.1b	160.3	66.73ab	2616c
Melkasa-4	20.40	1.3ab	174.2	79.53ab	2520c
Melkasa-6Q	20.50	1.2ab	178.3	83.47ab	4410a
Melkasa-7	20.10	1.2 ab	170.2	92.53a	2549c
Check (BH 140)	21.57	1.3ab	171.8	72.80ab	3675b
Grand mean	20.5	1.3	171.3	77.0	2750
$LSD_{(0.05)}$	4.02	0.33	NS	23.84	710
$CV_{(\%)}$	16.6	21.2	14.8	26.3	21.9

GY = grain yield, PH = plant height, EH = ear height, CL = cob length, CN = cob number.

Table 5: Mean values of agronomic traits for maize varieties at Salayish and Angila-4 locations during 2017 in Basketo special and Melokoza districts, Southern Ethiopia.

Varieties	Variables				
	CL (cm)	CN (count)	PH (cm)	EH (cm)	GY (kg/ha)
Melkasa-1	26.13ab	1.4	214.3 bc	73.70ab	1550bc
Melkasa-1Q	28.50ab	1.4	222.5ab	78.57ab	1350 cd
Melkasa-2	28.10ab	1.5	220.1ab	76.37ab	2024ab
Melkasa-3	27.03ab	1.1	229.0ab	81.60a	2101a
Melkasa-4	27.00ab	1.3	239.8ab	86.87a	2047ab
Melkasa-6Q	28.53ab	1.2	226.0ab	80.27a	2148a
Melkasa-7	30.20a	1.2	248.8a	94.77a	2199ab
Check (BH 140)	25.87b	1.3	188.4c	57.07 b	1150d
Grand mean	27.7	1.3	223.6	78.6	1830
$LSD_{(0.05)}$	3.69	NS	28.84	20.86	518
$CV_{(\%)}$	11.3	22.9	10.9	22.5	24.0

GY = grain yield, PH = plant height, EH = ear height, CL = cob length, CN = cob number.

for grain yield and the numerical variation may be due to the error effect. From the given results, most of the traits showed a wide range of variability. Therefore, the presence of such a range of variations in the traits indicated the presence of genetic variation among the genotypes which is the source of variables in genetic materials.

4. Conclusion

This study revealed that the combined effects of environments and varieties had little impact on grain yield. Therefore, the average mean value of the varieties for wider production could be taken into account. The high-yielding variety, Melkasa-6Q, had an advantage of 35% over the check and was found to be suitable for production in the study area. Therefore, it is better to popularize and scale up this variety in the area with similar agroecology. The information generated from the study gave a comprehension for further study about the effect of genotype interaction with the environment in maize varieties. Nevertheless, the study was conducted in four environments and two cropping seasons. For that reason, further studies using more diverse environments and seasons using more varieties are important to generate more reliable information on the effect of varieties, environments, and GEI interaction on grain yield and yield-related traits.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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