Original Research Article||

Performance evaluation and yield stability of maize (*Zea mays* L.) hybrid genotypes in southern Ethiopia

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Abstract

Improved Maize varieties were released by different agricultural research centers at different times in Ethiopia. However, the productivity of these varieties was not evaluated under wider environmental ranges. The variety choice of most farmers in Ethiopia is not suitable for their farm due to lack of awareness about varieties, their adaptability to various conditions and field conditions. The objective of this study was to evaluate the stability and yield potential of hybrid maize genotypes across locations. Seven maize hybrid varieties were evaluated at Sankura, Meskan, and Sodo in Ethiopia during the 2019 and 2020 main cropping seasons. The varieties were assigned in randomized complete block design with three replications. The major agronomic data were collected for each genotype for all locations. The combined analysis of variance showed that the effects of genotypes (G), environments (E) and their interaction (GEI) on grain yield were found to be highly significant. The highest grain yield recoded was 6674 kg ha^{-1} for BH546 while the lowest yield was 4330 kg ha^{-1} for SBRH. The first two principal component axis (IPCA1 and IPCA2) were significant ($p < 0.01$) and cumulatively contributed 95.12% of the total variations of GEI. The selection of one trait would influence the grain yield of variety. BH546 and PHB30G19 were most stable genotypes with better mean performance across testing locations. Thus, these two varieties were recommended for the study areas, although further studies will be required in multiple environments to confirm consistency in yield performance and stability across more environments.

Key words: AMMI, grain yield, hybrid, stability

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INTRODUCTION

Maize is one of the most important cereal crops grown in Ethiopia, with total annual production and productivity exceeding that of all other cereal crops. In terms of area coverage, it is only super passed by tef [*Eragrostis tef* (Zucc.) Trotter] (Mosisa *et al*., 2011; CSA, 2014). In Ethiopia, maize is one of the major cereals widely cultivated across diverse ecologies. These include lowland moist, lowland and highland moisture stress, mid altitude and highland sub-humid moist agroecology. As each of the agroecology is differing in altitudes, rainfall and soil properties, they possess their own characteristic limitations and opportunities revealed in production and productivity of maize varieties under the influence of prevailing weather conditions (Legesse *et al.*, 2012). Ethiopia's current average national maize yield is 3.43 metric tons per hectare whereas the developing and developed countries average yields are 2.5 and 6.2 metric tons per hectare, respectively (CSA, 2015).

Lower yields have been attributed to the use of low-yielding varieties, use of self-produced seed, poor soil fertility and limited use of fertilizers, low plant population, and inappropriate weed control methods. Hence, significant potential improvements in yields could be achieved through the use of hybrid maize varieties.

Cultivar performance is a function of the genotype and the environment. Environmental factors have a great influence on both qualitative and quantitative traits, and genotype-by-environment interaction makes it difficult to select the best-performing and most stable genotypes. It is an important consideration in plant breeding programs because it impedes progress from selection in any given environment (Yau, 1995).

Under these heterogeneous environments, allocating a variety that can successfully adapted to a certain location or across locations is difficult due to the interaction effects of genotypes with the environment. In order to solve this problem, experimental research need to be carried out in multi-environment variety trials to identify and analyze the major factors that are responsible for genotype adaptation (De Lacy *et al*., 1996). In multi-location experiments the influence of environment is basically attached to the expression of complex characteristics and reveals in high influence of environment. Genotype by environment interaction occurring due to differential response of genotypes to different growing conditions (Bernardo, 2002). The objective of this study was to evaluate the stability and yield potential of hybrid maize genotypes and to assess the effect of genotype-by-environment interaction on yield.

MATERIALS AND METHODS

Experimental Materials and Design

Seven hybrid maize (BH546, BH547, SBRH, SPRH MHQ138, MH140 and PHBG30) varieties were used for the experiment. The varieties were released at different times from the Bako and Melkasa Agricultural Research Centers for mid-altitude areas. They were evaluated at three different locations in the Gurage and Siliti Zones (Sankura, Meskan, and Sodo districts). The experiment was conducted using a randomized complete block design with three replications in the two main cropping seasons (2019 and 2020). The experimental plot size was 4.8 m x 3 m (14.4 m2) with inter and intra-row spacing of 80 x 20 cm for all locations over the crop years. The recommended field management practices were followed uniformly with 150 kg ha-1 NPS and 200 kg ha-1 Urea fertilizers used in the experiment.

Data Collections

The data were recorded on plant height, cob length, seed per cob, number of rows per cobs, 100 seed weight (g) and grain yield. The grain yield in kilograms per plot recorded was converted to grain yield in kg per hectare at 12.5% grain moisture.

Statistical Analysis

Analysis of variance was performed using the GLM procedure of SAS statistical software version 9.4. Effects were considered significant in all statistical calculations if the p-values were ≤ 0.05. Means were separated following the procedures of Fisher's least significant difference (LSD). Genotype-by-environment interaction was quantified using pooled analysis of variance, which partitions the total variance into its component parts: genotype, environment, genotype × environment interaction, and pooled error.

The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi), deviation from regression (S^2di) and coefficient of determination (R^2i). It was calculated by regressing mean grain yield of individual genotypes/ environments on environmental/ genotypic index. The genotype with value of regression coefficient (bi ~1) and smaller value deviation from regression (S^2di) value are thus more stable. Ecovalence measure (Wi) suggested by Wricke (1962) was also computed to further describe stability. The Ecovalence (Wi) or stability of the i^{th} genotype is its interaction with the environments, squared and summed across environments.

It is important that not only the IPCA scores be used for stability analysis to judge whether a given variety is stable across environments; other stability parameters would also provide information on the response of varieties across locations.

RESULTS AND DISCUSSION

Mean Performance of Hybrid Maize Genotypes

All the characters considered showed significant differences ($p<0.05$) among the evaluated genotypes indicating the presence of competent variability (Table 1). Among the tested cultivars, MH-140 and PHB30G19 had the highest plant height (2.5 m) while short statured plant height was recorded (2.2 m) was for MHQ-138 variety. On similar studies Hussain et al. (2011) reported differential pattern of maize varieties for plant height.

The highest cob length (20.4 cm) was recorded for PHB30G19, followed by BH546 (20.3 cm), while the shortest cob length corresponded to MHQ-138 (16.2 cm) (Table 1). The results obtained were comparable with the ranges reported in earlier studies by Hussain et al. (2011) and Nazir et al. (2010).

The highest number of seeds per cob was recorded for BH547 (629.6) followed by PHB30G19 (587.5) while the least corresponded to MHQ-138 (493.9). The number of rows per cob contributes to maximum grain yield. In the present study, the maximum number of rows recorded was 16.4 for PHB30G19, and the smallest, 13.3, corresponded to SPRH. Hundred seed weight (HSW) is an important yield component and varies among varieties. The maximum value for HSW was obtained for MH-140 (37.7 g) and the minimum value was obtained from cultivar MHQ-138 (25.9 g).

The BH546 variety recorded the highest average grain yield (6674 kg ha^{-1}), while the lowest average grain yield (4330 kg ha^{-1}) corresponded to SBRH.

Table 1. Mean performance of yield and yield components of maize varieties

Variety	PH (m)	EL (cm)	SE	NR	HSW (g)	GY (kg ha^{-1})
BH546	2.4^{ab}	20.3^{a}	$556.9a^{bc}$	15.1^{cd}	30.6^{c}	6674^{a}
BH-547	2.3^{bc}	19.8^{ab}	629.6^{a}	16.0^{ab}	37.2^{a}	6087^{b}
SBRH	2.4^{a}	19.4^{b}	495.2^{c}	15.6^{bc}	33.9^{b}	4330^{d}
SPRH	$2.4a^{b}$	18.0^{c}	511.9^{b}	13.3^{e}	30.0^{c}	5688^{bc}
MHQ-138	2.2^{c}	16.2^{d}	493.9c	14.9^{cd}	25.9^{d}	5448^{C}
MH-140	2.5^{a}	19.3^{b}	495.0^{c}	14.7^{d}	37.7^{a}	6051^{b}
PHB30G19	2.5^{a}	20.4^{a}	587.5^{ab}	16.4^{a}	36.7^{a}	6178^{ab}
Mean	2.4	19.1	538.6	15.1	33.1	5780
LSD (0.05)	0.1	0.7	79.3	0.7	2	553
CV (%)	5.9	4.4	15.5	5.4	6.5	10.1

Similar letters within a column were non-significant. LSD= Least significant difference, CV = coefficient of variation, PH = plant height (m), EL = Ear length (cm), SE = seeds per ear, NR = number of rows, HSW = hundred seed weight (g), GY = grain yield (kg ha^{-1})

Additive Main Effects and Multiplicative Interaction (AMMI)

The grain yields were significantly affected by the environment, which explained 41.1% of the total variation, whereas the genotype and genotype-by-environment interaction were significant and accounted for 30.96% and 27.94% of the variation, respectively (Table 2). A large yield variation attributed to environments indicating a significant role in the expression of traits being considered.

The genotypes perform better at Sankura compared to Sodo and Meskan. MH-140 gave the highest yield (8056 kg ha^{-1}) at Sankura and the smallest yield was recorded for MH-140 (3460 kg ha^{-1}) at Meskan (Table 3). Genotype-by-environment interaction effects were further partitioned into interaction principal components (IPCA) using the AMMI model.

Table 2. AMMI analysis of variance for grain yield of hybrid maize genotypes grown at three environments

Source of Variation	DF	SS	MS	F	%SS
Environment®	2	39975405	19987703	57.19	41.10
Genotype (G)	6	30114658	5019110	14.36	30.96
G x E	12	27180744	2265062	6.48	27.94
PC1	7	21741749	3105964	9.23	79.99
PC2	5	5438994	1087799	3.23	20.01
Residual	42	14679160	349503.8		

DF = degrees of freedom; SS = sum of squares; MS = means squares; F = Fischer's F-ratio as cut off point for significant variations

The principal component (PC1) explained 57.28% of total variation; while PC2 explained 37.84%, the two accounting for 95.12% of the total GEI variation for grain yield (Figure 1). The result from the present experiment was in agreement with the reports of Mohammadi *et al*. (2010), where the largest proportion of total variation in multi-environment trials is attributed to environment. Genotype SBRH was low yielder and unstable far from the origin. The greater the absolute length of the projection of a genotype, the less stable it is (Yan *et al*., 2000; Yan and Holland, 2010).

Stability Analysis

The responses of genotypes across the three locations were significantly different, indicating the sensitivity of genotypes to the environment. Six stability parameters were measured to evaluate the stability of genotypes across locations (Table 4). Genotype BH546 with the lowest (Sd = 310.58, CVi = 4.65, bi = 0.12, S^2di = 60268, Wi = 1629822) was more adapted to wider environments and stable, whereas MH-140 genotype with the highest (Sd = 2353, CVi = 38.89, bi = 2.41, S^2di = -103664, Wi = 3796700) was sensitive and adapted to ideal environments for selecting varieties with specific adaptation and unstable.

Table 3. Mean grain yield and rank (R) of 7 maize genotypes tested across three locations in southern Ethiopia

Variety	Sodo		Sankura		Meskan	
	GY (kg ha^{-1})	R	GY (kg ha^{-1})	R	GY (kg ha^{-1})	R
BH546	7027	1	6554	6	6441	1
BH-547	7000	2	6500	3	4762	3
SBRH	3889	7	5196	7	3906	6
SPRH	6250	4	6610	2	4204	4
MHQ-138	5417	6	6806	4	4121	5
MH-140	6638	3	8056	1	3460	7
PHB30G19	5893	5	6583	5	6057	2
Mean	6016		6615		4707	

GY = grain yield, R = rank Tiler number and spike length

Table 4. Mean grain yield and stability parameters for maize hybrid genotypes tested at 3 environments

Genotype	GY	Sd	CV (%)	bi	S^2di	R^2	Wi
BH546	6674	310.58	4.65	0.12	60268	0.15	1629822
BH-547	6087	1174.74	19.30	1.04	592510	0.75	699783
SBRH	4330	749.44	17.31	0.56	414405	0.54	880825
SPRH	5688	1297.80	22.82	1.31	-45320	0.97	282998
MHQ-138	5448	1342.34	24.64	1.34	86229	0.95	409160
MH-140	6051	2353.38	38.89	2.41	-103664	1.00	3796700
PHB30G19	6178	360.59	5.84	0.21	71384.29	0.33	1360960

Key: GY = grain yield, SD = standard deviation, CV = Coefficient Variability, bi = Eberhart & Russell coefficient, S^2d = deviation from regression, R = coefficient of determination, W_i = Wricke's Ecovalence,

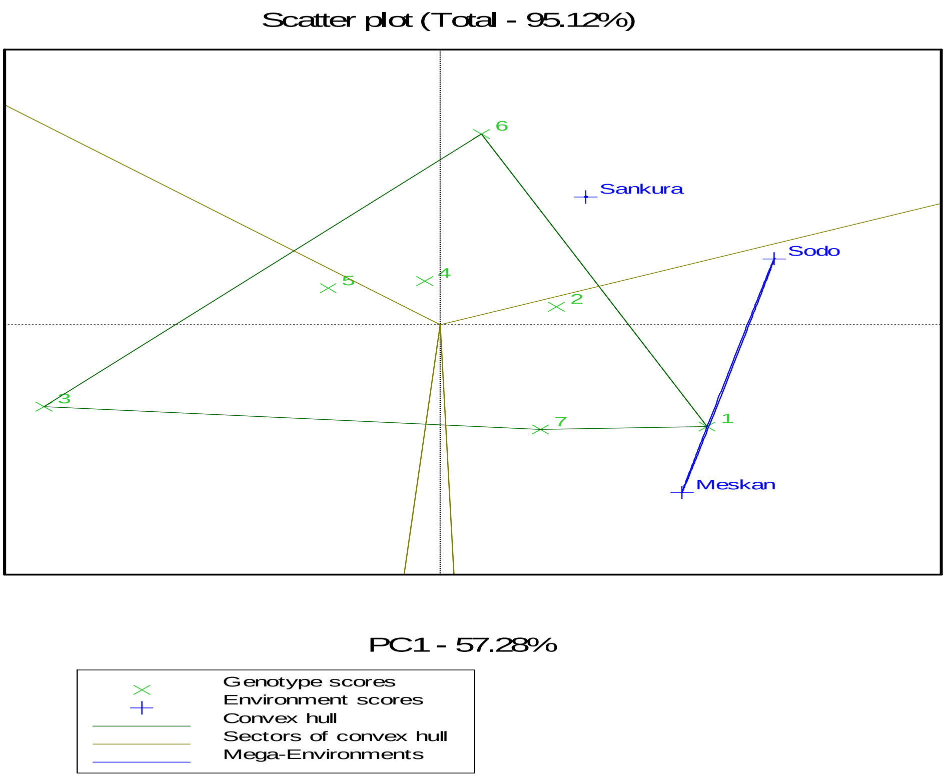

Figure 1. Biplot of PCA1 against PCA2 for both environments and genotypes

CONCLUSIONS

Based on the results of the multi-location analysis, genotypes BH546 and PHB30G19 were relatively stable, exhibiting yield performances above the mean across test environments. From this experiment, it is concluded that the genotypes BH546 and PHB30G19 were superior in their yield during the experimental years. Therefore, these varieties were recommended for Sodo and Meskan areas and other locations with similar agroecologies. MH-140 was found to be highly sensitive to environment and recommended for Sankura and other areas with similar agroecologies. The results of this study revealed a considerable degree of differences among the varieties that could be explored for further improvement in maize breeding.

CONFLICTS OF INTEREST

Author declares that there is no conflict of interest regarding the publication of this article.

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