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Evaluation of Open Pollinated Maize (*Zea mays* L.) Varieties for Mid Altitude Areas of Western Guzi Zone, Southern Oromia, Ethiopia

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Abstract: Maize is a major grain crop that is widely adaptable to many agro-ecologies across the world. The goal of the study was to see how adaptable and stable open pollinated maize varieties are in terms of grain yield and yield-related features in the Western Guji Zone's mid-altitude areas. Different genotypes perform differently in each location, which may be used to boost production. Six open pollinated maize varieties were transported from Bako National Maize Research Center and planted in RCBD with three replications at Yabello Pastoral and Dryland Agriculture Research Center's Galana and Abaya sub sites for three years. The results of the analysis of variance revealed that there was a substantial yield difference between genotypes. Gibe-2 had the greatest average grain production of 5.85 t/ha, followed by Kulani with 5.63 t/ha across years and locations, according to the combined analysis of variance. Kulani was found to be the most stable of all the varieties, whereas Gibe 2 was shown to be the most unstable. Kulani's and ABO-additive Bako's main and multiplicative interaction stability values (ASVs) were both near to zero (0.08 and 0.27, respectively), but Gibe 2's ASV was significantly higher (1.62) and deviated from zero. As a result, Kulani was stable and high yielding across settings, whereas Gibe 2 was high yielding in a single environment (unstable). So, and Kulani were recommended for cultivation in the Galana and Abaya districts of southern Oromia, as well as regions with comparable agro ecologies, while Gibe 2 was recommended for the Galana district.

Keywords: Adaptation, ASV, Genotypes, Stability, *Zea mays*

1. Introduction

Maize (*Zea mays* L.) (2n=20), popularly known as corn, belongs to the Poceaceae family and is a versatile crop that adapts well to a broad range of production settings [1, 2]. In terms of growing area, output, and grain yield, maize is the world's third most significant crop, trailing only rice and wheat [3] and it is important basic crop of trade product and recurring ingredient for millions of people in sub-Saharan Africa [4]. Maize is a versatile crop that adapts well to a wide range of production circumstances [5]. Maize is an important commodity in the global economy, and it is frequently traded [6]. Maize is one of the staple foods in Ethiopia, whose importance in consumption as well as production has significantly increased [7].

In Ethiopia average maize grain yield is low due to problems like insect pest damage, lack of high yielding varieties and poor crop management practices. The most important problem reported by farmers in Western Guji Zone was the lack of adaptable maize varieties and majority of the farmers in the area are growing local varieties. So far, no effort has been made in the zone to introduce and adapt improved maize varieties.

Genotype by environment interactions is the most importance to the plant breeder in selecting appropriate variety for appropriate environmental condition. Different genotypes may perform differently in each location, which may be leveraged to increase production. Variability in grain yield is due to difference in genetic potential among genotypes and environment effect. Grain yield is quantitative in nature, which usually exhibits GEI, which necessitates evaluation in multi-environment trials before doing advanced selection [8]. Due to cross interaction, the existence of genotype by environment interaction (GEI) commonly alters the rankings of varieties in various environments, making appropriate selection challenging. As a result, analyzing and conversing genotype by environment interactions is critical for obtaining knowledge on genotype adaptability and stability. The AMMI (Additive Main Effects and Multiplicative Interaction) approach is a frequently utilized way for analyzing GE interaction as a measure of stability and adaptability [9]. In multiplication varietal trials, the AMMI model is a better model for analyzing GxE interactions [10]. It not only gives an estimate of each genotype's overall GxE interaction impact, but also divides it into environment-related interaction effects. As a result, the current study will use open pollinated maize cultivars to evaluate the adaptability and stability of grain yield and yield-related features in the Western Guji Zone's mid-altitude areas.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted at Galana and Abaya districts of Western Guji Zone, southern Oromia (Table 1).

Table 1. *Descriptions of the study area.*

Sites	PH	Altitude	Available P. in ppm	CEC meq/100g soil	Texture			Soil class	Mean annual rainfall (mm)	Mean annual temperature (°C)
					%sandy	%clay	%silt			
Abaya	5.68	1480	1.42	20.40	50	30	20	Sandy clay loam	850	16-36
Galana	5.84	1670	1.84	60.60	48	20	32	Clay loam	950	14-34

Source: mereology station and soil analysis.

2.2. Descriptions of Experimental Materials and Design

Six open pollinated maize varieties (table 2) were imported from Bako National Maize Research Center and grown for three years at Galana and Abaya subsites of Yabello Pastoral and Dryland Agricultural Research Center. There were three replications of a totally randomized block design. The plants were cultivated in accordance with agronomic recommendations. Each plot was 12.6 m^2 in size, with 6 rows of 3 m length and spacing of 25cm x 75cm. Each plot was 8.4 m^2 in size, with four (4) rows in the centre. For all genotypes at each location, the prescribed fertilizer rate was applied.

Table 2. *Lists and description of materials used in an experiment.*

Variety	Year of release	Altitude (masl)	Rain fall (mm)	Maturity date	Yield on research field (kg/ha)	Production status
Kulani	1995	1700-1400	1000-1200	150	6000-7000	Under production
ABO-Bako	1985	500-1000	1000-1200	150	5000-7000	Under production
Gutto	1988	1000-1700	800-1200	126	3000-5000	Under production
Gibe 1	2001	1000-1800	1000-1700	145	6000-7000	Under production
Gambella	2002	500-1000	1000-1200	110	6000-7050	Under production

Source: (EARO, 2004).

2.3. Collected Data

Plant height, ear length, ear height, number of kernels per row, and number of rows per cob were gathered in plots, whereas all agronomic data such as days to physiological maturity, hundred kernel weights, and grain yield were obtained in plants.

2.4. Data Analysis

The PROC ANOVA program in SAS software was used to perform analysis of variance for phenological, yield, and yield-related data, with genotypes treated as fixed effects and replication within environment as a random effect, as stated by Gomez and Gomez [11]. Least significant different (LSD) was used for mean separation ($P<0.05$). Adaptability and stability of the genotypes was estimated using the Genstat 15^{th} edition. G x E biplots were generated to evaluate the genotypes simultaneously for yield and stability. ASV (AMMI Stability Values) were estimated for both genotypes and environments. The G E interaction was studied using the AMMI (Additive Main Effect and Multiplicative Interaction) model, which combines traditional analysis of variance and principal component analysis. The contribution of each genotype and environment to the G x E interaction in the AMMI model is measured using a biplot graph presentation in which yield means are displayed against IPCA (Interaction Principal Component Axis) scores) [12]. The AMMI model is:

$$Y_{ij}=\mu + g_i + e_j + \Sigma\lambda k + \alpha ik\ yjk + R_{ij}$$

Where, Y_{ij} is the yield of i^{th} genotypes in j^{th} environment; μ the overall mean; g_i is the effect of the i^{th} genotype; e_j is the effect of the j^{th} environment; λk is the square root of the eigenvalue of the PCA axis k. Then α_{ik} and y_{jk} are the principal components scores for PCA (Principal Component Axis) k of the i^{th} genotype and j^{th} environment, respectively, and R_{ij} is the residual. Environment and genotype PCA scores are expressed as unit vector times the square root of λk (environment PCA score = $\lambda k0.05yik$, genotype PCA score = $\lambda k0.05\alpha ik$ [10]. AMMI stability value (ASV) was computed for each genotype in order to rank the genotypes utilized in this study in terms of stability [13] as follows:

$$ASV = \sqrt{\left[\frac{(IPCA1\ scores)\ x\ (IPCA1ss)}{IPCA1SS}\right]^2 + [IPCA2score]^2}$$

Where, ASV=AMMI Stability Value; IPCA1SS = Interaction Principal Component Axis 1 sum of squares; IPCA1score = Interaction Principal Component Axis 1 score; IPCA2score = Interaction Principal Component Axis 2 score.

3. Results and Discussion

3.1. Days to Maturity

An analysis of variance revealed that there is a significant difference between types in days to maturity (P0.01) for three consecutive years for both sites. Kulani was late mature among all genotypes which took 153 days and 150.67 days in 2014 and 2015 cropping season respectively. Gambella matured earlier than other genotypes under study for Galana site (table 3). At Abaya site, Kulani was late maturing one among all genotypes under study, which took 150.67, 152.00 and 151.67 days in 2014, 2015 and 2016 cropping season respectively. Gambella variety took 103.67, 111.33 and 110.32 days to mature in 2014, 2015 and 2016 cropping seasons. (Table 3) Bakala et al. [14] found significant differences among genotypes in their study of high land maize evaluation.

3.2. Grain Yield

Grain yield differed significantly between genotypes in all cropping seasons, according to the analysis of variance. The higher grain yield was obtained from Kulani 6.48t/ha in 2014, 4.65t/ha in 2015 and 5.01t/ha in 2016 cropping season while, the lowest grain yield was obtained from Gutto LMS 4.31t/ha, 4.28t/ha and 4.28t/ha in 2014, 2015 and 2016 cropping seasons respectively (table 3). The yield variability observed among genotype, showed the potential of the variety and specific adaptability of the genotype. For Abaya site, maximum grain yield was obtained from Gibe 2 (5.08, 6.50 and 6.71t/ha in 2014, 2015 and 2016 cropping season respectively. Bassa and Goa [15] reported that different maize varieties produce significantly different grain yields at different locations over years. Taye et al. [16] also reported significant yield difference among diifferent maize genotypes.

Table 3. *Mean performance of days to maturity and grain yield for Abaya and Galana site.*

Varieties	Days to maturity (days)						Mean	Grain yield (t/ha)						Mean
	Galana site			Abaya Site				Galana site			Abaya Site			
	2014	2015	2016	2014	2015	2016		2014	2015	2016	2014	2015	2016	
Gibe-1	143b	141.67b	143.67c	141.67b	146b	146.33b	144.83b	5.21b	4.52ab	4.35b	4.52ab	4.47c	6.28a	5.42c
Gibe-2	132c	135.00c	137.67d	135.00c	139c	137.00c	136.17c	5.41b	4.65a	4.57b	4.65a	6.50a	6.65a	5.85a
ABO-Bako	152a	145.67b	152.33a	145.67b	149ab	150.67a	149.83a	5.44b	4.25c	4.68ab	4.25c	4.57c	5.49b	4.93e
Gutto-LMS	124d	127.33d	126.67e	127.33d	125d	126.00d	125.83d	4.31c	4.28bc	4.28b	4.28bc	4.26c	4.21c	4.03f
Gambella	110e	103.67e	110.67f	103.67e	111.33e	110.32e	110.11e	5.54b	4.52ab	4.67ab	4.52ab	4.15c	6.20a	5.16d
Kulani	153a	150.67a	147.67b	150.67a	152a	151.67a	151.06a	6.48a	4.42abc	5.01a	5.08a	5.47b	6.71a	5.63b
LSD	7***	4.45***	3.48***	4.45***	4.13***	3.34***	1.45***	0.76***	0.24**	0.42*	0.24**	0.42***	0.59***	0.22***
CV (%)	1.88	2.27	1.40	2.27	1.66	1.34	1.60	4.41	2.92	5.03	2.92	4.75	5.48	6.45

*, **, *** = significant at P < 0.05, at P < 0.01 and at P< 0.001, respectively, ns = non-significant. DM=days to maturity, Yld=grain yield, LSD=least significant difference, CV=coefficient of variance.

3.3. Combined Analysis of Variance

Combining analysis of variance (ANOVA) across sites for grain yield revealed a significant in genotype location interaction, indicating that genotype x environment interactions affected maize genotype yield performance. Similarly, Anley et al. [17] reported different genotypes perform differently for yield and yield related traits under different environmental conditions.

Combined analysis of variance showed that a very highly significant (P<0.0001) variation was observed between genotypes, environment and the genotypes x environment interaction for plant height, ear height, Cob diameter, hundred seed weight and grain yield (Table 4). This indicated that the varieties and the test environments are variable, and the varieties performed differently across locations and years for almost all traits. Combined analysis of variance indicated that genotypes and environment showed significant effect (P<0.05) while G x E had non-significant effect on number of rows per cob and number of seeds per row. Traits less affected by environments are high heritability [18].

Table 4. *Over all mean of maize genotypes for yield, yield related traits and phonological growths.*

Varieties	Traits mean							
	DM (days)	PH (cm)	EH (cm)	NRPC (no)	CD (cm)	NSPR (no)	HSW (g)	YLD (t/ha)
Gibe-1	144.83b	144.28c	97.48ab	13.69ab	4.39c	35.26ab	31.72b	5.42c
Gibe-2	136.17c	178.39a	90.41c	13.33bc	4.32c	34.04abc	31.67bc	5.85a
ABO-Bako	149.83a	181.57a	94.73bc	13.39b	4.34c	35.56ab	29.58cd	4.93e
Gutto-LMS	125.83d	163.53b	89.56c	12.44c	5.87b	33.56bc	29.03de	4.03f
Gambella	110.11e	180.78a	95.35bc	14.44a	4.27c	35.83a	27.64e	5.16d
Kulani	151.06a	181.74a	103.60a	13.33bc	6.33a	32.97c	34.00a	5.63b

Varieties	Traits mean							
	DM (days)	PH (cm)	EH (cm)	NRPC (no)	CD (cm)	NSPR (no)	HSW (g)	YLD (t/ha)
Significance level								
Genotype	4568.84***	4119.92***	470.81***	7.44**	15.45***	24.88*	9.36***	5.52***
Environment	27.55***	822.90***	296.06**	19.04***	38.68***	307.08***	66.07***	7.87***
Genotype x Environment	12.84**	327.37***	267.90***	1.85ns	16.35***	13.11ns	42.24***	1.20***
Error	4.83	113.91	85.13	1.96	0.15	9.36	6.85	0.09
CV	6.22	1.61	9.69	10.13	7.86	8.86	8.57	5.61

*, **, *** = significant at P < 0.05, at P < 0.01 and at P< 0.001, respectively, ns = non-significant. DM=days to maturity, PH=plant height, EH=ear height, NRPC=number of rows per cob, NSPR=number of seeds per row, HSW=hundred seed weight, CD=cob diameter and Yld=grain yield.

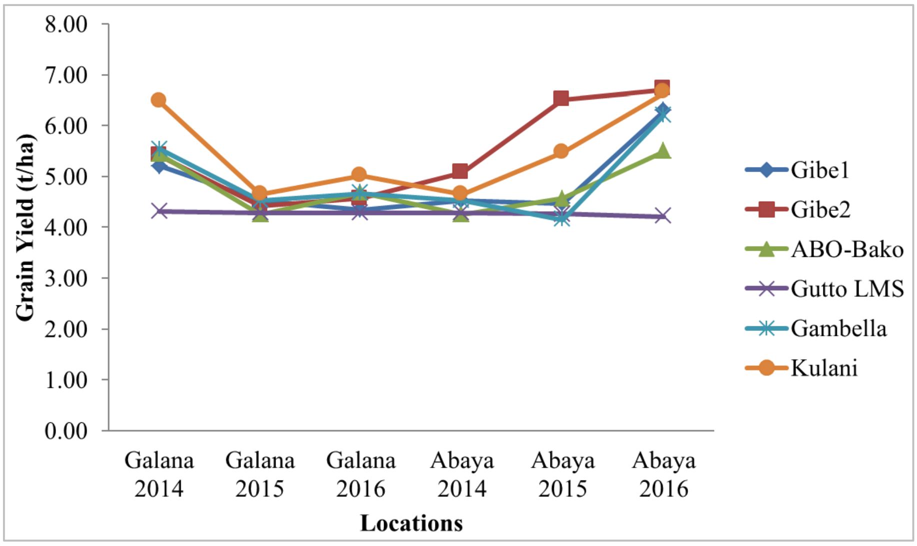

Figure 1. *The performance of maize varieties across three years at Abaya and Galana sub sites.*

GEI exists when the response standards for various genotypes are not parallel [19]. Cross-over interaction is a sort of GEI in which the genotypes' ranking varies depending on the environment [20]. There was a rank change of varieties across years which may mean the presence of crossover interaction. Kulani, Gibe 2 and Gambella were relatively well performed and high yielder across years, while Gutto LMS showed poor but consistent yield performance across years and locations (Figure 1). There was a change in rank of genotypes across years which may suggest the presence of crossover interaction. Similarly, Akbar et al. [21], Rehman et al. [22] reported significant differences among maize cultivars for grain yield under different environmental condition.

3.4. Stability Analysis

The AMMI analysis gives a graphical representation of the main impact and interaction effect information for genotypes and environments on the same graph. Variance in yield data revealed that all three components genotype (G), environment (E), and Gx E interaction were very significant, showing a wide range of variety occurred across varieties, location, and seasonal fluctuations (Table 5). Further, the mean squares from AMMI analysis indicated variation among G, E and G x E interaction showed highly significant different level at (P< 0.01) (Table 6). G x E interaction was further partitioned into two principal component analysis axis (IPCA) interactions. This variability was may be due to larger dissimilarity in rainfall, number of rainy days in each environment and high variation in mean sunshine hours among the environments. Several authors also reported supportive results [4, 23, 24].

Table 5. *Combined analyses of variance using AMMI Model.*

Source of variation	df	Sum Square	Mean Square	Sum Squares Explained	
				% total	% G x E
Total	107	101.25	0.5		
Genotypes	5	27.6	5.52**	27.26	
Environments	5	39.36	7.87**	38.87	
Genotype x environment	25	26.22	1.05**	25.90	
IPCAI	9	13.63	1.51**		51.98
IPCAII	7	7.47	1.07**		28.49
Residuals	9	5.13	0.57**		
Error	60	5.13	0.09		

** P <0.01.

Table 6. *IPCA 1 and IPCA 2 scores, genotypes mean and six open pollinated maize varieties tested at six locations.*

Genotypes	Graph ID	Genotype mean	IPCAg [1]	IPCAg [2]	ASV
ABO-Bako	ABO	4.93	0.46	0.01	0.29
Gambella	Gambella	5.16	0.40	0.52	0.49
Gibe-1	Gibe1	5.42	-0.61	0.54	0.79
Gibe-2	Gibe2	5.85	-0.92	-0.69	1.62
Gutto-LMS	Gutto	4.30	0.74	-0.68	1.20
Kulani	Kulani	5.63	-0.06	0.28	0.08
Grand mean		5.22			

IPCA=Interaction Principal Component Axis, ASV=AMMI stability value.

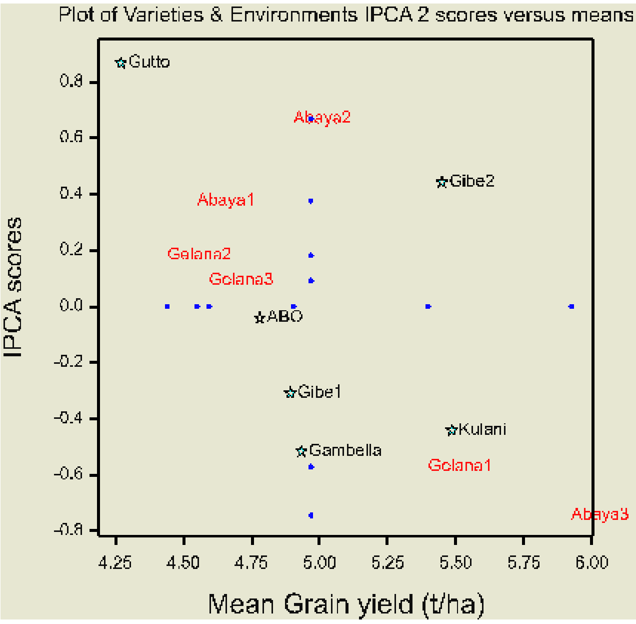

Figure 2. *AMMI-1 model for grain yield (t/ha) showing the means of genotypes (numbers) and environments (upper case letter followed by number).*

By plotting both the genotypes and the environments on the same graph, the relationship between genotypes and the environments can be seen clearly. The larger the IPCA scores, either positive or negative, as it is a comparative value, the better specifically a genotype is adapted to certain environments (Table 6). The more IPCA scores approximate to zero, the more stable the genotype is to overall environments. Accordingly, Kulani has IPCA value close to zero, high yielder and stable genotypes across environments (Table 6). ABO-Bako was a variety IPCA value relatively close to zero (stable) but gave lower yield below the average. Whereas, Gibe 1 and Gibe 2 were high yielder but, relatively higher IPCA score value deviating from zero, indicating that these varieties were not stable and thus adaptable for specific environment. The genotypes with high ASV were most unstable and while genotypes with low ASV were stable. The ASV indicated that the genotypes Kulani and ABO were most stable across environments and the genotypes, Gibe 2 and Gutto-LMS performed superiorly in certain environments (table 6). The sign of the scores indicate the pattern of interaction of the genotypes across environments and the reaction of environments for the different genotypes. Genotypes and environments with similar sign of IPCA1 scores interact positively for yield (tone/ha). But, if they have opposite sign of IPCA1 scores, their interaction is negative and the environment is not favorable for the genotype [10, 20]. Similar results were reported by Souza et al [26], Anley et al [17], Abera et al [25].

AMMI 2 bi-plot: the AMMI 2 bi plot with IPC1 in X-axis and IPC2 in the Y-axis were plotted below (figure 3). The first interaction principal component (IPC1) explained 73.19% and the second interaction principal component (IPC2) explained 14.79% of the sum of square of GEI. The two IPC's cumulatively explained about 87.98% of the sum of squares of GEI (figure 3). Purchase [27] stated that, genotypes close to origin are stable while those far from origin are considered to as unstable genotypes. In terms of adaptability, the genotype closest to a given vector in any environment is more adaptable to that environment, whereas the genotype furthest from a given vector in any environment is less adaptable to that environment [28]. Inline to the following principle Gibe 2 was adaptable to Abaya2 and Abaya1 environments while Kulani and Gibe 1 were adaptable to Abaya3, Galana1 and Galana3 environments (figure 3).

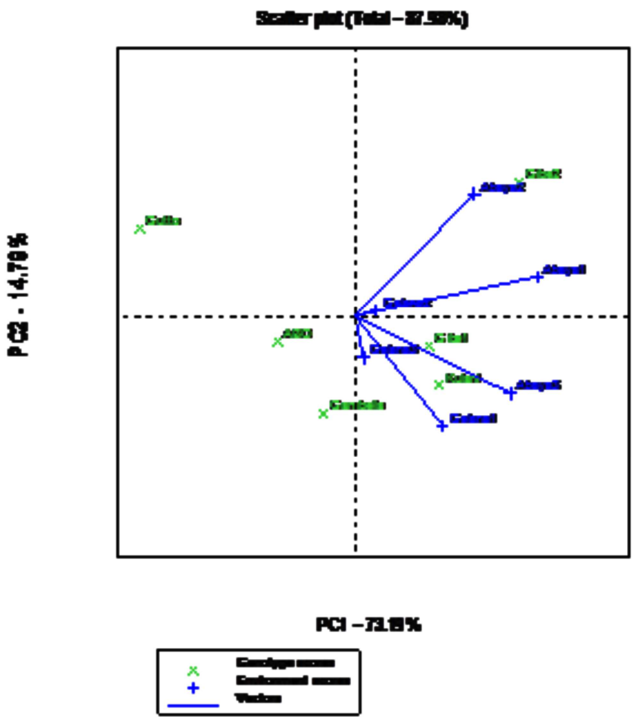

Figure 3. *AMMI-2 model for grain yield (t/ha) showing the IPCA scores of open pollinated maize genotypes (numbers) planted across environments (upper cases followed by numbers).*

4. Conclusion

In the West Guji zone, six open pollinated maize cultivars were evaluated for adaptation and grain yield performance. An analysis of variance for phenological, yield, and yield-related characteristics across locations and years revealed a significant difference across genotypes. The results indicated that the Kulani variety produced the highest yield at Abaya, followed by the Gambella variety. Gibe 2 was high yielder at Galana followed by Kulani. The result from stability analysis revealed that Kulani was high yielder and stable across test environments relative to other genotypes. ABO-Bako was also relatively stable but gave lower yield below the average. Gibe-1 and Gibe-2 varieties were high yielder but adaptable for specific environment. ASV analysis showed that Kulani and ABO-Bako were most stable across environments but Gibe 2 performed superiorly in certain environments. Generally, Kulani was recommended for wider adaptability, but Gibe 2 showed specific adaptability and recommended for specific area.

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