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Evaluating Agronomic Performance and Yield Stability of Improved Bread Wheat Varieties Across Low Moisture Stress Areas of Guji Zone, Southern Oromia

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Abstract

In Ethiopia, many low moisture stress tolerant bread wheat varieties that consistently have high yield in a variety of environments had been developed by different research centers. However, none of these cultivars are tested and selected for low moisture stressed areas of Guji Zone. As a result, the study was conducted at two mid land districts of Guji Zone (Adola and Wadera) at six testing sites (Dufa, Gobicha, Kiltu Sorsa, Chalo Sigida, Tulam and Andoya Haro) to evaluate the performance and yield stability of eight released low moisture stress tolerant bread wheat varieties in different low land areas of Guji Zone prior to varietal recommendation. Seven low moisture stress tolerant improved bread wheat varieties (Adel Werer, Amibara, Fantale, Gambo, Lucy, Mekele 01 and Mekele 02) were used as testing materials with local check (farmers variety. The analysis of variance (ANOVA) indicated presence of highly significant differences at (P≤0.01) among the evaluated bread wheat varieties, the testing sites and GEI for most of the characters studied. Different parametric and non-parametric stability models were used to assess stability and yield performance of the evaluated varities across the testing environment. The highest grain yield (25.66qt/ha) was recorded for Mekele 02 followed by Mekele 01 (24.13qt/ha). But, low yield of 10.0qt/ha was obtained from local (control) variety. Therefore, based on the agronomic performance and yield stability analysis, variety Mekele 02 followed Mekele 01 were high yielding and comparably stable across the tested environments and then recommended for production to the study areas.

Keywords: Bread wheat; Low moisture stress; Yield stability

Abbreviations: DTH: Days to Heading; DTM: Days to Maturity; GFP: Grain Filling Period; PH: Plant Height; SL: Spike Length; TPP: Total Number of Tillers/Plant; NPT: Total Number of Fertile Tillers/Plant; SPP: Spikelets Per Spike; KPS: Kernels Per Spike

Background & Justification

Ethiopia is inimitably characterized by diverse agro-ecology and climatic conditions which is suit for the production of various cereal crops. So, having different range of altitudes, soils and climatic conditions provide ecological settings suitable for the cultivation of diverse species of wheat [1]. Wheat is the second most important crop next to tef in terms of area coverage, but most of the production is concentrated in the highland plateaus of the country [2]. About one third of the developing world's wheat area is located in environments that are regarded as marginal for wheat production because of drought, heat and soil problems [3].

In Ethiopia, half percent of the arable land is classified as semi-arid and arid agro-ecology where moisture stress is the major problem in such areas. Development of drought tolerant wheat genotypes for such drought prone areas of the country would enhance utilization of the marginal areas of the country. Many low moisture stress tolerant bread wheat varieties that consistently have high yield in a variety of environments had been developed by different research centers of the country. However, none of these cultivars are tested and selected for low moisture stressed areas of Guji Zone. As a result, it's important to collect and test the adaptability and yield stability of these varieties under such marginal areas. The adaptability of a variety over a diverse environment is usually tested by the degree of its interaction with different environments under which it is planted [4]. This could be performed by exposing the varieties to different soil types, soil fertility, moisture levels, environments and cultural practices at farmers' fields in order to evaluate the performance and stability of the varieties across the various testing locations. Assessing grain yield of a set of cultivars in a multi-environmental trial, changes are commonly observed in the relative performance of genotypes with respect to each other across locations. This difference of genotypes from one environment to another is called genotype × environment (GE) interaction. This could enable the breeders to select superior genotypes for the target environment. In order to identify superior genotypes across multiple environments, plant breeders conduct trials across locations and years, especially during the final stages of cultivar development. When a genotype performs consistently over a wide range of environments, then the genotype is considered as widely adaptable. On the other hand, a genotype showing considerable genotype by environment interaction effects is not suited for diverse environments [5] and is said to have specifically adapted variety. A variety is more adaptive if it has a high mean yield with low degree of fluctuation in yield components grown over diverse climatic conditions [6].

Multi environment yield trial can be analyzed to extract more information on stability, adaptability and yield performance using various statistical methods. Stability analysis is performed using two ways models i.e. uni-variate and multivariate models. Uni-variate model is the most commonly used method which is based on regression and variance estimates. Among multi variate stability analysis, Additive main effect and multiplicative interaction is the most commonly used model to investigate GEI. AMMI is a better model for analysis of G×E interaction in multi-location varietal trials [7]. It not only gives estimate of total G×E interaction effect of each genotype but also partitions it into interaction effects due to individual environments. In addition to AMMI, GGBP is also another multivariate model recently developed to estimate GEI and varietal adaptability [8]. So, it's important to evaluate the adaptability and stability of yield performance of the variety using all the mentioned models to have a coincide result on the varietal recommendation there by to reduce the risk of varietal failure. Several studies of genotype by environment interactions (GxE) and yield stability have been reported on wheat grown under different locations and conditions of Ethiopia [9-11]. However, none of these studies have been performed under low moisture stressed conditions of Guji Zone. Therefore, the objectives of the present study were to evaluate the performance and yield stability of eight released low moisture stress tolerant bread wheat varieties in different low land areas of Guji Zone prior to varietal recommendation.

Materials and Methods

Description of the study area

The experiment was conducted at two mid land districts of Guji Zone (Adola and Wadera) at six testing sites (Dufa, Gobicha, Kiltu Sorsa, Chalo Sigida, Tulam and Andoya Haro). Adola district is located at 475km to the South from Addis Ababa and 120 km to the North from the Zone town (Nagele Borena) with a geographic coordinate of 5⁰44'10"-6ᵒ12'38"N latitudes and 38ᵒ45'10"-39ᵒ12'37"E longitudes. The district is situated at an altitude of 1500-2000masl. The average annual rainfall of the district is about 900mm and the mean annual temperature is 25 ˚C.

The first rainy season is from early March up to August and the second season starts in early September and ends to late November. The major soil types are Nitosols (red basaltic soils) and Orthic Aerosols [12]. The soil is clayey in texture and slightly acidic with pH value of around 6.4 [13]. Wadera district is located at 530 km to the South from Addis Ababa and 60km to the North from the Zone town (Nagele Borena) with a geographic coordinate of 5⁰39'5"- 6ᵒ2'28"N latitudes and 39ᵒ5'30"-39ᵒ27'52"E longitudes. The district is situated at an altitude of 1500-1900masl. The district is characterized by two type of typical climatic zone. Namely, an arid and semiarid climate with mean annual temperature of 12-34˚C and it has a bimodal rainfall pattern. The average annual rainfall of the district is about 1500mm.The long rainy season start from mid-March to May while the short rainy season starts from Mid-September to October. The major soil types are oxsois and alfisols [12].

Both districts are characterized by three agro-climatic zones, namely Dega (High land), Weina dega (Mid land) and Kola (Low land) with different coverage. Based on these conditions, two times cropping seasons were commonly practiced. For instance, Arfasa is the main cropping season and starts from March to April, especially for maize, haricot bean, wheat and barley. The second cropping season is called Gana (short cropping season) which was practiced as double cropping using small seeds cereal crops like tef, wheat and barley after harvesting previous main cropping season crops. This study was conducted during short cropping season at selected low moisture stressed areas.

Description of plant material and experimental design employed

Seven low moisture stress tolerant improved bread wheat varieties (Adel Werer, Amibara, Fantale, Gambo, Lucy, Mekele 01 and Mekele 02) were used as testing materials with local check (farmers variety) The treatments were arranged in randomized complete block design with three replications at each location. The selected materials were planted on a plot size 2.5m x 1.2m, 6 rows, 20cm between rows. In puts (seeds 150kg/ha, fertilizers P_20_5 60kg/ha, N; 60kg/ha) and management practices were applied as recommended for wheat production to the area.

Data collection: Data were collected from each plot and selected plants of the plot for agronomic traits and diseases resistance scores. Collected agronomic data includes: Days to heading (DTH), Days to 90% maturity (DTM), Grain filling period (GFP), Plant height (PH), Spike length (SL), Total number of tillers/plant(TPP), Total number of fertile tillers/plant(NPT), Number of spikelets per spike(SPP), Number of kernels per spike (KPS), 1000-seed weight (TSW) and Grain yield/ha (qt/ha).

Data analysis: Collected data was subjected to ''SAS' 'software (version 9.0) to evaluate the variability of the tested varieties across the locations. This was done through computing analysis of variance for all characters studied according to the method given by Gomez and Gomez [14].

Stability analysis was performed following different procedures: Regression coefficient (bi) was done following proce-

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dure developed by [15] later revised (b and S^2d) by Eberhart and Russell [16]. Ecovalence (Wi) which is the contribution of each genotype to the GEI sum of squares was estimated with the method Wricke's [17].

AMMI stability analysis was carried out using IRRISTAT computer software IRRI STAT. ASV was also done following the technique of Purchase et al. [18].

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1)^2\right] + [IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller IPCA score indicate a more stable genotype across environment.

Genotype Selection Index (GSI): Based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI Stability Value (RASVi) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSIi)[18] as:

$$GSIi = RYi + RASVi$$

GGBiplot analysis was also illustrated following the principle suggested by Yan and Rajcan [19].

Result & Discussion

The combined analysis of variance (ANOVA) over locations for grain yield and other agronomic characters of 8 bread wheat varieties is presented in Table 1. The analysis of variance (ANOVA) indicated presence of highly significant differences at (P≤0.01) among the evaluated bread wheat varieties and the testing sites for most of the characters studied except grain filling period. This indicates presence of variability among the evaluated bread wheat varieties as well as the testing sites. In other cases, highly significant effect of GEI was exhibited on days to heading, thousand seed weight and grain yield. In addition, non- significant effect of GEI was depicted on most of the characters considered. Several authors were also reported presence of highly significant difference among bread wheat genotypes for grain yield due to genetic variability of the genotypes and environments [10,11,20,21].

Mean performance of improved bread wheat varieties

Table 1: Combined analysis of variance for different agronomic parameters of 8 bread wheat varieties tested over six locations during 2017/18 cropping season.

Source of Variation	Mean Square										
	DH	GFP	DTM	PH (cm)	SL (cm)	SPPS	KPS	TPP	NPT	TSW (gm)	Gy (kg/ha
Genotypes (7)	70.15**	144.98ns	316.64**	186.63**	5.84**	9.49**	78.70**	1.24**	1.28**	80.51**	403.34**
Rep (2)	0.63ns	379.09**	397.58**	12.71ns	4.19ns	1.42ns	2.48ns	2.04*	1.85*	14.21ns	43.46ns
Locations (5)	373.08**	1961.24**	1877.1**	1426.87**	7.01*	19.18**	150.36**	15.99**	11.18**	214.79**	498.93**
G* L (35)	10.02**	81.71ns	57.68ns	34.52*	1.72ns	2.14*	25.56*	0.36ns	0.34ns	27.77**	47.19**
Error (84)	1.01	74.61	72.8	20.65	1.76	1.25	14.97	0.35	0.36	11.81	25.64
R	0.97	0.67	0.68	0.83	0.47	0.67	0.26	0.76	0.7	0.7	0.75
CV (%)	1.63	20.89	8.3	6.18	16.77	7.33	8.46	16.89	18.1	10.54	25.12

** = highly significant at P ≤ 0.001; *= significant at P ≤ 0.05; ns = not significant at P= 0.05; a Numbers in parentheses are degrees of freedom associated with the corresponding source of variation; DH: Days to heading, DTM: Days to maturity, GFP: Grain filling period, PH: Plant height in centimetre, SL: Spike length in centimetre, TPP: Tillers per plant, NPT: Number of productive tillers, TSW: Thousand seed weight in gram, Gy: Grain yield/ha in quintals.

The mean performance of the evaluated varieties across the testing sites showed highly significant variability for days to heading and days to maturity for the genotypes, locations as well as GEI. In other case, non-significant effect of genotypes was observed on grain filling period (Table 1). Thus, the study result clearly reflects that presence of variability among the evaluated varieties as well as the testing environments. Among the testing sites, varieties were early headed, grain filled and matured at Kiltu Sorsa (55.75 days,33.25 days and 89 days) respectively. Whereas late headed at Tulam (64.88 days), late grain filled and matured at Dufa (56.92 days and 114.08 days) respectively (Table 2).

From the combined analysis, the variation with respect to days to heading and days to maturity was ranged from 53 to 62 and 103 to 126.67 days respectively, showing a wide range of variation among the varieties for maturity. Based on the study result, the longest days to heading was revealed by control (62 days) followed by Gambo (58.33 days). However, early heading was recorded for varieties Fantale and Amibara (53 days) followed by Mekele 02 (56 days), Mekele 01 (56.33 days), Lucy (57 days) and Adel Werer (57 days). In other cases, variety Mekele 02 was early maturing variety (103 days) followed by Mekele 01 (111.33days). Among the tested varieties, control was late maturing variety with 126.67 days followed by Fantale (124 days).

With regards to growth parameters, the highest plant height was recorded at Chalo Sigida and Andoya Haro 80.89cm and 80.46cm respectively and the shortest was scored at Kiltu Sorsa (63.26cm) (Table 2). Plant height was sensitive to environmental fluctuations and it indicated that the relative performance of genotypes was markedly inconsistent over the locations [22]. Significant variability was also depicted among the evaluated bread wheat varieties and locations on spike length. The longest spike length was recorded at Andoya Haro and Chalo Sigida (8.61cm and 8.54cm) respectively and the shortest was scored at the rest of the testing sites (Table 2).

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The current study also illustrated significant variability of the evaluated bread wheat varieties for yield and related traits (Total number of tillers, number of productive tillers, number of spiklet per spike, number of kernels per spike, thousand seed weight and grain yield /hectare). As it is depicted from the study result, varieties were showed best performance in yield and related traits at Chalo Sigida and inconsistent performance for the traits in other locations (Table 2). These indicate the presence of variability among the varieties, environments and GEI for yield and related traits.

Table 2: Mean agronomic performance of 8 bread wheat varieties tested at six low moisture stress areas of Guji Zone, Southern Oromia during 2017/18 cropping season

Genotypes	DH	GFP	DTM	PH (CM)	SL (CM)	SPPS	KPS	TPP	NPT	TSW (gm)	Gy (qt/ha
Tulam	64.88^{a}	33.79^{c}	98.67^{c}	69.86^{b}	7.71^{b}	16.01^{ab}	48.27^{a}	3.84^{b}	3.33^{b}	28.83^{d}	17.66^{c}
Chalo Sigida	64.38^{a}	43.58^{b}	107.96^{b}	80.89^{a}	8.54^{a}	16.49^{a}	48.63^{a}	4.40^{a}	4.16^{a}	37.42^{a}	26.45^{a}
Gobicha	63.67^{b}	36.0^{c}	99.67^{c}	67.01^{c}	7.31^{b}	14.33^{c}	43.02^{b}	2.61^{d}	2.53^{d}	32.07^{bc}	20.73^{b}
Andoya Haro	62.75^{c}	44.5^{b}	107.25^{b}	80.46^{a}	8.61^{a}	15.62^{b}	46.81^{a}	4.37^{a}	4.09^{a}	33.32^{b}	18.34^{bc}
Kiltu Sorsa	55.75^{e}	33.25^{c}	89^{d}	63.26^{d}	7.68^{b}	14.44^{c}	43.31^{b}	2.72^{cd}	2.79^{dc}	30.30^{cd}	13.82^{d}
Dufa	57.17^{d}	56.92^{a}	114.08^{a}	79.32^{a}	7.58^{b}	14.76^{c}	44.28^{b}	3.01^{c}	2.95^{c}	33.7^{b}	23.95^{a}
Mean	61.43		41.34	73.47	7.9	15.27	45.7	3.49	3.31	32.6	20.16
MSE	1.01	74.61	72.8	20.65	1.76	1.25	15	0.35	0.36	11.81	25.64
LSD (0.05)	0.58	4.95	4.89	2.6	0.76	0.64	2.22	0.34	0.34	1.97	2.9

DHT: Days to heading, DTM: Days to maturity, GFP: Grain filling period, PHT: Plant height, SL: Spike length, SPPS: Spiklet per spike, KPS: Kernels per spike, TPP: Tillers per plant, NPT: Number of productive tillers, TSW: Thousand seed weight, Gy: Grain yield/ha.

The overall mean yield of the location varied from 13.82qt/ha to 26.45qt/ha (Table 3) and thus, the five environments showed wide variation in yield potential. The highest mean grain yield was obtained at Chalo Sigida (26.45qt/ha) and the lowest was from Kiltu Sorsa (13.82qt/ha). Among the evaluated varieties, Lucy (29.61qt/ha), Gambo (29.34qt/ha), Mekelle 02(33.11qt/ha), Amibara (31.93qt/ha) and Mekelle 01(31.18qt/ha) were best performed at Chalo Sigida. In other case two varieties; Fantele (23.52qt/ha) and Adel Werer (22.86qt/ha) were best yielded at Gobicha where as the local (control) variety was performed at Dufa site (Table 3).

Table 3: Mean grain yield of bread wheat varieties (qt/ha) across six testing sites during 2017/18 Cropping season.

Varities	Testing Environments						
	Tulam	Chalo Sigida	Gobicha	Andoya Haro	Kiltu Sorsa	Dufa	Varietal mean
Lucy	10.79	29.61	19.48	21.13	11.53	20.65	18.87
Fantele	16.63	21.28	23.52	14.39	13.66	23.19	18.78
Control	5.89	12.26	10.99	10.62	6.91	16.66	10.56
Gambo	14.48	29.34	26.99	16.4	13.83	24.38	20.9
Mekele 02	21.26	33.11	25.04	25.21	21.06	28.29	25.66
Amibara	24.71	31.93	16.72	26.17	15.05	28.97	23.93
Adel werer	20.05	22.85	22.86	19.36	13.09	22.42	20.11
Mekele 01	27.44	31.18	20.23	23.43	15.44	27.02	24.13
Location mean	17.66	26.45	20.73	19.59	13.82	23.95	3.49

DHT: Days to heading, DTM: Days to maturity, GFP: Grain filling period, PHT: Plant height, SL: Spike length, SPPS: Spiklet per spike, KPS: Kernels per spike, TPP: Tillers per plant, NPT: Number of productive tillers, TSW: Thousand seed weight, Gy: Grain yield/ha

Table 4: Combined mean values of different bread wheat varieties for grain yield and other agronomic characters at six locations during 2017/18 cropping season.

Genotypes	DH	GFP	DTM	PH (CM)	SL (CM)	SPPS	KPS	TPP	NPT	TSW (gm)	Gy (qt/ha)
Lucy	62.17^{c}	40.78^{abc}	102.94^{b}	71.89^{b}	7.89^{ab}	14.81^{cd}	44.40^{cd}	3.50^{a}	3.37^{a}	30.13^{d}	18.87^{b}
Fantele	61.44^{d}	42.89^{ab}	104.33^{b}	74.89^{b}	8.55^{a}	15.79^{a}	45.98^{bc}	3.51^{a}	3.26^{a}	30.19^{d}	18.78^{b}
Control	64.56^{a}	46.33^{a}	110.89^{a}	74.09^{b}	7.22^{bc}	14.61^{cd}	44.01^{cd}	2.89^{b}	2.69^{b}	32.71^{bc}	10.56^{c}
Gambo	63.06^{b}	40.28^{bc}	103.33^{b}	79.03^{a}	8.62^{a}	16.22^{a}	48.59^{a}	3.76^{a}	3.55^{a}	34.22^{ab}	19.24^{b}
Mekele 02	59.00^{e}	37.00^{c}	96.00^{c}	74.87^{b}	8.01^{ab}	15.70^{ab}	47.12^{ab}	3.49^{a}	3.34^{a}	35.73^{a}	25.66^{a}
Amibara	59.61^{e}	43.39^{ab}	103.00^{b}	72.11^{b}	8.08^{ab}	15.03^{bc}	45.57^{bc}	3.54^{a}	3.42^{a}	34.09^{ab}	23.93^{a}
Adel Werer	62.28^{c}	39.28^{bc}	101.56^{bc}	67.74^{c}	6.98^{c}	14.15^{d}	42.33^{d}	3.49^{a}	3.33^{a}	30.51^{cd}	20.10^{b}
Mekele 01	59.33^{e}	40.78^{abc}	100.11^{bc}	73.12^{b}	7.88^{ab}	15.88^{a}	47.76^{ab}	3.72^{a}	3.52^{a}	33.24^{b}	24.13^{a}

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Mean	61.43	41.34	102.77	73.47	7.9	15.27	45.72	3.49	3.31	32.6	20.16
CV (%)	1.63	20.89	8.3	6.18	16.77	7.33	8.46	16.89	18.1	10.54	25.12
LSD (0.05)	0.66	5.72	5.65	3.01	0.88	0.74	2.56	0.39	0.39	2.27	3.35

DHT: Days to heading, DTM: Days to maturity, GFP: Grain filling period, PHT: Plant height, SL: Spike length, SPPS: Spiklet per spike, KPS: Kernels per spike, TPP: Tillers per plant, NPT: Number of productive tillers, TSW: Thousand seed weight, Gy: Grain yield/ha.

The combined analysis also showed significant effect of genotypes, environments and GEI on mean grain yield of the evaluated bread wheat varieties which was ranged from 10.56 to 25.66qt/ha with the mean value of 20.16qt/ha and coefficient of variation 14.35%. The highest grain yield (25.66qt/ha) was recorded for Mekele 02 followed by Mekele 01 (24.13qt/ha). But, low yield of 10. qt/ha was obtained from local (control) variety (Table 4).

Stability Analysis

The results of different parametric and non-parametric stability statistics are discussed term by term following the models suggested.

Eberhart and Russell's joint regression stability analysis

Table 5: Mean yield response (qt/ha), regression coefficients (bi) and deviation from regression (S^2di) values of 8 bread wheat varieties evaluated across six environments during 2017/18 cropping season.

Variety	Mean	Rank of Gy	bi	S^2di	Rank
Lucy	18.87	6	1.32**	8.18	6
Fantele	18.78	7	0.78	1.49	2
Control	10.56	8	0.66	0.18	1
Gambo	19.24	5	1.51**	34.77	8
Mekele02	25.66	1	0.94**	-4.26	4
Amibara	23.93	3	1.11**	17.09	7
Adelwerer	20.1	4	0.71	-2.76	3
Mekele01	24.13	2	0.97**	8.17	5

Eberhart and Russel [16] developed a model to test the stability of varieties under various environments and defined a stable variety as having unit regression over the environments (b = 1.00) and with minimum deviation from the regression (S2di = 0). Regression values above 1.0 describe genotypes with higher sensitivity to environmental changes (below average stability) and greater specificity of adaptability to high yielding environments. A regression coefficient below 1.0 provides a greater resistance to environmental changes (above average stability) and, thus, increases the specificity of adaptability to low yielding environments [23].

Based on the analysis variance of E and R stability model, the current study showed the mean square for G × E (linear) interaction was highly significant which indicates presence of genetic differences among the varieties over the testing environments (Table 5). In such case, it's important to partition GEI into environment linear, G x E (linear) interaction effects (sum squares due to regression (bi) and unexplained deviation from linear regression (pooled deviation mean squares (S^2di). Further partitioning of GEI into linear and nonlinear components revealed highly significant mean squares (MS) for these components indicating the presence of both predictable and unpredictable components of GEI.

Table 6: Analysis of Variance of E and R stability model for 8 bread wheat varieties tested across six environments during 2017/18 cropping season.

Source	D.F.	S.S.	M.S.	% of Variance
Treatments	7	941.024	134.43**	40.51
Locations	5	831.553	166.31**	35.79
Treatment X Sites	35	550.623	15.73*	23.7
Trt X Site Reg (Linear)	7	65.3495	9.34	11.87
Environment	1	550.623	550.62**	
Deviations	28	485.273	17.33**	88.13
Total	47	2323.2		

The joint regression of the mean genotypic performance on the environment showed that results from the two stability parameters bi and S2di were not consistent in assessing the reaction of genotypes to varying environmental conditions. All genotypes showed regression coefficient (bi) values that were significantly different from unity (Table 6) but, in contrast, some genotypes showed significant deviation from regression (S^2di) values of greater than zero (Table 5). Thus, based on the regression coefficients, all genotypes had an average response in all test environments. According to Becker and Leon, genotypes with bi values of unity showed an average response to changing environmental conditions [24]. Eberhart and Russell found that genotypes with high mean performance, a regression coefficient of unity (bi = 1), and deviation from regression of zero (S^2di = 0) showed better general adaptability across environments. Based on this principle, none of the evaluated varieties showed better general adaptability even if three varieties, namely Mekele 02, Mekele 01 and Amibara were performing above-average grain yield but their regression coefficient (bi) values was significantly different from unity, and deviation from regression (S^2di) values also significantly different from zero. In other cases, three varieties namely Fantele, Adel Werer and Local were found to be among the lowest yielders with bi <1 indicating that the varieties were poorly adapted to the test environments.

Wricke's (Wi) ecovalence

Wricke's (Wi) ecovalence is the contribution of a genotype to the interaction sum of squares. The lower the value of Wi the smaller will be the fluctuations from the predictable response in different environments so much that the genotype with the least ecovalence is considered to be the ideal from the point of view of yield stability. From the current study, variety Mekele 02, Adel Werer and Fantele were showed lower Wi value indicating that the varities are stable. In other case, variety Gambo showed high Wi value which could reflects its instability (Table 7).

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Table 7: Wricke's (Wi) ecovalence value for 8 bread wheat varieties evaluated over six environments during 2017/18 cropping season.

GEN	Mean	Rank of Gy	Wi	Rank of Wi
Lucy	18.87	6	72.6	6
Fantele	18.78	7	40.31	3
Control	10.56	8	41.88	4
Gambo	19.24	5	195.33	8
Mekele 02	25.66	1	12.6	1
Amibara	23.93	3	98.88	7
Adel werer	20.1	4	27.04	2
Mekele 01	24.13	2	61.97	5

Additive main effects and multiplicative interaction (AMMI) analysis for grain Yield of bread wheat varieties

The AMMI analysis of variance of 8 bread wheat varieties tested over six Environments revealed that 40.51% of the total sum of squares (SS) was attributable to the genotypes (G), 35.79 % to the environment (E) and 23.70% to GE interaction effects (Table 6). A large SS due to G indicated that the genotypes were genetically different for mean yields as a result of their selection domains. The small proportion of SS due to E indicated that the differences among the environmental means were not very high. The magnitude of GE SS was 49.33 times smaller than that of SS due to G, thus, indicating that the differences in the response of the genotypes across environments were not that substantial and the genotypes need multi-location testing. Bose et al. [23] also reported larger SS variability attributed on rice genotypes due to genotype variability. In contrast, larger SS revealed due to environments on bread wheat was reported by many authors [10,11,20,21].

Among the four principal components, AMMI Component 1 and AMMI component 2 were highly significant at P = 0.01%. The AMMI Component 1 (IPCA-1) accounted for 56.65% of the interaction. Similarly, AMMI Component 2 (IPCA-2) explained further 20.09% of the interaction SS and cumulatively contributed to 76.74% of the total interaction and used for biplot. This indicates that the two AMMI components were adequately explained the variations existed on the yield of the tested bread wheat varieties due to GEI. Many authors also suggested that first two principal components of AMMI model are the most accurate in predicting total variation explained due to GEI [11,20,25-27].

AMMI stability value (ASV)

ASV measures the distance from the genotype coordinate point to the origin in a two-dimensional scatter diagram of IPCA2 against IPCA1 scores. Genotypes with the lowest ASV values are identified by their shortest projection from the biplot origin and considered the most stable. Accordingly, Mekelle 02 and Adel Were the most stable varieties. However, Gambo and Amibara were the most unstable varieties (Table 8).

Genotype Selection Index (GSI)

Table 8: AMMI analysis of variance for grain yields of 8 tested bread wheat varieties across six environments during 2017/18 cropping season.

Source	D.F.	S.S.	M.S.	F	F prob	% of Variance Explained
Treatments	7	941.02	134.43			40.51
Locations	5	831.55	166.31			35.79
Treatment x Sites	35	550.62	15.73			23.7
Ammi Component 1	11	311.9	28.35**	2.85	0.01	56.65
Ammi Component 2	9	110.62	12.29ns	1.44	0.26	20.09
Ammi Component 3	7	96.29	13.76ns	3.46	0.05	17.49
Ammi Component 4	5	26.73	5.35ns	3.16	0.19	4.85
Gxe Residual	3	5.08				
Total	47	2323.2				

It is a non-parametric index used to identify best performing and stable genotypes/variety based on the rank of ASV and mean grain yield. Mohammadi stated that, Stability per see alone not be the only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance unless supported by other approaches like GSI. In GSI, variety that holds the least value is considered as the most stable with high grain yield. Accordingly, Variety Mekelle 02, Adel were and Mekelle 01 with relatively lower values were found high seed yielding and broadly adapted varieties (Table 9).

GG Biplot analysis

By this analysis, which- won- where, mean performance and stability of genotypes, discriminating ability and representativeness of environments and others can be addressed graphically. So, the environments and genotypes obtained in the concentric are considered as ideal environments and stable genotypes respectively [19]. A variety is more desirable if it is located closer to the ideal variety. Using the ideal genotypes/variety as the center, concentric circles were drawn to help visualize the distance between each variety and the ideal variety. Therefore, ranking based on the genotypes-focused scaling, assumes that stability and mean yield are equally important [28]. Accordingly, Variety Mekelle 02 and Mekelle 01 which fells closest to the center of concentric circles were ideal varieties in terms of yielding ability and stability as compared to the rest of the tested bread wheat varieties.

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Table 9: Mean yield response (qt/ha) of 8 bread wheat varieties across six environments, AMMI stability value and genotype selection index.

TRT No	Variety	Mean	IPCA 1	IPCA 2	IPCA 3	IPCA 4	ASV	GSI
1	Lucy	18.86	0.34	2.43	0.7	0.77	2.61	4
2	Fantele	18.78	-1.09	-1.19	0.64	0.21	3.31	5
3	Control	10.56	0.47	-0.61	1.74	-1.25	1.46	1
4	Gambo	19.24	-3.12	0.45	-1.46	-0.43	8.8	8
5	Mekele02	25.66	0.23	0.77	0.42	-0.21	1.01	2
6	Amibara	23.93	2.18	0.1	-1.05	-0.85	6.14	7
7	Adelwerer	20.1	0.04	-1.19	0.5	1.36	1.2	3
8	Mekele01	24.13	1.36	-0.76	-1.5	0.4	3.91	6

With regards to the testing environments, Koba Sorsa, Dufa and Tulam which fells near to the ideal environment were identified as the best desirable testing environment in terms of being the most representative of the overall environments and powerful to discriminate the tested bread wheat varieties (Figure 1) [29,30].

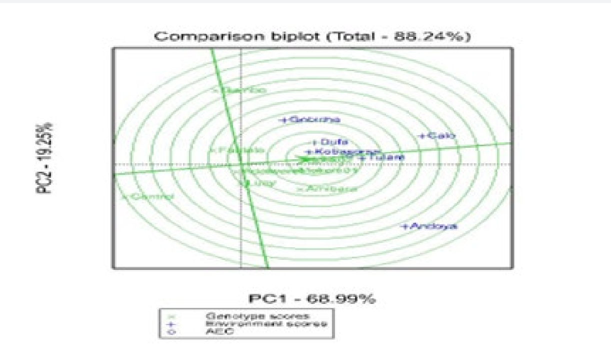

Figure 1: GGE biplot of eight bread wheat varieties across six testing environments using genotype-centered scaling.

Conclusion

With the current climate change, conducting varietal adaption across various environments is very pertinent to have good varietal recommendation. In such cases, the varieties are allowed to be tested whether they have specific or general adaptability to the testing environments. To concur such result, assessing the stability as well as the performance of the varieties across diverse environment is mandatory. So, the current study was conducted to evaluate the performance and yield stability of eight released low moisture stress tolerant bread wheat varieties in different low land areas of Guji Zone. The combined study result indicated that, highly significant difference (P≤0.01) was observed among the evaluated varieties across the testing environments as well as within their interaction for grain yield and other agronomic parameters. The highest mean grain yield was obtained at Chalo Sigida (26.45qt/ha) and the lowest was from Kiltu Sorsa (13.82qt/ha). The highest grain yield (25.66 qt/ha) was recorded for Mekelle 02 followed by Mekelle 01 (24.13qt/ha). But, low yield of 10. qt/ha was obtained from local(control) variety. In this study, different models were employed to test yield stability of the evaluated varieties. According to Joint regression model, none of the evaluated varieties showed better general adaptability. In other cases, three varieties namely Fantele, Adel Werer and Local were poorly adapted to the tested environments. As of Wi variety Mekele 02, Adel Werer and Fantele were showed lower Wi value indicating that the varieties are stable. In other case, variety Gambo showed high Wi value which could reflects its unstable. AMMI stability value indicated, Mekele 02 and Adel Werer the most stable varieties. However, Gambo and Amibara were the most unstable varieties. Genotypic selection found, Mekele 02, Adel werer and Mekelle 01 as high seed yielding as broadly adapted varieties.

Generally, the study results clearly indicated the possibility of exploiting the yield potential of bread wheat varieties namely; Mekele 02 and Mekele 01 under specific locations of low moisture stressed areas of Guji Zone. To give coincide conclusion, considering both yield performance and yield stability of the evaluated varieties are must. Accordingly, variety Mekele 02 followed Mekele 01 were identified as high yielder and comparably stable across the tested environments and then recommended for production to the study areas.

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