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Stability Models for Selecting Adaptable and Stable Bread Wheat (*Tritium aestivum* L.) Varieties for Grain Yield in Ethiopia

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Abstract

Grain yield of bread Wheat (*Triticum aestivum* L.) is a polygenic inherited trait and its expression is highly determined by environment. In Ethiopia a number of bread wheat varieties have been released for production but their specific or general adaptions were not clearly known. Moreover, due to dynamic nature of climate, evaluation of varieties for recent performances are crucial to select and recommend best commercial varieties. Hence, the objectives of study were to evaluate the released bread wheat varieties for their adaptability and stability over wider environments and to select and recommend the best varieties for production. Fifteen bread wheat varieties were evaluated across twenty-one environments in Ethiopia during 2017 cropping season. The varieties were arranged in Randomized Complete Block Design replicated three times. Data were taken for grain yield, plant height and thousand kernel weight. The varieties were evaluated for their adaptability and stability using different models. AMMI analysis was carried out using R software. The combined analysis of variance showed that highly significant differences ($P \leq 0.001$) were observed for grain yield among the genotypes, environments and genotype-environment interaction indicating the crossover nature of the varieties performances in different environments. The environment sum of squares dominated the total variations even though the interaction sum square was larger than genotypic sum square. The contribution of environments was 74.17%, indicating large differences in environments and the average grain yield for the environments ranged from 1.29 t/ha for Env-16 (Alemtena) to 5.66 t/ha for Env-4 (Asasa). The contribution of the varieties and GEI was 8.61% and 17.22% respectively to the total variation. Highest mean grain yield was obtained from variety Sanate (3.66 t/ha) followed by the variety Biqa (3.47 t/ha) while the lowest mean grain yield was obtained from the variety Hulluka (1.85 t/ha). The different stability parameters (ASV, YSI, regression model, etc.) identified the variety Obora and Shorima as stable and adaptable varieties and they can be widely cultivated while, Hulluka and Kingbird were unstable varieties.

Keywords

Adaptability, Bread Wheat, Ethiopia, GEI, Grain Yield, Stability Parameters

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1. Introduction

Bread wheat (*Triticum* aestivum L.) is one of the most staple food crops in the world and is one of the most important cereal crop cultivated in Ethiopia. It is used for both human and animal nutrition and plays an important role in the nutrition of rapidly growing populations in the world [1]. In Ethiopia, wheat is annually occupying over 1.7 million hectares of land which is 13.38% of the total area of land used for cereal production [2]. It ranks second after maize contributing 15.17% of the total annual cereal production. Adoption and dissemination of improved agricultural technologies play a great role in increasing

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production and productivity of the crops [3].

Wheat yield is a polygenic inherited trait and its productivity is determined by environmental factors. Bread wheat is a widely adapted crop that can be grown in many different environments, though its productivity is higher in suitable environments [4]. Due to climate change, a considerable challenge arose in achieving the 70%-increase target in world food production demand. Moreover, the intrinsic uncertainty of climate change predictions poses a challenge to plant breeders and crop scientists who have limited time and resources and must select the most appropriate traits for improvement [5]. The reliability of cultivar performance across locations and years can be an important consideration in plant breeding. Some cultivars are adapted to a broad range of environmental conditions, while others are more limited in their potential distribution. There are cultivars that perform similarly regardless of the productivity level of the environment, and others whose performance is directly related to the productivity potential of the environment [6]. In breeding, it is of interest to study and determine adaptation and stability parameters in conjunction with the increase in average yield [1]. In Ethiopia, a number of improved bread wheat varieties have been released by different breeding institutes and these have contributed to increased productivity and production for the last decade [2]. Though wheat production and productivity in the country has been increasing, it is still insufficient to meet the increasing food demand for the ever-increasing population. Lack of genotypes with wide stability across environments has been one of the most important constraints of wheat production in the country [7]. Performance of a variety is the resultant effect of its genotype and the environment in which the genotypes are tested. Multi-location trials are a key component of selection for stable and best-performing genotypes in different environments [8, 9, 10]. In Ethiopia, the processes of variety development is a continuous processes by various research institutes and universities. However, once the varieties are released for production, they are used for a long period of time without periodical evaluation for their adaptation and their stabilities. Therefore the study was designed to estimate the magnitude of GEI and to select and recommend stable and adaptive varieties for production of bread wheat in Ethiopia.

2. Materials and Methods

2.1. Experimental Sites, Plant Materials, Treatments and Design

Fifteen bread wheat varieties were tested in 21 environments in Ethiopia during 2017 main cropping season (Tables 1, 2 and Figure 1). The experiment was laid out in Randomized complete block design replicated three times. The net plot size was 3m^2 (2.5 m length x 6 rows x 20 cm between rows). Seed rate of 150 kg/ha was used across the test environments. NPS/Urea fertilizer rates were applied according to the specific site recommendation. Urea was applied twice (half at planting and the remaining half at booting stage). All other agronomic management practices were applied uniformly in test environments. Data were taken for grain yield ton per hectare, plant height and thousand kernel weight.

2.2. Statistical Analysis

The agronomic data were subjected to analysis of variance in order to partition sum of squares to genotype, environment and genotype-environment interaction effect using R-software. AMMI stability analysis was done and Stability and adaptability performance across environments were estimated following different procedures. Regression coefficient (bi) and deviation square from regression (S^2di) were computed following the procedure developed by Eberhart and Russell [11]. Ecovalence (Wi) which is the contribution of each genotype to the GEI sum of squares were also estimated with the methods of Wricke [12]. ASV and CVi were done following the technique of Purchase [13], and Francis and Kannenberg [14] respectively.

Table 1. List of bread wheat varieties evaluated in 2017 main cropping season.

S/No	Varieties	Pedigree	Year of released	Adaptation areas (m)
1	Wane	SOKOLL/EXCALIBUR	2016	2100-2700
2	Lemu	WAXWING*2/HEIL0	2016	>2200
3	Kingbird	TAM200/TUI/6/PVN//CAR422/ANA/5/BOW/CROWN//BUC/PVN/3/YR/4/TRAP#1	2015	1500-2200
4	Liben	CULA/KAUZ/6/PSN/BOW/4/MAYA/NAC/3/RPB14.68//PYN/PHO/5/MUNIA	2015	2300-2500
5	Bulluq	UTQE96/3/PYN/BAU//MILLANU TIQ U E96/FLA G –1AGUILAL/3/ PYN/BAU//MILAN	2015	2300-2700
6	Obora	U TIQ U E96/FLA G -1AGUILAL/3/ PYN/BAU//MILAN	2015	2000-2400
7	Dambal	AGUILAL/3/ PYN/BAU//MILAN	2015	2000-2400
8	Honqolo	-	2014	2200-2600
9	Biqa	PASTOR//HXL7573/2*BAU/3/WBLL1	2014	1600-2200
10	Sanate	14F/HAR1685	2014	2300-2600
11	Mandoyu	Worrakatta/Pasto	2014	2200-2500
12	Hidase	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC-1/AE. SQUAROSA(224)//OPATTA	2012	2100-2800
13	Ogolcho	WORRAKATTA/2*PASTOR	2012	1500-2100
14	Hulluka	-	2012	2200-2800
15	Shorima	-	2011	2100-2700

Table 2. Locations (environments), geographical position, altitude, temperature and rainfall data of the experimental sites.

S/No	Environment	Geographic position		Altitude (m)	Temperature (°c)		Rainfall (mm)
		Latitude	Longitude		Min	Max	
1	Kulumsa	08°01'10"N	39°09'11"E	2200	10.5	22.8	820
2	Etaya	08°08′N	39°14′E	2215	12.0	25	NA
3	Arsi Robe	07°53'02"N	39°37'40"E	2420	6.0	21.1	890
4	Asasa	07°07'09"N	39°11'50"E	2340	5.8	24	620
5	Bekoji	07°32'37"N	39°15'21"E	2780	7.9	18.6	1020
6	Sagure	07°45′N	39°09′E	2568	-	-	-
7	Arsi Negele	7°21′N	38°42′E	2043	10.0	25	750
8	Hosanna	7°33′N	37°51′E	2177	-	-	-
9	Kokate	6°52'42" N	37°48' 25" E	2156	-	-	-
10	Areka	7°3′25" N	37°40'52" E	2230	-	-	1290
11	Shambu	9° 34′ 0″ N	37° 6′ 0″ E	2503	-	-	-
12	Bako	9°06′N	37°09′E	1590	9.0	34.4	1245
13	Arjo	9.2188° N	36.6967° E	1322	-	21.7	1504
14	Debre Brehan	9°41′N	39°32′E	2840	8.2	20.7	964
15	Debre Zeit	08° 44' N	38° 58' E	1900	8.9	28.3	851
16	Alemtena	08°.30N	38°.95E	1611	NA	NA	728
17	Chefe Donsa	8°44′N	39°95′E	2450	8.9	28.3	851
18	Haramaya	9.4083° N	42.0345° E	2047	9.9	24.18	800.9
19	Halaba	07°18'45"N	37°06'49"E	1765	17.6	22.5	857
20	Hawasa	7.0524° N	38.4856° E	-	-	-	-
21	Holeta	09°03′41″N	38°30′44″E	2400	6.2	22.1	1044

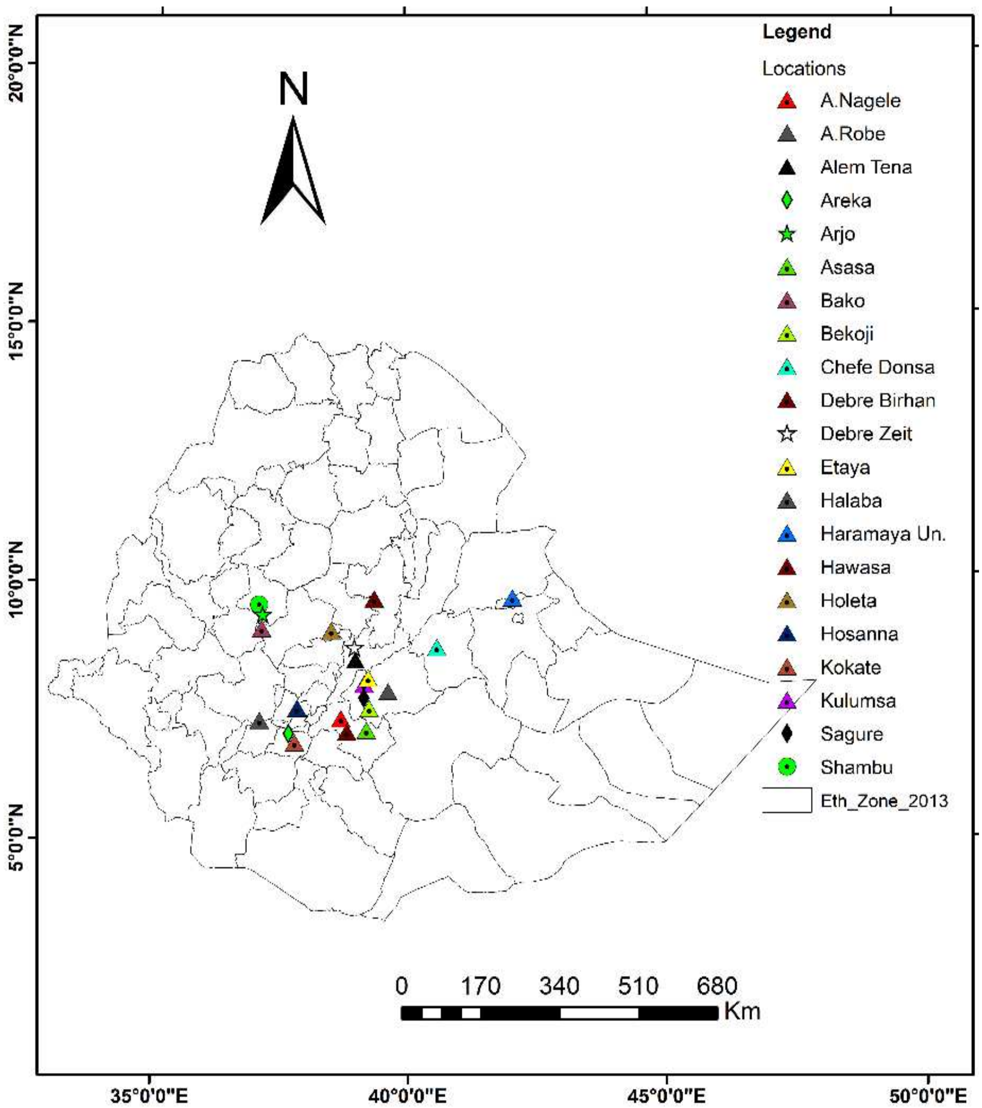

Figure 1. Map of Ethiopia and the experimental sites.

3. Results and Discussion

3.1. Analysis of Variance

The combined analysis of variance (ANOVA) indicated highly significant differences (P≤0.001) among the evaluated bread wheat varieties, the testing environments and their interactions for grain yield (Table 3). This indicates that the presence of genetic differences in the materials and environmental differences under study. Further, the need to further studies for stability and adaptabilities in the materials. Several authors also reported presence of highly significant differences among bread wheat genotypes for grain yield due to genetic differences of the genotypes and environments [15, 16, 17, 18]. The highest magnitude of variation caused by environment is an indication for complex external factors (biotic and abiotic) and challenges in wheat breeding. Most of the elements of environment are difficult to manage in the best interest of breeder during field experiment. The highly significant GEI effects suggest that genotypes may be selected for adaptation to specific environments in rice [19] and in bread wheat [17]. Additionally, highly significant differences (P ≤ 0.001) were recorded among the genotypes, environments and their interaction for plant height and thousand kernel weight (Table 3). Significant differences were also reported among the evaluated bread wheat genotypes for plant height, grain yield and thousand kernel weight by other researchers [20, 21].

3.2. Mean Yield Performance Across Testing Environments

The basic cause for differences in the performance of genotypes over environments is the occurrence of genotype-environment interaction (GEI) [22]. In varying environments it may be expected that the interaction of genotype with environment is varying and ample. As a result one cultivar may have the highest yield in one environment, while a second cultivar may excel in others. Variability is essential for wide adaptability and resistance to biotic and abiotic factors.

Considerable differences among environmental means resulted significant variations in yield and presented wide variations that need to be understood and explored for effective improvement in bread wheat production in rain fed areas of Ethiopia (Table 3). Environments differed in climate (mostly rainfall amount, distribution and temperature), thus providing contrasting growing conditions that led to a range of grain yields (Table 1). Genotypes were therefore exposed to both rainfall and temperature variations, which are limiting factors in rain fed wheat growing areas of Ethiopia. Environment was the main cause of variations observed in grain yield. Studies have shown that the environmental portion in MET analysis can be the largest among all sources of variations [16, 17, 18, 23, 24]. There was a significant difference in grain yield between environments, owing to the significant (P<0.001) effect of favorable (greater than mean grain yield) versus unfavorable conditions (less than mean grain yield), which yielded 5.7 t/ha at Asassa (E-4) and 1.3 t/ha at Alemtena (E-16) respectively (Table 4). The environments with mean grain yield above the grand mean include E-1, E-3, E-4, E-11, E-12, E-14, E-17 and E-18. Mizan *et al*. [25] reported that variable yield responses due to the differences between the test environments. The present study showed that there were significant differences among varieties for grain yield. The average yield ranged from 0.3 t/ha at E-16 (Alemtena) for the variety Obora to 7.7 t/ha at E-4 (Asassa) for variety Biqa which indicated a wide gap between the test envioments. Considering grain yield as a first parameter across environments grain yield ranged from 1.9 t/ha for Hulluka variety to 3.7 t/ha for Sanate variety with a grand mean yield of 3.2 t/ha. Combined analysis across twenty one environments showed that variety Sanate ranked first in mean yield (3.7 t/ha) and Biqa ranked second (3.5 t/ha) and Hidase came third (3.5 t/ha). The GE interaction had a strong impact on grain yield (P<0.001), which explained 17.23% of the total sum of squares (about two times that of the genotype effect). METs have often shown that yield variation due to GE interaction exceeds that due to genotype [26].

Table 3. Combined analysis of variance (ANOVA) for grain yield, plant height and thousand kernel weight of bread wheat varieties evaluated across 21 environments.

Source of variations	DF	Grain yield (t ha^{-1})		Plant height (cm)		Thousand kernel weight (g)	
		MS	SS explained	MS	SS explained	MS	SS explained
Varieties	14	12.43^{**}	8.608	1250.01^{**}	13.13	21549.5^{**}	3.53
Environments	20	74.94^{**}	74.167	4934.43^{**}	74.07	351235.02^{**}	82.29
Interaction	280	1.24^{**}	17.225	57.14^{**}	12.8	4322.69^{**}	14.18
PC1	33	4.6^{***}	43.6	134.07^{**}	25.95	3.81^{**}	52.41
PC2	31	1.61^{***}	14.3	125.49^{**}	22.81	1.57^{*}	20.36
PC3	29	1.29^{***}	10.8	70.55^{**}	12.00	1.5^{*}	18.27
PC4	27	1.31^{***}	10.1	74.93^{**}	11.86	0.6^{ns}	6.99
PC5	25	0.91^{***}	6.5	59.51^{**}	8.72	0.1^{ns}	1.23
PC6	23	0.76^{**}	5	37.76^{ns}	5.09	0.05^{ns}	0.53
Residual	266	1.13^{**}	-	28.14	-	3940.65	-

Where DF: degrees of freedom; MS: mean squares, SS: sum squares; PC; principal components; **: sign-ificant at P<0.01; *: significant at P<0.05 and ns: non-significant.

Table 4. Mean Grain yield (t ha^{-1}) of 15 bread wheat varieties across twenty one environments.

No.	Variety	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-10	E-11	E-12	E-13	E-14	E-15	E-16	E-17	E-18	E-19	E-20	E-21	Mean
1	Wane	7.3	3.7	4.3	7.3	3.8	3.1	1.3	2.8	1.9	2.6	4.3	4.0	2.1	4.6	2.4	1.4	5.4	3.9	2.2	2.3	1.3	3.4
2	Lemu	5.7	3.0	4.8	4.8	4.1	2.5	1.3	3.0	2.3	1.8	3.7	4.9	3.3	5.6	2.8	1.0	4.1	3.4	2.5	2.4	2.5	3.3
3	Kingbird	5.3	2.9	3.8	4.1	0.7	2.3	1.3	2.7	2.3	2.1	3.4	3.6	2.2	4.9	3.2	1.3	4.5	4.1	2.7	0.7	0.8	2.8
4	Liben	6.8	3.2	3.1	5.9	4.4	3.0	1.0	2.8	2.3	2.5	3.8	4.4	3.2	5.4	3.3	1.3	3.4	4.1	2.3	2.3	1.8	3.3
5	Bulluq	3.8	3.0	3.8	5.1	1.4	2.3	1.1	3.0	2.2	2.3	3.0	4.4	3.2	5.1	2.9	1.0	3.5	3.9	2.7	1.8	2.0	2.9
6	Obora	5.9	2.8	4.8	5.7	2.8	2.6	1.3	2.5	2.6	2.8	3.3	4.3	2.8	5.1	2.3	0.8	4.4	3.6	2.6	2.4	1.8	3.2
7	Dambal	5.2	3.2	4.7	5.6	2.1	2.2	1.3	2.4	2.4	2.8	4.2	4.7	4.8	5.3	3.0	1.7	5.2	4.1	2.5	2.1	2.0	3.4
8	Honqolo	4.6	2.7	2.7	4.7	1.7	1.4	1.4	2.8	1.9	2.3	3.0	3.7	2.4	4.7	3.0	1.6	3.9	3.9	2.3	1.0	1.2	2.7
9	Biqa	6.3	3.3	2.5	7.7	1.9	1.7	1.8	3.2	2.5	2.6	4.5	5.3	3.5	5.3	3.2	1.2	4.4	4.2	3.2	2.2	2.5	3.5
10	Sanate	6.4	2.9	3.4	7.2	4.9	2.2	2.0	2.9	1.9	3.1	4.1	4.4	3.7	5.5	2.7	1.6	6.1	4.0	2.4	2.3	3.3	3.7
11	Mandoyu	5.2	3.3	3.0	7.5	3.3	2.3	1.7	2.8	1.9	2.1	4.5	4.2	2.0	5.1	2.3	1.4	4.6	3.9	2.3	2.3	1.3	3.2
12	Hidase	6.4	4.0	3.8	6.8	4.6	2.3	1.5	2.5	2.0	2.1	4.9	4.6	1.7	5.9	3.3	1.1	5.2	3.5	2.6	2.4	1.6	3.5
13	Ogolcho	5.7	3.5	4.6	4.8	1.9	2.7	1.7	3.0	1.9	2.6	3.9	4.4	3.4	5.3	3.2	1.5	4.5	5.0	3.3	1.1	1.1	3.3
14	Hulluka	2.6	1.4	1.7	2.3	0.3	0.6	1.6	2.1	1.5	1.5	1.0	2.4	1.1	3.6	2.4	1.2	3.4	4.4	2.4	0.5	0.8	1.9
15	Shorima	5.4	2.5	4.5	5.5	4.2	2.3	1.3	3.2	2.2	1.5	4.2	4.4	2.2	5.2	2.5	1.3	4.1	4.3	3.0	2.4	2.3	3.3
	Mean	5.5	3.0	3.7	5.7	2.8	2.2	1.4	2.8	2.1	2.3	3.7	4.3	2.8	5.1	2.8	1.3	4.4	4.0	2.6	1.9	1.8	3.2

Var: Variety; V1-V15: Variety 1-15; E-1 to E-21: Environment 1-21.

3.3. AMMI Stability Value (ASV)

ASV was proposed by Purchase *et al*. [27] to quantify and rank genotypes according to their yield stability. The ASV is the distance from zero in a two-dimensional scatter graph of IPCA1 (interaction principal component analysis axis 1) scores against IPCA2 scores. Since the IPCA1 score contributes more to GE sum of square (Table 3), it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 total GE sum of squares. In ASV method, a genotype with least ASV score is the most stable; accordingly varieties such as Obora (0.57), Dambal (0.95) and Shorima (1.04) had the lowest values for the ASV statistic and hence were considered as stable genotypes while; Hulluka (4.59), Hidase (2.82) and Wane (2.73) had high ASV statistic and hence were considered as most unstable varieties (Table 5). According to this model, variety such as Obora (3.19 t/ha), Dambal (3.39 t/ha) and Shorima (3.25 t/ha) as stable varieties which have high average grain yield which is greater than overall mean grain yield (3.15 t/ha).

3.4. Yield Stability Index

Yield stability index (YSI), is calculated by ranking the mean grain yield of genotypes (RY) across environments and rank of AMMI stability value (RASV). In YSI, variety that holds the least value is considered as the most stable with high grain yield. Based on the simultaneous selection of yield and stability varieties Dambal, Biqa and Obora relatively had lower values and identified as high yielding and stable varieties whereas, the varieties such as Hulluka, Kingbird, Bulluq and Honqolo had high values and identified as low yielding (less than overall mean grain yield of 3.15 t/ha) and unstable varieties. Among the high yielding-stable genotypes mentioned above the Dambal and Obora were released from Sinana Agricultural Research Centre for high moisture areas; while Biqa was released by Kulumsa agricultural Research Centre, for low moisture stress areas of Ethiopia. All selected varieties based on simultaneous selection for yield and stability had the highest grain yield. It seems that when the grain yield of genotypes is close to each other, this method is considered more efficient to select high-yielding and stable genotypes, while based on AMMI method it may be led to select genotypes with low stability due to small contribution to the first and second components of GxE interaction, but low grain yield. Dashtaki *et al*. [28] has emphasized effectiveness of the simultaneous selection for yield and stability method to select high yielding and stable genotypes. Moghadam [29] compared the simultaneous selection for yield and stability with other stability statistics and concluded that this measure due to the emphasis given on stability component could be more reliable.

3.5. Regression Coefficient

The performance of a genotype in an environment depends on a mean performance, a linear response to the environment and deviation from regression. Eberhart and Russell [11], proposed an assessment of cultivar response to environmental changes using a linear regression coefficient and the variance of the regression deviations. A regression coefficient (*bi*) approximating one coupled with deviation from regression (S^2di) of zero indicates average stability. According to this model a regression values above one describe varieties with higher sensitivity to environmental change (below average stability) and greater specificity of adaptability to high yielding environments. A regression coefficient below one provides a measurement of greater resistance to environmental change (above average stability), and thus increases the specificity of adaptability to low yielding environments [30, 31]. The present results indicated that linear regression for the average grain yield of a single genotype on the average yield of all varieties in each environment resulted in regression coefficients (*bi* values) ranging from 0.54 to 1.24. This variation in regression coefficients indicates different responses of varieties to environmental changes (Figure 2 and Table 5). The following varieties viz. Ogolcho, Obora, Dambal and Shorima had mean regression coefficient (bi) close to one; minimum values for deviation from regression, and higher grain yield than the grand mean indicting they are adapted well to all environments (wider adaptation over different environments); whereas the varieties Kingbird with grain yield lower than the grand mean adapted poorly to all environments. Therefore, this variety is resistant to environmental changes and can be recommended for cultivation under unfavourable conditions. Similar findings were reported by different researchers [32, 33, 34, 35, 36]. In contrast, varieties viz. Hidase, Wane, Biqa, Mandoyu and Sanate had regression coefficients greater than 1, and they were regarded as sensitive to environmental changes; therefore, can be recommended for cultivation under favourable conditions (adapted well to good conditions). The varieties viz. Hulluka, Bulluq and Honqolo having the regression coefficient lower than 1 and lower grain yield than the grand mean and adapted badly to poor conditions (poorly adapted across environments and might have specific adaptation to unfavourable conditions); and the variety Lemu adapted moderately to bad conditions [37].

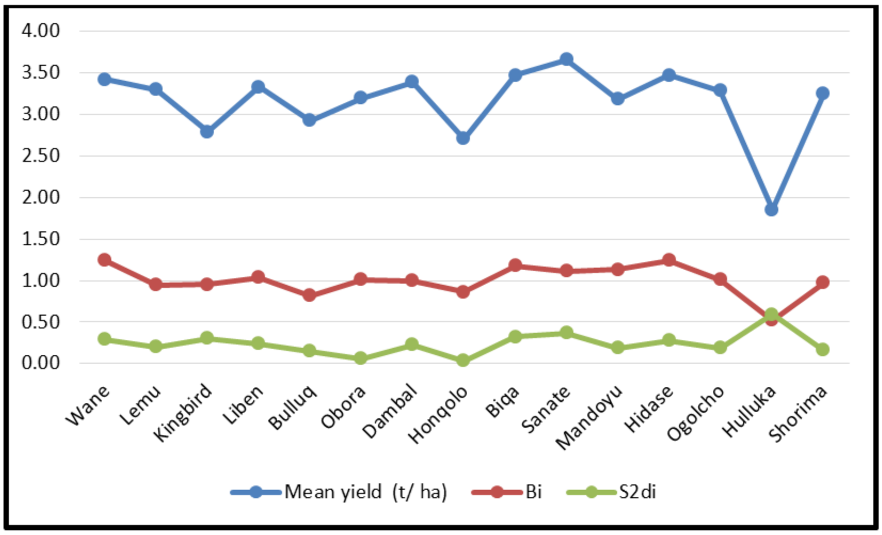

Figure 2. Relationship between the regression coefficient, deviation from regression and mean grain yield.

3.6. Francis and Kannenberg's Coefficient of Variability (CVi)

The mean and CV analysis introduced by Francis [38] was designed to aid in studies on the physiological basis of yield stability. The researcher introduced a simple graphical approach to assess performance and stability concurrently. It measures the grain yield performance and CV for each genotype over all environments. It was found to characterize genotypes in groups rather than individually [14]. Stability and mean yield of the genotypes were being simultaneously considered and genotypes with lower coefficient of variability are considered as stable while, genotypes with higher coefficient variability unstable but the gain yield for selection should be simultaneously considered. In the present study, the varieties viz. Bulluq, Lemu, Dambal, Shorima, Obora, Ogolcho and Sanate had lower coefficient variability and considered as stable. However, the varieties including Hulluka, Wane, Kingbird and Hidase were the most interactive genotype with higher coefficient variations. When both mean grain yield and coefficient of variation are considered the varieties Lemu, Dambal, Shorima, Obora, Ogolcho, Sanate and Liben were the best performed and stable varieties (Figure 3).

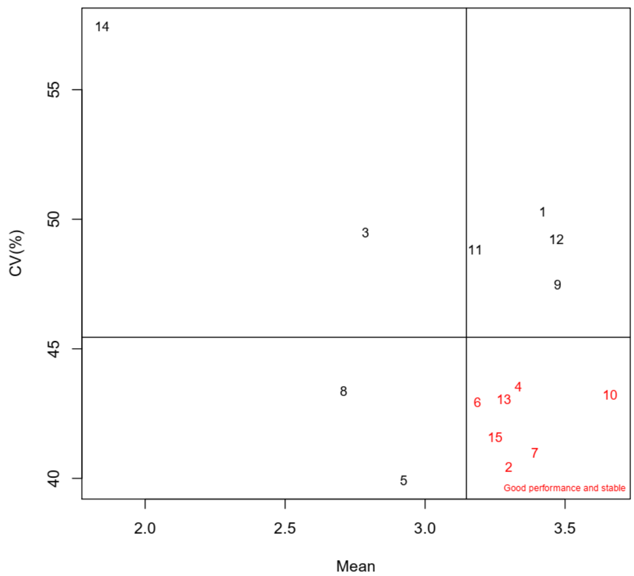

Figure 3. Coefficient of variation as stability parameter.

3.7. Lin and Binns's Cultivar Performance Measure (Pi)

According to Lin and Binns [39] the genotypes with the lowest (Pi) values are considered the most stable. From the present results, the most stable cultivar ranked first for Pi and for mean yield was Sanate followed by Wane, (Table 5). Others with low Pi values and high ranking for mean yield were Hidase and Biqa. The ranks of the Pi measurement and mean yield are in agreement indicating that the Pi measure is more an indication of performance and not really an indication of stability. The most unstable bread wheat varieties according to this analysis were; Hulluka, Kingbird, Honqollo and Bulluq which are also having low yield less than over all mean yields.

3.8. Shukla's Stability Variance Procedure (σ^2)

Shukla [40] stability variance values and the stability ranking as well as the mean yield with its ranking are given in Table 5. The most stable bread wheat varieties as indicated by this stability parameter were Obora, Honqolo, Shorima and Ogolcho and they had small contribution to GxE interaction. The bread wheat varieties with a poor stability according this procedure were Hulluka, Wane, Sanate and Biqa. The bread wheat varieties Sanate and Biqa were respectively ranked first and second for mean yield. The bread wheat varieties Sanate and Biqa showed unstable and ranked 13th and 12th for Shukla's stability variance respectively.

3.9. Wricke's Ecovalence Analysis (Wi)

Wricke [41] defined the concept of ecovalence, to describe the stability of a genotype, as the contribution of each genotype to the genotype x environment interaction sum of squares. Genotypes with low ecovalence have smaller fluctuations across environments and therefore are stable. The most stable bread wheat varieties were Obora, Honqolo, Shorima and Ogolcho. These bread wheat varieties were not the best ranked for mean yield, being 10th, 14th, 9th and 8th respectively. The most unstable bread wheat varieties according to the ecovalence method were Hulluka, Wane, Sanate and Biqa; and these bread wheat varieties were ranked 15th, 4^{rth}, 1st and 2nd for mean yield respectively (Table 5).

4. Summary and Conclusion

Plant improvement involves jointly the manipulation of genetic characteristics to optimize productivity in relation to the limitations of the environmental factors. The combination of rich genomic information and detailed environmental assessments allows not only an enhanced ability to quantify and mitigate the unrepeatable portion of G XE, but also to genetically characterize it in economically important crops in the context of relevant production conditions. In varying environments it may be expected that the interaction of genotype by environment will also be varying and ample. As a result one cultivar may have the highest yield in one environment, while a second cultivar may excel in others. This necessitated the study of genotypes by environment interaction to estimate the magnitude of interactions in the selection of genotypes across several environments by calculating the average performance of the genotypes under evaluation. Several stability parameters and approaches that have been employed in the present study determined stability of bread wheat varieties with respect to yield, stability, and both parameters. In conclusion, the present study found that among the various stability statistical parameters used, nearly all analyses identified the variety Obora as the most stable one followed by Shorima and Dambal with higher grain yields and highest stability for variable environments and would be recommended for wide adaption, and for more favorable environments; while Hulluka and Kingbird were unstable varieties.

Table 5. Mean grain yield (t ha $^{-1}$) and different stability analyses of 15 bread wheat varieties.

S/No	Variety	Grain yield	Bi	S2di	Shukla	Wi	Pi	CV%	ASV	YSI	PCA1	PCA2
1	Wane	3.42	1.24	0.29	0.52	9.61	0.52	50.29	2.73	17	-0.60	-0.1
2	Lemu	3.30	0.94	0.20	0.32	6.02	0.66	40.44	1.22	11	-0.13	0.70
3	Kingbird	2.79	0.95	0.30	0.43	8.00	1.57	49.47	2.44	25	0.53	-0.03
4	Liben	3.33	1.03	0.24	0.36	6.73	0.61	43.52	1.56	12	-0.33	0.21
5	Bulluq	2.92	0.82	0.15	0.33	6.20	1.29	39.90	1.99	22	0.43	0.04
6	Obora	3.19	1.01	0.06	0.16	3.32	0.75	42.92	0.57	11	-0.07	0.31
7	Dambal	3.39	0.99	0.22	0.33	6.32	0.59	40.98	0.95	7	0.21	0.06
8	Honqolo	2.71	0.86	0.03	0.16	3.35	1.52	43.36	1.68	21	0.36	-0.23
9	Biqa	3.47	1.18	0.32	0.51	9.34	0.58	47.46	1.34	7	-0.12	-0.80
10	Sanate	3.66	1.11	0.36	0.52	9.51	0.25	43.22	2.28	12	-0.49	-0.17
11	Mandoyu	3.18	1.13	0.19	0.33	6.26	0.77	48.80	1.97	20	-0.41	-0.42
12	Hidase	3.47	1.24	0.27	0.50	9.25	0.53	49.22	2.82	17	-0.62	0.01
13	Ogolcho	3.28	1.01	0.19	0.31	5.85	0.82	43.05	1.88	16	0.41	0.09
14	Hulluka	1.85	0.52	0.59	1.18	21.08	3.85	57.45	4.59	30	1.00	-0.12
15	Shorima	3.25	0.97	0.16	0.27	5.18	0.73	41.56	1.04	12	-0.17	0.46

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