

Genotype X Environment Interaction for Quality Traits in Advanced Bread Wheat Genotype in Ethiopia

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Abstract

The study was conducted to evaluate the effect of GEI and its magnitude on the grain quality of bread wheat genotypes in Ethiopia. 15 bread wheat genotypes were evaluated using RCBD with four replications at six different locations in Ethiopia during 2017/18 cropping season. Combine Analysis of variance showed highly significant ($P < 0.001$) differences among genotype, environment and GEI for investigated quality traits except GEI shows non-significant difference in dry gluten and gluten index. The environment contributed more than 50% only in PC (83.6%) and HLW (56.1%). The three components, G, E and GxE made almost similar contribution to most of the quality traits (WG, DG and GI), although the contribution of the environment was a little higher. Hardness index was determined mainly by the genotype (69.3%). The contribution of GxE was higher than that of genotype in all quality traits except in HDI and GI, again indicating the important role of GxE in the determination of wheat quality traits. Genotype ETBW9045 and ETBW8065 gave the best value of protein in the favorable means (15.05% and 14.75%) respectively. The Hidase had the highest value of wet gluten (58.2%) and dry gluten (24.38%) in average for all investigated locations (58.2%). GGE biplot declared ETBW9045 (#10) and ETBW8065 (#6) genotypes as stable in all quality. These two genotypes ETBW9045 (#10) and ETBW8065 (#6) are recommended for wide adaptation and for crossing. This study demonstrates success in wheat breeding for improved quality in bread wheat. The study also provides information on the combined stability of improved quality of the nationally important bread wheat genotypes. Therefore, the results of this study could be valuable for national bread wheat breeding programs to develop new varieties with high stable grain quality.

Keywords: Dry Gluten; Protein Content; Wet Gluten

Introduction

Knowledge of the relative contributions of genotype, environment and genotype by environment interaction effects on wheat (*Triticum aestivum L.*) quality leads to more effective selection in breeding programs and

segregation of more uniform parcels of grain better suited to the needs of customers. Grain quality is a complex character that depends on a number of traits, and the individual contribution of each trait varies depending on specific reaction to environmental conditions [1]. Improvement of end-use quality in bread wheat depends

on a thorough understanding of current wheat quality and the influences of genotype, environment and genotype by environment interaction on quality traits. The successful process of wheat breeding is based on the knowledge of characteristics of genotypes, environment and its interaction. Evaluation of genotypes across diverse environments and over several years is needed in order to identify spatially and temporally stable genotypes that could be recommended for release as new cultivars and/or for use in the breeding programs [2].

More information about GE interaction for grain quality characters of bread wheat is needed. It is important to determine and quantify the extent to which factors like the genotypes, environment and genotype x environment interaction contribute to variations in each wheat quality parameter [3]. The performance of many quality characteristics depends greatly on environmental conditions, which result in differential expression of grain quality from site to site. The effects of genotype, environment, and their interaction on wheat quality, determined using multiplication trials have been used to enhance wheat breeding for quality [4,5]. Numerous investigations have been conducted on the influence of environmental conditions Peterson et al. [1], Guttieri, et al. [6] on particular quality traits. The results of these investigations showed that environments have an influence on quality traits, and, in some environmental conditions the direction of influence on the trait is known. However, it is the cultivar that responds to the growing conditions and several researches have shown evidence for variation in genetic responses to environments for the various measures of end-use quality [7]. Several studies have generally shown that environment, genotype and G ×

E interactions are all significant factors contributing to different expression of quality [8,9].

There is a lack of information on the effect of GE interaction on the quality of bread wheat in Ethiopia. In order to develop bread wheat genotypes acceptable to farmers, the stability of the grain quality traits must be determined. In Ethiopia, many studies have been carried out on bread wheat to evaluate effects of genotype, environment and their interaction. However no information is available on the GEI, stability in grain yield performance of bread wheat genotypes and information is limited on the relative importance of the effects of genotype, environment and GEI on the quality characteristics of wheat grown in Ethiopia. Now a day's emphasis has been given to the quality analysis of bread wheat. This showed the importance of developing a research activity to investigate the differential expression in different quality traits among the bread wheat varieties developed by the national wheat-breeding program. Keeping in view the importance of GEI in reference to its application for identifying stable genotypes, the present experiment was conducted with the objective to evaluate the effect of genotype x environment interaction and its magnitude on the grain quality of bread wheat genotypes in Ethiopia.

Material and Methods

Thirteen advanced bread wheat genotype and two recently released varieties were evaluated across six locations in 2017 / 2018 main cropping seasons. Description of test locations and wheat genotype is provided in (Tables 1 & 2) respectively.

Loc	Annual Temp (°c)		Annual RF(mm)	pH	Soil type	Altitude	Geographic position	
	Latitude	Longitude						
Holeta	6.2	22.1	1044	5	clay loam	2400	-	-
Dhera	14	27.8	680	7	silt loam	1650	08°19'10"N	39°19'13"E
A. Robe	6	21.1	890	5.6	vertisol	2420	07°53'02"N	39°37'40"E
Kulumsa	10.5	22.8	820	6	clay soil	2200	08°01'10"N	39°09'11"E
Bekoji	7.9	18.6	1020	5	clay loam	2780	07°32'37"N	39°15'21"E
Asasa	5.8	24	620	6.5	clay loam	2000	07°07'09"N	39°11'50"E

Table 1: Location and descriptions of weather condition for six locations.

The field experiment was laid out in RCBD with four replications. The experimental field plot was 6 rows of 2.5 m long with a 0.2 m inter-row spacing. Each plot was planted at a rate of 150 kg ha⁻¹. The fertilizer application

and other crop management practices were done as per recommendations of each test locations. Weeds grown in the plots were removed manually starting from two weeks after sowing.

Name	Pedigree
Lemu	WAXWING*2/HEILO
ETBW8070	Line 1 Singh/ETBW4919
ETBW8078	Line 1 Singh/(Cham6/WW1402)
ETBW8084	Line 3 Singh/(Cham6/WW1402)
ETBW8311	ND643/2*WBLL1/3/KIRITATI//PRL/2*PASTOR/4/KIRITATI//PBW65/2*SERI.1B
ETBW8065	Line 1 Singh/ETBW4919
ETBW8427	SERI.1B//KAUZ/HEVO/3/AMAD/4/PYN/BAU//MILAN/5/ICARDA-SRRL-1
ETBW8459	CHIL-1//VEE'S'/SAKER'S'
ETBW9037	SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU
ETBW9045	KINDE/4/CMH75A.66//H567.71/5*PVN/3/SERI
ETBW8075	Line 1 Singh/(Cham6/WW1402)
ETBW9464	MARCHOUCH*4/SAADA/3/2*FRET2/KUKUNA//FRET2*2/4/TRCH/SRTU//KACHU
ETBW9466	ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARRO SA(224)//2*OPATA*2/6/HUW234+LR34/PRINIA//UP2338*2/VIVITSI
ETBW9470	BAVIS#1/5/W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1
Hidasse	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC-1/AE.SQUAROSA(224)//OPATTA

Table 2: The names, pedigree and selection history of the genotypes were evaluated in the experiment in 2017/18 cropping season at six locations.

Quality Assessment

Wheat samples was uniformly divided through Boerner Divider and analyzed for quality characteristics such as HLW, hardness index, **protein** and gluten according to standard procedures as described in AACC [10].

Protein Content (PC)

PC in grain was determined Near Infra-Red Spectroscopy [10].

Hectoliter Weight (HLW)

HLW was determined using the approved method of the American Association of Cereal Chemists 55-10 and the results was reported in kg/hL whereas TKW was taken on analytical balance after counting wheat kernels on seed counter [10].

Gluten Content

The gluten quality was evaluated by the standard methods of AACC test procedure [10].

Statistical Analysis

The grain quality data for fifteen bread wheat from six environments were used to combine analysis of variance

(ANOVA) to determine the effects of environment, genotype and GEI. Before combine the data Bartlett's test was used to determine the homogeneity of variances between environments to determine the validity of the combined ANOVA on the data and the data collected was homogenous The GGE biplot is a biplot that displays the GGE part of MET data. The basic model for a GGE biplot is:

$$Y_{ij} - \mu - \beta_j = \lambda_1 \xi_{i1} \eta_{j1} + \lambda_2 \xi_{i2} \eta_{j2} + \epsilon_{ij}$$

where Y_{ij} is the mean for the i^{th} genotype in the j^{th} environment, μ is the grand mean β_j is the main effect of environment j , λ_1 and λ_2 are the singular values of the 1st and 2nd principal components (PC1 and PC2), ξ_{i1} and ξ_{i2} are the PC1 and PC2 scores, respectively, for genotype i^{th} , η_{j1} and η_{j2} are the eigenvectors for the j^{th} environment for PC1 and PC2 and ϵ_{ij} is the residual error term.

Result and Discussion

Combined ANOVA depicted very highly significant differences among environments and among genotypes for all quality traits. The GxE interaction was also very highly significant for all traits except for dry gluten content and gluten index (Table 3).

Traits	Source of variation					
	Env't(5)	Rep(evn't)(18)	Genotype(14)	GEI (70)	Error(267)	CV%
HLW	609.51***	8.29	76.49***	20.02***	2.57	2.26
TKW	505.65***	11.38	295.2***	60.4***	2174.36	8.06
HDI	955.77***	35.47	1899.35***	99.85***	12.84	4.88
PC	182.75***	2.38	2.32***	2.1***	0.5	4.96
WG	3464.92***	105.2	523.25***	155.78***	95.89	21.69
DG	560.07***	21.55	159.03***	36.69 ^{ns}	34.37	33.95
GI	2752.13***	83.61	959.46***	146.93 ^{ns}	114.92	14.91

Table 3: ANOVA for grain quality of 15 bread wheat genotypes over six locations.

*** Highly significant at $P < 0.001$

Where HLW=hectoliter weight, TKW=thousand kernel weight, HDI=hardness index, PC=protein content, WG=wet gluten content, DG=dry gluten content, GI=gluten content, CV=coefficient of variations

This indicated that quality traits of bread wheat were highly influenced by environmental factors. This significance of environment on quality traits of wheat is in agreement with results of previous investigations those reported that environment had significant effect on grain quality of bread wheat genotypes [9,11,12]. The greater significance of environmental variation for protein content in bread wheat, in this study, is in agreement with the results of Drezner, et al. [11], Bilgin, et al. [13] those stated strong environmental impact on bread wheat protein content. Many other studies demonstrated that environmental conditions have a larger effect on protein content than the genotype [14,15]. The greater significance of environmental variation for wet gluten content in bread, in this study, is in agreed with the results of Drezner et al. [11], Bilgin, et al. [13] stating that strong environmental impact on bread wheat wet gluten content and also in line with other finding of Mikulíková,

et al. [16], Zecevic, et al., [12] those reported that wet gluten content significantly depended on environment, cultivar, year and their interactions. In this result genotype as source variation was least important than environmental and GEI. Significant genotype x environment interaction was found for all quality traits studied (except for dry gluten and gluten index). This would mean that evaluation of bread wheat genotype of several environments would give a more accurate estimate of their quality potential.

The relative contribution of genotype, environment and their interaction to the total variation of 10 quality traits is shown in (Table 4). For all the traits investigated in this study, the component of variation due to environment was larger than the component of variation due to the genotype and genotype by environments interaction and varied from 12.5-83.8%.

Traits	GENOTYPE	ENVIRONMET	G XE interaction
Hardness index	69.3	12.5	18.2
Protein content	3	83.6	13.5
Wet gluten content	20.6	48.7	30.7
Dry gluten content	29.3	36.9	33.8
Gluten index	35.8	36.7	27.4
Hectolitre weight	20.4	56.1	23.5
Thousand kernel weight	38	23.2	38.8

Table 3: Proportion of Total Treatment (G+E+GEI) contributed by G, E and GxE Interaction In quality traits.

The variances associated with environment effects were larger than the variances associated with genotypes effects for all quality traits (except thousand kernel weight and hardness index) indicating the relatively greater influence of environment factors and less influence by genotypic effects. The environment contributed more than 50% only in PC (83.6%) and HLW (56.1%). The dominant contribution of environment over

that of the genotype and GEI was detected for protein content, accounting for 83.6% of sum of squares. According to Williams, et al. [9] protein content was one of the most responsive traits since it was predominantly affected by environment and GEI. The greater significance of environmental variation for protein content in bread wheat, in this study, is in agreed with the results of Drezner et al. [11], Bilgin, et al. [13], stating strong

environmental impact on bread wheat protein content. Many other studies demonstrated that environmental conditions have a larger effect on protein content than the genotype [14,15]. The three components, G, E and GxE made almost similar contribution to most of the quality traits (WG, DG and GI), although the contribution of the environment was a little higher. Hardness index was determined mainly by the genotype (69.3%). Strong genotype effects for hardness should be expected when cultivars of different hardness have been tested because hardness is relatively simply inherited [9]. The contribution of GxE was higher than that of genotype in all quality traits except in HDI and GI, again indicating the important role of GxE in the determination of wheat quality traits. Panozzo & Eagles [17] found that the relative influence of GEI was greater than that of genotype on the variability of some quality traits but this was always less than the influence of environment.

Mean Comparison of the Genotypes for Grain Quality

The differences among the genotype were important. The HLW of the genotypes ranged from 66.58 to 73.56

kg/hl and TKW ranged from 27.32 to 40.89g) (Table 5). The result of this finding was in line with finding of Zhang who reported that the range in thousand kernel weight and hectoliter weight among environments (29.3-39.6 g and 74.1-78.8 kg/hL) was somewhat larger than that measured across genotypes (31.0-38.0g and 75.5-77.4 kg/hL). The highest mean values of HLW were observed from genotype ETBW9045 (73.56 kg/hl) while the lowest mean values of HLW were obtained from genotype ETBW9464 (66.58 kg/hl) (Table 5). The highest mean value of TKW was obtained from ETBW9470 (40.89g), while the lowest was that of ETBW8075 (27.32g) (Table 5). Generally, the results of the HLW and TKW demonstrated that the environmental and wheat genotypes could affect the grain physical characteristic and hence the flour yield and enduse quality. Previous reports showed that environmental conditions and fertilizers application had a significant impact on the HLW and TKW of various wheat genotypes [18-20]. The highest mean values of hardness index was observed from genotype ETBW9466 (#13), while the lowest hardness index from Hiddase (#15).

SN	Genotype	HLW	TKW	HDI	PC	WG	DG	GI
1	Lemu	69.62 ^{d-f}	31.93 ^e	68.92 ^{ed}	14.3 ^{c-f}	44.11 ^{cb}	16.82 ^c	73.33 ^{cde}
2	ETBW8070	73.38 ^{ab}	35.45 ^{b-e}	68.63 ^{ed}	14.27 ^{c-f}	45.37 ^{cb}	17.13 ^c	65.20 ^g
3	ETBW8078	69.75 ^{de}	33.82 ^{de}	66.28 ^{gf}	14.36 ^{b-d}	44.7 ^{cb}	17.60 ^{cb}	71.44 ^{def}
4	ETBW8084	70.18 ^{c-e}	35.71 ^{b-e}	72.45 ^{cb}	14.3 ^{c-f}	45.43 ^{cb}	17.71 ^{cb}	67.16 ^{fg}
5	ETBW8311	70.62 ^{b-e}	31.4 ^{ef}	71.97 ^{cb}	14.29 ^{d-f}	44.57 ^{cb}	15.99 ^{cd}	72.60 ^{def}
6	ETBW8065	73.02 ^{ab}	34.56 ^e	71.94 ^{cb}	14.75 ^{ab}	46.12 ^{cb}	16.83 ^c	69.28 ^{efg}
7	ETBW8427	72.69 ^{a-c}	39.22 ^{ab}	71.78 ^{cb}	14.07 ^{d-f}	36.49 ^d	12.81 ^d	78.97 ^{abc}
8	ETBW8459	71.13 ^{a-e}	33.18 ^e	79.62 ^a	14.51 ^{bc}	42.61 ^c	15.59 ^{cd}	76.43 ^{abcd}
9	ETBW9037	72.04 ^{a-d}	35.32 ^{b-e}	70.99 ^{cb}	14.63 ^{bc}	42.69 ^c	16.35 ^c	82.23 ^a
10	ETBW9045	73.56 ^a	38.66 ^{a-c}	70.52 ^{cd}	15.04 ^a	45.39 ^{cb}	17.85 ^{cb}	70.55 ^{defg}
11	ETBW8075	67.06 ^{ef}	27.32 ^f	67.68 ^{ef}	14.37 ^{c-e}	46.72 ^{cb}	17.66 ^{cb}	74.48 ^{cde}
12	ETBW9464	66.58 ^f	34.7 ^{c-e}	72.75 ^b	13.96 ^{ef}	44.46 ^{cb}	16.54 ^c	76.10 ^{bcd}
13	ETBW9466	69.73 ^{de}	31.93 ^e	80.43 ^a	14.27 ^{c-f}	41.26 ^{cd}	15.18 ^{cd}	80.69 ^{ab}
14	ETBW9470	70.31 ^{a-e}	40.89 ^a	65.07 ^g	13.92 ^f	48.35 ^b	20.56 ^b	79.17 ^{fg}
15	Hidasse	69.76	38.21 ^{a-c}	41.0 ^h	13.94 ^{ef}	58.82 ^a	24.38 ^a	58.55 ^h
	Mean	70.56	35.07	69.66	14.34	45.23	17.29	73.79
	LSD _{0.5}	2.71	4.47	1.29	0.4	3.52	2.11	6.59

Table 4: Mean values of quality traits of bread wheat genotypes tested at six locations.

Values with the same letter in a column are not significantly different.

Where: HLW= hectoliter weight, TKW= thousand kernel weight, HDI= hardness index, PC= protein content, WG=, wet gluten content, DG=dry gluten content, GI=gluten index, LSD=Least significance difference

Wheat grain protein is of primary importance in determining the end use quality of the flour and variations in both protein content and composition could significantly affect the flour quality. In this result protein

content varied from 13.93 to 15.05 %. This result was in agreed with finding of Taghouti, et al. [21] who reported that the protein content of the genotypes varied from 12.52 to 16.28% with an average value of 14.58%. This

result also was in line with the finding of Branković, et al. [22] who reported that protein content was varied from 12.4 to 15.4% in bread wheat. The differences among the genotype were important. Genotype ETBW8065, ETBW8484 and ETBW9464 gave the best value of protein in the favorable means (15.05%, 14.76% and 14.64% respectively (Table 5).

The genotypes used in the study gave rise to significant differences in wet gluten values. In this result the wet gluten ranged from 36 to 58% which is larger range of variation compared to variation of 24-40.5% for wet gluten content reported in bread wheat by Bilgin, et al. [13]. Similarly higher and wider range in comparison to results who reported that the wet gluten content ranged from 22.8% to 30.3% for bread wheat genotypes [22]. The highest mean value for wet gluten was obtained for Hidasse (58.82%), while the lowest value was recorded for genotype ETBW8427 (36.49%) (Table 5). The highest mean for dry gluten was obtained for variety Hiddase 24.38% while the lowest value was obtained for genotype ETBW8427 (12.81%) (Table 5). The determination of the gluten index is a widely used method for analyzing the gluten strength of bread wheat and durum wheat genotypes. The gluten index (GI) is a predictive method of gluten strength and thus it is a good indicator for gluten quality and quantity [23-28]. Among genotypes, the results showed that genotype ETBW9037 had the highest (82.23%) mean value of gluten index while genotype Hidase had the lowest (58.55%) mean value (Table 5). The released variety Hidasse (#15) had low hardness index, protein content, and gluten index and high wet and dry gluten contents when compared with advanced genotypes (Table 5).

Difference between Environments for Grain Quality

Wide ranges in all quality parameters and significant differences among samples collected from the various locations were observed. When locations were compared, the highest hectoliter weight was obtained from Holeta, while lowest from Asasa. Kulumsa, Arsi Robe and Holeta had greater than over all mean of HLW and Asasa, Dhera and Bekoji had low HLW less than over all mean. There the difference in TKW between all six locations. Arsi Robe had high TKW when compared to other location followed by Kulumsa and Asasa had low TKW. The highest hardness index was obtained from Holeta while the lowest hardness index obtained from Dhera.

Wheat samples from Dhera are characterized by high protein content (16.43%) and wet gluten(52.2%) when compared with other locations., while the lowest protein content and wet gluten content obtained from Arsi Robe. According to locations means the wet gluten contents of all wheat genotypes in the current study are more than 32.27%. Recently, in a multi-environment trial for Turkish wheat genotypes the wet gluten content was varied from 28 to 37% depending on the variation in the Kaya & Akcura [20]. Environment, genotype, and their interaction. Concerning growing area, dry gluten content was higher at Asasa (19.54%) followed by Dhera (19.23%) and Kulumsa (18.87%), while the lowest mean value of dry gluten content was obtained from Arsi Robe (11.79%) (Table 6). Throughout the six growing environments, the highest mean value for gluten index obtained were 78.18% and 78.06% at Asasa and Arsi Robe respectively, while the lowest value (60.36%) was observed at Holeta (Table 6).

Loc	HLW	TKW	HDI	PC	WG	DG	GI
KUL	70.76 ^c	36.64 ^b	68.98 ^c	15.31 ^b	48.83 ^a	18.865 ^a	69.25 ^c
ASA	66.42 ^e	30.89 ^e	66.78 ^d	15.36 ^b	51.63 ^a	19.538 ^a	78.18 ^a
DHE	69.57 ^d	35.14 ^c	62.85 ^e	16.43 ^a	52.2 ^a	19.238 ^a	75.41 ^{ab}
BKJ	68.97 ^{cd}	34.89 ^c	72.77 ^{ab}	13.52 ^c	40.99 ^c	15.507 ^b	72.26 ^b
ARO	72.44 ^b	38.97 ^a	71.55 ^b	11.53 ^d	32.27 ^d	11.788 ^c	78.06 ^a
HOL	75.68 ^a	32.37 ^d	73.10 ^a	13.85 ^c	44.93 ^b	18.667 ^a	60.36 ^d
Mean	70.67	34.82	69.34	14.33	45.14	17.27	72.25
CV	2.26	8.2	5.17	5.02	21.69	33.95	25.08
LSD%	2.72	1.29	1.29	0.26	3.5	2.1	3.8

Table 5: Mean values of quality traits of bread wheat at six locations.

Values with the same letter in a column are not significantly different

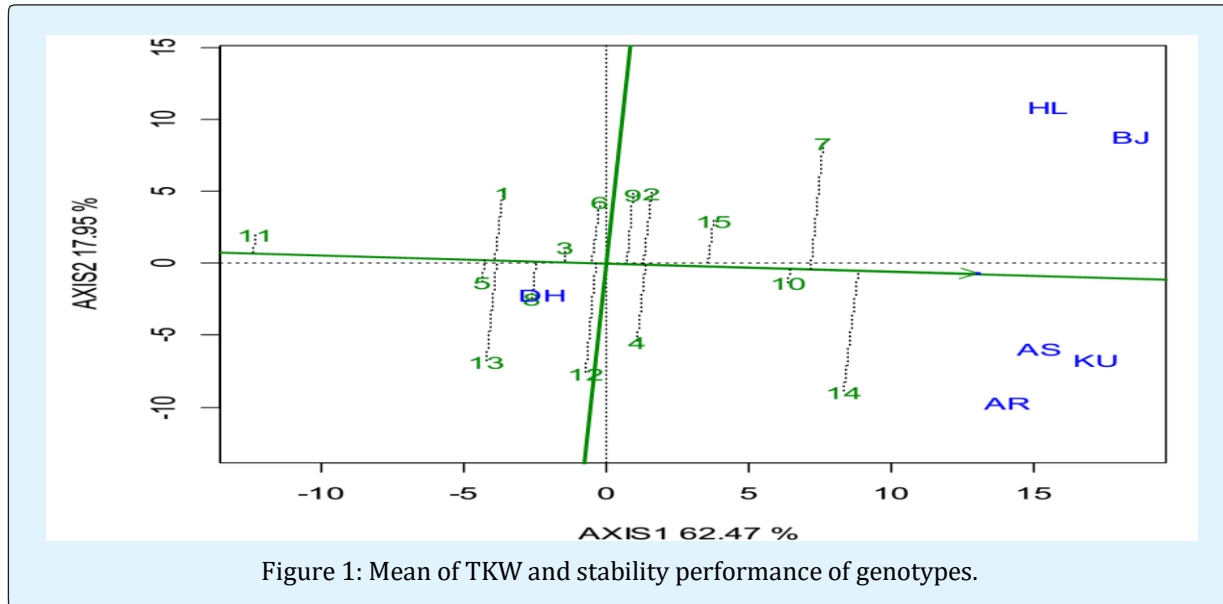
ARO= Arsi Robe, ASA= Asasa, BKJ= Bekoji, DHE= Dhera, HOL= Holeta and KUL=Kulumsa

GGE Biplot Analysis demonstrated that ETBW9470 (G14), ETBW8427 (G7) and ETBW9045 (G9) were the most superior genotypes for TWT (Figure 1). A longer

projection to the AEC ordinate, regardless of the direction, represents a greater tendency of the GE interaction of a genotype, which means it is more variable and less stable

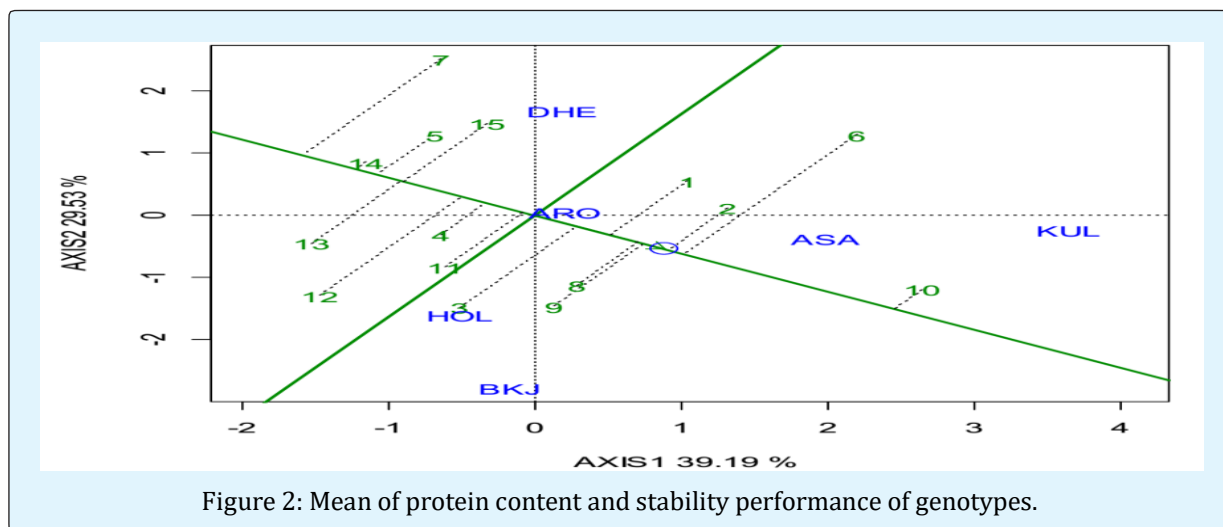
across environments or vice versa. For instance, genotype G3 (ETBW8078) and G8 (ETBW8459) were more stable as well as low TKW. Considering simultaneously high mean and stability, Genotype G9 (ETBW9037), G2 (ETBW8070) and G15 (Hiddase) showed the best performances (Figure 1), suggesting their adaptation to a

wide range of environments. Conversely genotype G7 (ETBW8427) and G14 (ETBW9470) both had high TKW, but were less stable. Genotype G11 (ETBW8075) was the least stable with low TKW and had a large contribution to the GEI, having the longest distance from the average environment (Figure 1).



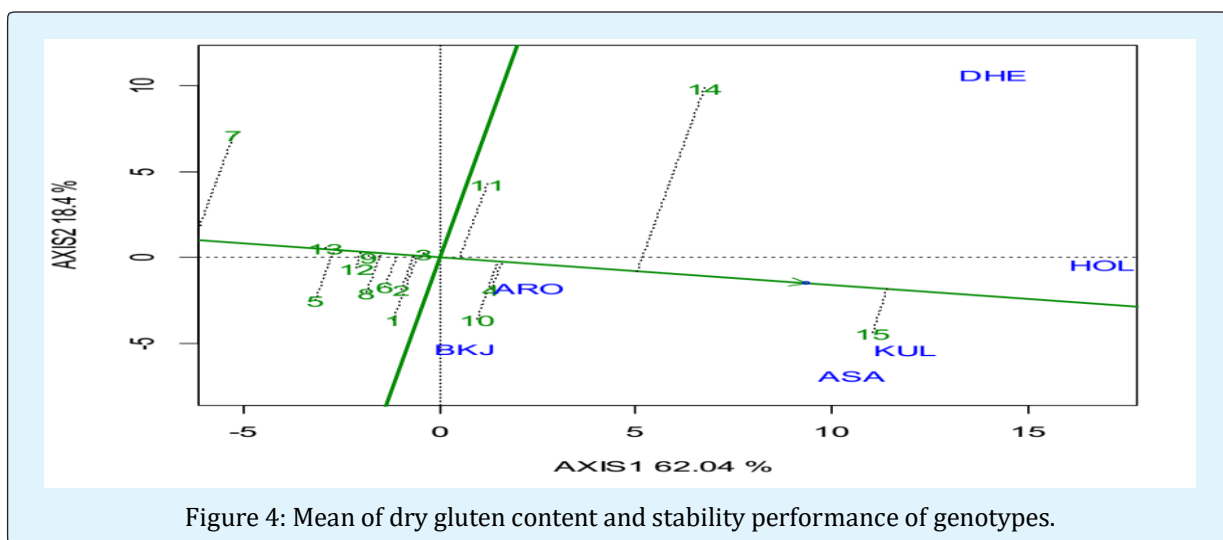
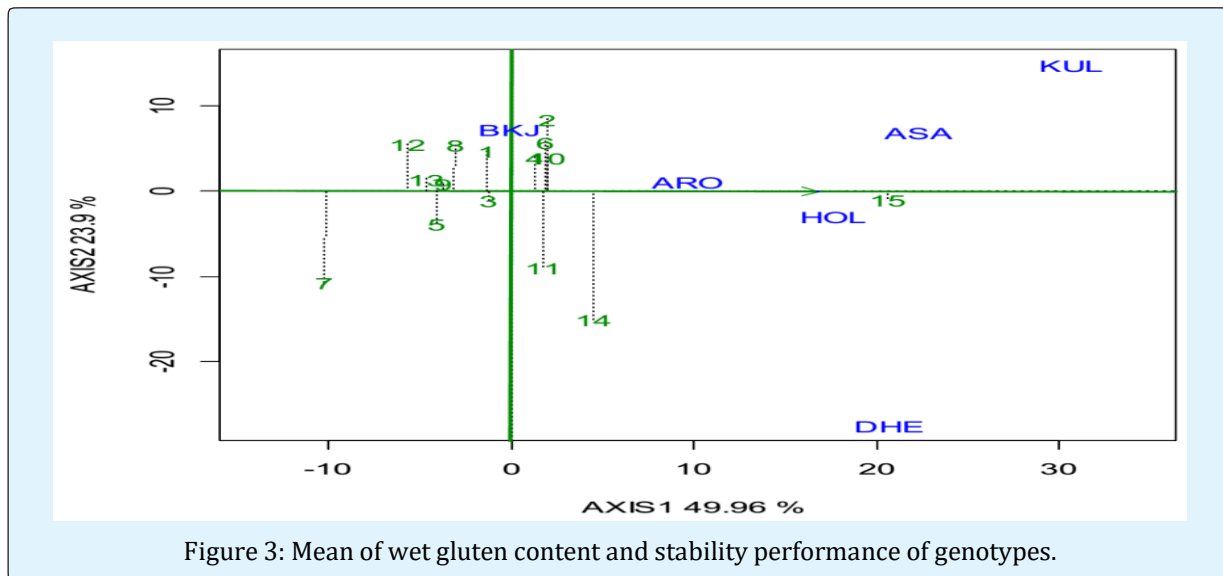
The genotype ETBW9045 (G10), ETBW8065 (G6) and ETBW9037 (G9) had high protein content when compared with other genotypes (Table 5). GGE biplot analysis demonstrated ETBW9045 (G10), ETBW8065 (G6) and ETBW9037 (G9) were the most superior genotypes for TWT (Figure 2). The genotype G4 (ETBW8084) and G11 (ETBW8075) were more stable. The genotype G4 (ETBW8084) has low protein content (less than over all

mean) but, G11 (ETBW8075) high protein content which is greater than mean. The genotypes G6 (ETBW8065) has high protein content, but was less stable. Genotype G7 (ETBW8427) was the least stable with low protein content and had a large contribution to the GEI, having the longest distance from the average environment (Figure 2).



Based on the GGE biplot analysis Hidasse (G15), ETBW9470 (G14) and ETBW8065 (G6) were the most superior for wet gluten content (Figure 3). The genotype ETBW8078 (G3), ETBE9037 (G9), ETBE8084(G4) and ETBW9045(G10) were the most stable. The genotype ETBW8078 (G3) and ETBE9037 (G9), had low wet gluten content. Genotype ETBE8084 (G4) and ETBW9045 (G10) had high wet gluten content. Genotype ETBW9470 (G14) has high wet gluten content and less stable (Figure 3). Genotype ETBW8427 (G7) was least stable and has low wet gluten content (Figure 3). The GGE biplot analysis of the dry gluten content also identified Hidasse (G15), ETBW9470 (G1) and ETBW9045 (G10) as the most superior genotypes (Figure 4). The genotype ETBW8078 (G3) and ETBE8084 (G4) were the most stable. The genotype ETBW8078 (G3) has low dry gluten content.

Genotype ETBW8084 (G4) has high dry gluten content. Genotype ETBW9470 (G14) has high dry gluten content and less stable (Figure 4). Genotype ETBW8427 (G7) was least stable and has low dry gluten content (Figure 4). GGE biplot declared ETBW9045 and ETBW8065 as stable genotypes for quality traits across locations. The GGE biplot analysis allowed identification of superior genotypes for quality-related traits. However, genotypic superiority based on the GGE biplot analysis, as shown by GGE rank, differed for quality traits among the genotypes. The superior genotypes were not the same for the individual quality traits. However, a few genotypes were stable for quality-related traits. This is in agreement with the results published by Grausgruber who reported the possibility of identifying wheat genotypes stable for multiple quality traits.



Conclusion

Quality traits of grain were affected by genotype, location and their interactions. Growing location had significant effect on quality traits. Significant differences among wheat genotype according to analyzed quality parameters were established. This difference was based on genetic specificity of wheat genotype according to expression of quality characteristics and genotype reaction to environmental factors which were different in year of investigation. The results showed that the genotype ETBW9045 had excellent HLW and genotype ETBW9470 had excellent TKW. Genotype ETBW9045 (15.05%) and ETBW8065 (14.75%) gave the best value of protein content. The Hidase had the highest value of wet gluten (58.2%) and dry gluten (24.38%) in average for all investigated locations (58.2%). According to locations means, both protein and wet gluten content was measured at location Dhera.

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