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Effect of Genotype by Environment Interactions on Quality Traits of Bread Wheat in Ethiopia

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ABSTRACT

The presence of genotype by environment interaction complicates selection of superior genotypes. 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 4 replications at 6 different locations in Ethiopia. Analysis of variance showed highly significant (P<0.001) differences among genotype, environment and its interactions for investigated quality properties. The results showed that the genotype ETBW9045 had excellent HLW followed by ETBW8070 (73.38 kg/hl) and ETBW8065 (73.02 kg/hl), while the lowest mean values of HLW was obtained from genotype ETBW9464 (66.58 kg/hl) and genotype ETBW9470 had excellent TKW followed by ETBW8427 (39.22 g), while the lowest was that of ETBW8075 (27.32 g). The mean value of moisture content of wheat genotype was ranged from 10.5% to 10.99%. In this result protein content varied from 13.93 to 15.05%. Genotype ETBW8065, ETBW8484 and ETBW9464 gave the best value of protein in the favorable means (15.05%, 14.76% and 14.64%) respectively, while the genotype ETBW9470 had lowest mean value of protein. The Hidase had the highest value of wet gluten (58.2%) and dry gluten(24.38%) in average for all investigated locations (58.2%), while lowest wet gluten and dry gluten was obtained from genotype ETBW8427 with the value of (36.49%) and 12.81% respectively. 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. Regarding the environments, the highest mean values of HLW for all genotypes were at Holeta (75.68 kg/hl), while the lowest values were at Asasa (66.42 kg/hl). The highest mean values of TKW were recorded at Arsi Robe (38.97 g) and lowest mean value at Asasa (30.89 g). According to locations means, both protein and wet gluten content the highest wet gluten was measured at location Dera, while the lowest at location Arsi Robe. The highest mean value for gluten index obtained were 78.18% at Asasa, while the lowest value (60.36%) was observed at Holeta.

Key words: *Bread wheat; Genotype; HLW; TKW; Location*

Introduction

Wheat is an important and most widely cultivated food crop in the world and quantity produced is more than that of any other crop, feeding about 40% of the world population. This crop played a central role in combating hunger and improving the global food security. The grains of this plant provide about 20% of all calories and proteins consumed by people on the globe [1].

The basic principles to quality improvement are understanding effects of GE interactions on the expression of quality traits and understanding genetic control and diversity associated with quality traits [2]. 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 [3]. The ideal cultivar for high grain yield or for any other desirable traits needs to express genetic potential with low value of variance in different environmental factors of growing.

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 [4]. The magnitude of the effect of genotype and environment differs among most quality components [5,6]. The presence of GE interaction complicates selection of superior genotypes and understanding of environmental and genotypic causes of significant GE interaction is important at all stages of plant breeding [7]. The interaction of environmental and genetic factors on wheat plants, have effect on grain quality as well as gluten quality [8]. Several studies have generally shown that environment, genotype and GE interactions are all significant factors contributing to different expression of quality [9,10]. For an effective selection for a particular trait, it is important to determine and quantify the extent to which factors like the genotype, environment and genotype x environment interaction contribute to variations in each wheat quality parameter [2]. The understanding of genotype, environment and genotype x environment interaction effects is essential to help breeders to set proper objectives and strategies to develop wheat varieties with high yield potential as well as with specific and consistent quality attributes to meet market needs [10]. The objective of this research was to evaluate the effect of genotype x environment interaction and its magnitude on the grain quality of bread wheat genotypes in Ethiopia.

Materials 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 table 1 and 2, respectively.

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.

Quality Assessment

Wheat samples was uniformly divided through Boerner divider and analyzed for quality characteristics such as HLW, grain hardness, moisture content, protein and gluten according to standard procedures as described in **AACC (2000**).

Protein Content (PC)

PC in grain was determined Near Infra-Red Spectroscopy [11].

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 [11].

Gluten Content

The gluten quality was evaluated by the standard methods of AACC test procedure [11].

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 AMMI analysis was performed using the model suggested by Crossa et al. as [12]:

$$Y_{ij} = \mu + G_i + E_j + \sum_{n=1}^{n} \lambda_n \alpha_{in} y_{jn} + e_{ijk}$$

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

Loc	Annual Temp (°c)		Annual RF(mm)	pH	Soil Type	Altitude	Geographic Position		A. ecology
							Latitude	Longitude	
Holeta	6.2	22.1	1044	5	clay loam	2400			Highland
Dhera	14	27.8	680	7	silt loam	1650	08°19'10"N	39°19'13"E	D. prone
A. Robe	6	21.1	890	5.6	vertisol	2420	07°53'02"N	39°37'40"E	W. logged
Kulumsa	10.5	22.8	820	6	clay soil	2200	08°01'10"N	39°09'11"E	Midland
Bekoji	7.9	18.6	1020	5	clay loam	2780	07°32'37"N	39°15'21"E	Highland
Asasa	5.8	24	620	6.5	clay loam	2000	07°07'09"N	39°11'50"E	T. d. prone

Table 2: The names, pedigree and selection history of the genotypes were evaluated in the experiment in 2016/17 cropping season at six locations.

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.SQUARROSA(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

Where Y_{ij} is the yield of the i^{th} genotype in the j^{th} environment, μ is the grand mean, G_i is the mean of the i^{th} genotype minus the grand mean, E_j is the mean of the j^{th} environment minus the grand mean, λ_n is the square root of the Eigen value of the principal component analysis (PCA) axis α_{in} and y_{jn} are the principal component scores for PCA axis n of the i^{th} genotype and j^{th} environment and e_{ijk} is the error term.

Results and Discussion

Physical Quality

AMMI analysis showed highly significant (P<0.001) differences among genotypes, environment and genotypes x environments interaction for the studied physical quality traits (Table 3).

Hectoliter weight

AMMI analysis of variance showed that the strongest influence for HLW had environment, 33.1% while the lowest influence had GEI and genotype respectively 25.97% and 25.28% (Table 3). This strong influence of environment on HLW is in agreement with Kaya and Akcura [6]. In contrast Finlay et al. indicate that HLW mainly influence by genotype when compared with the environment and GEI [9]. Results from AMMI analysis showed that the PCA1 of the interaction captured 62.9% of the interaction sum of square whereas, PCA 2 of the interaction capture 19.5% of the interaction sum of square. The other interaction effects explained by the remaining principal components (Table 3).

The performance for physical quality traits varied across environments. The highest mean values of HLW was observed from genotype ETBW9045 (73.56 kg/hl) followed ETBW8070 (73.38 kg/hl) and ETBW8065 (73.02 kg/hl), while the lowest mean values of HLW was obtained from genotype ETBW9464 (66.58 kg/hl) (Table 4). Regarding the environments, the highest mean values of HLW for all genotypes were at Holeta (75.68 kg/hl), followed by Arsi Robe (72.44 kg/hl), while the lowest values were at Asasa (66.42 kg/hl) (Table 5).

Thousand kernel weight

The AMMI analysis for TKW at six environments showed that TKW was significantly affected by GEI, which explained 32.32% of the total treatment (G+E+GEI) variation, whereas the genotype and environment were significant and accounted for 31.6 and 19.33%, respectively. Results from AMMI analysis showed that the IPC1 captured 39.1% of the interaction sum of square TKW, IPC2 capture 31 of the interaction sum of square. The other interaction effects explained by the remaining principal components. The mean squares of TKW for IPC1 and IPC2 cumulatively contributed to 70.1% of the total GEI (Table 3).

The highest mean value of TKW was obtained from ETBW9470 (40.89 g) followed by ETBW8427 (39.22 g), while the lowest was that of ETBW8075 (27.32 g) (Table 4). Regarding the environments highest mean value TKW was recorded at Arsi Robe (38.97g), followed by Kulumsa (36.64 g) and lowest mean value at Asasa (30.89 g) (Table 5). Previous reports showed that environmental conditions and fertilizers application had a significant impact on the TKW and HLW of various wheat genotypes [6,13,14].

Table 3: AMMI analysis of HLW and TKW of 15 bread wheat genotypes across 6 environments.

	Hectolitre Weight			Thousand Kernel Weight	
Source of variation	**D f**	**SS**	**SS%**	**SS**	**SS%**
Genotype	14	1070.96***	25.28	4132.7***	31.6
Rep(Env)	18	154	-	204.8	-
Environment	5	3047.50***	33.1	2528.2***	19.33
GEI	70	1356.56***	26.97	4227.6***	32.32
PC1	18	509.19***	62.9	1653.15***	39.1
PC2	16	158.16***	19.5	1310.55***	31
PC3	14	84.58**	10.4	994.83***	23.5
Error	252	735.02	-	2174.36	-
Total	359	6219.96	-	13079.43	-
Mean	-	71.01	-	34.82	-

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

Genotype	HLW	TKW	MC	PC	WG	DG	GI
Lemu	69.62	31.93	10.502	14.300	44.11	16.821	73.33
ETBW8070	73.38	35.45	10.813	14.272	45.37	17.13	65.20
ETBW8078	69.75	33.82	10.911	14.365	44.7	17.60	71.44
ETBW8084	70.18	35.71	10.759	14.301	45.43	17.71	67.16
ETBW8311	70.62	31.40	10.792	14.292	44.57	15.99	72.60
ETBW8065	73.02	34.56	10.779	14.757	46.12	16.83	69.28
ETBW8427	72.69	39.22	10.687	14.077	36.49	12.81	78.97
ETBW8459	71.13	33.18	10.765	14.517	42.61	15.59	76.43
ETBW9037	72.04	35.32	10.837	14.637	42.69	16.35	82.23
ETBW9045	73.56	38.66	10.549	15.045	45.39	17.85	70.55
ETBW8075	67.06	27.32	10.992	14.375	46.72	17.66	74.48
ETBW9464	66.58	34.70	10.790	13.960	44.46	16.54	76.10
ETBW9466	69.73	31.93	10.845	14.272	41.26	15.18	80.69
ETBW9470	70.31	40.89	10.811	13.927	48.35	20.56	79.17
Hidasse	69.76	38.21	10.595	13.942	58.82	24.38	58.55
Mean	70.56	35.07	10.77	14.34	45.23	17.29	73.79
$LSD_{0.5}$		1.62	0.16	0.4	3.520	2.107	6.59
CV%	2.44	8.20	2.66	5.02	21.69	33.953	25.08
Where: HLW= Hectoliter Weight, TKW= Thousand Kernel Weight, MC=Moisture Content, PC= Protein Content, WG=Wet Gluten Content, DG=Dry Gluten Content, GI=Gluten Index							

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

Loc	HLW	TKW	MC	PC	WG	DG	GI
ARO	72.44	38.97	10.88	11.53	32.27	11.788	78.06
ASA	66.42	30.89	10.64	15.36	51.63	19.538	78.18
BKJ	68.97	34.89	11.14	13.52	40.99	15.507	72.26
DHE	69.57	35.14	10.58	16.43	52.2	19.238	75.41
HOL	75.68	32.37	11.10	13.85	44.93	18.667	60.36
KUL	70.76	36.64	10.31	15.31	48.83	18.865	69.25
CV	2.44	8.20	2.66	5.02	21.69	33.95	25.08
LSD%		1.03	0.1	0.26	3.5	2.1	3.8
Where: HLW= Hectoliter Weight, TKW= Thousand Kernel Weight, MC=Moisture Content, PC= Protein Content, WG=Wet Gluten Content, DG=Dry Gluten Content, GI=Gluten Index, ARO= Arsi Robe, AS= Asasa, BKJ= Bekoji, DRA= Dera , HLT= Holeta, KUL=Kulumsa							

Chemical Quality

AMMI analysis showed highly significant (P<0.001) differences among genotypes, environment and genotypes x environments interaction for the studied chemical quality traits (Table 6).

Moisture content

Environments accounted for the largest proportion of the sum of squares (40.81%) for moisture content, followed by genotypes (8.4%) and GEI (2.16%) (Table 6)**.** It can be inferred from the large sum of squares for environment that

Table 6: AMMI analysis of chemical quality traits of 15 wheat genotypes across 6 environments.

	Moisture content			Protein content	
Source of Variation	**D f**	**SS**	**SS%**	**SS**	**SS%**
Genotype	14	6.24***	8.40	32.44***	2.62
Rep(Env)	18	6.97	-	42.26	-
Environment	5	30.32***	40.81	913.76***	73.86
GEI	70	14.98***	20.16	147.12***	11.89
PC1	18	12.47***	83.3	61.10***	41.5
PC2	16	1.38	9.2	42.25***	28.7
PC3	14	0.51	3.4	30.30***	20.6
Error	267	21.4	-	134.99	-
Total	359	74.29	-	1237.22	-
Mean	-	10.77	-	14.33	-

the environments were diverse, with large differences among environmental means causing most of the variation in moisture content. The moisture content displayed greater influence of environmental effects than GEI and genotypic factor which supported by the observations of Rharrabti et al. [15]. Results from AMMI analysis showed that the IPCA1 captured 83.3% of the interaction sum of square, IPCA2 of the interaction capture 9.2% the interaction sum of square, the other interaction effects explained by the remaining principal components (Table 6).

Most genotypes were observed to have high moisture content at Bekoji (11.14%) followed by Holeta (11.1%), while the lowest moisture content was observed from kulumsa (10.31%) when compared with other locations (Table 4). Significant differences in moisture content among all environments, indicating that environments had influenced the grain moisture content. The highest mean value for moisture content (10.99%) among all genotypes was observed from ETBW8078 followed by ETBW8427 (10.91%), while lowest value (10.5%) was recorded from Lemu when compared to other genotypes (Table 5). The mean value of moisture content of wheat genotype was ranged from 10.5% to 10.99%. The results achieved agreed with values obtained by Makawi et al. who stated that the moisture content of Sudanese wheat cultivars ranged from 10.40 to 12.07% [16]. The variation in moisture content of the different wheat genotypes may be due to the variations in environmental conditions between the six environments, the genotypes, and GEI.

Protein content

The grain protein is an important parameter analyzed to evaluate quality attributes of wheat genotype. The ANOVA revealed highly significant GEI as well as significant differences among genotypes and environments for protein content. As for AMMI, the proportion of variation contributed by the environment effect was much greater than that from the other sources of variation. The dominant contribution of environment over that of the genotype and GEI was detected for protein content, accounting for 73.86% of sum of squares. 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. and Bilgin et al. stating strong environmental impact on bread wheat protein content [17,18]. According to Wılıams et al. protein content was one of the most responsive traits since it was predominantly affected by environment and GEI [10]. Many other studies demonstrated that environmental conditions have a larger effect on protein content than the genotype [19,20].

The AMMI analysis revealed that the IPCA1 and IPCA2 was highly significant, capturing 41.5 % and 28.7 % of the interaction sum of squares (Table 6). In this result protein content varied from 13.93 to 15.05 %. This result was in line with the finding of who reported that protein content was varied from 12.4 to 15.4% in bread wheat [21]. A similar range for protein content of 10.5 to 16.3% as reported for 330 Chinese bread wheat cultivars, whereas larger variation of 8.3 to 17.6% for 162 bread wheat cultivars from European Wheat Catalogue was shown by Branlard et al. [22]. The protein content of the genotype was higher in Dera when compared with other locations. Terman et al. noted that protein content varied more widely among locations than among varieties at the growing location [23].

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)**.** This result is similar with previous study which pointed out that the protein content of wheat was mainly dependent upon genotype [24]. Variation in PC in the current study may be due to variation in environmental conditions such as heat and drought and genotypes [25]. Protein content was greatly influenced by environment, although they were significantly influenced by genotype and GEI [26]. Similarly, many other studies demonstrated that environmental conditions have a larger effect on protein content than genotypes [19,20].

Gluten Quality

Wet gluten content

AMMI analysis showed highly significant (P<0.001) differences among genotypes, environment and GEI for the wet gluten content. The environment capture maximum sum 28.14%, GEI was represented with 17.71% and 11.9% was the effect of genotype (Table 7). These result indicated the wet gluten content of bread wheat genotypes were significantly affected by environment, genotype and GEI. 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. and Bilgin et al. stating that strong environmental impact on bread wheat wet gluten content and also in line with other finding of Mikulíkova et al. and Zecevic et al. those reported that wet gluten content significantly depended on environment, cultivar, year and their interactions [17,18,27,28]. In this result genotype as source variation was least important than environmental and GEI. Results from AMMI analysis showed that the PCA1 of the interaction captured 40% of the interaction sum of square; PCA2 of the interaction capture 37.7% of the interaction sum of square, and both PC accounted that 77.7% of the total GEI (Table 7).

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 environment, genotype, and their interaction [6]. Environmental factors are always different in time and space and their changes are mostly the greatest. The genotypes used in the study gave rise to significant differences in wet gluten values. The highest mean value for wet gluten was obtained for Hidasse (58.82%), followed by genotype ETBW8470 (48.35%) and genotype ETBW9037 (42.69), while the lowest value was recorded for genotype ETBW8427 (36.49%) (Table 5). Throughout the growing environment Asasa, Kulumsa and Dera are suitable conditions for wet gluten content compared to Arsi robe, Bekoji and Holeta (Table 4). This result indicates that the growing environment influence wet gluten content of these genotypes. The variation in wet gluten could be attributed to the differences in the genotypes, agronomical practices, and environmental conditions such as temperature and soil fertility. Similarly, significant variation in wet gluten content due to the difference in wheat genotypes and growing environment has been reported [6]. In this result the wet gluten ranged from 36% to 58% which is a higher and wider range in comparison to results Brankovic et al. who reported that the wet gluten content ranged from 22.8% to 30.3% for bread wheat genotypes [21]. Similarly this is larger range of variation compared to variation of 24-40.5% for wet gluten content reported in bread wheat by Bilgin et al. [18].

Dry gluten content

AMMI analysis showed highly significant (P<0.001) differences among genotypes and environment but there is no significant interaction GEI for dry gluten content. AMMI analysis of variance for dry showed that the total sum of squares attributed to the impact of environments was 16.63%), GEI was represented with (15.25%) and 13.22%), was the effect of genotype .Results from AMMI analysis showed that the PCA 1 of the interaction captured 48% of the interaction sum of square, PCA 2 of the interaction capture 25.9% of the interaction sum of square, both PC accounted that 73.9% of the total GEI. whereas the other interaction effects were explained by the remaining principal components (Table 7).

Concerning growing area, dry gluten content was higher at Asasa (19.54%) followed by Dera (19.23%) and Kulumsa (18.87%), while the lowest mean value of dry gluten content was obtained from Arsi Robe (11.79%) (Table 4). 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 yield of dry gluten was closely associated with the total protein of this wheat genotype. These results agreed with those reported previously for other of wheat genotypes [16].

Table 7: AMMI analysis of Wet gluten, Dry gluten and Gluten index of 15 bread wheat genotypes across six environments

		Wet Gluten		Dry Gluten		Gluten Index	
Source of Variation	**D f**	**SS**	**SS%**	**SS**	**SS%**	**SS**	**SS%**
Genotype	14	7325.6***	11.90	2226.4***	13.22	13432***	19.69
Rep(Env)	18	1894.2		388	-	1505	-
Env't	5	17324.6***	28.14	2800.3***	16.63	13761***	20.17
GEI	70	10904.7**	17.71	2568^{ns}	15.25	10285^{ns}	15.07
PC1	18	4357.95**	40	1233.91*	48	5074.15*	49.3
PC2	16	4107.95**	37.7	664.94	25.9	2342.9	22.8
PC3	14	1232.56	11.3	444.87	17.3	1400.94	13.6
Error	267	25603.06	-	9177.55	-	30682.9	-
Total	359	61563.07	-	16834.97	-	68230.18	-
Mean	-	45.14542	-	17.27	-	72.25	-

Gluten Index (GI)

AMMI analysis showed highly significant (P<0.001) differences among genotypes and environment but there is no significant interaction for GEI for gluten index. The variation of gluten index was mainly determined by the influence of environment (20.17%), GEI (15.07%) and genotype (19.66%) (Table 7)**.** The results indicated that the gluten index had little dependence on the environment when compared with genotype and GEI. In disagreement with our findings, Vida et al. reported that the gluten index had the greatest dependence on the genotype compared to environmental factors and agronomic treatments [29]. Furthermore, the more significant effect of genotype on the gluten index compared to the impact of environment and fertilizer application was recently reported [14]. Results from AMMI analysis showed that the PC1 captured 49.3% of the interaction sum of square, PC2 capture 22.8% of the interaction sum of square both PC1 and PC2 accounted that 72.1% of the total GEI (Table 7).

Throughout the 6 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 4). 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).

Conclusion

The presence of Genotype by Environment Interaction (GEI) complicates selection of superior genotypes and an understanding of environmental and genotypic causes of significant GEI is important in all stages of plant breeding. A quality trait of grain was affected by genotype, location and their interactions. Growing location had significant effect on physical, chemical quality traits and gluten content. 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. Also, Physical and chemical quality traits as well as wet gluten content are influenced by interaction of genotype and environment. The results showed that the genotype ETBW9045 had excellent HLW followed by ETBW8070 (73.38 kg/hl) and ETBW8065 (73.02 kg/hl), while the lowest mean values of HLW was obtained from genotype ETBW9464 (66.58 kg/hl) and genotype ETBW9470 had excellent TKW followed by ETBW8427 (39.22 g), while the lowest was that of ETBW8075 (27.32g). The mean value of moisture content of wheat genotype was ranged from 10.5% to 10.99%. In this result protein content varied from 13.93 to 15.05%. Genotype ETBW8065, ETBW8484 and ETBW9464 gave the best value of protein in the favorable means (15.05%, 14.76% and 14.64%) respectively, while the genotype ETBW9470 had lowest mean value of protein. The Hidase had the highest value of wet gluten (58.2%) and dry gluten (24.38%) in average for all investigated locations (58.2%), while lowest wet gluten and dry gluten was obtained from genotype ETBW8427 with the value of (36.49%) and 12.81% respectively. 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. Regarding the environments, the highest mean values of HLW for all genotypes were at Holeta (75.68 kg/hl), while the lowest values were at Asasa (66.42 kg/hl). The highest mean values of TKW were recorded at Arsi Robe (38.97 g) and lowest mean value at Asasa (30.89 g). According to locations means, both protein and wet gluten content the highest wet gluten was measured at location Dera, while the lowest at location Arsi Robe. The highest mean value for gluten index obtained were 78.18% at Asasa, while the lowest value (60.36%) was observed at Holeta.

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References

1. Shiferaw B, Smale M, Braun HJ, Duveiller E, Reynolds M, et al. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Secur*. **2013,** 5:291-317.

2. Abugalieva A, Pena RJ. Grain quality of spring and winter wheat of Kazakhstan. *Asian Austral J Plant Sci Biotechnol*. **2010**, 4(1):87-90.

3. Sharma RC, Morgounov AI, Braun HJ, Akin B, Keser M, D, et al. Identifying high yielding stable winter wheat genotypes for irrigated environments in Central and West Asia. *Euphytica*. **2010**, 171:53-64.

4. Peterson CJ, Graybosch RA, Shelton DR, Baenziger PS. Baking quality of hardred winter wheat: Response of cultivars to environments in the Great Plains. *Euphytica*. **1998**, 100(1-3):157-162.

5. Caffe-Treml M, Glover KD, Krishnan PG, Hareland GA, Bondalapati KD, et al. Effect of wheat genotype and environment on relationships between dough extensibility and bread making quality. *Cereal Chem*. **2011**, 88:201-208.

6. Kaya Y, Akcura M. Effects of genotype and environment on grain yield and quality traits in bread wheat (*T. aestivum*L.). *Food Sci Technol*. **2014**, 34(2):386-393.

7. Dhungana P, Eskridge KM, Baenziger PS, Campbell BT, Gill KS, et al. Analysis of genotype-by-environment interaction in wheat using a structural equation model and chromosome substitution lines. *Crop Sci*. **2007**, 47:477-484.

8. Jing Q, Jiang D, Dai YD, Cao WX (2003) Genotype and environment effects on wheat grain quality and protein components. *J Applied Ecol*. **2003**, 14:1649-1653.

9. Finlay GJ, Bullock PR, Sapirstein HD, Naeem HA, Hussain A, et al. Genotypic and environmental variation in grain, flour, dough and bread-making characteristics of western Canadian spring wheat. *Can J Plant Sci*. **2007,** 87:679-690.

10. Williams RM, O'Brien L, Eagles HA, Solah VA, Jayasena V. The influences of genotype, environment, and genotype environment interaction on wheat quality. *Aust J Agric Res*. **2008**, 59:95-111

11. AACC. Approved Methods of the American Association of Cereal Chemists. AACC, St. Paul, MN. **2000**.

12. Crossa J, Gauch HG, Zobel RW. Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Sci*. **1990**, 30:493-500.

13. Li Y, Wu Y, Hernandez-Espinoza N, Pena RJ. The influence of drought and heat stress on the expression of end-use quality parameters of common wheat. *J Cereal Sci*. **2013,** 57:73-78.

14. Bouacha OD, Nouaigui S, Rezgui S. Effects of N and K fertilizers on durum wheat quality in different environments. *J Cereal Sci*. **2014**, 59:9-14.

15. Rharrabti Y, Villegas D, Royo C, Martos-Núñez V, Del-Moral LFG. Durum wheat quality in Mediterranean environments: II. Influence of climatic variables and relationships between quality parameters. *Field Crop Res.* **2003,** 80:133-140.

16. Makawi AB, Mustafa AI, Ahmed IAM. Characterization and improvement of flours of three Sudanese wheat cultivars for loaf bread making. *Innov Roman Food Biotechnol*. **2013.** 13:30-44.

17. Drezner G, Dvojkovic K, Horvat D, Novoselovic D, Lalic A. Environmental impacts on wheat agronomic and quality traits. *Cereal Res Comm*. **2007**, 35:357-360.

18. Bilgin O, Korkut KZ, Baser I, Daglioglu O, Ozturk I, et al. Variation and heritability for some semolina characteristics and grain yield relations in durum wheat (*Triticum durum* Desf). *World J Agric Sci*. **2010**, 6(3):301-308.

19. Mut Z, Aydin N, Bayramoglu HO, Ozcan H. Stability of some quality traits in bread wheat (*Triticum aestivum*) genotypes. *J Environ Biol*. **2010**, 31:489-495.

20. Surma M, Adamski T, Banaszak Z, Kaczmarek Z, Kuczyńska H, et al. Effect of genotype, environment and their interaction on quality parameters of wheat breeding lines of diverse grain hardness. *Plant Prod Sci*. **2012**, 15(3):192-203.

21. Brankovic G, Dodig D, Pajic V, Kandic V, Knežević D, et al. 2018. Genetic parameters of bread wheat and durum wheat genotypes for technological quality properties in Serbia. *Zemdirbyste-Agriculture*. **2018**, 105:39-48.

22. Branlard G, Dardevet M, Saccomano R, Lagoutte E, Gourdon J. Genetic diversity of wheat storage protein and bread wheat quality. *Euphytica*. **2001**, 119:59-67.

23. Terman GL, Ramig RE, Dreier AF, Olson RA. Yield-protein relationships in wheat grain, as affected nitrogen and water. *Agron J*. **1969**, 61:755-759.

24. Stoddard FL, Marshal DR. Variability in grain protein in Australian hexaploid wheat's, *Aus J Agric Res*. **1990**, 41:277-288.

25. Elmobarak A, Elnaem A, Adam A, Richter C. Effect of different nitrogen sources to wheat on two soils in Sudan. *Deutscher Tropentag*. **2004,** October 5-7, Berlin.

26. Rharrabti Y, Villegas D, Del-Moral LFG, Aparicio N, Elhani S, et al. Environmental and genetic determination of protein content and grain yield in durum wheat under Mediterranean conditions. *Plant Breeding*. **2001,** 120:381-388.

27. Mikulíkova D, Masár S, Horváthová V, Kraic J. Stability of quality traits in winter wheat cultivars. *Czech J Food Sci*. **2009,** 27(6):403-417.

28. Zecevic V, Kneževic D, Boškovic J, Madic M. Effect of genotype and environment on wheat quality. *Genetika*. **2009**, 41(3):247-253.

29. Vida G, Szunics L, Veisz O, Bedo Z, Lang L, et al. Effect of genotypic, meteorological and agronomic factors on the gluten index of winter durum wheat. *Euphytica*. **2014,** 197:61-71.