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Evaluation of Physical and Chemical Quality Characteristics of Elite Bread Wheat (*Triticum aestivum L.*) Genotypes

Cherinet Kasahun[1, *], Gadisa Alemu[2]

[1]Ethiopian Institute of Agricultural Research, Food Science and Nutrition Research Directorate, Kulumsa Agricultural Research Center, Assela, Ethiopia

[2]Ethiopian Institute of Agricultural Research, Crop Directorate, Kulumsa Agricultural Research Center, Assela, Ethiopia

Email address:
cherukas05@gmail.com (Cherinet Kasahun)
[*]Corresponding author

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Abstract: In wheat development programs, the evaluation and identification of superior lines from introduced plant materials, is the first and leading step in a crop improvement program. The study was conducted to evaluate the physical and chemical quality characteristics of elite bread wheat genotypes. The genotypes were consisted of 30 promising line obtained from the National Wheat Research Program during 2017 and 2018 two consecutive crops season consisted including two standard check. The experiment was conducted at Kulumsa Agricultural Research Center and genotypes were arranged in alpha lattice design with three replications. Analysis of variance showed significant ($P < 0.001$) differences among genotypes for all 14 agronomic and quality parameters. The results showed grain yield had a positive correlation with days to heading days to maturity, plant height (agronomic data), thousand kernel weight, hectoliter weight, grain kernel weight, grain hardness, grain diameter (grain physical quality) and flour protein content, wet gluten, gluten index, at both genotypic and phenotypic levels. However, grain yield (Ton/ha) showed a negative association with moisture content and dry gluten at both genotypic and phenotypic ratios and a wide range of variations for grain kernel weight, grain hardness, and dry gluten, wet gluten, and gluten index. Advanced genotypes had between 28.9 to 41.55mg-grain kernel weight, 53.87 to 84.93%-grain hardness, 2.51 to 2.94mm-grain kernel diameter, 12.68 to 14.83% protein content, 12.26 to 13.35% moisture content, 13.6 to 21% dry gluten, 31.2 to 42.3% wet gluten, and 64.34 to 85.73% gluten index. ETBW9554 showed superior overall agronomic performances over the standard check Wane and Hidasse and it had a 9% and 14% yield advantage respectively. The ETBW9554 had a plumper seed size than the two checks. ETBW9554 variety is known for its higher protein content than standard check Wane and local check Hidasse.

Keywords: Wheat, Genotype, Elite, Quality, Protein, Gluten

1. Introduction

Among the wheat species, bread wheat (*Triticum aestivum* L.) is the most widely cultivated food crop 94% of the total wheat cultivated area is dedicated to this crop. One of the main reasons behind bread wheat's success is its versatility to produce diverse food products due to the presence of gluten [22]. It has been one of the major cereals of choice, dominating the food habits and dietary practices of the highland population of Ethiopia. With the emergence and increase of food processing industries utilizing bread wheat as a raw material, information on rheological quality characteristics to match end use quality is very essential [24].

The bioactive components in whole grains that exert these beneficial effects are: phytosterols, tocols, beta-glucan, gamma-oryzanol, phytic acid, carotenoids, lignans, alkylresorcinols, flavonoids and phenolic acids [10].

Wheat supplies the most calories and proteins to the global population in the form of diverse wheat-based foods [20].

The wheat economies of Africa are characterized by a growing gap between wheat supply and consumption [18]. It is the main part of the food. It has covered the most cultivation area and its product is the most generally used in the world and of primary importance for human nutrition [2]. It is a crucial industrial and grain that ranks second among the foremost important cereal crops in the world after rice and is traded internationally. Wheat plays a significant role in supplying carbohydrates, protein, and minerals in human diets [3]. About 21% of wheat is used in various industries and bakeries for bakery products such as bread, biscuits, pizza, cakes, and pastries [25].

The development of wheat cultivars with good bread-making quality is a challenging objective for many wheat breeding programs [15].

A gluten network is formed after mixing wheat flour with water and confers the unique visco-elastic properties (elasticity and extensibility) of wheat [22]. About 21% of wheat is used in various industries and bakeries for bakery products such as bread, biscuits, pizza, cakes, and pastries [26]. Wheat is also a strategic commodity that generates farmer income and improves food security status in sub-Saharan African countries [19]. In developing countries, wheat demand will increase dramatically by 2050 ([21]. In Ethiopia, wheat is among major important cereal crop occupying 1.79 million hectares of land with a total production of 5.32 million tones and productivity of 2.97 t ha^{-1} [8]. Ethiopia is the largest wheat producer in sub-Saharan Africa and remains a net importer of wheat, meeting just over 70% of demand from domestic production [23]. Wheat has been one of the major cereals of choice, dominating the food habits and dietary practices of the highland population of Ethiopia, in nutritional terms; wheat is known to be a major source of energy and protein [12]. Wheat quality is closely related to the physical, chemical, and nutritional properties of wheat varieties. The most determinants of wheat quality are endosperm proteins, in terms of quantity and quality. Grain protein is a complex parameter affecting both nutritional value and dough rheological properties [11]. Protein is a key quality factor that determines the suitability of wheat for a particular type of product as it affects other factors including mixing tolerance, loaf volume and water absorption capacity [27]. Thus knowing the physical and nutritional characteristics of the wheat genotypes is of vital importance for improving the bread quality for consumers and all other stakeholders. Cultivators, millers and bakers choose these physical and processing characteristics of wheat analysis methods to distinguish wheat for production purposes [29].

Phenotypic and genotypic correlation studies enable to identify and determine the proportion of the phenotypic correlation that is associated with genetic causes, to verify whether the selection for a certain trait influences another one, to quantify indirect gains due to selection on correlated traits, and to evaluate the complexity of the traits [28]. Keeping the above facts in mind, the main objectives of the study were a) to evaluate the grain physical qualities and end -use quality characteristics of elite bread wheat cultivars and b) to estimate genotypic and phenotypic correlation coefficients between yield, yield components and quality parameters. Improvement of end-use quality in bread wheat depends on a thorough understanding of current wheat quality and the influences of genotype (G), environment (E), and genotype by environment interaction (G × E) on quality traits [30].

2. Materials and Methods

2.1. Location Descriptions

Kulumsa Agricultural Researcher Center is located in the 08°01'10"N and 39°09'11"E with an altitude of 2200 masl. It received 820mm rainfall annually. It is categorized under cool highland to semi-arid agro-ecologies. The Kulumsa Agricultural Research Center is nationally mandated to coordinate wheat, malt barley and highland pulse crops research and serve as the regional Wheat Center of Excellence for East Africa (Ethiopia, Kenya, Uganda, and Tanzania).

2.2. Experimental Materials

Twenty-eight advanced bread wheat genotypes and two bread wheat varieties for a check (Wane and Hidasse) which were released (2016, 2012) respectively by National Bread Wheat Research Coordinating Center based at Kulumsa Agricultural Research Center (KARC) were evaluated in this study during 2017-2018 cropping year. The two check wheat varieties (Wane and Hidasse) were hard wheat and soft wheat varieties respectively.

2.3. Experimental Layout

The trial was sown in an alpha lattice design with three replications. Sowing was done using plots of 3 m^2 (6 rows, 2.5 m long, spaced 20 cm apart). Genotypes were sown using a seeding rate of 150 kg seeds per ha. NPS and Urea fertilizer rates were applied according to the recommendations [9].

Table 1. *List of genotypes and descriptions.*

Name	Pedigree
Wane	SOKOLL/EXCALIBUR
ETBW 8751	SUP152//ND643/2*WBLL1
ETBW 8858	SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU
ETBW 8870	WAXWING*2/TUKURU//KISKADEE #1/3/FRNCLN
ETBW 8802	CHAM-4/SHUHA'S'/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S"

Name	Pedigree
ETBW 8991	SUP152//ND643/2*WBLL1
ETBW 8862	C80.1/3*BATAVIA//2*WBLL1/3/C80.1/3*QT4522//2*PASTOR/4/WHEAR/SOKOLL
ETBW 8804	TURACO/CHIL/6/SERI 82/5/ALD'S'/4/BB/GLL//CNO67/7C/3/KVZ/TI
ETBW 8996	FALCIN/AE.SQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/DANPHE#1/11/CROC_1/ AE. SQUARROSA(213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA
ETBW 8583	MINO/898.97/4/PFAU/SERI.1B//AMAD/3/KRONSTAD F2004
ETBW 8668	BAVIS*2/3/ATTILA/BAV92//PASTOR
ETBW 8595	BAVIS*2/3/ATTILA/BAV92//PASTOR
ETBW 8684	PASTOR//HXL7573/2*BAU/3/WBLL1/4/1447/PASTOR//KRICHAUFF
ETBW 9486	FRANCOLIN#1/3/PBW343*2/KUKUNA*2//YANAC/4/KINGBIRD#1//INQALAB 91*2/TUKURU
ETBW 9547	MUTUS*2/AKURI//MUTUS*2/TECUE #1
ETBW 9548	REEDLING #1//KFA/2*KACHU
ETBW 9549	KFA/2*KACHU/3/KINGBIRD #1//INQALAB 91*2/TUKURU/4/KFA/2*KACHU
ETBW 9550	KFA/2*KACHU*2//WAXBI
ETBW 9551	KFA/2*KACHU/4/KACHU #1//PI 610750/SASIA/3/KACHU/5/KFA/2*KACHU
ETBW 9552	KACHU#1/4/CROC_1/AE.SQUARROSA 205)//BORL95/3/2*MILAN/5/KACHU/6/KFA/2*KACHU
ETBW 9553	MURGA/KRONSTAD F2004/3/KINGBIRD #1//INQALAB 91*2/TUKURU
ETBW 9554	SAUAL/MUTUS/6/CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/FH6-1-7/7/CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/FH6-1-7
ETBW 9555	KFA/2*KACHU/5/WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/6/KFA/2*KACHU
ETBW 9556	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR
ETBW 9557	SOKOLL/WBLL1/4/D67.2/PARANA 66.270//AE.SQUARROSA (320)/3/CUNNINGHAM
ETBW 9558	BABAX/LR42//BABAX/3/ER2000/5/ATTILA/4/WEAVER/TSC//WEAVER/3/WEAVER/6/KA/NAC//TRCH
ETBW 9559	CHIBIA//PRLII/CM65531/3/MISR *2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07
ETBW 9560	CHWINK/GRACKLE #1//FRNCLN
ETBW 9561	TRAP#1/BOW/3/VEE/PJN//2*TUI/4/BAV92/RAYON/5/KACHU #1*2/6/KINGBIRD #1
Hidasse	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC-1/AE.SQUAROSA(224)//OPATTA

2.4. Quality Parameters

Thousand kernel weight: The wheat sample was taken on the analytical balance after counting 1000 wheat kernels on the seed counter (India Mart, VT54, India), whereas, test weight was determined with Schopper Chondrometer (Graintec, QLD4350, Australia).

Hectoliter weight (HLW): HLW was measured in special Seedburo Filling Hopper (model 151) according to AACC-2000, method No. 55-10. After cleaning and passing through specific sieves, the hopper was filled with the sample. Excess grains were scraped off with a strike. Reading was noted on the scale and the result was calculated as Kg/hl.

Single Kernel Characterization System (SKCS): It was used for, kernel weight, diameter, hardness/softness, and moisture based on the [6]. method 55-31. A sample of wheat kernels (12-16 grams) was prepared by removing broken kernels, weed seeds, and other foreign matter, and then the sample was poured into the access hopper of the SKCS instrument. The SKCS instrument analyzes 300 kernels individually and records the results on a computer graph [1].

Grain protein: The protein content of the wheat grains, was determined by using NIR (Near Infrared) spectroscopy technique by running the grain samples through FOSS infratec 1241 model [1]method No. 44-16.

Gluten Content and Gluten Strength: Gluten content and quality that indicates gluten strength were determined according to the AACC method. A Ten-gram sample of flour or ground wheat was weighed and placed into the glutomatic washing chamber on top of the polyester screen. The sample was then mixed and washed with a 2 percent salt solution for 5 minutes. The wet gluten was then removed from the washing chamber, placed in the centrifuge holder, and centrifuged. The residue retained on top of the screen and through the screen was weighed. Pakistani wheat varieties differ significantly in their physicochemical, rheological and technological characteristics [7]. Then the total gluten was dried in glutork, then the wet gluten, dry gluten, and gluten index were calculated.

Gluten constituents were calculated as follows:

$$\text{Gluten index (GI)} = \left(\frac{[(\text{total wet gluten (g)} - \text{wet gluten passed through sieve (g)}]}{\text{Total wet gluten (g)}}\right) \text{x} 100\%$$

$$\text{Wet gluten content (WGC)} = \left(\frac{\text{total wet gluten (g)}}{\text{Weight of sample}}\right) \text{ x } 100\%$$

$$\text{Dry gluten content (DGC)} = \left(\frac{\text{dry gluten (g)}}{\text{Weight of sample}}\right) \text{ x } 100\%$$

2.5. Statistical Analysis

Data obtained from the field and laboratory analysis were evaluated using two-way ANOVA and the significant difference of means was reported at $p < 0.05$, $p<0.01$, $p<0.001$, and mean separation was carried out with Least Significant Difference (LSD) comparison. SAS-software was used for the statistical analysis [13].

3. Result and Discussion

3.1. Agronomic and Morphological Characteristics

Highly significant mean squares due to genotypes for all the characters in thirty wheat genotypes revealed the presence of enough genetic variability in the material under study (Table 2). The result implied that the population of wheat genotypes would respond positively to selection. The extent of variability for any character is very important for the improvement of a crop through breeding. The magnitude of genetic variability for days to heading was ranged from 61 to 71.67 days with the mean value of 64.93 days, for days to maturity 112.67 to 123.67 days with the mean value of 118.4days, for plant height was ranged from 89 to 111.33 cm with the mean value of 98.22 cm (Table 2). The grain agronomy parameters (grain yield, data of heading, data of maturity, plant height, thousand kernel weight, and hectoliter weight) varied greatly in advanced genotypes, showing earliness, lateness, medium-large properly filled grains with high HLW and TKW values (18 genotypes had HLW greater than the mean value of 67.89 kg/hL, 18 genotypes had TKW greater than the mean value of 32.89 g) respectively and others with deficient grain density and small size (Table 2). All most of the advanced genotypes had a greater HLW value than standard checks (Wane and Hidasse). The highest mean values of HLW were observed from genotype ETBW9561 (70.41 kg/hl) and the least mean values were obtained from variety Hidasse (56.49 kg/hl) while, the highest TKW of genotypes were found ETBW8684 (37.33g) and the lowest TKW were observed in Hidasse. The highest grain yield was obtained from genotypes ETBW8751 (8.83 t/ha) and the lowest found in genotypes Hidasse (3.79 t/ha).

Table 2. *Mean performance of some important agronomic traits of 28 genotypes and 2 checks tested in 2017 and 2018 cropping season.*

Genotype	DH	DM	PHT	TKW	HLW	GYLD
Wane	66.00	123.00	89.00	38.30	71.20	4.61
ETBW 8751	65.00	123.00	89.00	39.60	73.20	5.12
ETBW 8858	67.00	124.00	91.00	39.30	73.10	4.77
ETBW 8870	67.00	126.00	94.00	37.90	72.80	4.87
ETBW 8802	68.00	129.00	90.00	33.00	71.80	4.36
ETBW 8991	65.00	123.00	85.00	37.40	72.70	5.04
ETBW 8862	69.00	127.00	100.00	40.20	73.80	4.88
ETBW 8804	65.00	123.00	80.00	34.00	72.10	3.67
ETBW 8996	64.00	124.00	93.00	39.80	73.40	4.99
ETBW 8583	68.00	127.00	89.00	38.70	73.40	4.77
ETBW 8668	65.00	125.00	95.00	43.30	74.80	5.00
ETBW 8595	65.00	126.00	95.00	42.80	74.30	4.88
ETBW 8684	64.00	125.00	90.00	40.50	74.10	4.60
ETBW 9486	66.00	123.00	87.00	41.10	73.80	4.37
ETBW 9547	72.00	128.00	87.00	43.40	73.40	4.91
ETBW 9548	72.00	128.00	87.00	40.00	73.40	4.49
ETBW 9549	70.00	129.00	88.00	39.20	73.10	4.31
ETBW 9550	68.00	126.00	85.00	36.50	73.90	4.17
ETBW 9551	67.00	127.00	87.00	38.70	71.50	4.24
ETBW 9552	69.00	128.00	89.00	42.70	72.70	3.91
ETBW 9553	74.00	131.00	92.00	40.40	72.30	4.90
ETBW 9554	70.00	128.00	94.00	42.70	71.40	5.10
ETBW 9555	67.00	127.00	88.00	36.90	71.60	4.14
ETBW 9556	68.00	125.00	91.00	39.80	73.50	4.63
ETBW 9557	68.00	126.00	90.00	37.30	69.70	4.87
ETBW 9558	67.00	126.00	91.00	40.50	73.90	4.79
ETBW 9559	69.00	126.00	92.00	40.20	72.60	4.49
ETBW 9560	66.00	125.00	89.00	37.80	72.00	4.75
ETBW 9561	72.00	130.00	90.00	39.80	74.40	4.59
Hidasse	66.00	124.00	92.00	38.10	70.80	4.42
Grand mean	68.00	126.00	90.00	39.30	72.80	4.62

GYLD=grain yield, DTH=data of heading, DTM=data of maturity, PHT=plant height, THK=thousand kernel weight, HLW=hectoliter weight.

Finally, based on the results for agronomic performance; disease resistance, and quality parameters two candidate genotypes viz. ETBW953 and ETBW9554 were selected and verified on farmer's fields along with two standard checks Wane and Hidasse in 2019. Therefore, the National Variety Release Committee has evaluated with the farmers and proposed for release a candidate variety viz. ETBW9554 (Boru) for official registration in the country as a commercial variety.

3.2. Quality Characteristics

The protein content of genotypes was ranged from Wane (12.14%) to ETBW 9549 (14.83%). The highest moisture content was obtained in wane (13.43%) while the lowest moisture content was found in ETBW9553 (12.26%). The highest grain weight was observed inETBW8595 (41.55g) while the lowest grain weight was found in ETBW8802

(28.99 g). The highest mean value for the grain hardness index obtained was ETBW8802 (84.93%) genotype, while the lowest mean value (38.94%) was observed in Hidasse. The results showed that genotype ETBW9556 had the highest (2.94mm) mean value of grain diameter while genotype ETBW9552 had the lowest (2.51mm) mean value. The genotype ETBW 9550 had the highest value of wet gluten (42.30%) while the lowest mean value was found in ETBW8802 (31.20%) and dry gluten was obtained from genotype Hidasse with the value of (27.96%) and lowest in ETBW8802 (13.60%) respectively. The results showed that genotype ETBW9557 had the highest (85.73%) mean value of gluten index while genotype Hidasse had the lowest (40.28%) mean value. This study demonstrates success in wheat breeding for improved quality in bread wheat breeding. This study also provides information on the combined stability of improved quality of the nationally important bread wheat genotypes. bread making quality is influenced by both protein quantity and quality therefore breeder must apply strategies to increase one without affecting the other to achieve specific wheat quality classes [4].

The priorities of the national wheat research breeding program are high grain yield, disease resistance, and tolerance to abiotic stresses like drought and warmth, and desirable quality. Wheat quality may be a very broad subject that may be defined differently by the various stakeholders of the wheat chain, which makes it a very complex and variable concept. The environment will influence most bread wheat grain traits. When variation in a trait is caused more by differences in the environment the plants are grown in than by genetic differences among those plants it can be difficult for the breeder to select the desired genotype. Most quality traits of wheat were primarily controlled by genotype (G), although environment (E) and G×E also had significant effects [16].

Wheat genotype from *Triticum aestivum* L. grown at the same location was chosen and ranged from 12.14%–14.83% protein contents (Table 2). The wheat protein content is a crucial consideration for all end products (uses of wheat) from bread baking to noodles, pasta, cakes, and biscuits. Wheat protein content varies widely counting on wheat class, growing region, type and quality of soil, and of course fertilizers input (amount and timing), nitrogen particularly. All other factors being equal, flour from higher protein wheat has the greater water-absorbing capacity and thus greater bread volume potential, depending somewhat on the baking process used. While protein content is an intrinsic genetic trait and thus a variety criterion in breeding programs, environmental impact is considerably greater than that controlled by the breeders. The recently released variety contains higher protein content than standard check wane and local check Hidasse. ETBW9554 (Boru) had 37.09, 73.67, 2.75, 15.5, 33.95, and 83.98 of grain weight, grain hardness, grain diameter, dry gluten, wet gluten, and gluten index, respectively (Table 3). The range and average values for kernel characteristics (Grain weight, Grain diameter, moisture content, and Grain hardness), grain protein, and dry gluten content, Wet gluten content, and gluten index) are shown in (Table 3). The result showed a wide range of variations for grain weight, grain hardness, dry gluten, wet gluten, and gluten index. Advanced genotypes had in between 12.68 to 14.83% protein content, 12.26 to 13.35% moisture content, 28.9 to 41.55-mg grain weight, 53.87 to 84.93%-grain hardness, 2.51 to 2.94mm-grain diameter, 13.6 to 21% dry gluten, 31.2 to 42.3% wet gluten, and 64.34 to 85.73% gluten index with the mean of 13.93, 13.01, 36.58, 74.79, 2.76, 17.08, 37.39 and 76.61, respectively. Thus, these results indicated that the presence of a wide range of genetic variability in the material.

Table 3. *Mean performance of some important quality traits of 28 genotypes and 2 checks tested in 2017 and 2018 cropping season.*

Genotype	PC (%)	MC (%)	GW (mg)	GH (%)	GD (mm)	DG (%)	WG (%)	GI (%)
Wane	12.14	13.43	36.49	62.63	2.74	17.65	38.25	73.13
ETBW 8751	12.68	13.17	36.74	74.60	2.88	16.65	36.60	80.28
ETBW 8858	14.06	12.74	36.47	72.89	2.70	21.00	40.95	74.57
ETBW 8870	14.03	12.62	34.78	74.25	2.66	17.50	38.35	70.31
ETBW 8802	14.12	13.22	28.99	84.93	2.55	13.60	31.20	83.27
ETBW 8991	13.19	13.30	35.45	76.33	2.82	17.65	38.95	73.63
ETBW 8862	14.14	13.21	38.94	70.85	2.78	20.55	41.20	73.04
ETBW 8804	13.68	12.64	33.59	78.95	2.69	14.55	34.45	82.65
ETBW 8996	13.83	13.33	37.11	67.45	2.81	17.30	39.90	69.47
ETBW 8583	14.02	12.33	35.16	80.13	2.69	17.30	36.80	83.84
ETBW 8668	13.22	13.19	34.70	67.46	2.68	16.80	38.45	68.00
ETBW 8595	13.26	12.51	41.55	70.40	2.87	15.35	36.55	71.76
ETBW 8684	13.01	13.19	36.75	78.40	2.85	20.05	41.35	68.84
ETBW 9486	14.32	12.61	39.06	73.12	2.90	16.23	39.48	64.34
ETBW 9547	14.62	13.23	38.36	82.94	2.80	17.70	38.55	71.34
ETBW 9548	14.17	12.57	39.12	79.03	2.85	20.35	41.70	75.01
ETBW 9549	14.83	13.15	36.70	77.88	2.81	16.00	36.25	73.34
ETBW 9550	14.40	13.16	36.60	78.96	2.83	19.70	42.30	72.49
ETBW 9551	13.29	13.24	32.35	74.05	2.68	16.00	34.70	78.79
ETBW 9552	14.22	13.25	39.96	81.22	2.51	16.25	35.15	83.31
ETBW 9553	13.67	12.26	38.41	77.53	2.93	18.45	37.00	77.95
ETBW 9554	14.37	13.12	37.09	73.67	2.75	15.50	33.95	83.98
ETBW 9555	14.17	13.32	34.60	70.71	2.65	17.25	39.95	78.69

Genotype	PC (%)	MC (%)	GW (mg)	GH (%)	GD (mm)	DG (%)	WG (%)	GI (%)
ETBW 9556	14.28	13.16	40.45	53.87	2.94	16.05	36.00	82.44
ETBW 9557	13.65	13.25	33.19	77.13	2.59	15.45	35.15	85.73
ETBW 9558	14.27	12.53	37.26	71.46	2.83	15.50	33.70	79.76
ETBW 9559	13.91	13.35	37.84	76.67	2.82	15.40	33.45	83.92
ETBW 9560	14.62	13.27	35.94	64.94	2.73	17.25	39.10	69.49
ETBW 9561	13.93	13.35	37.15	84.42	2.88	16.95	35.90	84.94
Hidasse	12.30	13.43	36.57	38.94	2.70	27.96	38.88	40.28
Mean	13.81	13.04	36.58	73.19	2.76	17.46	37.47	75.29
CV (%)	3.21	2.49	4.41	4.22	3.12	16.73	8.16	12.50
LSD (0.05)	0.77	0.56	4.84	10.50	0.21	8.40	6.01	15.34
R^2	0.80	0.70	0.87	0.95	0.81	0.79	0.66	0.62

PC=protein content, MC=moisture content, GW=grain weight, GH =grain hardness, GD=grain diameter, DG=dry gluten, WG=wet gluten, GI=gluten index.

3.3. Correlation of Grain Yield with Other Characters

A positive value of r shows that the changes of two variables are in the same direction, that is, high values of one variable are associated with high values of the other and vice versa. In general, the magnitude of genotypic correlations (rg) was higher than those of phenotypic correlations (rp). This revealed that association among these characters was under genetic control and indicating the preponderance of genetic variance in the expression of characters. When the value of "rp" was greater than "rg", it showed that the apparent association of two traits was not only due to genes but also due to the favorable influence of the environment. The yield components exhibited varying trends of association among themselves. Grain yield in wheat, as in other crops, is a complex character, the sum total of the contributions made by its individual components [19].

A It might be due to the depressing effect of environment on character association as reported earlier for the wheat crop [5]. Grain yield had positive correlation with days to heading (0.04), days to maturity (0.2*), plant height (0.17*). TKW (0.58***, 0.49***), HLW (0.64***, 0.59***), grain weight (0.17*), grain hardness (0.44*, 0.40***), grain diameter (0.27***), gluten index (0.19*) at both genotypic and phenotypic levels respectively (Table 4). Grain yield showed a negative association with moisture content -0.16*) and dry gluten (-0.18*) at both genotypic and phenotypic levels. However, the associations were insignificant at the genotypic level (Table 4). Large variability was found among most of the quality attributes evaluated; wider ranges of quality traits were observed in the environments than among the genotypes [14].

Analysis of residuals from a regression of grain protein concentration on grain yield (grain protein deviation, GPD) showed that some cultivars had a higher grain protein concentration than was predicted from grain yield alone [17].

Table 4. *Estimation of genotypic (below diagonal) and phenotypic (above diagonal) correlation coefficient for 14 morphological and quality traits in 30 bread wheat advanced lines.*

Variable	GYLD	DTH	DTM	PHT	TKW	HLW	PC	MC	GW	GH	GD	DG	WG	GI
GYLD	1	0.04ns	0.20*	0.17*	0.49***	0.59***	0.13ns	-0.16*	0.17*	0.40***	0.27***	-0.18*	0.03ns	0.19*
DTH	0.01ns	1	0.57***	-0.03ns	-0.08ns	0.06ns	0.001*	-0.10ns	0.07ns	0.31***	0.04ns	-0.10ns	-0.17*	0.2*
DTM	0.18ns	0.71***	1	-0.09ns	0.15*	0.35***	0.36***	-0.07ns	0.09ns	0.48***	0.05ns	-0.07ns	-0.04ns	0.24**
PHT	0.16ns	-0.04ns	-0.15ns	1	0.004ns	-0.19*	-0.11ns	-0.06ns	0.13ns	-0.3	-0.01ns	0.03ns	-0.07ns	-0.10ns
TKW	0.58***	-0.08ns	0.17ns	0.05ns	1	0.61***	0.18*	0.10ns	0.39***	0.16*	0.31***	-0.04ns	0.17*	0.12ns
HLW	0.64***	0.09ns	0.43*	-0.17ns	0.64***	1	0.39***	-0.16*	0.16*	0.59***	0.25**	-0.24**	-0.01ns	0.26**
PC	0.11ns	0.31ns	0.43*	-0.09ns	0.27ns	0.47**	1	-0.21*	0.22**	0.43***	0.11ns	-0.23**	-0.08ns	0.17*
MC	-0.26ns	-0.23ns	-0.13ns	-0.05ns	-0.08ns	-0.26ns	-0.20ns	1	-0.25**	-0.28**	-0.21**	0.22**	0.12ns	-0.09ns
GW	0.10ns	0.05ns	0.08ns	0.23ns	0.61**	0.08ns	0.12ns	-0.19ns	1	0.12ns	0.71***	-0.29***	-0.18*	-0.22**
GH	0.44*	0.37*	0.59***	-0.36*	0.28ns	0.73***	0.41*	-0.23ns	-0.19ns	1	0.16*	-0.56***	-0.31***	0.38***
GD	0.30ns	0.04ns	0.04ns	0.04ns	0.43*	0.24ns	-0.004ns	-0.22ns	0.61**	-0.08ns	1	-0.29**	-0.10ns	-0.19*
DG	-0.27ns	-0.01ns	-0.15ns	0.11ns	-0.21ns	-0.52**	-0.33ns	0.10ns	0.20ns	-0.52**	0.09ns	1	0.72***	-0.37***
WG	0.21ns	-0.21ns	-0.01ns	-0.01ns	0.29ns	0.07ns	-0.05ns	0.009ns	0.31ns	-0.19ns	0.26ns	0.65***	1	-0.26**
GI	0.33ns	0.36*	0.39*	-0.20ns	0.26ns	0.58**	0.34*	-0.12ns	-0.15ns	0.64***	-0.10ns	-0.75***	-0.54**	1

ns=non significance,*=significant at P < 0.01,***=significant at P < 0.05,,**=significant at P < 0.01 GYLD=grain yield, DTH=data of heading, DTM=date of maturity, PHT=plant height, THK=thousand kernel weight, HLW=hectoliter weight, PC=protein content, MC=moisture content, GW=grain weight, GH =grain hardness, GD=grain diameter, DG=dry gluten, WG=wet gluten, GI=gluten index.

4. Conclusion

The development of improved varieties of bread wheat has always remained a focal point for wheat breeders. Each variety has a genotype-specific ability to maintain performance over a wide range of environmental conditions. The study indicated the presence of wide genetic variation among the wheat genotypes which can be exploited to develop high-yielding varieties with desirable grain quality traits. Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most of the traits. Grain yield had a positive correlation with days, days to maturity, plant height, Thousand kernel weight

(TKW), HLW (Hectoliter weight), grain kernel weight, grain hardness, grain kernel diameter and Protein content, wet gluten, gluten index, at both genotypic and phenotypic levels. Wheat variety ETBW9554 (Boru) out agronomic performance and good quality traits all the tested varieties. Therefore, this variety could be recommended for cultivation in mid to highland areas of Ethiopia.

Conflict of Interest

The author declares no conflict of interest for this article.

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