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Genetic variability and heritability among durum wheat (*Triticum turgidum* L.) accessions for yield and yield related traits performance

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Durum wheat is the second most important *Triticum* species next to bread wheat. Ethiopia is one of the centers of diversity for durum wheat. The aim of this study was to assess variability, heritability and genetic advance for some yield and yield-related traits. A total of 97 durum wheat accessions along with 3 improved varieties were evaluated in 10 x 10 simple lattice designs during the 2018 main cropping season at Mata Subsite of Haro Sabu Agricultural Research Center. Twenty parameters were collected and analyzed. Statistically significant ($p \leq 0.01$) variation was observed among materials tested for important quantitative and qualitative traits. Genotypic coefficient of variation (GCV) ranged from 3.77 to 44.81% for days to maturity and grain yield (tons ha^{-1}), respectively. Broad sense heritability ranged from 72.33 to 99.95% for plant height and number of kernels per spike, respectively. The highest genetic advance as percent of mean recorded for grain yield (88.80%) and the least for moisture (5.22%). Generally, the magnitude of genetic variability among the studied durum wheat accessions showed great variations for desirable traits and thus confident enough to expect genetic progress if further breeding activities are carried out.

Key words: Coefficient of variation, durum wheat (*Triticum turgidum* L.), genetic advance, heritability.

INTRODUCTION

Durum wheat (*Triticum durum* L.) is a monocotyledonous plant of the *Gramineae* family. It is the only tetraploid (AABB, 2n=4x=28) species of wheat which has commercially great importance and is a promising and viable alternative crop for farmers (Blanco et al., 1998; Shewry, 2009). Durum wheat is one of the important cereal crops in many countries in the world (Maniee et al., 2009; Kahrizi et al., 2010a, b; Mohammed et al., 2011). It is a tetraploid cereal crop grown in a range of climatic zones varying from warm and dry to cool and wet environments (Giraldo et al., 2016). Its global acreage is estimated at 17 million hectares (ha) and the major growing areas are situated in North America, North, and East Africa and southwest Asia (Maccaferri et al., 2014).

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Durum wheat has been under cultivation in Ethiopia since ancient times and the country is considered as the center of genetic diversity for durum wheat (Vavilov, 1951). Reduction in genetic variability makes the crops increasingly vulnerable to diseases and adverse climatic changes (Aremu, 2012).

The introduction of exotic wheat replacing the durum wheat accessions resulted in the loss of genetically diverse, locally well-adapted landraces (Royo et al., 2009). The research finding shows that the narrowing of the gene pool in durum wheat leads to an increased risk of vulnerability to diseases and pests (Frankel et al., 1995). For effective selection in durum wheat, breeders should increase their efforts to know the genetic variability and heritability of important agronomic traits (Abinasa et al., 2011).

Genetic variability, which is due to genetic differences among individuals within a population, is the foundation of plant breeding since proper management of diversity can produce a permanent gain in the performance of plants and can safeguard against seasonal fluctuations (Sharma, 2004; Welsh, 2008).

Phenotypic variation is the observable variation present in a character of a population, includes both genotypic and environmental components of variation and, as a result, its magnitude differs under different environmental conditions (Singh, 2006). Heritability can be defined, in a broad sense, as the proportion of the genotypic variability to the total variance (Allard, 2006). It refers to the portion of phenotypically expressed variation, within a given environment and it measures the degree to which a trait can be modified by selection (Christianson and Lewis, 2003). Heritability is a property not only of a character being studied but also of a population being sampled, of the environmental circumstance to which the individuals are subjected, and the way in which the phenotype is measured (Falconer and Mackay, 1996). Although, estimates of heritability provide the basis for selection on phenotypic performance, estimates of heritability and genetic advance should be considered simultaneously because high heritability should not always associate with high genetic advance (Amin et al*.,* 2004). Hence, high heritability coupled with genetic advance is more dependable, while for others, the intensity of selection should be increased; gives an idea of the possible improvement of new populations through the selection and high heritability with low genetic advance indicates the presence of non-additive gene action (Vimal and Vishwakarma, 2009). Therefore, the present study was designed to determine the extent of genetic variability present in the available germplasm and to explore the possibility of improving them through breeding programmes.

MATERIALS AND METHODS

The experiment was conducted during the main cropping season of 2018 at Mata research sub-site of Haro-Sabu Agricultural Research Center (HSARC), Kellem Wollega zone of Oromia region, Ethiopia. Mata research sub-site is located at 652 km West of Addis Ababa. It is located between 8^{o}10'00''N to 8^{o}50'00''N and 34^{o}39'30''E to 34^{o}59'30''E with an elevation of 2025 m above sea level. Soil types of the study area classified as 90% loam, 6% sand, and 4% clay soil type. The mean annual rainfall of the area is 1219.15 mm and the minimum and maximum annual temperatures are 16.21 and 27.77°C, respectively.

Materials of this study consisted of 100 durum wheat, of which 97 accessions and three released varieties as standard checks (Bekalcha, Dire and Obsa). The materials were obtained from Sinana Agricultural Research Center and originally introduced from Ethiopian Biodiversity Institute (Appendix Table A). The materials were arranged in 10 x 10 simple lattice designs with two replications. Each accession was planted in two rows of 1m long, 20cm spacing between rows and 1m between each block. Seeds were planted by hand drilling in the rows at seed rate of 150 kg ha^{-1}. A combination of UREA and NPS fertilizers were applied at the recommended rate of 100 kg ha^{-1}. UREA was applied in the split form (half at planting and the rest half at tiller initiation (35 days after emergence). All the other agronomic practices were uniformly applied as per the recommendation for the crop.

Data collection

Ten plants were selected randomly before heading from each row and tagged with thread and all the necessary plant-based data were collected from these ten sampled plants.

Plant-based data

The plant based data comprised number of kernels per spike, plant height, spike length, spike weight per plant and number of spikelets per spike.

Plot based data

Days to heading, days to maturity, days to grain filling period, susceptibility to lodging, thousand seed weight, grain yield, biological yield, harvest index, the susceptibility of stem rust (Puccinia graminis), and leaf rust (Puccinia triticina). susceptibility to lodging (assessed visually by1-5 scale,and stem rust and leaf rust were scored by using 1-5 scales visual observations at dough stage (once at dough stage)).

Moisture content

Moisture content of the whole meal flour sample was determined by the Approved AACC method 44-15 (AACC, 2000). The moisture percent was calculated according to the following equation.

$$\%\ \text{Moisture content} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weiht}} \times 100\%$$

Water absorption (WAB) (%)

The amount of water required to reach a value of optimum consistency, *i.e.,* 500 farinograph units (FU) at the point of optimum development. To calculate the WAB, a fixed amount of flour (normally 300 g) was mixed with calculated flour water requirement. The value was corrected for the desired consistency and for the moisture base of 14%.

Table 1. The structure of ANOVA table for simple lattice design.

Source of variation	DF	SS	MS	F-value	Pr>F
Replication	(r-1)	SSR	MSR		
Genotype					
-(Unadj.)	(k^2-1)	SSG_U	MSG_U		
-(adj.)	(k^2-1)	SSG_A	MSG_A		
Blocks within rep (adj.)	r(k-1)	SSB_A	MSB		
Error					
-Effective	(k-1) (rk-k-1)				
-RCB Design	$(r-1)(k^2-1)$				
-Intra block	(k-1) (rk-k-1)	SSE	MSE		
Total	(rk^2-1)	TSS			

k =blocks, r = number of replications, G = genotype, MSR = mean square of replication, MSG_A = mean square of genotype adjusted, MSG_U = mean square of genotypes unadjusted, MSE = Environmental variance (error mean square) = $\sigma^2 e$.

Protein

Protein analysis was conducted by the Dumas method (Leco model FB-428) and expressed using the conversion factor (N · 5.7).

Gluten percentage

Gluten content of each sample was determined according the AACC Method 38-11 (AACC, 2000).

Hectoliter weight (HLW)

Test weight was estimated standard procedure (method 55-10A) on dockage free basis, using laboratory hectoliter and weighed using electronic balance (AACC, 2000).

Thousand kernel weight (TKW)

TKW was measured on dockage free basis by taking mass of thousand grains counted by Chopin grain counter (model-NMU2, France) and weighing on sensitive electronic balance (+ 0.1g).

Statistical analysis

All measured agro-morphological traits were subjected to analysis of variance using Proc lattice and Proc GLM procedures of SAS version 9.2 (SAS, 2008) (Table 1).

Analysis of phenotypic and genotypic coefficient of variation

Quantitative traits variances (phenotypic, genotypic and environmental variances) and the respective coefficient of variations were calculated following the formula suggested by Burton and DeVane (1953) as follows:

Genotypic Variance ($\sigma^2 g$): $\sigma^2 g = \frac{MSg - MSe}{r}$

Where MSg= mean square of genotypes, MSe = error mean square, r = number of replications.

Environmental Variance or error variance ($\sigma^2 e$): $\sigma^2 e$=MSe

Phenotypic Variance ($\sigma^2 p$): $\sigma^2 p = \sigma^2 g + \sigma^2 e$

Estimates of the coefficient of variation were carried out as follows:

Phenotypic Coefficient of Variation (PCV %): $PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} x100$

Genotypic Coefficient Variation (GCV %): $GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} x100$

Environmental coefficient of variations (ECV%): $ECV = \frac{\sqrt{\sigma^2 e}}{\bar{X}}$

$ECV = \frac{\sqrt{\sigma^2 e}}{\bar{X}} x100$

Where $\bar{x}$= mean for the trait considered; $\sigma^2 p$=phenotypic variance; $\sigma^2 g$ =genotypic variance; $\sigma^2 e$= environmental variance,PCV(%)= Phenotypic coefficient of variation; GCV(%)= Genotypic coefficient of variation, ECV(%)=Environmental coefficient of variations.

Broad sense heritability (H^2) and genetic advances

Heritability (H^2): Heritability in the broad sense for all characters was computed using the formula given by Falconer and Mackay (1996).

$H^2 = (\delta^2 g/\delta^2 p)$ x 100

where H^2 = heritability in broad sense $\delta^2 g$ = genotypic variance and $\delta^2 p$ = phenotypic variance.

Genetic advance under selection (GA): Expected genetic advance for each character assuming a selection intensity at 5% (K =2.056) were computed using the formula developed by Johnson et al. (1955) as GA =k $(\sqrt{\delta^2 p})$ H^2. Where GA = expected genetic advance, k is constant (selection differential (K=2.056 at 5% selection intensity), $\sqrt{\delta^2 p}$ = is the square root of the phenotypic variance. Genetic advance as percent of the mean (GAM) was calculated to compare the extent of the predicted advance of different traits under selection using the formula.

$GAM = \frac{GA}{\bar{X}} X\ 100$

Table 2. Analysis of variance (ANOVA) for quantitative and qualitative traits of 100 durum wheat accessions evaluated.

Traits	Mean squares						
	Treatments	**Replications**	**Blocks within replications**	**Intra block error**	**CV%**	**Eff**	**R^2(%)**
	DF=99	DF=1	DF=18	DF=81			
Days to heading	18.41**	1.28	0.99	0.85	1.34	100.38	97.00
Days to maturity	33.58**	0.05	0.77	1.14	1.03	94.12	97.00
Grain filling period	52.75**	1.81	1.78	1.55	3.83	108.69	97.00
Plant height (cm)	366.00**	9.25	58.76	58.76	8.76	100.00	90.00
Biological yield (t ha^{-1})	9.29**	1.83**	0.02	0.03	1.88	96.61	100.00
Grain yield (t ha^{-1})	1.10**	0.02	0.05	0.04	11.93	101.69	97.00
Harvest index (%)	147.33**	1.78	6.45	5.37	12.27	100.60	97.00
Lodging (%)	0.72**	3.43**	0.06*	0.02	9.06	116.47	98.00
spike weight (g)	0.44**	4.81**	0.01	0.01	7.25	101.14	98.00
Thousand kernel weight (g)	206.23**	18.91*	6.95*	3.87	6.07	105.92	99.00
Number of kernels per spike	102.31**	2461.91**	0.02	0.02	0.29	101.29	100.00
Number of spikelet per spike	40.51**	2119.01**	0.81	0.51	2.36	103.63	99.00
Spike length (cm)	9.39**	109.52**	0.22	0.21	5.99	100.04	99.00
Leaf rust	0.46**	0.12	0.07	0.05	8.52	103.20	93.00
Stem rust	0.57**	0.00	0.07	0.04	11.65	102.75	94.00
Gluten (%)	16.77**	33.29**	0.49	0.60	2.44	96.67	97.60
Moisture (%)	0.30**	17.36**	0.04	0.07	2.49	92.26	90.20
Protein (%)	7.95**	11.43**	0.04	0.03	1.04	100.52	99.70
Hectoliter weight (kg hl^{-1})	76.80**	9.54**	0.02	0.03	0.23	96.44	100.00
Water absorption (%)	25.99**	42.30**	0.26	0.38	3.74	94.29	99.00

Key: *and ** indicates significance at 0.05 and 0.01 probability levels, respectively. CV (%) = coefficient of variation, DF= degree of freedom Eff. = efficiency of lattice design relative to randomized complete block design and R^2= r- square.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance (ANOVA) showed mean square due to genotypes were the highly significant differences for all evaluated traits (p<0.01). Highly significant differences were recorded for parameters like days to heading, days to maturity, grain filling period, plant height, biological yield, grain yield, harvest index, lodging, spike weight, thousand kernel weight, number of kernels per spike, number of spikelets per spike, spike length, leaf rust, stem rust, gluten (%), moisture (%), protein (%), hectoliter weight and Water absorption (%) (Table 2). Several researchers reported significant differences among bread and durum wheat genotypes studied (Kifle et al., 2016; Kumar et al., 2016; Wolde et al., 2016; Birhanu et al., 2016). Similarly, significant differences were reported for major traits in bread wheat (Shashikala, 2006; Kalimullah et al., 2012; Naik et al., 2015; Rahman et al., 2016).

Variance components and coefficients of variation

In the present study, the phenotypic variance was found relatively greater than its corresponding environmental variance (Table 3). The environmental variance was found to be lower than its corresponding genotypic variance for most of the quantitative traits as well as for all quality parameters. In agreement with the present finding, Ahmed et al. (2008) reported a high level of the genotypic variance than the environmental variance for days to heading, day to maturity, spikelets per spike, grains per spike, spike weight, thousand kernel weight, spike length, plant height, and biological yield. Selection is more effective when the genetic variance is higher relative to environmental variance (Poehlman and Sleeper, 2005).

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values greater than 20% are regarded as high values, PCV and GCV values between 10% and 20% are regarded as medium values and PCV and GCV values that are less than 10% are regarded as low values according to Deshmukh et al. (1986). High phenotypic coefficient of variations (PCV) was recorded for biological yield (25.10%), grain yield (46.59%), lodging (37.55%), harvest index (46.28%), spike weight per plant (34.13 %), thousand-seed weights (31.60%), and spike length (28.79 %) (Table 3). In line with present finding, Chand et al. (2008) reported a

Table 3. Estimation of the different variance parameters, heritability and genetic advance for 18 traits of 100 durum wheat accessions.

Traits	Mean± SE	Estimates of			PCV (%)	GCV (%)	ECV (%)	H^2 (%)	GA (5%)	GAM (%)
		σ^2 e	σ^2 g	σ^2 p						
DH	68.77(±)0.92	0.85	8.78	9.63	4.51	4.31	1.34	91.17	5.83	8.48
DM	103.57(±)1.07	1.14	15.24	16.38	3.91	3.77	1.03	93.04	7.76	7.49
GFP	34.80(±)1.33	1.78	25.49	27.27	15.00	14.51	3.83	93.47	10.05	28.89
PH	87.54(±)7.67	58.76	153.62	212.38	16.65	14.16	8.76	72.33	21.71	24.81
Bytha	8.60(±)0.16	0.03	4.63	4.66	25.10	25.02	2.01	99.36	4.42	51.38
Gytha	1.57(±)0.19	0.04	0.50	0.54	46.59	44.81	12.74	92.52	1.39	88.80
HI	18.88(±)2.32	5.37	70.98	76.35	46.28	44.62	12.27	92.97	16.73	88.63
LDG	1.62(±)0.15	0.02	0.35	0.37	37.55	36.52	8.73	94.59	1.19	73.17
SWT	1.39(±)0.10	0.01	0.22	0.23	34.13	33.36	7.19	95.56	0.93	67.17
TKW	32.43(±)1.97	3.87	101.18	105.05	31.60	31.02	6.07	96.32	20.34	62.71
NKPS	42.61(±)0.12	0.02	43.64	43.66	15.51	15.50	0.33	99.95	13.60	31.93
NSPS	30.40(±)0.72	0.51	6.18	6.69	8.51	8.17	2.35	92.37	4.92	16.18
SL	7.61(±)1.46	0.21	4.59	4.80	28.79	28.15	6.02	95.63	4.32	56.71
GLT	31.72 (±)0.77	0.60	8.09	8.69	9.29	8.96	2.44	93.09	5.65	17.82
MTR	10.56 (±)0.26	0.07	0.12	0.19	4.07	3.21	2.51	62.16	0.55	5.22
PRT	16.61(±)0.17	0.03	3.96	3.99	12.03	11.98	1.04	99.25	4.08	24.59
HLW	69.42(±)0.16	0.03	38.39	38.42	8.93	8.92	0.25	99.92	12.76	18.38
WAB	16.38 (±)0.61	0.38	12.81	13.19	22.17	21.85	3.76	97.12	7.26	44.35

* The selection differential =2.06 at 5% selection intensity, BY= biological yield tons ha-,[1] H^2(%)= broad sense heritability, DH= days to heading, DM= days to maturity, ECV(%) =environmental coefficient of variation, σ^2e = environmental variance, GAM(%) = genetic advance as percent of mean, GA(5%) = genetic advance, GCV(%) = genotypic coefficient of variation, σ^2g = genotypic variance, GLT= gluten (%),GFP = grain filling period, GY = grain yield tons ha-,[1] HI = harvest index (%),HLW= hectoliter weight (kg hl^{-1}), LDG = lodging(%), MTR= moisture(%),NKPS= number of kernels per spike, NSPS= number of spikelets per spike, PCV(%)= phenotypic coefficient of variation, σ^2p = phenotypic variance , PH = plant height(cm), PRT= protein (%), SL= spike length(cm) , SW = spike weight(g), TKW = thousand kernels weight(g) and WAB=water absorption (%).

higher phenotypic coefficient of variation (PCV) for grain yield per plant and the number of grains per spike. In this study, high genotypic coefficient of variations (GCV) was recorded for biological yield (25.02%), grain yield (44.81%), lodging (36.52%), harvest index (44.62%), spike weight per plant (33.36%), thousand-seed weights (31.02%), and spike length (28.15 %). This implied that the genotypic component had higher roles for phenotypic expression while environmental effects had a lower share in the expression of these traits. In agreement with this result, Chand et al. (2008) and Jalata et al. (2010) reported high values of GCV for grain yield and biological yield. Several authors' also reported supportive findings in line with the present results (Sharma et al*.,* 2005; Amsal et al., 2006; Desalegn et al., 2007; Bekele et al*.,* 2008).

Broad sense heritability and genetic advance

Heritability values classified as very high (≥ 80%), moderately high (60-79%), moderate (40-59%), and low (≤ 40% (Pramoda and Gangaprasad, 2007). If the heritability of a character is very high, selection for such characters could be very easy. Heritability values were ranged of 62.16% for moisture contents and 99.95% for the number of Kernels per spike, respectively. Genetic advance as percent of mean varied from 5.22% for the moisture contents to 88.80% for grain yield tons ha^{-1}, respectively. While genetic advance varied from 0.55 for the moisture contents to 21.71 cm for plant height respectively (Table 3).

In the present study, the magnitude of heritability was very high for all the characters recorded except for plant height (72.33%) and percent moisture (62.16%) which was moderately high (Table 3). Similar findings were reported by many authors (Dwived et al*.,* 2002; Yousaf et al*.,* 2008; Shankarrao et al*.,* 2010; Abinasa et al., 2011; and Azeb et al., 2016). In addition, Tazeen et al. (2009) found high heritability for days to heading and thousand kernels weight in wheat. Besides, Kumar et al. *(*2016) reported high estimates of heritability for days to heading, number of spikelets per spike, days to maturity, spike length, grain yield, biological yield, and harvest index. Falconer and Mackay (1996) classified genetic advance as percent of the mean as low (0 -10%), medium (10 - 20%), and high (20% and above). Accordingly, for characters like grain filling period (28.89%), plant height (24.81%), biological yield (51.38%), grain yield (88.80%), harvest index (88.63%), lodging (73.17%), number of

Table 4. Summary of descriptive statistics of mean performances for 15 and 5 quantitative and qualitative traits of 100 durum wheat accessions respectively.

Traits	Mean± SE	Min	Max	CV	LSD 5%	Pr > F
Days to heading	68.77(±)0.92	54.50	73.00	1.34	1.86	**
Days to maturity	103.57(±)1.07	99.00	124.50	1.03	2.06	**
Grain filling period	34.80(±)1.33	27.5	55.50	3.83	2.61	**
Plant height (cm)	87.54(±)7.67	54.25	128.75	8.76	15.21	**
Biological yield (t ha-^{1})	8.60(±)0.16	4.33	14.94	1.88	0.32	**
Grain yield (t ha-^{1})	1.57(±)0.19	0.64	4.58	11.93	0.38	**
Harvest index (%)	18.88(±)2.32	6.28	52.76	12.27	4.68	**
Lodging (%)	1.62(±)0.15	0.96	2.85	9.06	0.33	**
spike weight(g)	1.39(±)0.10	0.70	3.00	7.25	0.20	**
Thousand kernel weight (g)	32.43(±)1.97	13.14	48.50	6.07	4.18	**
Number of kernels per spike	42.61(±)0.12	26.00	58.55	0.29	0.25	**
Number of spikelet per spike	30.40(±)0.72	21.50	42.75	2.36	1.50	**
Spike length (cm)	7.61(±)1.46	4.75	19.25	5.99	0.91	**
Leaf rust	2.53(±)0.23	1.65	4.00	8.52	0.45	**
Stem rust	1.82(±)0.22	1.00	3.50	11.65	0.44	**
Gluten (%)	31.72 (±)0.77	26.25	39.40	2.44	1.53	**
Moisture (%)	10.56 (±)0.26	9.82	12.30	2.49	0.52	**
Protein (%)	16.61(±)0.17	12.30	23.40	1.04	0.34	**
Hectoliter weight (kg hl^{-1})	69.42(±)0.16	54.90	87.60	0.23	0.32	**
Water absorption (%)	16.38 (±)0.61	8.65	24.69	3.74	1.22	**

CV=coefficient of variation, LSD = Least significant difference at 5% ,SE=standard error of mean, Min = minimum, Max = maximum, ** significance at 0.01 probability levels.

kernel per plant (31.93%), spike weight (67.17 %), protein (24.59%), thousand kernels weight (62.71%), spike length (56.71%) and water absorption (44.35%) showed higher genetic advance as percent of the mean (Table 3). This indicates that most likely the heritability of these characters is due to additive gene effects, and selection might be effective for these characters (Salman et al., 2014; Rahman et al., 2016).

Similarly, Johnson et al. (1955) and Johnson et al. (2010) reported that the estimate of genetic advance is more useful as a selection tool when considered jointly with the estimates of heritability. This means that heritability value by itself cannot provide the amount of genetic progress that would result from a selection of the best individuals. It is not necessarily true that high estimates of heritability are always associated with high genetic gain (Ghuttai et al., 2015). Singh and Upadhyay (2013) reported a high magnitude of heritability and high genetic advance as a percentage of mean along with the high genotypic and phenotypic coefficient of variation for the number of grains per spike, thousand-grain weights and grain yield per hectare. Selection based on these characters would be fruitful for improvement in durum wheat. This suggests that these characters were governed by additive genes and recurrent selection could be effective. As a result, there is wide genetic variability within the studied accessions and hence several traits can be improved through conventional breeding activities.

Patterns of quantitative and qualitative traits variation and its importance value for breeding

Wider ranges of variations were observed among durum wheat accessions for all quantitative and qualitative Traits (Table 4). The observed wider range of variation in days to heading, maturity and grain filling period which ranged from 54.50 to 73.00 days (with mean of 68.77 days) and 99.00 to 124.50 days (with mean of 103.57days) and 27.50 to 55.50 days (with mean of 34.80 days), respectively. In present study offers great flexibility for developing improved varieties suitable for various agro-ecologies with a variable length of the growing period. Early maturing genotypes were desirable in areas where the terminal moisture is the limiting factor for durum wheat production. It also guides breeders to develop a variety that can escape late-season drought by improving traits that correlate to days to maturity in the required direction. Supportive findings were reported by (Wosene et al., 2015; Wolde et al., 2016). The mean of plant height was in the range of 54.25 to 128.75 cm. However, Wolde et al. (2016) report indicated that plant height for durum wheat varied from 81-144.15 cm. Spike length varied from 4.75 to 19.25 cm. This variability resulted from the morphological character of the accessions that might be due to variable genetic expression among genotypes and /or spatial environmental influence on the genotypes (Eid, 2009). In some accessions, there was an absence of exact correspondence between days to heading and days to maturity. That means most accessions with early heading did not show early maturity and late-maturing was not matched with late days to heading (Appendix Table B). This is in agreement with the finding of Khan (2013) who reported that the two characters do not coincide with each other for most of the studied genotypes. However, Mollasadeghi et al. (2012) reported the two characters' days to heading and maturity coincides with each other.

Grain yield, spike weight, and a number of spikelets per spike were ranged from 0.64 to 4.58 tons per hectare (with an average of 1.57), 0.70 to 3.00 g (with an average of 1.39 g), and 21.50 to 42.75 (with an average 30.40) respectively. Parameters like 1000-seed weight, biological yield and harvest index ranged between 13.14 to 48.50 g (with an average 32.43 g), 4.33 to 14.94 tons per hectare (with an average 8.60) and 6.28 to 52.76 % (with an average of 18.88%) respectively. (Table 4). Variation in grain yield, grain weight per spike, spike weight per plant and number of spikelets per spike, 1000-seed weight, biological yield and harvest index implied that it is possible to create a variety with higher grain yield and/or other biological yields (Appendix Table C) Variation for percent gluten varied from 26.25 to 39.40 % (with mean of 31.72 %), moisture (9.82 to 12.30 % and mean of 10.56%), protein (from 12.30 to 23.40 % with a mean of 16.61%) and water absorption from 8.65 to 24.69 % with a mean of 16.38 %. Hectoliter weight (kg hl^{-1}) varied from 54.90 to 87.60 kg hl^{-1} (with 34 mean value of 32.70 kg hl^{-1}). The Mean scores for leaf rust and stem rust were ranged from 1.65 to 4.00 (1 to 5 scale) (with mean of 2.53) and 1.00 to 3.50 (1 to 5 scale) (with mean of 1.82), respectively (Table 4)

CONCLUSION AND RECOMMENDATIONS

The present study revealed that there is comprehensive genetic variability among the studied materials with better agronomic performance that can provide basic information for further breeding activities for improvement and thus confident enough to expect genetic progress if further breeding activities are carried out. Accessions, such as Acc. No. 5510, 242784, 7375, 7683, 5609, 7710, and 5666 were found to have high grain yield and most of these accessions were more tolerant to economically important leaf rust and stem rust diseases reaction and suggested to be used in breeding programs. Generally, the present findings revealed adequate existence of variability for most of the traits in the studied accessions which need to be exploited in future durum wheat breeding programs for the study area.

Finally, it should be emphasized that the present data was generated from an experiment conducted for one season and at one location and might not be sufficient to measure the average improvement and hence suggests further multi-location and multi-season investigation. Therefore, efficient utilization of the available genetic resource and identification of superior genotypes for future breeding still urges intensive and multi-location morphological diversity study supported by the molecular marker system.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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APPENDICES

Table A. List of checks and 97 durum wheat accessions collected from different regions of Ethiopia and standard checks (Bekalcha, Dire and Obsa) from Sinana ARC.

Entry code	Acc. No.	Region	Latitude	Longitude	Altitude (m.a.s.l)
1	7375	Oromia	07-07-00-N	40-43-00-E	1710
2	5582	Oromia	08-57-00-N	37-52-00-E	2280
3	7710	Oromia	07-08-00-N	40-43-00-E	1980
4	238891	Oromia	07-01-30-N	40-21-07-E	2200
5	7207	Oromia	07-01-40-N	40-23-55-E	1990
6	5181	Oromia	07-01-20-N	40-19-46-E	1900
7	242782	Amara	11-05-00-N	37-52-00-E	2400
8	242793	Amara	10-18-00-N	38-12-00-E	2460
9	7532	Amara	10-18-00-N	38-12-00-E	2460
10	7056	Oromia	09-00-00-N	38-07-00-E	2350
11	7880	Oromia	07-17-00-N	38-36-00-E	2030
12	242781	Oromia	07-44-00-N	39-34-00-E	2140
13	5182	Oromia	08-24-00-N	39-52-00-E	2040
14	5171	Amara	10-34-00-N	38-14-00-E	2390
15	222393	Oromia	08-49-00-N	38-54-00-E	2400
16	7649	Amara	10-26-00-N	38-20-00-E	2460
17	5216	Oromia	08-12-00-N	39-34-00-E	2150
18	5020	Oromia	08-24-00-N	39-52-00-E	2040
19	6102	Oromia	07-46-00-N	39-47-00-E	2440
20	242790	Oromia	07-41-00-N	40-13-00-E	2395
21	5184	Oromia	07-45-00-N	39-40-00-E	2400
22	5515	Oromia	07-44-00-N	39-53-00-E	2430
23	5528	Amara	10-18-00-N	38-12-00-E	2460
24	7084	Amara	10-14-00-N	38-01-00-E	2440
25	7683	Oromia	07-39-00-N	39-46-00-E	2430
26	242785	Oromia	07-50-00-N	39-38-00-E	2410
27	7343	Amara	10-18-00-N	38-12-00-E	2460
28	7832	Amara	11-21-00-N	39-18-00-E	2300
29	6983	Amara	10-28-00-N	38-17-00-E	2430
30	5472	Amara	10-28-00-N	38-18-00-E	2410
31	5354	Oromia	08-53-00-N	37-51-00-E	2310
32	5729	Amara	11-06-00-N	39-45-00-E	1790
33	7647	Amara	11-05-00-N	37-42-00-E	2470
34	6988	Oromia	09-14-00-N	41-09-00-E	2260
35	5583	Oromia	08-54-00-N	38-54-00-E	2300
36	7020	Oromia	09-00-00-N	39-07-00-E	2330
37	239694	Oromia	38-54-00-N	38-54-00-E	2300
38	5183	Oromia	08-47-00-N	39-15-00-E	2300
39	5556	Oromia	09-47-00-N	39-16-00-E	2200
40	5175	Oromia	08-52-00-N	39-01-00-E	2133
41	5373	Oromia	38-54-00-N	38-54-00-E	2300
42	6968	Oromia	09-24-00-N	38-47-00-E	2160
43	7664	Oromia	09-01-00-N	39-15-00-E	2300
44	7218	Oromia	09-00-00-N	39-07-00-E	2330
45	5043	Amara	08-50-00-N	39-19-00-E	2260
46	6978	Amara	08-50-00-N	39-19-00-E	2260
47	7009	Oromia	08-51-00-N	38-30-00-E	2333
48	5174	Oromia	08-59-00-N	38-52-00-E	2300

Table A. Contd

49	7709	Oromia	09-01-00-N	39-03-00-E	2450
50	230678	Oromia	08-51-00-N	38-52-00-E	2300
51	242789	Oromia	08-54-00-N	39-01-00-E	2350
52	242792	Oromia	08-59-00-N	38-52-00-E	2300
53	5214	Oromia	08-58-00-N	39-00-00-E	2420
54	5428	Oromia	08-47-00-N	39-15-00-E	2300
55	7801	Oromia	09-01-00-N	39-15-00-E	2300
56	242791	Oromia	09-01-00-N	39-15-00-E	2300
57	5491	Oromia	08-59-00-N	38-52-00-E	2300
58	5510	Oromia	08-54-00-N	39-05-00-E	2200
59	7015	Oromia	08-49-00-N	39-00-00-E	1915
60	242784	Oromia	08-45-00-N	39-08-00-E	2350
61	5635	Tigray	14-10-00-N	38-42-00-E	2367
62	5609	Oromia	08-48-00-N	38-54-00-E	2080
63	5666	Tigray	14-07-00-N	38-29-00-E	2487
64	5572	Oromia	08-45-00-N	39-13-00-E	2070
65	5504	Oromia	08-45-00-N	39-15-00-E	2120
66	5197	Oromia	08-45-00-N	39-13-00-E	2160
67	7827	Oromia	08-47-00-N	39-15-00-E	2300
68	242786	Oromia	08-45-00-N	39-15-00-E	2120
69	5653	Oromia	08-45-00-N	39-08-00-E	2340
70	5534	Oromia	08-45-00-N	39-15-00-E	2120
71	242783	Oromia	09-47-00-N	39-46-00-E	2300
72	226897	Oromia	09-47-00-N	39-46-00-E	2300
73	5168	Oromia	09-47-00-N	39-16-00-E	2200
74	5179	Oromia	09-47-00-N	39-16-00-E	2300
75	7825	Oromia	09-47-00-N	39-16-00-E	2300
76	5198	Amara	08-50-00-N	39-19-00-E	2260
77	8072	Amara	08-50-00-N	39-19-00-E	2260
78	242779	Amara	08-50-00-N	39-19-00-E	2260
79	5492	Amara	08-50-00-N	39-19-00-E	2260
80	243733	SNNP	09-29-00-N	38-30-00-E	2333
81	5638	Oromia	08-51-00-N	38-30-00-E	2330
82	242780	Amara	08-50-00-N	39-19-00-E	2260
83	5597	Amara	12-38-00-N	37-28-00-E	2100
84	5044	Oromia	09-47-00-N	39-46-00-E	2300
85	5152	Oromia	08-47-00-N	39-46-00-E	2300
86	5554	Amara	10-34-00-N	37-29-00-E	2145
87	7018	Amara	11-00-00-N	36-54-00-E	2489
88	5669	Oromia	07-12-00-N	38-35-00-E	1773
89	7828	Oromia	08-50-00-N	38-22-00-E	1773
90	5367	Oromia	08-54-00-N	39-01-00-E	2350
91	5344	Amara	12-19-00-N	37-33-00-E	2145
92	5434	Oromia	08-47-00-N	39-15-00-E	2300
93	5166	Oromia	08-51-00-N	38-30-00-E	2333
94	5149	Oromia	08-16-00-N	38-52-00-E	1791
95	5169	Oromia	08-59-00-N	38-52-00-E	2300
96	5441	Oromia	07-47-00-N	39-39-00-E	2415
97	5557	Oromia	08-58-00-N	37-36-00-E	2430
98	Bekalcha	SARC			
99	Dire	SARC			
100	obsa	S ARC			

Table B. Mean for agro-morphological traits of durum wheat accessions tested in 2018 cropping season.

E.C	Acc. No.	DH	DM	DGFP	PH	LDG	SL	BY	GY	HI	SWT	TKW	NKPS	NSPS
1	7375	67.50	104.00	36.50	105.00	1.25	8.50	10.78	3.13	29.04	1.02	35.50	39.50	32.00
2	5582	69.50	101.00	31.50	101.25	1.25	7.50	7.19	1.28	17.70	1.41	15.50	36.55	28.50
3	7710	66.50	105.50	39.00	128.75	1.00	19.25	13.47	2.88	21.32	1.95	17.00	50.00	25.50
4	238891	69.00	104.50	35.50	89.00	1.60	8.00	8.52	0.97	11.31	0.83	14.50	49.00	31.50
5	7207	70.00	101.50	31.50	95.25	1.60	7.25	10.90	1.49	13.65	1.02	36.00	43.00	24.50
6	5181	66.50	107.50	41.00	84.00	1.60	11.50	9.82	1.88	19.17	3.00	15.50	26.00	29.00
7	242782	67.00	99.50	32.50	94.00	1.00	7.50	9.72	1.84	18.90	1.84	15.50	50.00	29.50
8	242793	69.50	103.00	33.50	107.75	1.00	7.00	12.66	1.82	14.34	1.54	32.50	46.00	28.00
9	7532	70.50	101.00	30.50	90.00	2.60	8.00	10.16	0.64	6.28	0.79	45.50	40.00	30.00
10	7056	64.50	105.50	41.00	97.00	1.60	7.25	8.07	1.84	22.81	1.13	44.50	44.80	29.50
11	7880	72.00	106.50	34.50	92.50	2.85	8.00	10.02	1.08	10.75	1.21	15.50	48.45	37.50
12	242781	70.00	104.00	34.00	106.50	1.00	7.00	8.88	2.54	28.59	1.33	41.50	56.00	33.50
13	5182	65.50	105.50	40.00	69.25	1.60	7.75	11.14	1.42	12.70	1.54	39.50	47.50	34.50
14	5171	66.50	103.50	37.00	78.00	1.00	5.00	6.98	1.97	28.08	1.21	36.50	38.00	32.00
15	222393	66.00	102.50	36.50	88.25	1.60	8.25	7.35	1.97	26.76	2.62	42.50	46.00	22.50
16	7649	70.50	101.50	31.00	90.25	2.85	7.00	9.84	0.94	9.54	1.31	32.50	50.00	34.50
17	Bekalcha	67.50	103.50	36.00	96.00	1.75	7.75	10.12	1.78	17.58	2.01	29.00	49.20	36.00
18	5216	67.50	102.50	35.00	85.50	1.50	7.00	12.15	1.36	11.12	2.02	14.75	35.00	22.75
19	5020	72.00	102.50	30.50	116.25	1.00	9.50	11.12	2.52	22.63	2.14	39.50	50.80	38.75
20	6102	71.50	103.00	31.50	76.75	2.85	6.00	6.39	0.75	11.75	2.37	45.50	40.00	24.00
21	242790	68.50	102.00	33.50	71.25	1.00	6.00	8.45	1.96	23.06	0.82	15.50	46.50	27.00
22	5184	71.50	100.00	28.50	91.75	1.50	6.50	7.59	1.16	15.12	1.39	37.50	48.80	30.75
23	5515	71.50	99.50	28.00	97.00	2.70	6.50	5.62	0.95	16.90	1.19	19.00	35.00	29.00
24	5528	72.50	101.50	29.00	91.25	2.70	6.50	7.03	0.73	10.30	1.38	18.50	53.50	24.50
25	7084	71.00	99.00	28.00	84.25	1.50	7.00	8.45	1.70	20.09	1.64	32.50	42.00	30.00
26	7683	71.50	99.50	28.00	65.75	1.00	6.50	7.64	2.99	39.04	1.76	18.50	33.55	26.00
27	242785	66.50	103.00	36.50	85.25	2.70	7.00	9.98	0.75	7.52	1.31	45.50	38.50	32.00
28	7343	72.00	100.50	28.50	96.00	1.60	6.00	7.77	1.86	23.82	1.06	17.50	42.45	31.75
29	7832	63.50	104.50	41.00	89.25	1.25	6.50	8.29	2.72	32.78	1.57	40.50	42.00	29.00
30	6983	69.50	106.00	36.50	93.75	1.25	9.25	9.12	1.19	13.03	1.27	18.75	44.00	35.25
31	5472	68.50	103.50	35.00	66.00	1.25	7.75	5.18	1.52	29.19	2.40	37.50	26.00	29.00
32	5354	67.50	102.00	34.50	87.25	1.25	5.75	4.33	0.99	22.91	1.11	36.50	38.00	30.00
33	5729	72.50	101.00	28.50	105.25	1.25	6.50	9.98	1.46	14.55	1.13	43.50	34.60	32.25
34	7647	66.00	106.50	40.50	90.25	1.25	9.25	9.20	2.14	23.26	1.08	31.50	42.80	25.50
35	6988	65.50	103.50	38.00	60.50	2.60	8.25	9.24	0.72	7.71	1.61	32.50	46.00	40.50
36	5583	69.50	109.00	39.50	104.25	1.25	5.75	10.37	1.99	19.16	1.07	46.50	45.30	25.00
37	7020	64.00	100.50	36.50	93.00	2.60	7.25	8.54	0.73	8.49	1.62	39.50	44.60	35.00
38	239694	69.50	101.00	31.50	94.75	1.25	8.25	9.10	1.47	16.09	1.09	42.50	48.00	36.50
39	5183	69.00	101.50	32.50	96.25	1.25	9.00	7.97	1.77	22.12	1.10	46.50	52.00	39.00
40	5556	71.50	120.00	48.50	75.00	2.75	8.25	12.35	1.87	15.10	1.38	45.50	44.70	29.00
41	5175	66.50	104.50	38.00	96.25	2.75	7.00	7.96	0.69	8.64	1.74	44.50	29.50	26.00
42	5373	69.00	103.50	34.50	80.25	2.75	6.25	9.98	0.84	8.40	1.05	38.50	43.40	28.50
43	6968	69.50	104.50	35.00	101.50	1.35	7.75	9.10	2.72	29.79	1.23	39.50	52.00	26.00
44	7664	65.50	103.50	38.00	62.75	1.25	4.75	6.23	1.79	28.67	0.99	14.50	42.00	23.75
45	7218	68.50	104.50	36.00	79.50	1.00	7.00	8.28	1.28	15.38	2.95	38.75	42.70	36.25
46	5043	69.00	103.00	34.00	95.50	1.75	7.25	12.41	1.06	8.47	1.26	14.50	43.60	28.75
47	6978	70.50	100.00	29.50	98.75	1.60	9.00	8.89	0.98	10.96	1.59	39.50	49.00	36.00
48	7009	71.50	103.50	32.00	79.50	2.85	7.75	7.24	0.65	8.99	1.81	41.50	26.00	23.00
49	5174	73.00	124.00	51.00	65.25	1.60	6.50	6.21	1.25	20.12	1.28	38.50	38.50	37.25
50	7709	64.50	105.50	41.00	69.25	1.60	8.25	6.36	1.88	29.56	1.19	18.50	48.45	32.75
51	230678	67.00	109.00	42.00	83.50	1.75	9.00	14.22	1.01	7.04	0.98	16.50	43.00	31.25

Table B. Contd.

52	242789	69.00	103.50	34.50	94.00	1.60	5.75	9.53	1.73	18.10	1.44	40.50	42.40	32.75
53	242792	69.50	101.00	31.50	66.75	2.60	7.25	8.05	0.94	11.67	0.75	37.50	56.00	40.00
54	5214	69.00	104.00	35.00	75.75	1.85	5.25	6.48	0.88	13.47	1.22	13.50	32.35	25.25
55	5428	69.50	107.00	37.50	90.25	2.35	5.50	7.43	0.86	11.47	1.04	34.50	40.00	27.75
56	7801	70.50	100.50	30.00	65.00	1.25	5.75	8.04	2.15	26.74	1.81	43.50	40.00	32.50
57	242791	69.00	100.50	31.50	65.75	1.25	7.75	6.23	1.67	26.49	1.85	37.50	35.55	26.00
58	5491	65.50	103.50	38.00	86.75	1.85	7.00	7.57	1.00	13.24	1.17	13.00	49.60	31.75
59	5510	67.00	106.00	39.00	108.25	1.25	17.25	11.14	4.58	41.06	1.44	20.00	44.00	25.75
60	7015	69.50	101.50	32.00	54.25	1.25	9.25	11.76	1.87	15.84	1.28	21.50	49.50	26.00
61	242784	65.50	104.50	39.00	78.50	1.60	8.75	13.49	3.69	27.33	0.97	19.50	46.00	27.25
62	5635	64.50	112.00	47.50	99.75	1.25	6.75	5.87	2.27	38.53	0.77	31.50	49.00	28.00
63	5609	71.50	101.00	29.50	71.25	1.25	6.00	5.52	2.92	52.76	1.57	19.50	36.40	30.75
64	5666	67.50	104.00	36.50	120.00	1.25	18.00	14.94	2.86	19.08	1.89	43.50	49.00	23.50
65	5572	71.00	102.50	31.50	63.25	2.60	9.50	8.66	1.89	21.81	0.74	36.50	36.35	37.75
66	5504	70.00	102.00	32.00	85.25	2.85	7.00	10.18	0.80	7.88	1.40	30.50	42.45	27.00
67	5197	72.00	99.50	27.50	94.25	1.00	6.50	8.58	1.94	22.57	1.18	35.50	46.00	32.50
68	7827	72.50	102.50	30.00	73.75	1.25	5.00	5.98	1.28	21.39	1.22	41.50	26.00	25.75
69	242786	71.50	101.50	30.00	96.25	1.25	6.75	5.08	1.22	23.84	1.28	43.50	32.45	35.00
70	5653	69.00	102.00	33.00	88.75	1.00	6.00	11.05	2.54	22.96	0.79	14.50	48.00	29.00
71	5534	72.50	100.50	28.00	90.25	1.35	6.00	5.20	1.22	23.26	0.80	35.50	38.00	28.50
72	242783	71.50	100.00	28.50	72.75	1.25	7.50	8.93	1.08	12.03	2.23	43.50	31.55	29.25
73	226897	68.50	104.50	36.00	91.50	2.60	9.00	10.97	1.17	10.62	0.75	36.50	46.00	32.50
74	5168	71.50	102.50	31.00	68.50	1.60	8.50	5.16	1.03	19.94	1.35	18.50	27.00	34.25
75	5179	69.50	103.50	34.00	67.00	1.25	5.75	4.71	1.87	39.58	0.80	36.50	48.00	32.25
76	7825	69.50	102.50	33.00	68.75	2.60	8.50	8.52	0.97	11.33	0.91	31.50	45.35	34.00
77	5198	69.00	124.50	55.50	89.25	1.25	8.00	6.46	2.19	33.88	2.03	35.50	36.00	29.75
78	8072	68.50	104.00	35.50	87.50	1.00	7.25	5.19	1.30	24.94	1.02	41.50	37.00	35.00
79	242779	72.50	101.50	29.00	79.00	1.00	9.25	9.46	2.44	25.82	2.16	41.50	48.00	42.00
80	5492	65.00	102.50	37.50	105.25	1.60	8.50	7.89	1.64	20.80	1.24	45.50	45.00	42.75
81	243733	68.50	103.50	35.00	85.25	2.60	7.25	5.26	0.74	14.07	1.57	48.50	44.00	26.50
82	5638	71.00	102.50	31.50	95.25	1.60	7.50	10.64	1.18	11.06	1.10	17.00	41.30	21.50
83	242780	70.50	101.00	30.50	75.50	1.00	8.25	6.87	0.89	12.97	0.95	48.50	37.00	25.00
84	5597	72.50	103.50	31.00	108.75	1.25	7.25	10.47	2.15	20.57	1.22	16.25	50.00	21.50
85	5044	71.00	103.00	32.00	112.00	1.25	7.25	8.38	2.54	30.32	2.11	36.50	48.00	34.75
86	5152	72.50	103.50	31.00	92.00	1.50	7.25	6.49	0.73	11.18	0.70	17.75	36.00	27.50
87	5554	55.50	101.50	46.00	96.00	1.00	5.75	6.77	1.16	17.06	1.39	35.50	30.00	28.25
88	7018	68.00	102.50	34.50	71.75	1.60	6.50	8.37	0.73	8.67	1.62	18.50	45.55	26.25
89	5669	68.00	101.00	33.00	101.25	1.00	6.00	6.94	1.27	18.22	1.42	31.50	40.00	29.25
90	7828	65.00	107.00	42.00	87.25	2.60	7.25	7.73	0.81	10.37	1.95	43.50	44.50	34.25
91	5367	68.00	102.50	34.50	90.00	1.00	8.25	6.14	1.01	16.31	1.24	35.50	35.65	36.50
92	5344	54.50	101.50	47.00	85.25	1.25	10.50	9.01	1.00	11.11	1.07	39.50	48.00	37.00
93	5434	69.00	100.00	31.00	95.25	1.00	7.25	8.88	1.29	14.54	0.98	19.50	55.00	29.00
94	5166	67.00	102.00	35.00	100.25	2.25	6.25	9.37	0.97	10.28	1.35	24.50	42.35	28.75
95	5149	71.00	101.50	30.50	97.00	1.00	5.75	8.87	2.41	27.06	1.24	40.50	46.00	26.50
96	5169	68.00	103.50	35.50	90.25	1.00	6.75	7.53	1.69	22.39	1.19	44.50	56.00	37.00
97	5441	72.00	102.00	30.00	85.75	1.60	6.75	10.27	2.48	24.11	0.77	41.50	40.20	25.00
98	5557	65.00	106.00	41.00	73.50	1.00	4.75	5.12	1.02	19.80	1.38	41.50	58.55	24.75
99	Dire	71.00	102.50	31.50	73.25	2.35	6.75	9.89	0.99	10.00	0.89	38.50	26.25	30.00
100	obsa	72.00	103.50	31.50	99.25	1.25	8.75	11.24	1.11	9.78	2.33	41.50	41.50	35.75
	Minimum	54.50	99.00	27.50	54.25	0.96	4.75	4.33	0.64	6.28	0.70	13.14	26.00	21.50
	Maximum	73.00	124.50	55.50	128.75	2.90	19.25	14.94	4.58	52.76	3.00	48.79	58.55	42.75
	Mean	68.77	103.57	34.80	87.54	1.62	7.61	8.60	1.57	18.88	1.39	32.43	42.61	30.40

Table B. Contd.

SE(±)	0.92	1.07	1.33	7.67	0.15	0.46	0.16	0.19	2.32	0.10	1.97	0.12	0.72
CV%	1.34	1.03	3.83	8.76	9.06	5.99	1.88	11.93	12.27	7.25	6.07	0.29	2.36
LSD 5%	1.86	2.06	2.61	15.21	0.33	0.91	0.32	0.38	4.68	0.20	4.18	0.25	1.50

E.C = Entry code Acc. No = accession number, DH = days to heading, DM= days to maturity, DGFP =days to grain filling period, PH=plant height, LDG = lodging (1-5 scale) and SL = spike length, BY= biological yield tons ha,$^{-1}$ GY = grain yield tons ha^{-},^{1} HI = harvest index (%), SW = spike weight(g), TKW = thousand kernels weight(g), NKPS= number of kernels per spike, NSPS= number of spikelets per spike, SE=standard error of mean, CV%= coefficient of variation, LSD 5%= least significant difference at 5%.

Table C. Major diseases and qualitative traits mean performance for 100 durum wheat accessions tested in 2018/19 cropping season.

E.C	Acc. No.	LR	SR	GLT	MTR	PRT	HLW	WAB
1	7375	3.75	3.25	34.35	10.35	16.75	70.75	12.82
2	5582	2.50	1.70	28.30	12.30	13.35	73.00	16.09
3	7710	3.50	3.00	33.00	9.96	14.25	83.00	22.30
4	238891	2.00	1.50	30.95	10.40	19.15	73.40	12.91
5	7207	2.50	1.70	30.40	10.30	15.80	72.20	15.62
6	5181	2.60	1.85	32.75	10.15	15.30	66.10	15.64
7	242782	2.55	1.75	30.45	10.50	17.40	70.40	10.01
8	242793	2.55	1.75	32.70	10.50	16.20	74.20	14.30
9	7532	1.70	1.00	35.40	10.20	17.15	81.90	23.02
10	7056	2.60	1.85	27.45	10.55	16.15	69.95	17.22
11	7880	2.25	1.60	27.45	10.55	15.95	69.95	23.89
12	242781	3.10	2.50	29.50	10.55	13.45	72.20	17.57
13	5182	2.50	1.70	26.80	11.10	15.85	68.00	17.87
14	5171	2.65	1.90	27.85	10.15	13.10	70.20	11.13
15	222393	2.65	1.90	29.30	10.30	16.80	69.40	14.58
16	7649	2.00	1.50	30.85	10.45	15.40	70.55	12.77
17	Bekalcha	2.55	1.75	31.45	11.15	15.20	72.60	15.40
18	5216	2.50	1.70	31.00	11.10	15.10	71.80	16.65
19	5020	3.10	2.50	31.35	10.55	14.10	76.60	23.98
20	6102	2.00	1.00	31.45	10.25	15.10	67.80	18.15
21	242790	2.65	1.90	35.45	10.15	17.15	71.80	15.56
22	5184	2.25	1.60	36.85	10.24	18.10	61.80	17.58
23	5515	2.25	1.60	36.75	10.35	18.19	62.50	15.21
24	5528	1.75	1.25	35.35	10.35	19.15	57.30	17.80
25	7084	2.55	1.75	30.90	10.70	15.05	71.50	15.96
26	7683	3.75	3.25	31.30	10.45	15.35	74.60	11.49
27	242785	1.75	1.00	28.25	11.35	19.50	58.50	22.95
28	7343	2.60	1.85	34.40	10.55	17.25	64.10	17.36
29	7832	3.50	3.00	26.40	10.45	12.30	77.40	18.11
30	6983	2.50	1.70	33.90	10.35	19.75	73.00	16.84
31	5472	2.50	1.70	27.25	11.85	17.20	78.60	22.46
32	5354	2.25	1.60	30.45	10.45	15.35	68.20	11.63
33	5729	2.50	1.70	32.30	10.30	15.00	74.20	16.54
34	7647	2.70	2.00	30.30	10.40	14.25	75.00	13.40
35	6988	1.85	1.00	33.05	10.10	16.55	77.80	17.63
36	5583	2.65	1.90	29.75	10.45	13.95	85.40	15.25
37	7020	1.95	1.00	31.25	10.30	16.75	62.90	10.50
38	239694	2.50	1.70	31.25	10.60	15.90	72.60	19.86
39	5183	2.55	1.75	27.85	11.15	16.25	69.80	13.29
40	5556	2.60	1.85	28.95	10.75	16.40	69.80	17.66

Table C. Contd.

41	5175	1.75	1.00	39.40	10.25	23.15	55.30	14.64
42	5373	2.00	1.50	28.90	11.05	18.30	68.60	15.76
43	6968	3.50	3.00	29.90	10.35	14.15	73.80	17.47
44	7664	2.60	1.85	32.30	10.20	15.15	76.20	11.09
45	7218	2.50	1.70	35.35	10.10	17.24	71.40	14.02
46	5043	2.50	1.70	29.35	10.55	16.05	73.80	18.74
47	6978	2.25	1.60	26.30	10.40	16.75	68.20	13.14
48	7009	1.65	1.00	37.80	10.75	22.20	58.50	16.44
49	5174	2.50	1.70	34.40	10.45	16.35	66.10	24.69
50	7709	2.60	1.80	35.30	10.35	15.40	75.80	12.94
51	230678	2.25	1.60	34.55	10.20	17.75	69.80	12.87
52	242789	2.55	1.75	32.55	10.40	15.45	70.60	15.93
53	242792	2.25	1.60	26.75	10.85	18.05	60.50	15.01
54	5214	2.25	1.35	38.85	10.15	20.31	70.20	14.13
55	5428	1.95	1.25	34.30	10.10	16.45	59.70	18.79
56	7801	2.70	2.00	30.80	11.05	17.07	68.60	14.13
57	242791	2.55	1.75	31.45	10.90	15.20	67.80	18.18
58	5491	2.25	1.60	30.70	10.70	15.80	75.40	16.62
59	5510	4.00	3.50	33.35	10.15	14.30	67.80	21.53
60	7015	2.65	1.90	29.75	10.40	17.20	78.60	16.65
61	242784	4.00	3.50	32.95	10.40	15.45	76.60	13.31
62	5635	2.70	2.00	27.90	11.15	13.15	78.20	17.07
63	5609	3.75	3.25	28.90	9.82	15.00	60.50	18.96
64	5666	3.50	3.00	30.60	10.30	13.40	87.60	15.07
65	5572	2.65	1.90	34.45	10.05	16.15	76.60	23.19
66	5504	1.75	1.25	28.85	10.60	17.30	66.60	23.19
67	5197	2.65	1.90	26.25	10.95	15.40	81.00	16.49
68	7827	2.50	1.70	35.90	10.55	19.22	55.30	13.88
69	242786	2.50	1.70	32.95	10.20	17.25	69.80	11.83
70	5653	3.10	2.50	28.00	11.15	15.85	73.80	15.80
71	5534	2.50	1.70	33.80	10.65	17.88	68.20	13.33
72	242783	2.25	1.60	31.40	10.50	20.70	69.40	14.26
73	226897	2.50	1.70	28.80	11.25	16.45	69.00	22.03
74	5168	2.25	1.60	31.75	10.90	17.15	62.10	18.19
75	5179	2.65	1.90	31.25	10.80	15.45	63.30	16.23
76	7825	2.25	1.60	33.90	10.90	18.10	63.70	10.99
77	5198	2.70	2.00	27.95	10.55	16.30	73.80	22.64
78	8072	2.50	1.70	33.70	10.95	17.30	59.70	22.92
79	242779	2.70	2.00	30.40	10.60	14.45	69.40	10.18
80	5492	2.55	1.75	34.05	11.20	17.75	64.50	18.37
81	243733	2.00	1.00	34.95	11.00	22.20	65.70	14.35
82	5638	2.50	1.70	28.90	10.60	18.07	64.90	18.84
83	242780	2.00	1.50	28.10	10.45	17.10	74.40	10.72
84	5597	2.70	2.00	30.20	10.20	14.10	76.60	24.01
85	5044	3.10	2.50	30.45	10.15	13.60	80.20	8.65
86	5152	2.00	1.00	36.75	10.05	17.35	62.50	9.85
87	5554	2.5.00	1.70	32.50	10.35	16.25	65.70	11.40
88	7018	1.75	1.00	32.85	10.05	16.35	64.10	16.32
89	5669	2.50	1.70	31.75	10.45	16.35	63.70	19.81
90	7828	2.00	1.25	34.95	10.10	17.10	67.60	18.72
91	5367	2.50	1.70	33.40	10.95	22.60	60.90	21.55
92	5344	2.25	1.60	26.75	10.25	13.35	69.80	15.75

Table C. Contd.

93	5434	2.50	1.70	33.65	10.65	17.00	62.90	17.31
94	5166	2.25	1.60	34.90	10.75	17.60	61.70	16.85
95	5149	3.10	2.50	31.20	11.00	16.15	70.20	17.60
96	5169	2.55	1.75	34.05	10.85	17.45	67.80	15.45
97	5441	3.10	2.50	30.50	10.75	15.25	68.60	12.54
98	5557	2.50	1.70	39.40	10.30	23.40	54.90	15.32
99	Dire	2.25	1.60	37.85	10.20	19.30	58.50	18.29
100	obsa	2.50	1.70	28.40	11.30	17.45	64.90	15.25
	Minimum	1.65	1.00	26.25	9.82	12.30	54.90	8.65
	Maximum	4.00	3.50	39.40	12.30	23.40	87.60	24.69
	Mean	2.53	1.82	31.72	10.56	16.61	69.42	16.38
	SE(±)	0.22	0.21	0.77	0.26	0.17	0.16	0.61
	CV%	8.52	11.65	2.44	2.49	1.04	0.23	3.74
	LSD 5%	0.45	0.44	1.53	0.52	0.34	0.32	1.22

E.C = Entry code, Acc. No = accession number, LR =leaf rust, SR = stem rust (1-5 scale), GLT= gluten (%), MTR= moisture (%), PRT = protein (%), HLW= hectoliter weight (kg hl^{-1}) and WAB = Water absorption (%) SE=standard error of mean, CV%= coefficient of variation, LSD 5%= least significant difference at 5%.