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Phenotypic screening and performance evaluation of durum wheat landraces in the highland areas of North Gondar

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Abstract

Durum wheat (2n=28, AABB, *Triticum turgidium* L. ssp. Durum) is the most commonly cultivated form of allotetraploid wheat and is grown on 8% of the world's wheat area. The trial was conducted at Dabat Station of Gondar Agricultural Research Center, northern Ethiopia, with the objective of screening and advancing the best-performed landraces with respect to disease and other quantitative parameters. One hundred durum wheat landraces were evaluated using a 10*10 simple lattice design. The analysis of variance revealed the presence of highly significant ($p<0.01$) variation among the landraces for all traits. The highest and the lowest plant height was recorded from genotype 206421 (143cm) and Mangudo (82.45cm), respectively. The highest number of kernels per spike was obtained from Workaye (51.75) while the lowest was from 8019 (19.90). Genotype 236986 and 229251B had the highest and the lowest thousand kernels weight of (44.24) and (10.8 gm). The highest grain yield was recorded from 219368 (7.27t/ha) while the lowest was obtained from 206421 (0.64t/ha). The observed wide range of differences among the genotypes for these main traits may be due to genetic differences. According to this result, none of the landraces were immune and highly susceptible to septoria tritici blotch, the majority was moderately resistant (68) to moderately susceptible (30), while only the two landraces resistance to septoria. According to the result, 61 genotypes were found immune against stripe rust. 14 genotypes showed the symptom of resistance, while 13 lines in the range of resistance to moderate resistance. Only 4% of the observed landraces were moderately susceptible and 8% observed to be highly susceptible to stripe rust. These results indicated that a large number of genotypes have a high level of resistance against wheat stripe rust and create more genetic variations through the crossing.

Keywords: durum wheat, landraces, screening, wheat disease

Introduction

Durum wheat (2n = 28, AABB, *Triticum turgidum* L. ssp. durum) is the most commonly cultivated form of allotetraploid wheat and is grown on 8% of the world's wheat area (FAOStat, 2016) [10]. It originated in the Mediterranean region and is used to make pasta and semolina products (Ren *et al*., 2013) [24]. Approximately 75% of durum wheat is still grown in the Mediterranean basin in irrigated and rainfed environments, which contributes to 50% of the worldwide production (Kabbaj *et al*., 2017) [13].

Durum wheat landraces were specifically adapted to their region of origin, representing a diversity of agro-ecological zones, and are considered to be the most important sources of biodiversity within the species (Nazco *et al*., 2012) [19]. Landraces were largely cultivated until the first decades of the twentieth century, being progressively abandoned from the early 1970s and replaced with improved, genetically uniform semi-dwarf cultivars as a consequence of the Green Revolution (Soriano *et al*., 2018) [29]. However, scientists believe that local landraces represent an important group of genetic resources for the improvement of commercially valuable traits (Lopes *et al*., 2015) [17].

Ethiopia is the center of diversity for durum wheat (Tesfaye Wolde *et al*., 2016) [32]. It is one of the major cereal crops grown at an altitude ranging from 1500 to 3200 meters above sea level (m.a.s.). It is grown over a wide range of environments, which are different in soil fertility, the incidence of weeds, disease, pests, and waterlogged conditions. Durum wheat research in Ethiopia started back in 1949 at the Paradiso Experimental Station near Asmara (Tesemma, T., & Mohammed, 1982) [31]. Among several local durum landrace collections tested for productivity and stem and leaf rust resistance, four selections (A10, H23, P20, and R18) were developed and released to farmers in Eritrea in 1952 (Sall *et al*., 2019) [25].

According to the Central Statistics Agency (CSA, 2018) [8] the average yield of durum wheat in Ethiopia is estimated to be 27.4 q/ha. Ethiopian farmers usually grow tetraploid wheat as a mixture of different morph types (Workineh Abebe, 2008)Variations of Ethiopian wheat landraces for morphological and cytological markers have been studied (Tesfaye Wolde *et al*., 2016) [32]. However, currently, this broad genetic diversity is being threatened in different ways (Bogale *et al*., 2011) [6]

Reduction in genetic variability makes the crops increasingly vulnerable to diseases and adverse climatic changes (Ghaneie *et al*., 2012) [11]. The introduction of exotic wheat replacing the durum wheat landraces resulted in the loss of genetically diverse, locally well-adapted landraces (Soriano *et al*., 2018) [29]. 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 (Ceoloni *et al*., 2017) [7]. 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) [1]

Genetic potential of different genotypes available to plant breeders can be exploited only if a systematic evaluation for various traits is undertaken. Possible segregations in morphological traits are essential for genetic improvement programs and genetic diversity of durum wheat genotypes could be evaluated using morphological variation (De Vita *et al*., 2010) [9]. Description of the morphological traits has been used for genetic diversity analyses and cultivar development (Afrooz *et al*., 2015) [3]

Genetic variability among durum wheat genotypes can be estimated based on qualitative and quantitative traits. The choice of parents is of paramount importance in the breeding program. For effective selection, information on nature and magnitude of variation in the population, an association of character with yield and among themselves, and the extent of environmental influence on the expression of these characters are necessary (Yagdi & Sozen, 2009) [34]

However, in recent times the research work has been focused mainly on genetic improvement of introduced wheat than indigenous durum wheat accessions. These make gradual reducing the variability of Ethiopian durum wheat landraces and farmers use available local varieties that are low yielding and susceptible to diseases due to a shortage of improved verities.

Genetic divergence arises either as a result of geographic separation or genetic barriers to crossability (Sharma *et al*., 2018) [27]. Knowledge of the extent and pattern of genetic diversity within and between populations (accessions) is very important for the identification of useful materials for plant breeding purposes and to better understand the crop to design appropriate collection and conservation strategies. It is believed that crosses between genetically diverse parents are likely to produce higher heterosis, desirable genetic recombination, and segregation in progenies (Asmamaw Meseret, 2019) [5]

Besides, knowledge of the naturally occurring diversity in a population of durum wheat landraces helps to identify diverse groups of genotypes that can be useful for the breeding program. Therefore, the present investigation was conducted with the objective of this study was to select and advance the best genotypes based on the required traits to preliminary yield trials PYT.

Materials and Methods

The experiment was conducted in the 2019/2020 cropping season at Dabat Agricultural Research Station under Gondar Agriculture Research Center (GARC). The experimental site is located at 248 km distant from Bahir Dar (the capital city of Amhara Regional State) and 809.09 km from Addis Ababa to the Northern part of the country, and 75.8 km from Gondar town. Dabat Research Site/Station is located at "12°59′03″N latitude and " 37°45′54″E longitude, with an altitude of 2607 m.a.s.l. The minimum annual temperature ranges between 4.6°C and 24.5°C. Dabat has a unimodal rainfall. According to the available digital data, the mean annual rainfall for the area ranges from 1250 to 1565mm. The rainy months extend from June to the end of September, and dominant soil in the area is Vertisol (Nigus Demelash *et al*., 2013) [20]

Experimental Materials

A Total of 100 durum wheat genotypes were used for the experiment. These genotypes were obtained from the Institute of Bioversity Research International, Addis Ababa, Ethiopia. All the genotypes are local collections from the major durum wheat-growing regions of the country.

Experimental Design and Procedure

The trial was laid down using a 10 x 10 simple lattice design. Each genotype would have been planted in a plot size of 1m^2 (2.5m x 0.4m). Each plot had two rows with 20 cm row spacing, and the spacing between was 0.3m, 1m, and 2m plots, blocks, and replications respectively. The experiment had a total of 200 plots (100plots per replication) with a total area of 27m x15.4m (415.8m^2**)**. Seeding rate of 150kg /ha and recommended fertilizer rate, 100kg DAP, and 50 kg Urea was used. All DAP fertilizer was applied at planting while nitrogen fertilizer was applied in split (½ at planting, ¼ at tillering, and ¼ at head initiation (MOARD, 2012). Weeding and other agronomic management practices were done as per the recommendation for durum wheat.

Data Collection

Phenological Traits

Days to heading (days): The number of days was recorded from the date of emergency to the stage when the spikes of 50% of the plants are fully visible (exerted*)*.

Grain filling period (days): The grain filling period in days was computed by subtracting the number of days to heading from the number of days to maturity.

Days to physiological maturity (days): It was calculated as the number of days from emergence to 95% maturity that is the number of days to maturity minus the number of days to emergence.

Yield and Yield Related Traits

Plant height (cm): The average height of ten plants randomly taken from each plot at physiological maturity and measured from the ground to the tip of the panicle excluding the awns.

Biological yields (t/ha): It was record by weighing the total above-ground yield harvested from the two rows of each experimental plot at the time of harvest.

Thousand kernels weight (gm): The weight of one thousand randomly taken kernels from each experimental plot.

Grain yield (t/ha): The grain yield per plot was measured in gram using sensitive balance after moisture of the seed is adjusted to 12.5%. The total dry weight of grains harvested from the two rows was taken as grain yield per plot and expressed as a ton per hectare for analysis.

Kernels per spike: Number of kernels per spike were counted from ten randomly taken plants and the average was worked out.

Spikelet per spike: Number of spikelets per spike were counted from ten representative spikes per plant and average was worked out.

Spike length (cm): The average spike lengths of ten plants on the main Culm from the base of the spike to the top of the last spikelet excluding awns.

Disease data: The major wheat disease was recorded based on the standard recording method

Rust Severity is recorded as a percentage, according to the modified Cobb scale, based on visual observations. Disease reaction is recorded as no infection (0), resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S).

Description

00 No visible infection on plants

RR visible chlorosis or necrosis, no uredia present

MR small uredia present and surrounded by either chlorotic or necrotic areas

MS medium size uredia present and possibly surrounded by chlorotic areas

SS large uredia present, generally with little or no chlorosis and no necrosis.

Lodging

Lodging is the permanent displacement of stem from its upright position. When stems of normally upright plants fall over and do not return to their upright position, the plant is said to have lodged (Pinthus, 1973). Lodging is often not distributed uniformly throughout an affected field but maybe scattered over certain sections or spots.

Uncertainty in climatic and weather conditions may result in lodging. Lodging reduces the yield in cereals and oilseeds which ranges from 25-75% depending upon the stage of the crop (Kesarwani, 2020). In India, about 6.3 m ha area under wheat crop suffered due to lodging in 2015 (Kesarwani, 2020).

The lodging in wheat landraces was termed as natural lodging due to factors like wind, storm, and rain (Khakwani *et al.*, 2010). An area of each plot was assessed carefully for recording and data using plot populations how much the plot populations and to what extent of the crop was lodged. taking as a percentage for each genotype both under normal and lodged conditions. Crop standing ≈90^0 were considered normal or upright plants whereas plants bent to ≥ 30^0 were designated as a lodged crop (Khakwani *et al.*, 2010)

Statistical Analysis

Analysis of variance (ANOVA) was computed to test the presence of significant differences among genotypes for studied traits. The data were collected for each quantitative trait and would be subject to analysis of variance using Proc lattice of SAS version 9.2, (SAS Institute, 2008). Fisher's protected least significant difference (LSD) test at 1% or 5% level of significance was used for mean comparisons, whenever the Analysis of Variance (ANOVA) result showed difference among genotypes for traits.

Results and Discussions

The analysis of variance (ANOVA) showed that there was a highly significant difference among the genotypes of most of the studied traits. This gives an ample opportunity to plant breeders for the improvement of those traits through selection. highly significant difference among durum wheat genotypes for days to heading, days to maturity, plant height, number of kernels per spike, spike length, and thousand-grain weight (Abinasa *et al.*, 2011) [1] The significant difference among the landraces for the traits indicates that the presence of genetic variation among the genotypes which in turn suggests that selection of lines can be effective in improving both yield and quality traits. Similarly, (Pandey *et al.*, 2009) and (Shah *et al.*, 2019) reported that there is a considerable genetic variability existing for quantitative and qualitative traits in durum wheat.

Table 2: The mean values of phenological, yield and yield-related traits, and disease data

Traits	Range	Mean	R2	CV	Sig
DH	63-77.5	69.78	0.83	3.53	***
GFP	41-68.5	51.75	0.73	8.06	**
DM	118-130	120	0.91	1.21	***
BY	0.85-20	1.34	0.77	13.45	***
GY	6.42-72.7	30.54	0.91	23.88	***
TSW	10.8-44.2	26.86	0.89	15.28	***
PH	82.45-143	112.72	0.87	4.90	***
SPL	6.8-9.9	8.42	0.73	5.12	**
SPS	14.85-20.7	18.01	0.74	6.04	**
KPS	19.9-51.8	34.24	0.75	17.04	**
SEP	13.79-48.9	30.80	0.89	16.55	***
StR	0-80	13.63	0.83	124.08	***
Lodg	0-90	34.36	0.84	52.05	***

DH=days to heading, GFP=grain filling period, DM =days to maturity, BY=biological yield, GY=grain yield, TSW=thousands seed weight, PH=plant height, SPL=spike length, SPS=spiklets per spike, KPS=kernels per spike, SEP=septoria, STR=stripe rust, LODG=lodging, R^2=determination of coefficient CV=coefficient of variation, Sig=significant level

The variations of phenological traits such as days to heading and grain filling period of the genotypes influences directly on grain yield and the genetic bases for these traits. This would be more advantageous according to the given environmental conditions because lengthening or shortening of these traits has to be based on breeding objectives and environmental conditions for the effective breeding program (Shimels, 2015). The longest and the shortest days to maturity were recorded on local variety (130.5 days) and genotype 231572 (118 days). The variations influence directly grain yield and help to plan our breeding program

by grouping lines which are early and late maturing. This selection of lines is based on their own genetic bases and advance them on different agro-ecologies which are favorable to durum wheat production and productivity.
The longest and shortest plant height was recorded on genotype 206421 (143 cm) and Mangudo (82.45cm), respectively. Genotype 236986 and 229251B had the highest and the lowest thousand kernels weight of (44.24) and (10.8 gm). The highest grain yield was recorded from 219368 (7.27t/ha) while the lowest was obtained from 206421 (0.64t/ha). The highest and the lowest number of kernels per spike were recorded from genotype Workaye (51.75) and 8019 (19.90), respectively. Hence, the number of kernels per spike is an important grain yield components and it has been reported that high grain yield in the new bread durum wheat varieties are associated with the increasing number of grains per spike or per unit area and thousand kernels weight (Nuno *et al*., 2013).

Table 3: disease data, its reaction and host response for Septoria

Disease	No. Observations	Reaction Response	Host Response
Septoria	00	00	IM
	02	01-14	RS
	68	15-35	MR
	30	36-55	MS
	00	56-79	SS
	00	>80	HS

IM=immune, RS=resistance, MR=moderetly resistance, MS=moderately susceptible, SS=sucseptable, HS=highly suceptable

Disease Data
The disease data were scored septoria by double-digit (00-99) method and rust disease by modified cobb scale (0-100%). From this information, our durum wheat landraces were in the range from resistance to highly susceptible to both of septoria and stripe rust.

Septoria
Most of the landraces 68 are ranged between 15-35% which are moderately resistant. 30 genotypes are ranged between 36-55% which are moderately susceptible to septoria, and only tow genotypes are resistant (0-14%) and zero/none of the genotypes are immune, susceptible, and highly susceptible.

Table 4: Disease data, its reaction and host response for stripe rust

Disease	No. Observ	Reaction Level	Host Response
Stripe Rust	61	00	MI
	14	5-20	RS
	13	21-40	MR
	4	41-60	MS
	8	>61	SS

IM=immune, RS=resistance, MR=moderetly resistance, MS=moderately susceptible, SS=sucseptable

Stripe Rust
Stripe rust was recorded by cobbs scale method the severity of stripe rust infection ranged from 0-90s and the genotypes infection level and reaction response were considered as the recommended level.
According to the result, most of the landraces are free from stripe/yellow rust, from 100 observations, which were found immune against stripe rust. 61 Genotypes were free from disease (00 scored), which means that not infected by stripe rust and its reaction is immune, while 14 genotypes were in the ranged resistance (5-20%) which showed that the symptoms of chlorosis without uredia. Of total observations, 13 landraces were in the range of resistance to moderately resistance (21-40%) along with chlorosis and necrosis uredia was also observed.
After the immune, the maximum landraces showed the symptom of resistance to moderate resistance as small uredia were observed with some chlorosis without necrosis. Durum wheat Landrace screening against stripe rust in field condition indicated that most of the landraces were moderately resistant after the resistance status which is suggested to use in the wheat breeding program because resistance varieties are the best option for successful wheat production and productivity (Admassu Belay, 2012).
Four lines were found moderately resistant (41-60%) while the rust of eight landraces showed the symptom of highly susceptible (>60%) as large uredia observed without chlorosis and necrosis. The field data showed that almost 61% of landraces were immune while 14% were resistant and 13% moderately resistance. Only 4% of the observed landraces were moderately susceptible and 8% observed to be highly susceptible to stripe rust.

Fig 1: The picture shows the durum wheat landraces infected with stripe rust disease.

In the present study that stripes rust resistance of wheat germplasm having a varied genetic background. So, in order to identify the resistance sources of germplasms screened under field conditions at the full stage of disease exposed (Raza & Ghazanfar, 2019). investigated the resistance potential of wheat germplasm against stripe rust under a rainfed climate of Pakistan and observed 188 lines, most of them were resistant to disease and have the potential to be used as a resistant germplasm source against stripe rust. And also this result inline with (Ali *et al*., 2009) who observed that most of the lines exhibit more resistance and resistance to moderate resistance under high disease pressure as compared to the susceptible check.

Table 5: Lodging percentage and stand field performance of durum wheat landraces

Field observation	Observations	Response Levels	Performance
Stand performance	12	1	V.good
	33	2	Good
	46	3	Poor
	09	4	V.poor
	Observations	Lodging%	Lodging Response
Lodging	39	0-20	Minimum
	26	21-40	m. resistance
	20	41-60	M. Susceptible
	15	>60	H. susceptible

Under field condition durum wheal landraces were exposed to lodging. The causes of Lodging were influenced mainly by two factors (internal and external/ the variety itself and environmental factors). Cultivar susceptibility to lodging depends on three main factors: the exact size and dynamics of the forces to which it is exposed to, the correlation of stem bending strength to lodging resistance, and the anchorage power of the root system (Shah *et al*., 2019) While, the external or environmental conditions such as wind, rain, thunderstorm, and hail or the combined effect of the two (Telker, 2017)

Fig 1: The picture shows the durum wheat landraces susceptible to lodging

Our landraces were classified into subgroups with regarding lodging to the tendency which is minimum/less response (0-20%), moderately susceptible (21-40%), intermediate (41-60%), and highly susceptible (>60%) to lodging. During the growing season there was a prolonged rainfall up to end October and high-speed wind also their around. These factors individually or combined effect take the lion share of landrace field lodging problem and leads to different effects on grain yield and quality.

The effect of lodging on grain yield depends on its severity and on the time of occurrence. Lodging close to maturity can not affect grain yield directly but may cause losses due to its interference with the harvest. But, at the heading stage reduced grain yield by 27-40% whereas yield reduction due to lodging at about soft dough stage 24% (Pinthus, 1974). Khakwani *et al*. (2010) demonstrate that lodging is an important factor in reducing yield up to 38% than the normal wheat crop produced. (Kelbert *et al*., 2004) reported that lodging can cause yield loss up to 40% of happens during the 10 days after heading. Lodging may cause shriveling of the grain and reduce its test it may reduce milling quality of wheat (Hirano *et al*., 1970) whereas sprouting in the heads has also been found to occur frequently in lodged than in standing crop.

Stand Performance

Infrequent field assessments, observations, and disease scouting all the appropriate and important traits/data which are helpful for landrace screening were collected and analyzed with the appropriate software. In general, the overall performance of the landraces field stand, general plot performance, lodging tendency, and disease response was indifferent situations. Hence, the stand performance of the landraces on each plot level the field was classified as Very good (01), good (02), poor (03), and very poor (04). This classification was done by field observation/ assessments at full maturity time based on the plot performance of each landrace. We have select the best genotypes which are the best stand performed and disease-free/resistance on the field and discard the rest of the poor performed once (diseased, lodged, poor, and very poor stand and agronomic performance) theirs.

Conclusions and Recommendations

The analysis of variance showed the genotypes had highly significant variations for most of phenological and yield and yield-related traits. The present study revealed that the landraces showed from immune to highly susceptible to wheat stripe rust. And also showed that none of the genotypes were immune and highly susceptible to septoria tritici blotch, the majority was moderately resistant to moderately susceptible. Therefore, based on this information twenty-five best performed in landraces were advanced to the next breeding step, preliminary yield trial. The screened material will be incorporated further in hybridization programs to create more genetic variability against wheat diseases (stripe rust and septoria tiritici blotch), and for the development of new cultivars.

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