Screening Durum Wheat Genotypes (*Triticum turgidum* var. durum Desf.) for Soil Acidity Tolerance

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Abstract

The production and productivity of durum wheat is threatened by different biotic and abiotic stresses in different parts of the country. Soil acidity associated with Al toxicity is one of the limiting a biotic factor for the production of durum wheat. A pot experiment was conducted at Debre Zeit Agricultural Research Center in 2020. A total of 102 durum wheat genotypes were grown with and without lime treatment to screen the genotypes for tolerance to soil acidity. The treatments were laid out in Completely Randomized Design (CRD) with two replications. The results of the experiment showed that shoot and root growth were enhanced under lime treated than untreated conditions. Significant variations were observed among the durum wheat genotypes for shoot fresh and dry weight, root fresh and dry weights, relative shoot and root yield, root to shoot ratio, and root volume under both limed and unlimed conditions. Genotypes, that showed consistently better performance based on various growth parameters used for screening purposes such as shoot and root growth parameters under un-limed condition were selected as acid soil tolerant. Accordingly, genotypes 81, 24, 2, 71, 90, 74, 70, 6, 18, 102, 17, 98, 4, 60, 96, 99, 15, 62, 32, 93, 91, 77, 30 and 75 were identified as consistently acid soil tolerant. Among these, thirteen of them (81, 71, 90, 70, 6, 98, 4, 99, 15, 91, 77, 30, and 75 were Ethiopian land races, two of them (2 and 60) were ICARDA materials, four of them (18, 102, 96 and 62) were CIMMYT materials, two of them namely, Tesfaye and Asasa (32 and 93) were Ethiopian improved varieties, and three of them (24, 74 and 17) were Debre Zeit Agricultural Researcher Center durum wheat breeding program advanced lines. Thus, the identified acid soil tolerant durum wheat released varieties can be recommended for acid soil affected areas while the rest tolerant genotypes can be used as parental lines in durum wheat breeding program to develop tolerant varieties for acid soil prone areas of Ethiopia.

Keywords: Acid soil tolerance, Durum wheat, Lime application, Relative shoot yield, Root Volume, shoot dry weight,

Introduction

Durum wheat (*Triticum turgidum* var. durum Desf) is among the oldest traditional and the most diversified crop species in Ethiopia (Mengistu *et al*. 2016). Ethiopia is a center of diversity and hosts rich genetic resources of tetraploid wheat (Tsegaye and Berg 2006), which can be used for different breeding objectives. The production and productivity of the crop is currently threatened by different biotic and abiotic stresses in different parts of the country. Soil acidity associated with Al toxicities, soil erosion and soil nutrient depletion are among the major constraints that limits durum wheat productivity in developing countries including Ethiopia (Tolera *et al*. 2006). Currently, Agricultural Transformat-ion Agency estimated that about 43% of the total arable land of Ethiopia is affected by soil acidity (ATA, 2013).

Soil acidification is the result of a complex set of processes caused both naturally and by human activity (Amede *et al*., 2019). Soil acidity highly reduces crop productivity due to deficiencies of basic cations, reduced phosphorus availability and toxicities of Aluminum and Manganese. Eyasu (2016) also reported that 80% of Nitisols in Ethiopia is originally highly acidic. Amelioration of acid soils using lime remains challenging for sustainable and profitable durum wheat production due to the bulkiness nature and high transportation costs. Although limited work on genetic variability for aluminium resistance, (Stodart *et al*., 2005) has been reported in tetraploid wheat, it was hypothesized that use of large number of genotypes from different sources and evaluation for acid soil tolerance to be an alternative option for identification of tolerant genotypes targeting acid prone environment in order to expand wheat area and production. Thus, the objective of this study was to screen durum wheat genotypes for acid soil tolerance and responsiveness to lime application.

Materials and Methods

Study area

Lath house experiment was carried out at Debre Zeit Agricultural Research Center which is located at 8° 44 N and 38° 58’ E and an altitude of 1900 m above sea level. The center is located at 47 km south eastern Addis Ababa and is characterized by a mean annual rainfall of 851 mm and mean maximum and minimum temperature of 28.3^0C and 8.9^0C, respectively.

Experimental treatments and design

About 102 durum wheat genotypes obtained from different sources (twenty-six land races, 15 released varieties, 12 breeding lines, 34 CIMMYT and 15 ICARDA materials) were grown with and without lime (Appendix Table 1). The treatments were laid out in a Completely Randomized Design with two replications.

Soil sampling and analysis

Soil samples were collected from Midakegn District, West Shoa Zone, Oromia Regional State, in Ethiopia where soil acidity is a serious problem for crop production. The collected soil sample was air-dried and roots, sands and other impurities were separated from the soil. Soil analysis was done for both lime treated and untreated samples for major soil chemical properties at Debre Zeit agricultural research center Soil Laboratory. Soil pH and electric conductivity (EC) were measured with soil extract at a soil/deionized water ratio of 1:2.5 (w/v) using a digital pH meter and electric conductivity meter respectively.

Exchangeable acidity Al^{3+}, was determined using 1N KCl Extraction-titration method Cation exchange capacity (CEC), using by ammonium acetate method, and organic carbon content, by Walkley and Black methods (Walkley and Black, 1934). Total nitrogen was determined by Kjeldahl Method, available phosphorus using Olsen's method **(**Olsen *et al***.,** 1954) and aluminum saturation was calculated as the ratio of exchangeable aluminum to the CEC.

Lime amount determination

The amount of lime required for a kilogram of soil to raise the soil pH to a level suitable for the growth of crops was determined in a separate incubation experiment following a procedure described in Fekadu *et al*. (2017). The soil for the incubation experiment was treated with 5, 10,15,20,25 and 30 grams of lime per kilogram of soil and incubated for 45 days in two replications. The level of pH and electric conductivity was determined using potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils to water ratio and conductivity meter, respectively.

Planting and crop management

The homogenized soil sample was prepared and two kilograms of soils were filled in the plastic pot of five kilograms capacity. A total of 408 pots were filled with soils where 204 pots were treated with lime and the other 204 pots were left untreated. Ten seeds of durum wheat genotypes were sown into lime ($CaCO_3$) treated and untreated pots. The same amount of nitrogen (N) fertilizer (0.304 gram per 2 kilograms of soil) in split half at the time of sowing and half at tillering stage in the form of urea. Phosphorus (P) fertilizer (0.33 gram per 2 kilograms of soil) was applied to all the treatments at the time of sowing in the form of triple superphosphate (TSP). Thinning was done after the seedlings were establishment to maintain uniform number of plants in each pot. The pots were watered at field capacity throughout the growing period of the crop.

Data collection and analysis

The above ground plant parts were collected 80 days after planting and their fresh were weighed and recorded for each plots. The samples were further oven dried to record shoot fresh and dry weight. Moreover, root to shoot ratio and relative shoot and root yield were calculated. Root to shoot ratio was calculated by dividing the root weights for the corresponding shoot weights, while the relative shoot/root yield was calculated by dividing shoot/root weight of the lime untreated treatment for the corresponding lime treated treatment and multiplying by 100. Data were subjected to analysis of variance using the GLM procedure of SAS software version 9.3 (Anonymous, 2004) to see if each parameter was affected by lime treatments and wheat genotypes.

Result and Discussion

Determination of lime requirement for the experimental soil

According to the classification of soil pH ranges reported by Obi *et al.* (2017), the present soil under study before lime treatment was classified as strongly acidic. Pre-experimental soil treatment with different levels of lime application increased the pH of the experimental soil. Accordingly, the application of 10-gram lime per kilogram of soil raised the soil pH to a level suitable for the growth of crop plants while use of 15 to 30 gram lime per kilogram of soil did not show significant changes on pH of the soil (Figure 1).

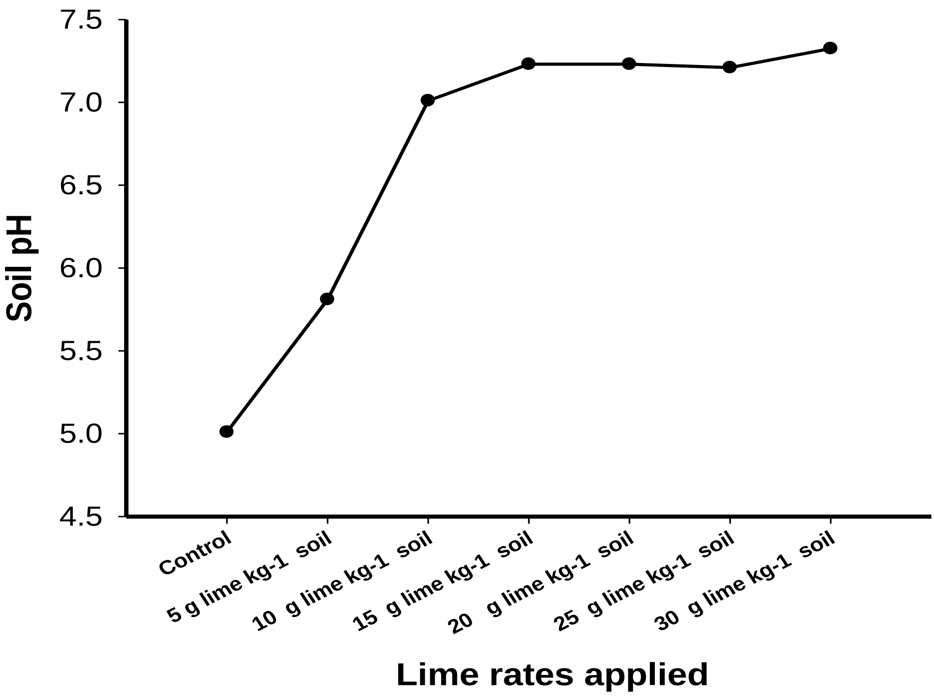


Figure 1: Changes in soil pH under different levels of lime application for the experimental soil samples

Effect of lime application on soil chemical properties

The results indicated that soil pH, available phosphorus, electrical conductivity, cation exchange capacity, exchangeable acidity, total nitrogen and organic matter content significantly responded to the application of lime (Table 1). However, lime application reduced the exchangeable and saturation of Al in the soil (Table 1). This might be due to Al ion neutralization in the soil through the hydrolysis reaction of the liming material added to the soils. PH of the soil was 5.01 and 7.01 for the limed and without treatment respectively (Table 1). These indicates that amelioration of acid soil with lime improved the most important soil chemical properties and make the soil more suitable for crop production. The findings of Sisay and Balemi (2014) and Obi *et al* (2017) showed that reclamation of acid soil using lime increased the soil pH from 5.2 to 6.8. The probable reason for increasing soil pH could be due to ionization of hydrogen and supply of calcium and magnesium in the soil and phosphorus and nitrogen availability could also be enhanced there by accelerating organic matter decomposition due to lime application.

Table 1: Chemical properties of the experimental soil under lime treated and untreated conditions

Soil chemical properties	Lime untreated soil	Lime treated soil
pH	5.01	7.01
Available phosphorus(mg/kg/soil)	11.7	12.1
EC (ds/m)	0.049	0.087
CEC (cmol(+)/kg	19.3	26.8
Exchangeable Al (meq/100g soil)	0.24	0.1
Aluminum saturation	1.24	0.37
Exchangeable acidity (meq/100g soil)	10.9	21.7
Total nitrogen	0.097	0.125
OM (%)	2.74	3.65

Traits considered for the screening

Soil acidity affects crop growth, development and grain yield. It affects from primarily root elongation to the growth of above ground parts of the crop. In the current study shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, relative shoot yield, and relative root weight and root volume were measured to screen and identify durum wheat genotypes tolerant to acid soil condition. Similarly, Ma *et al*, (2004) measured root and shoot biomass yield at early stage to identify and rank barley cultivars for acid soil tolerance. Similarly, Sisay and Balemi (2014) recommended that shoot weight, root weight, root volume, relative yield and total p uptake as an important trait for screening barley cultivars for acid soil tolerance.

Shoot fresh weight

Durum wheat genotypes significantly (P<0.001) varied in shoot fresh weight (SFW) under both lime treated and untreated soil conditions (Table 2). This indicates that durum wheat genotypes responded differently to lime application. The results presented in figure 2 showed that, based on SFW parameter, genotypes such as 6, 49, 2, 81, 71, 70, 37 and 34 were classified as highly tolerant to soil acidity as well as responsive to lime application, while the genotypes 87, 78, 89, 36, 47, 76,7 and 9 were grouped into acid intolerant and non-responsive(Figure 2). Generally, SFW of durum wheat genotypes was lower under lime untreated than lime treated soil condition, which could be attributed to toxicity and deficiency of some nutrients which are essential to plant growth.

Table 2: Analysis of variance (ANOVA) for mean square values of the evaluated traits of durum wheat genotypes influenced by lime application

Source of variations	Df	SFW	SDW	RFW	RDW	RV	RSR
Genotypes	101	0.34**	0.043**	0.29**	0.0075**	0.497**	0.038**
Replications	1	0.05NS	0.00005NS	0.021NS	0.0004NS	0.056NS	0.012NS
Type(a and b)	1	90.78**	14.75**	15.37**	0.694**	16.288**	1.523**
Genotypes*Type	101	0.16**	0.021**	0.093**	0.0025**	0.177**	0.011**
Error	203	0.04	0.006	0.009	0.0003	0.026	0.005
Total	408						
Grand mean		1.19	0.64	0.77	0.15	1.18	0.36
R-square		94.8	94.4	96.6	96.2	94.1	87.1
CV		16.4	16.9	12.5	12.1	13.7	18.9

Where, a=lime treated, b=lime untreated, SFW=Shoot fresh weight, SDW=Shoot dry weight, RFW=Root fresh weight, RDW=Root dry weight, RV=Root volume and RSR=Root to shoot ratio

Supporting the present result, Sisay and Balemi (2014) also found similar result on shoot fresh weight of barley genotypes grown in soils treated with lime and without lime. Moreover, Malede *et al*. (2020) reported the presence of significant genotypic variation among soybean varieties for soil acidity tolerance and observed a 16.7 % increase in average shoot fresh weight under liming than without liming.

Shoot dry weight

The result of the present study revealed that the shoot dry weight of durum wheat genotypes was significantly affected by liming, genotypes and their interaction (Table 2). Under un limed soil condition, genotypes 102, 49, 81, 43, 32, 24, 39, 37, 62, 70 and 56 had significantly higher shoot dry weight compared to genotypes 47, 78, 36, 87, 1 and 12 which produced lower shoot dry weights (Figure 3). Therefore, genotypes with significantly higher shoot dry weights under lime untreated soils condition were considered as acid tolerant whereas those with lower shoot dry weight under unlimed soil condition are categorized as acid intolerant when shoot dry weight is considered as parameter for ranking the genotypes for acid soil tolerance. On the other hand, under limed soil condition, genotypes 49, 101, 6, 2, 48, 44, 39, 81, 43, 32 and 102 showed significantly higher shoot dry weight compared to genotypes77, 79, 75, 23, 83 and 36 (Figure 3).

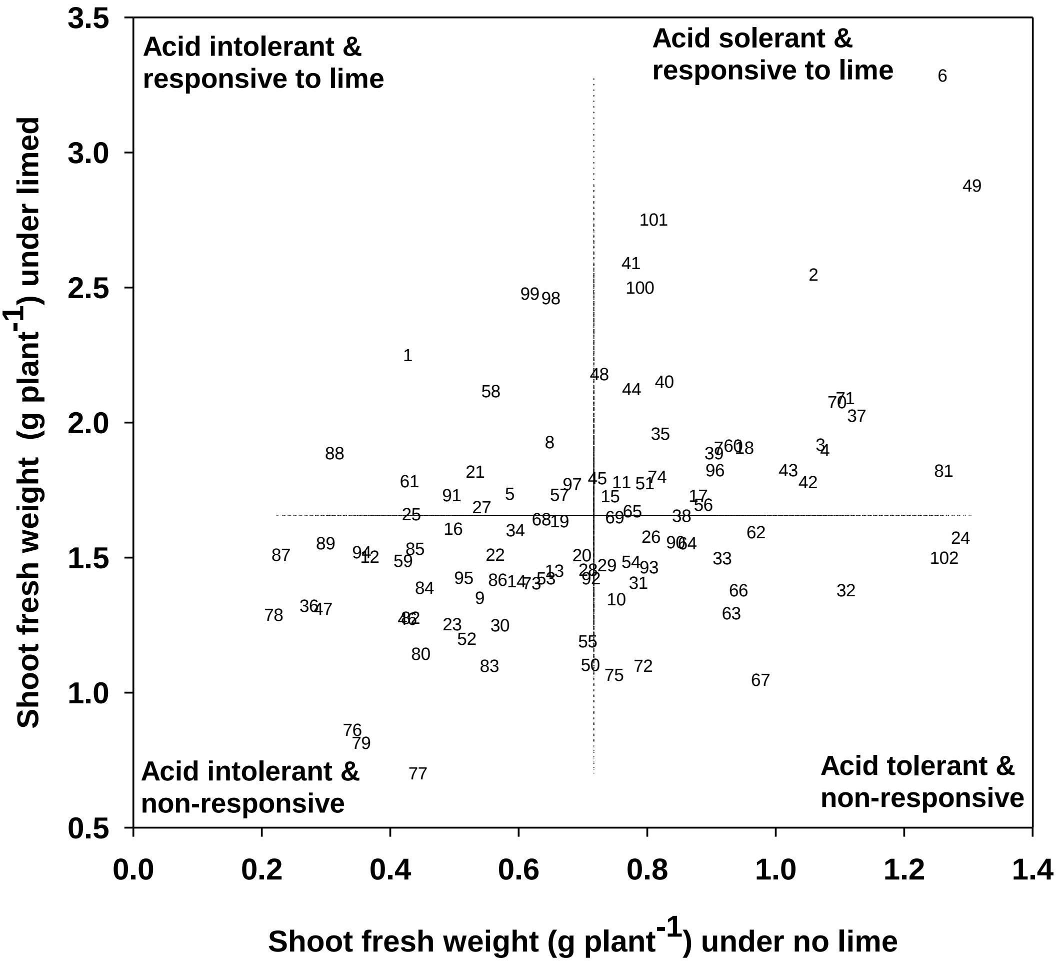


Figure 2: Categorization of acid soil tolerant and intolerant genotypes based on shoot fresh

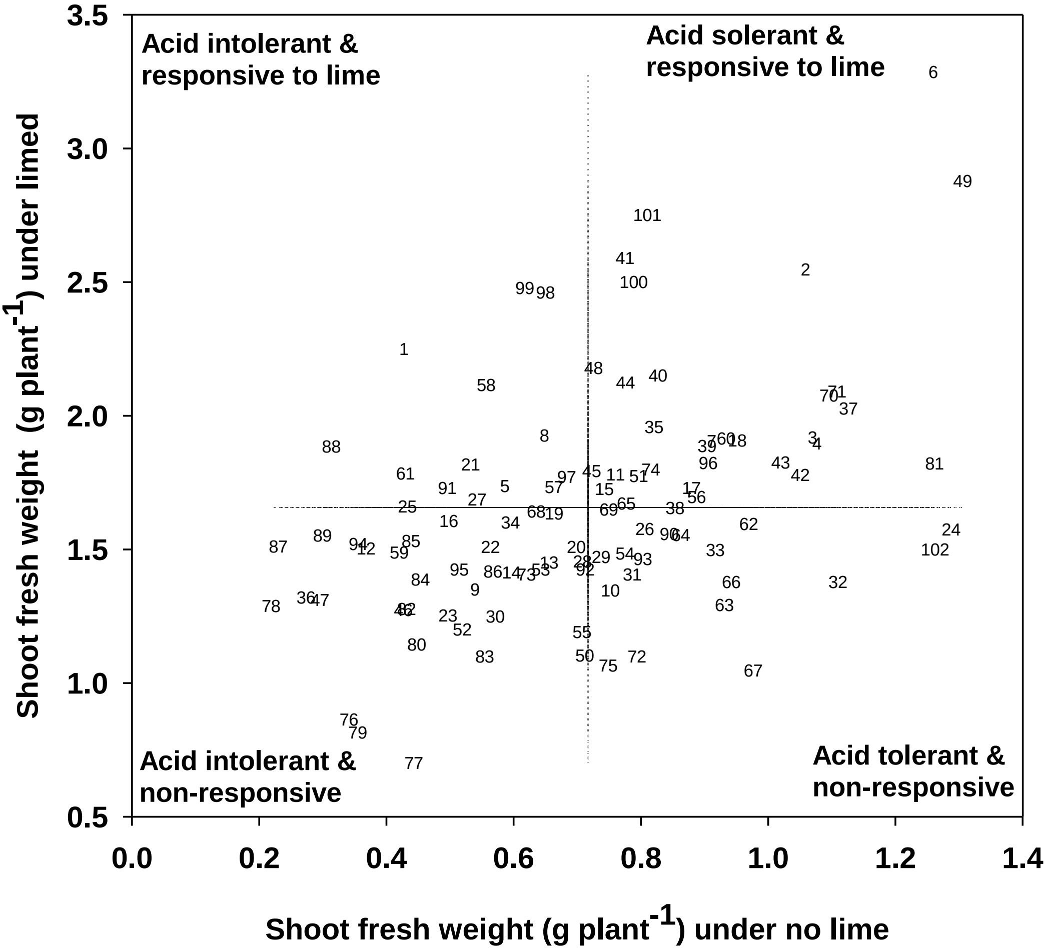


Figure 3: Categorization of acid tolerant and intolerant genotypes based on shoot dry weight

Thus, genotypes having significantly higher shoot dry weight under limed soil condition were regarded as responsive to lime application whereas those genotypes that showed lower shoot dry weight under lime treated soils condition were classified as non-responsive. Taking shoot dry weight as a selection parameter, the genotypes 49, 39, 81, 43, 6 and 102 were found both responsive to liming and tolerant to acid soils. Thus, these genotypes could be used for further evaluation and hybridization in the future breeding program. In line with this finding Tang *et al.* (2001) reported that shoot weight of Al sensitive wheat genotypes increased by 60% using subsurface liming. Moreover, Arshad *et al.* (2012) suggested that acid soil treatment with wood ash and lime increased shoot dry matter production of barley, canola and field pea crops. In contrast, to the current study, Tang *et al.* (2001) stated that shoot dry weight of Al-tolerant wheat genotype was not affected by subsurface soil acidity.

Root fresh weight

Analysis of variance showed that root fresh weight was significantly (P<0.001) varied among durum wheat genotypes grown under lime treated and untreated soil conditions (Table 2). The result implies that the genotypes gave higher root fresh weight under lime treated soils condition as compared to the unlimed soil condition. This might be due to a high concentration of aluminum and manganese which inhibit root growth and development under lime untreated condition. Based on mean values of root fresh weight, about half (49%) of the genotypes were categorized under intolerant and non-responsive to liming and accordingly, genotypes 81, 91, 70, 6, 86, 64 and 41 were among the best performing genotypes under both limed and unlimed soil conditions (Figure 4 and Table 3).

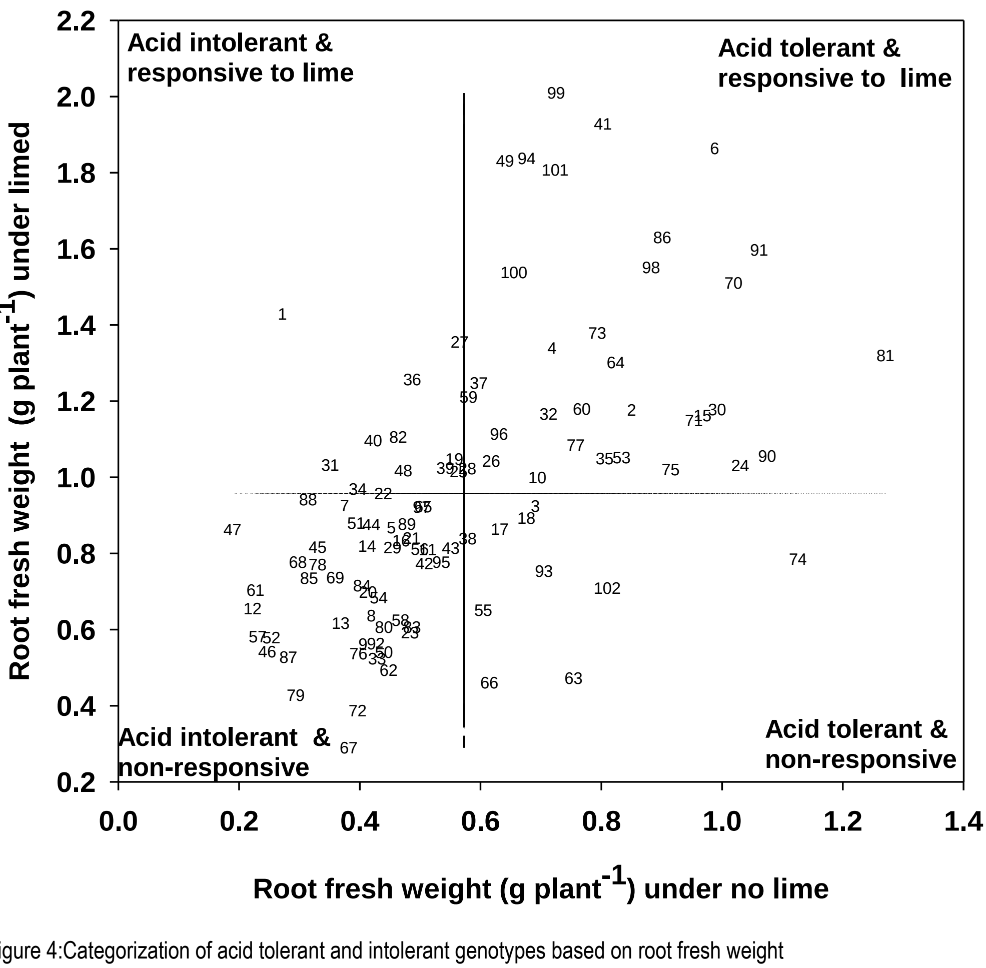


Figure 4:Categorization of acid tolerant and intolerant genotypes based on root fresh weight

Similarly, Haling *et al.* (2010) demonstrated that root hair length and density were adversely affected by soil acidity. Moreover, they identified that fine root growth was highly reduced in Al sensitive line of wheat and barley while Al-resistant lines maintain root growth under these conditions. Likewise, Caires *et al.* (2008) described that liming improved root growth and it was well correlated with the grain yield of wheat. Moreover, Raman *et al.* (2002 and 2008) reported aluminum resistant wheat and barley varieties possessing a higher root growth as compared to sensitive varieties under acid soil conditions. Generally, root development was lower under unlimed soil than the lime treated soil, which is in agreement with Whalley *et al.* (2008), who suggested that breeding for resistance to Al is required because soil amelioration by liming is effective only in the upper root zone and susceptible or moderately susceptible cultivars do not develop extensive root systems. In contrary to the present finding, Wayima et al. (2019) who evaluated 595 Ethiopian landrace durum wheat accessions in hydroponic by their length of seminal root reported some level of tolerance, however, all of the accessions were rated as aluminum intolerant categories while evaluated by molecular markers.

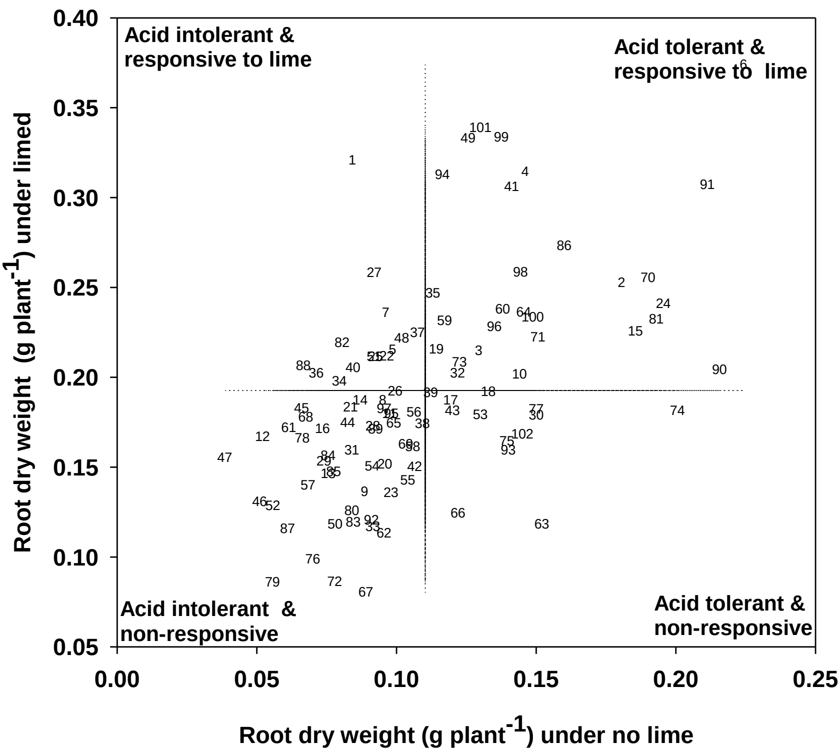


Figure 5: Categorization of acid tolerant and intolerant genotypes based on root dry weight

Root dry weight

The value of root dry weight per plant was significantly (P<0.001) affected by the main effects of genotypes, lime application and by their interaction effect (Table 2). Durum wheat genotypes in root dry yield production showed similar performance as that of root fresh yield where majority of them were grouped under acid soil intolerant and non-responsive to lime application category (Figure 5). However, higher root dry weight was recorded from genotypes grown under lime treated soil condition than the untreated soils and genotypes 6,90,91,74,24,81, 15,70, 2 and 86 were among the good performing in root dry mass production (Figure 5 and Table 3). Incongruent with this study, Baquy *et al.* (2018) reported that shoot and root dry matter is changing with soil pH in maize inbred lines.

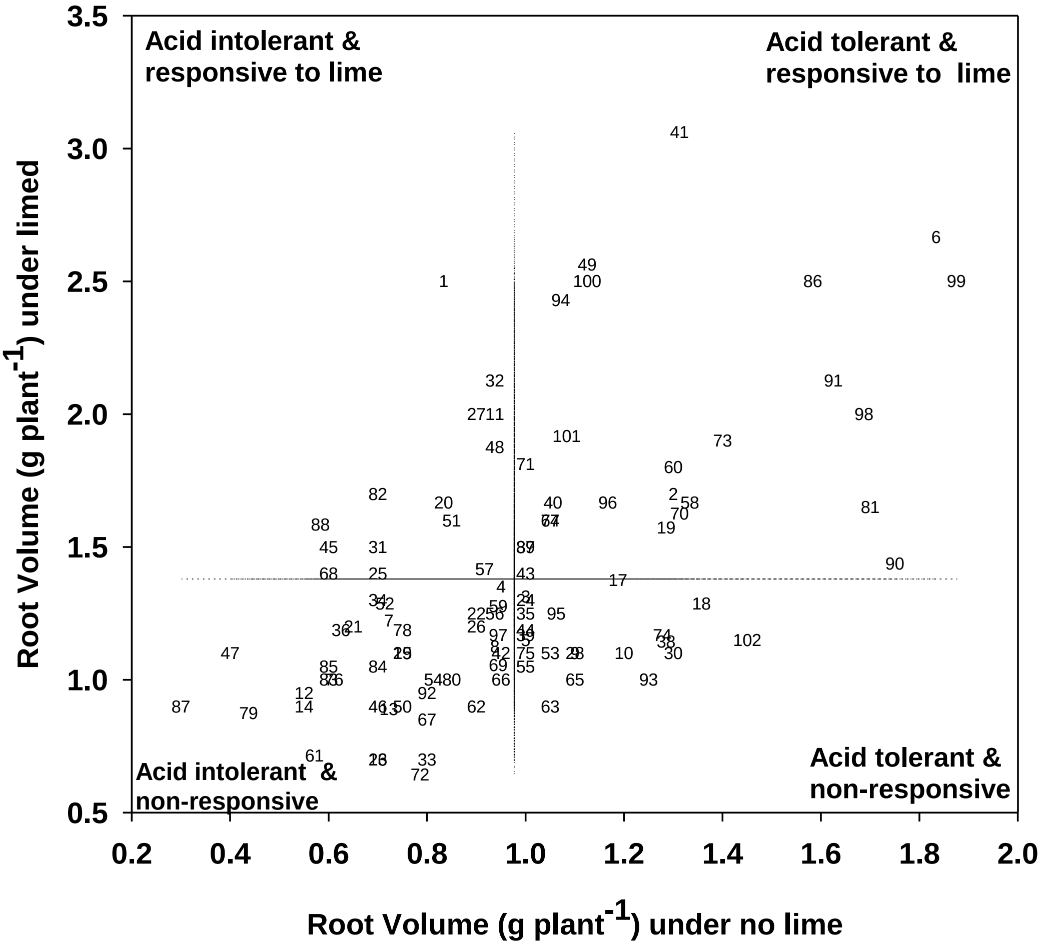


Figure 6: Categorization of acid tolerant and intolerant genotypes based on the root volume

Similarly, Sisay and Balemi (2014) observed differences among barley cultivars in terms of root dry weight under lime untreated and lime treated soil conditions. Additionally, Malede *et al*. (2020) indicated that soil acidity reduced root fresh and dry weight and total dry biomass yield per plant in soybeans.

Root volume

The result of this study revealed that, the mean value of root volume significantly (P<0.001) differed among durum wheat genotypes grown in lime treated and untreated pots (Table 2). Genotypes 6, 99, 98, 91, 81, 90, 73, 41 and 102 had the highest root volume under both lime untreated and limed condition compared to genotypes 87, 47, 79, 61, 14, 12 and 85 (Figure 6). Under lime untreated conditions genotypes 99, 6, 90, 81, 98, 91, 86and 102 were among the best performing durum wheat genotypes and 41, 6, 49, 1, 86, 99, 100, 94 and 32 were genotypes produced the highest root volume under limed pots. Considering root volume as selection criteria for acid soil tolerant and responsive to lime application, 6, 99, 98, 91, 86 and 41 were the most preferred durum wheat genotypes from the tested materials (Figure 6 and Table 3).

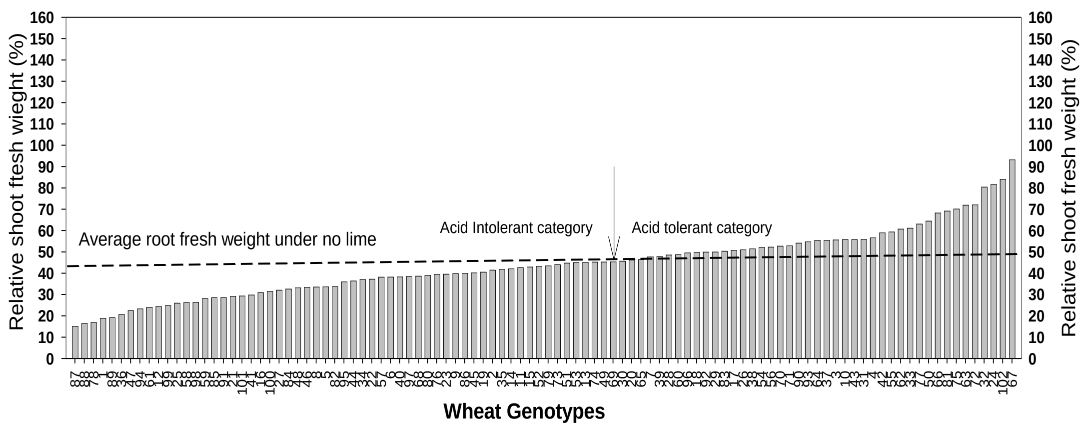


Figure 7:Categorization of acid tolerant and intolerant genotypes based on relative shoot fresh weight

Genotypes evaluated in this study showed a difference in root volume under both lime treated and lime untreated soil conditions demonstrating the existence of genetic variation in acid soil tolerance among the durum wheat genotypes. Comparable with this result, Sisay and Balemi (2014) reported significant variation between barley cultivars in root volume production under lime untreated soil conditions compared to lime treated soils.

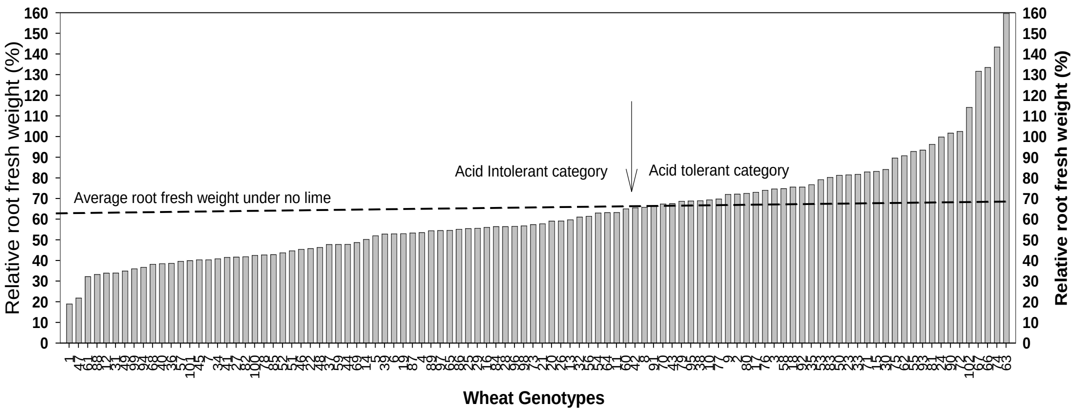


Figure 8: Categorization of acid tolerant and intolerant genotypes based on relative root fresh weight

Relative shoot yield

Relative shoot yield was computed as the yields under no lime soil condition expressed as a percentage of shoot yields under limed conditions for the same treatment. In this study, relative shoot yield varied considerably among the durum wheat genotypes ranging between 15.2% for genotype 87 to 93.3% for genotype 67. A similar observation was made by Tang *et al.* (2003) who stated that the relative yields of wheat genotypes on acid soil ranged from 50 to 89% of yields on lime treated soils. In this study, genotypes such as 102, 24, 32, 72, 63, 75 and 81had a relative shoot yield of 84.2, 81.8, 80.5, 72.2, 72, 70 and 69.3% which was higher when compared to durum wheat genotypes88, 78, 1, 89, 36, 47 and 94 in which a lower relative shoot yields of 16.6, 17, 19, 19.3, 20.7, 22.6 and 23.4%were recorded, respectively (Figure 7, Table 3). Genotypes that had a relative yield above the average (36 durum wheat genotypes or 35.3%) can be classified as acid soil tolerant whereas the rest (66 durum wheat genotypes or 64.7%) can be classified as acid soil intolerant categories. However, in this study, relative shoot yield was not a good parameter for comparing genotypes for acid soil tolerance since most of the selected genotypes based on this parameter produced lower shoot yield under lime treated soil conditions. Similar to this observation, Balemi (2011) reported that comparing genotypes with their relative yield without considering their responsiveness is potentially misleading since high relative yield can result from low yield at high nutrient supply for P efficiency in potato cultivars.

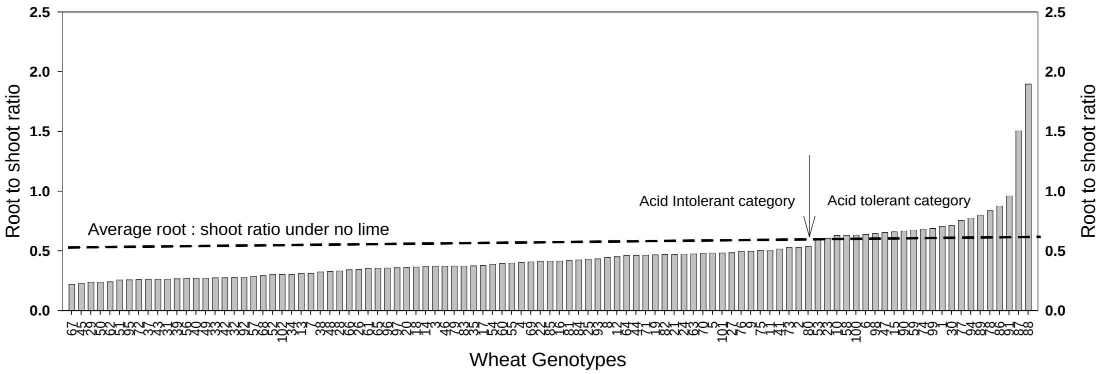


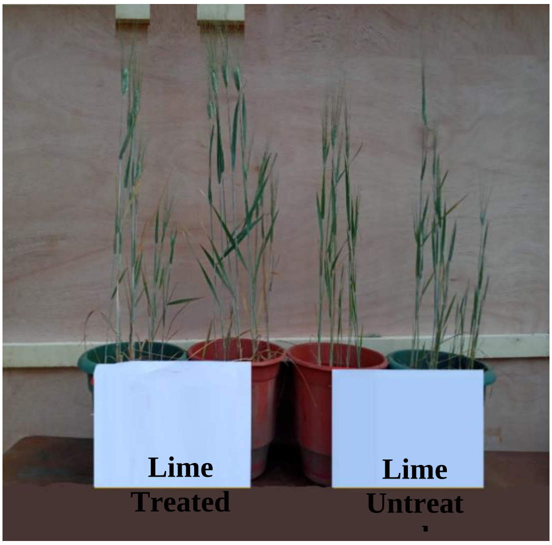
Figure 9: Categorization of acid tolerant and intolerant genotypes based on the root to shoot ratio

Relative root fresh weight

Relative root weight considerably varied among the durum wheat genotypes where 39.2 percent of the tested genotypes were acid soil tolerant while 60.8 percent of the genotypes were categorized as acid soil intolerant group (Figure8). Variation in relative root yield shows the presence of variability among durum wheat genotypes in terms of acid soil tolerance since most of the genotypes studied were responsive to lime application. Genotypes such as 63, 74, 66, 67, 102, 72, 30, 24, 81, 93, 55, 62, 75, 30, 15 and 71 gave higher relative root weight among which genotypes 81, 24, 30 and 71 were responsive to lime application and best performing under both soil conditions (Figure 8 and Table 3).Parallel with this result, Cosic *et al.* (1994) described that genotypes of durum wheat differed in relative root length and Al tolerance, but the span of the tolerance was relatively narrow.

Root to shoot ratio

The value of root to shoot ratio was highly different among durum wheat genotypes grown under limed and unlimed soil conditions (Table 2). The highest value of root to shoot ratio was recorded from genotype 88 followed by 87, 91, 86 and 78while the lowest value was obtained from genotype 67 followed by 45, 29, 50 and 62 genotypes. Among the 102 durum wheat genotypes evaluated in this study, only 21 genotypes were categorized under acid soil tolerant based on this parameter (Figure 9). Similar results were reported by Malede *et al*. (2020), Adie and Krisnawati (2016) and Kuswantoro (2015) that, the effects of genotype and genotypes by soil interaction on the root to shoot ratio were highly significant.



Acid Soil Tolerant Durum Wheat Genotype

Acid Soil Sensitive Durum Wheat Genotype

Table 3. Summary of multi-criteria classification of durum wheat genotypes for acid soils tolerance

Parameters	Tolerant Genotypes
Shoot fresh weight	49, 6,81,37,2,70,71,3,4,42,43,18,60,39,96,7,24,10,2,32,17,56,49,35,74,51,62
Shoot dry weight	49,102,81,43,32,4,37,39,62,96,6,56,42,24,70,3,18,51,40,2,66,38,71,17
Root fresh weight	81,91,70,74,90,24,71,15,30,75,2,98,86,64,53,41,77,60,4,32,35,73,99
Root dry weight	6,90,91,74,24,81,15,70,2,86,71,100,98,4,41,99,64,60,96,101, 18, 3, 63, 93,77,75, 102,53
Root volume	6,99,98,91,81,90,73,41, 102,60,2,58,70,19,18,96,17,74,38,30,93,49,100,101,94
Root-shoot ratio	88,87,91,86,78,89,94,77,30,1,99,74,59,90,15,47,98,6,100,58,10
Relative shoot yield	67,102,24,32,72,63,75,81,66,50,77,33,62,55,42,4,31,43,10,3,37,64,93,90,71,70,56,54,38,26,17,83
Relative root weight	63,74,66,67,102,72,90,24,81,93,55,62,75,30,15,71,33,23,50,83,53,35,92,18,58,76,3,17,80,2
Genotypes selected using different traits	81, 24, 2, 71,90, 74, 70, 6, 18, 102, 17 98, 4, 60, 96, 99, 15, 62, 32, 93, 91, 77, 30, 75

Common ≥ 4

Conclusion

Results of the durum wheat genotypes screening experiment for tolerance to soil acidity and responsiveness to lime application showed the presence of considerable variability among the genotypes under lime untreated and treated conditions. Shoot fresh and dry weights, root fresh and dry weights, relative shoot and root yields, root to shoot ratio and root volume were used to screen the genotypes. Genotypes showing superior performance in terms of the most parameters were selected as acid soil tolerant and responsive to lime application. Accordingly, genotypes 81, 24, 2, 71, 90, 74, 70, 6, 18, 102, 17, 98, 4, 60, 96, 99, 15, 62, 32, 93, 91, 77, 30, 75 were identified as consistently acid soil tolerant durum wheat genotypes. Among these, thirteen of them (81, 71, 90, 70, 6, 98, 4, 99, 15, 91, 77, 30 and 75 were Ethiopian land races, two of them (2 and 60) were ICARDA materials, four of them (18, 102, 96 and 62) were CIMMYT materials, two of them namely, Tesfaye and Asasa (32 and 93) were Ethiopian improved varieties, and three of them (24, 74 and 17) were Debre Zeit Agricultural Research Center breeding program advanced lines. Thus, the identified acid soil tolerant durum wheat improved varieties can be recommended for acid soil affected areas and the rest tolerant genotypes can be used as parental lines in the durum wheat breeding program to develop tolerant varieties for acid soil prone areas of Ethiopia. Moreover, the tolerant genotypes should be further studied using molecular markers to confirm their genetic variation with phenotypic performance and on multi-locations acidic soil areas to investigate for mechanisms of tolerance to soil acidity.

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Appendix Table 1: Description of durum wheat genotypes studied in the trial

No	Genotype Name	Pedigree or Accession number/description
1	CDSS09B00191T-099Y-020M-6Y00M	RBC/7/CMH83.2578/4/D88059//WARD/YAV79/3/ACO89/5/2*S00TY-9/RASCON-37/6/…
2	ICARASHA2	Stj3/Ber/Lks4/3/Ter3
3	CD15DZ_ELT/off/950/2015	YAVA 79/9/ USDA 595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV-1/6/ARDENTE /7/HUI/YAV 79/8/…
4	Land race	ETH 208474
5	FIGSDRYWET0144	IRNS382/ID-119026
6	land race	222414
7	land race	236988
8	Breeding pipeline, DWNL p#2	C F4 20 S/4/YAZI-1/AKAKI-4//SOMAT-3/3/AUK/GUIL//GREEN/5/CANELO-9.1//SHAKE-3/…
9	FIGSDRYWET001	OMN87:113/ID-43315
10	Land race	208162
11	CD15DZ_ELT/off//1086/2015	CMH83.2578/4/D88059//WARD/YAV 79/3/AC089/5/2*SOOTY-9/RASCON-37/6/1A.1D 5+1.06/…
12	CD15DZ-ELT/off/935/2015	C0RDEIR0/9/GUAYACAN INIA/GUANY/8/GEDIZ FG0//GTA/3/SRN-1/4/TOTUS/5/ENTE/MEXI-2//…
13	CD15DZ_ELT/off/994/2015	JUPARE C 2001* 2/RBC/5/MOHAWK/3/GUANAY//TILD-1LDTUS-4/4/ARMENT //SRN- 3/…
14	DURUM_PANEL_UNIBO-054	D333/GAVIOIA/4/AVETORO//ALUINCO/D/EIOD/ID-MARJANA MOROCCO
15	Land race	202012
16	Ude	CHEN/ALTAR84//JO69
17	2015 offseason DW/F3 DZ #33	Yere/Mova/DZ 2013meh F1 P#9/DZ 2014meh F2 P#9-2
18	CD15DZ-ELT/off/802/2015	GER0MTEL-3/9/GUANCAN INIA/GUANAY/8/GEDIZ FG0//GTA/3/SRN-1/4/T0TUS/5/ENTE/MEXI-2//…
19	CDSS10Y00164S-099Y-030M-5Y-3M-06Y-0B	C F4 20 S/4/YAZI-1/AKAKI-4//SOMAT-3/3/AUK/GUIL//GREEN/5/CANELO-9.1//SHAKE-3/…
20	ICD08-291-0AP	otb4/3/HFN94N-8/Mrb5//Zna-1/4/5+j3//Dra2/Bcr/3/Ter-3
21	CD15DZ-ELT/off/891/2015	GEROMTEL-3/7/ALTAR84/BINTEPE85/3/ST0T//ALTAR84/ALD/4/P0D-11/YAZI-1/5/…
22	DURUM_PANEL_UNIBO-092, ICA#360	ID-DUREX south-western USA, elite
23	CD15DZ_ELT/off/980/2015	ALTAR.84/STINT//SILVER-45/3/GUANAY/4/GREEN-14//YAV-10/AUK/10/CMH79.959/CHEN//…
24	CD15DZ_ELT/off/1103/2015	KOFA/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV-1/6/ARDENTE/7/HUI/YAV79/8/…
25	Land race	238498
26	CDSS09B00190T-099Y-036M-18Y-0M	RBC/HUALITA/5/MOHAWK/3/GUANAY//TILO-1/LOTUS-4/4/ARMENT//SRN-3/NIGRIS-4/3/…
27	CD15DZ_ELT/off/1069/2015	CHAM1/4/INRAM-1005//SOMAT-4/INTER/8/3/SOOTY-9/RASOON-37//TILO-1/LOTUS-4/5/…
28	DURUM_PANEL_UNIBO-081	ID-BRAVADUR,SW USA
29	DURUM_PANEL_UNIBO-048	INRA1807 /ID-CHAOUI MOROCCO
30	Land race	8034
31	CD15DZ_ELT/off//248/2015	CF4 20S/4/YAZI-1AKAKI-4//SOMAT 3/3/AUK/GUIL//GREEN/5/CANELD-9.1//SHAKE-3/…
32	Tesfaye	ARMENT//SRN-NIGRIS-4/3/CANED-9.1/4/TOSKA-26RASCON-37//SNITSN/5/PLAYERO
33	CD15DZ-ELT/off/889/2015	GEROMTEL-3/7/ALTAR84/BINTEPE85/3/ST0T//ALTAR84/ALD/4/P00-11/YAZI-1/5/…
34	2015 offseason DW/F3 DZ #27	Yerer/UC 1113GPC Lr 19/DZ 2013mehF1P#8/DZ 2014 mehF2 P#8-2

No	Genotype Name	Pedigree or Accession number/description
35	Land race	222655
36	Land race	228862
37	CD15DZ_ELT/off/943/2015	LILE/6/CF4 205/4/YAZI-1AKAKI-4//SOMAT3/3AUK/GUIL//GREEN /5/CANELD-9.1//…
38	Werer	1346/LAHN//BICRE/LOUKOS-4
39	FIGSDWHOTCLD009	ETH74::56/ID-79653
40	FIGSDWHOTCLD051	AFG54::17 ID-85521
41	Land race	238498
42	Land race	ETH 2368039
43	ICARASHA2	Stj3/Ber/Lks4/3/Ter3
44	Utuba	Icajihan42) Omruf1/Stojocri2/3/1718/BeadWheat24//Karim
45	CD15DZ_ELT/off/275/2015	CF4 20S/4/YAZI-1/AKAKI-4//SOMAT-3/3/AUK/GUIL//GREEN/5/CANELD-9.1//SHAKE-3/…
46	CD15DZ_ELT/off/1034/2015	CMH83.2578/4/D88059//WARD/YAV79/3/AC089/5/2*S00TY-9/RASCON-37/6/1A.1D 5+1-06/…
47	CD15DZ_ELT/off/1035/2015	CMH83.2578/4/D88059//WARD/YAV79/3/AC089/5/2*S00TY-9/RASCON-37/6/1A.1D 5+1-06/…
48	FIGSDRYWET016	RUSS199/ID-82244
49	2015 Offseason DW/F3 DZ # 20	Yerer/UC 1113GPC Lr 1908001/59/ DZ 2013mehF1P#7/DZ 2014 mehF2 P#7-2
50	Mangudo	MRF1/STJ2|/3/1718/BT//KARIM,TUN
51	2015 offseason DW/F3 DZ #77	Mangudo/Mekuye/DZ 2013 meh DW F1 P#20/DZ 2014 meh DW F2 P#19-8
52	Mukiye	STJ3//BICRE/LOUKOS-4/3/TER3
53	Improved variety	Bichena
54	Durum wheat 301/10-Italy	NA
55	FIGSDRYWET134	IRAN931:19
56	QUAMY	FLAMINGO,MEX/CRANE//FLAMINGO/3/HUIT[2837][3589]; TEZONTLE/YAVAROS-79//HUITLE/3/ALTAR
57	2015 offseason DW/F3 DZ #19	Yerer/UC 1113GPC Lr 1908001/59/ DZ 2013mehF1P#7/DZ 2014 mehF2 P#7-1
58	Improved variety	Boohai
59	Land race	208316
60	FIGSDRYWET108	IRNS294/ID-98797
61	CD15DZ_ELT/off/1084/2015	CMH83.2578/4/D88059//WARD/YAV 79/3/ACO89/5/2*SOOTY.9/RASCON-37/6/1A.1D 5+1-6/…
62	CD13DZOS F6SR 2013 MS DZLS/97	K0FA/9/USDA595/3/D67.3/RABI//CRA/4/AL0/5/HUI/YAV-1/6/ARDENTE/7/HUI/YAV79/8/…
63	CD15DZ-ELT/off/1032/2015	JUPARE C 2001*2/KHAPLI/5/M0HAWK/4/DUKEM-1//PATKA-7/YAZI-1/3/PATKA-7YAZI-1/11/…
64	Land race	ETH CHEFE-9
65	Durum wheat 301/11-Italy	NA
66	CD15DZ_ELT/off/989/2015	TRIDENT /3*KUCUK/7/CMH83 2578/4/D88059//WARD/YAV 79/3/AC089/5/2*SOOTY-9/RASCON-37/6/…
67	AlemTena	Icasyr-1/3/Gcn//Sti/Mrb3
68	CD15DZ_ELT/off/998/2015	JUPARE C 2001*2/RBC /11/PLATA-10/6/MQUE/4/USDA573//QFN/AA-7/3/ALBA-D/5/AVO/HUI/7/…
69	CD15DZ_ELT/off/1000/2015	JUPARE C 2001*2/RBC /11/PLATA-10/6/MQUE/4/USDA573//QFN/AA-7/13/ALBA-D/5/AVO/HUI/7/…

No	Genotype Name	Pedigree or Accession number/description
70	Land race	ETH 203762
71	Land race	ETH 2368039
72	CD15DZ-ELT/off/306/2015	AG 1-22/2*AC089//2*UC1113/3/5*K0FA/5/K0FA/4/DUKEM-1//PATKA-7/YAZI-1/3/PATKA-7/…
73	Land race	236270
74	2015 offseason DW/F3 DZ #70	Mangudo/Mekuye/DZ 2013 meh DW F1 P#20/DZ 2014 meh DW F2 P#19-1
75	Land race	222856
76	CD15DZ-ELT/off/995/2015	JUPARE C 2001*2/RBC/11/PLATA-10/6/MQUE/4/USDA573//QFN/AA-7/3/ALBA-D/5/AV0/HUI/7/…
77	Land race	238531
78	Kilinto	IUMILLO/INRAT-69//BOOHAI/3/HORA/JORRO/4/COCORIT-71[1922][2837]; IUMILLO/INRAT-69//BOOBY/3/HORA/JORRO/4/COCOBAS[1551]; IUMILLO/INRAT-69/BOOHAI/3/HORA/4/COCORIT-71/JORI
79	CD15DZ-ELT/off/1081/2015	CMH83.2578/4/D88059//WARD/YAV79/3/AC089/5/2*S00TY-9/RASC0N-37/6/1A.1D5+1-06/…
80	CD15DZ-ELT/off/973/2015	ALAM0:DR/4/ARMENT//SRN-3/NIGRIS-4/3/CANEL0-9.1/5/PLATA-6/GREEN-17//SNITAN/4/…
81	Land race	215411
82	DURUM PANELUNIBO0177 ID-RAZZAK(TUN)	NA
83	CD15DZ-ELT/off/849/2015	NASSIRA/10/PLATA-10/6/MQUE/4/USDA573//QFN/AA-7/3/ALBA-D/5/AV0/HUI/7/PLATA-13/8/…
84	Improved variety DU-2018	CGS
85	Land race	208217
86	Land race	227009
87	CDSS09B00408D-5Y-014B-4Y-5B-9Y-3B-06Y-0B	AG 1-22/2*ACO89//2*UC1113/3/5*KOFA/5/KOFA/4/DUKEM-1//PATKA-7/YAZI-1/3/PATKA-7/…
88	2015 offseason DW/F3 DZ #20	Yerer/UC 1113GPC Lr 1908001/59/ DZ 2013mehF1P#7/DZ 2014 mehF2 P#7-2
89	Yerer	CHEN/TEZONTLE/3/GUILLEMOT//CANDEAL-II
90	Land race	238555
91	Land race	236269
92	CDSS09B00203T-099Y-066M-2Y-0M	CIT71/5/MOHAWK/4/DUKEM-1//PATKA-7/YAZI-1/3/PATKA-7/YAZI-1/7/CMH83.2578/4/D88059//…
93	Asasa	CHORLITO/YAVAROS//FREE-GALLIPOLI/3/FREE-GALLIPOLI/CANADIAN-RED/4/FREE-GALLIPOLI/DON-PEDRO/5/HUITLE
94	FIGSDRYWET091	ETH731::112/ID-90482
95	CD15DZ-ELT/off/1239/2015	GER0MTEL-3/8/ST0T//ALTAR84/ALD/3/THB/CEP7780//2*MUSK-4/6/EC0/CMH76A.722//…
96	CDSS09B00067S-099Y-035M-3Y-0M	STORLOM/3/RASCON-37//TARRO-2//RASCON-37/4/D00003A/5/1A.1D5+1-06/3*Mojo/3/AJAIA-12/…
97	CD15DZ_ELT/off/1024/2015	JUPARE C2001*2/1M/10/KOFA/9/USDA 595 /3/D67.3/RABI//CRA/4/ALD/5/HUI/YAV-1/16/…
98	Land race	222859
99	Land race	210817
100	Improved variety	Foka
101	Land race	208215
102	CD15DZ_ELT/off/1006/2015	JUPARE C2001*2/RBC/6/STORLOM/3/RASCON-37/TARRD-2//RASCON-37/4/D00003A/5/…