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Performance Evaluation of Elite Durum Wheat Genotypes for Yield and Stem Rust Response

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Research Article

Volume 1 Issue 1

Received Date: September 18, 2023

Published Date: November 15, 2023

DOI: 10.23880/oajbi-16000105

Abstract

Durum wheat is one of the most important crops worldwide and Ethiopia is the major producer in sub-Saharan Africa (SSA). However, there is a huge gap between domestic production and demand in Ethiopia. Hence, getting high yielder with resistant for multiple races of rusts especially for stem rust became challenging. This could be due to limited availability of resistance to multiple stem rust races coupled with the rapid occurrence and spread of virulent races of stem rust. Hence, objective of this study is to identify high yielding and stem rust resistant genotypes and use them as parents in the breeding program and advance to national variety trial to select for wide adaptability. Sixty advanced genotypes were evaluated across three locations during 2020/21 cropping season. The trial was set up using row-column design in two replications. Data on grain yield, yield related traits and stem rust were collected. Stem rust was scored following the modified Cobb's scale. Under high disease pressure the genotypes showed disease response and severity variations from RMR to S and from 5% to 100%, respectively indicating the presenece of variation for stem rust response. There were also genotypes which showed suceptable reaction and high grain yield and yield related traits. Hence, this may be due to minor gene resistance to stem rust. Generally, about 13 genotypes had good grian yield, thousand kernel weight and stem rust resistance. We can recommend these genotypes to test across country for their wide adaptability and as a parents for crossing.

Keywords: Durum Wheat; Grain Yield; Yield Related Traits; Stem Rust; Genotype

Introduction

Durum wheat [1] is one of the most important crops worldwide with an annual production of 37 million tons. Ethiopia is the major durum wheat producer in sub-Saharan Africa (SSA), with an acreage of 0.6 million ha. Durum wheat is known as an indigenous predominant tetraploid wheat species in Ethiopia and among the diversified crop species. It constitutes about 12% (7000 accessions) of the accessions in the Ethiopian national gene bank. Ethiopia is also known as a center of diversity for tetraploid wheat including durum wheat. Recent genetic analysis indicated that the country might actually represent a second center of origin for durum wheat. Apart from that, Ethiopia is among very few countries gifted with highly suitable environmental conditions to produce durum wheat and Ethiopian farmers have cultivated this crop for long years. This crop is traditionally grown by small-scale farmers on heavy black soils (vertisols) at altitudes ranging from 1800 to 2800 meters above sea level, mostly under rain-fed conditions until recently [1], but currently also started under irrigation condition. Durum wheat is considered as a potential crop by the government to supply for food industry and substitute wheat import. It is also one means of income diversification for the farmers [2]. In Ethiopia, durum wheat nearly accounts for 15–20% of wheat production and 30% of the whole acreage [3]. Hence, it contributes about 18 to 20% to the national wheat production [3]. Nowadays, irrigated wheat is expanding in Ethiopia and the production of durum wheat is expected to increase under irrigation. This may address the issue of limited domestic supply to the local food processors.

Durum wheat is primarily used for the processing of pasta, macaroni, pastni and couscous. In addition, it is used to make flour for leavened biscuits, cookies, biofuel, and for fermentation to make alcoholic beverages such as beer and liquors. Its stalk is a good source of animal feed and serves as a much for different agronomic practices in agriculture [3,4].

The demand for durum wheat in the local industry is high due to urbanization driven need for pasta and related products. However, several biotic and abiotic factors challenge the production and quality of durum wheat like many other crops. Among the biotic factors, stem rust (*Puccinia graminis* f.sp*. tritici*) [2] is becoming the most devastating disease. Hence, the development of high-yielding genotypes with resistance/ tolerance to diverse biotic and abiotic stresses is critical. For identifying stable and best-performing genotypes multi-environmental trial is a key step [5]. The objective of this study was to identify high yielding genotypes with stem rust resistant and use them as parents in the breeding program and advance the best genotypes for national variety trails to test across location for wide adaptability.

Materials And Methods

Planting Material and Experimental Set Up

Sixty advanced durum wheat genotypes including the two checks, one newly released variety *Alem tena* as a standard and *Quamy* as a local check were evaluated across three moisture stress locations in Ethiopia during 2020/21 main cropping season. These locations are representing lowland agro-ecologies (Table 1). The experiment was laid out in row-column design with two replications. The total plot area was 3m^2; each plot had six rows of 2.5 m length with 0.2 m inter-row spacing. The seed rate was 125 kg/ha. Planting time, fertilizer application and other agronomic practices were carried out as per the recommendation of each location.

Location	Altitude	Geographical position		Rainfall (mm)	Soil type/texture	Temprature (^{0}C)	
		latitude	Londtude			Min	Max
Alem Tena	1611	08^{0}30'N	38^{0}95'E	728	Haplic andosol	NA	NA
Dhera	1660	08^{0}19'10"N	39^{0}19'E	680	Andosol	14	27.8
Minjar	1810	08^{0}55'N	39^{0}45'E	867	Andosol	10	28

Source KARC and DZARC NA = not available

Table 1: Description of the study environments/locations.

Data Collection and Analysis

Data collections were done for grain yield, TKW, other yield related traits and stem rust disease**.** The disease data was collected at all locations by observing the severity on the stem surfaces of each genotype. Disease severity as a percentage of stem area covered with rust postule was assessed following the modified Cobb's scale. The genotypes response to the infection in the field was assessed using "I" or immune (no uredinia on stem , pure green stem), ''R'' or resistant (small uredinia surrounded by chlorosis or necrosis); ''MR'' or moderately resistant (medium sized uredinia surrounded by chlorosis or necrosis); "M" (Intermediate; Moderately Resistant-to-moderately susceptible), (''MS'' or moderately susceptible (medium large, compatible uredinia without chlorosis and necrosis); MSS (Moderately susceptible to susceptible) and ''S'' or susceptible (large, compatible uredinia without chlorosis and necrosis). Thus, rust scores 10M means 10% severity of moderately resistant-to-moderately susceptible response while the 40MSS score indicates 40% severity of moderately susceptible-to-susceptible response and rust score 50S means 50% severity of susceptible type response.

The last disease score when the disease progress is ceased was used to calculate the coefficient of infection (CI) following Pathan Park, et al. and Stubbs, et al. CI value calculated by multiplying the disease severity with constant values for each response class. The constant values of 0, 0.2, 0.4, 0.6, 0.8, 0.9 or 1.0 represent host response ratings of immune (I), resistant (R), moderately resistant (MR), intermediate (M), moderately susceptible (MS) and susceptible, respectively.

Before data analysis data cleaning for traits was done. Data analysis was conducted using R software for yield, yield related traits and Coefficient of infection for stem rust (CI).

Result and Discussion

Response of the Tested Genotypes for Grain Yield, TKW and Stem Rust Disease

The distribution plot of grain yield, thousand kernel weights, hectoliter weight and other agronomic traits such as DTH, DTM and PHT showed normal frequency distribution. The statistical analysis of variance for grain yield across locations showed that there was a significant variation (P<-0.001) among genotypes, environments, and genotype by environment interaction (GEI) (Table 2). The statistical analysis difference of genotypes and environments indicates that there is a variation among genotype for response of grain yield performance, on the other hand different environment also treating the tested genotypes differently for grain yield performance. Hence, this result leads to recommend best performing genotype for specific location adaptation and for crossing program.

Source	Df	DTH	DTM	PHT	TKW	HLW	GYLD	CI
Entry	59	4.41e-16 ***	5.71e-08 ***	2e-16 ***	1.86e-07 ***	7.41e-14 ***	2e-16 ***	2e-16 ***
Rep	1	0.2251	0.000286 ***	1.91e-07 ***	0.254	0.8954	0.000347 ***	0.100662
ENV	2	2e-16 ***	2e-16 ***	2e-16 ***	2e-16 ***	2e-16 ***	2e-16 ***	2e-16 ***
GxE	118	0.09211	0.721624	0.01292 *	0.331	0.0896	1.48e-08 ***	0.000125 ***
Residuals	153							
CV		3.92	5.09	5.65	17.67	2.44	14.01	24.57
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1								

Table 2: The analysis of variance for grain yield, yield related traits and CI.

The statistical analysis of variance for yield related traits (TKW, HLW, PHT, DTH and DTM) across locations also showed that a significant variation (P<-0.001) between genotypes and environments, however there is no variation genotype by environment interaction (GEI). Statistical analysis revealed that there is highly significant variance for stem rust coefficient of infection (CI) between different tested durum wheat genotypes, testing environments and the interaction of environments x genotypes (Table 2).

The average mean grain yield of the tested genotypes was range from 1532kg-ha (Omrabi5) to 4298kg-ha (DW193582). Genotype DW193582, is the highest yielder among the tested genotypes and resistant to the stem rust, so this genotype is the best to use as a parent as resistant and also for yield gain. The lowest grain yield was observed at Alem Tena site (1160kg/ha) followed by Dhera (1450kg/ha). This was due to high stem rust pressure at Alem Tena (up to 100%) followed by Dhera (up to 90%). Sixteen (16) genotypes at Dhera site and 14 genotypes Alem Tena site had better grain yield than the standard check (Alemtena) (Table 3). Thirteen genotypes DW193582, DW193543, DW193461, DW193467, DW193465, DW193502, DW193563, DW193636, DW193523, DW193472, DW193509, DW193541 and DW193517 performance was better as compared to the standard check Alemtena at all-testing site.

	GYLD				TKW			C.I			Infection Type			Severity %		
Genotype	AT	DR	MJ	Average	AT	DR	MJ	AT	DR	MJ	AT	DR	MJ	AT	DR	MJ
DW193625	1160	1851	2768	1926	26	30	32	65	55	13.5	S	S	MSS	60	40	10
DW193466	2025	4884	2823	3244	30	40	44	22	50	8	MRMS	S	MS	20	40	5
Atlhagy	2253	4555	2555	3121	31	40	40	39	40	0.08	MSMR	S	MS	30	40	0
Berghisyr	2005	5038	2400	3148	26	44	38	2.3	0	0.08	MRMS	0	MS	5	0	0
Ouhassan	2260	5160	2375	3265	27	25	38	1.8	6	4.04	MR	MS	MS	5	10	0
DW193575	2473	5716	2503	3564	30	37	36	49	10	4	MRMS	MS	MS	30	20	5
DW193636	2145	5617	3798	3853	26	22	34	25	28	6	MRMS	MS	MS	30	20	10

DW193517	2480	5040	3523	3681	30	28	36	51	20	24	MS	MS	MS	40	20	10
DW193552	2265	4688	2468	3140	34	45	40	46	12	6.5	MS	MS	MS	40	10	5
DW193502	3060	6058	2925	4014	27	25	38	65	46	8	S	MS	MS	50	40	5
DW193560	2055	4989	3155	3400	28	22	34	27	10	6	S	MS		50	10	15
DW193582	2700	5784	4410	4298	28	33	36	43	25	12	MRMS	MS	MS	15	20	10
DW193482	2713	4187	2815	3238	28	28	36	48	10	10	MSS	S	MS	40	20	20
DW193465	3063	6028	3010	4033	21	25	36	65	24	10	MSS	MS	MS	40	15	20
DW193639	1935	5244	3185	3455	26	40	34	53	12	10	S	MS	MS	60	10	20
DW193566	2195	4892	2445	3177	27	23	30	28	24	18	SMS	MS	MS	40	20	20
DW193533	2235	4676	3150	3394							MS	MS	MSS	30	10	30
DW193556	2725	5506	2643	3625	22	17	26	42	35	2.04	MSMR	S	MS	40	30	0
DW193580	2220	5110	2418	3249	36	53	36	44	8	8.04	MRMS	MS	MS	30	20	20
DW193563	2813	5467	3558	3946	24	32	36	55	23	25.5	S	S	MS	60	30	30
DW193590	1985	4501	3025	3170	20	27	36	63	23	12	SMS	S	MS	50	30	20
DW193476	2213	4926	3880	3631							SMS	S	MS	40	30	20
DW193621	1668	4497	2683	2949	26	36	36	80	30	37	S	S	MS	70	30	30
DW193509	2848	5325	2925	3699	24	25	36	60	27	14	S	S	MS	60	30	30
DW193608	2088	4248	2680	3005	24	21	34	70	75	26	S	S	S	70	90	40
DW193545	1558	3596	2830	2661	24	32	36	56	55	16	S	S	MSS	80	60	20
DW193634	2180	5153	3220	3518	16	25	36	80	28	8	S	S	MS	90	40	15
DW193592	1370	4774	1973	2706	30	32	34	80	24	4.04	S	MS	MS	90	10	10
DW193543	2715	6268	3520	4297							S	MS	MS	60	5	15
DW193615	2545	4911	2580	3345	30	36	34	65	38	10	S	MS	MS	70	20	20
DW193483	2150	4929	2303	3127	10	36	40	50	16	18	S	MS	MS	50	10	15
Polluce	2183	4242	2983	3136	22	22	32	70	24	4.04	S	MS	MS	60	10	10
DW193499	1803	3815	2935	2851	28	36	38	80	6	12	S	MS	MS	70	5	30
DW193523	2733	4675	3920	3776	30	35	36	48	23	16	S	MS	MS	50	20	30
DW193472	2340	5775	3008	3708	22	35	34	65	20	20	S	MS	MSS	70	20	30
DW193611	1788	3169	3028	2661	26	34	30	80	43	18	S	MS	MSS	100	20	40
DW193500	2100	4711	2698	3170	26	37	38	60	40	18	S	S	MSS	60	40	30
DW193461	3088	5360	4193	4213	28	32	36	55	33	8.04	S	MS	MS	60	20	20
DW193567	2053	5703	2565	3440	28	25	32	60	14	14	S	MS	MS	50	15	15
DW193505	2198	4817	3520	3510							S	MS	MS	50	40	20
DW193633	2938	4298	2963	3399	34	24	32	50	31	14	S	MS	MS	50	15	20
DW193501	2148	4929	3223	3433	28	23	38	60	40	10	S	S	MS	50	40	15
DW193486	2230	5412	2600	3414	20	27	28	60	38	19.5	S	MS	MS	50	20	30
DW193561	2280	5156	2955	3565							S	MS	MS	80	20	30
DW193481	1685	2854	2620	2386	20	33	38	70	30	36	S	S	MS	70	30	40
DW193462	2000	5102	3430	3527							S	S	MS	70	30	30
Omrabi5	1530	1450	1618	1532	28	39	36	95	85	24	S	S	MSMR	90	80	20
DW193473	1975	4120	3115	3070	24	27	38	85	60	31.5	S	S	MSS	100	70	30

DW193536	2045	3868	3045	2986	30	38	38	58	40	12	S	S	MS	70	40	30
DW193528	2223	5012	2823	3352	26	25	36	3	0	4	RMR	0	MS	10	0	5
DW193489	2010	4829	3115	3318	28	22	36	85	50	12	S	S	MS	80	70	30
DW193568	2105	2573	2120	2205							S	S	MS	80	40	20
DW193467	2923	5149	4870	4203							S	S	MS	90	50	20
DW193541	2223	5291	3435	3692							SMS	S	MS	40	40	20
DW193471	1388	2870	2685	2314	24	21	34	34	21	16	SMS	MS	MS	40	15	30
DW193463	2398	3860	3965	3407	24	36	36	55	26	14	S	MS	MS	60	15	15
DW193573	1950	4992	2660	3201	26	24	30	55	10	34	S	MS	MS	50	20	10
DW193597	1820	4789	3685	3380							RMR	MS	MS	5	10	5
Alemtena	2365	5259	2298	3307	26	24	38	75	35	4.04	S	S	MS	70	30	10
Quamy	2280	4740	3983	3667	36	45	42	3.8	6	2.04	RMR	MS	MS	5	10	5

Table 3: The response of tested genotypes for yield, yield component and stem rust response.

There are some genotypes that showed high grain yield and yield related traits under high stem rust disease pressure. These genotypes showed tolerance to stem rust would be Adult Plant Resistant (APR). This may be due to accumulation of multiple minor genes. as indicated by Soko, et al. [6] single APR gene alone does not confer adequate resistance especially under high disease pressure, hence combination of four to five such gene may result resistant and minimize yield and yield related traits. Generally, from the total tested genotypes more than 50% had better grain yield than the standard check Alemtena.

The distribution of coefficient of infection was close to normal at Alem Tena and Dhera but skewed to the resitant score at Minjar. Most of the genotypes showed scuceptable response at Alem Tena this indicates that at this location there was high disease pressure than the other two locations with suitable environment for stem rust development. At Dhera about 30% of the genotypes were susceptible and at Minjar the disease pressure was less and most of the genotypes showed less stem rust response.

This study showed that the tested durum wheat genotypes had different severity and reaction response for stem rust and varying levels of grain yield loss due to stem rust and genetic makeup of genotype. In most of the tested genotypes the stem rust response and severity had negative correlation with grain yield, i.e., the genotypes that has high disease severity with susceptible and moderately susceptible reaction response showed low grain yield than the genotypes that have low severity percentage with resistant and moderately resistant reaction on the other hand, some genotypes that exhibited high disease pressure showed high grain yield. There are also genotypes that showed low grain yield under low disease severity with resistant and moderately resistant response; hence these genotypes may be genetically poor for grain yield potential (Figure 1).

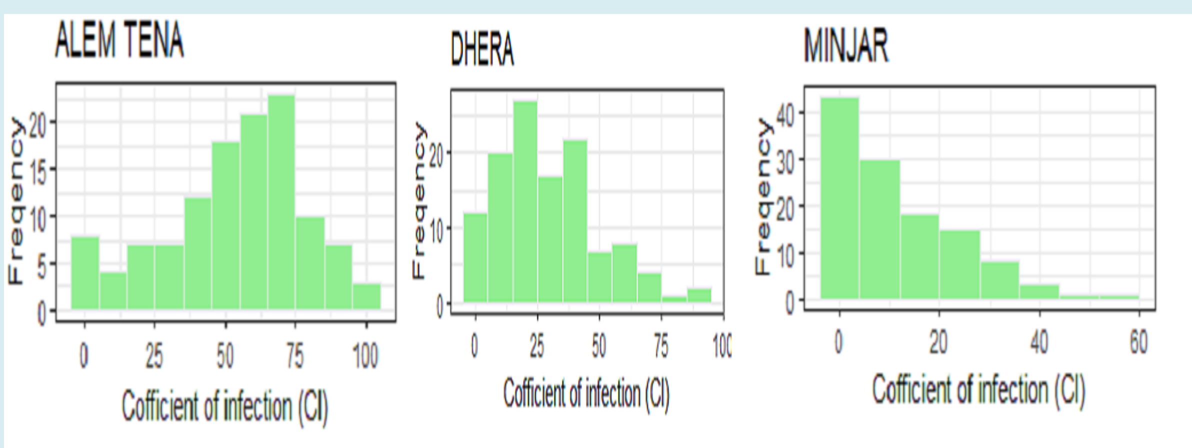

Figure 1: Distribution of Coefficient of infection for the Tested Genotypes across the 3 locations.

About five Genotype such as; DW193466, Atlhagy, Berghisyr, DW193575 and DW193636 showed MRMS reaction and are good sources of resistance for stem rust and have good grain yield and yield related performance and 7 genotypes (DW193528, DW193597, Ouhassan, DW193556, DW193580, DW193528, DW193597) also revealed RMR reaction and have good grain yield and yield related traits performance.

There are also genotypes that showed high stem rust severity with moderately susceptible reaction but no reduced yield. These types of genotypes may be durable resistant for this disease and may carry minor gene resistance, that means the disease severity may be high but its impact on grain yield is very low (Table 2). The genotypes that showed resistance may carry more.

Than one resistance gene. As reported by Emad M. Al-Maaroof, et al. [7] possessing more than one resistant gene increase the time of resistance stability in each cultivar, also the pathogen needs more time to develop virulence against the resistant genes.

The disease severity and reaction varied from 5% to 100% and RMR to S, respectively for Alem Tena location, However for Dhera site the response was from immunity to susceptible and severity raged from 0 to 90%.and at Minjar the severity ranged from trace to 40% with reaction from susceptible (S) to moderately susceptible moderately resistant (MSMR) (Table 2). High disease pressure occurred at Alem Tena in this season which is expected as this site is among the hotspot area for stem rest screening (Table 2). Thousand kernel weight (TKW) showed a positive correlation with grain yield but negative correlation with stem rust. This is an expected result, because TKW is one of the yield components positively correlated with yield. Generally, the stem rust affects seed size and quality by shriveling the durum wheat kernel. Similar result was reported by Nzuve F [8]. Susceptible lines had very shriveled grains in the field and in some cases no grain is harvested at all indicating the negative impact of stem rust on grain yield and quality [9].

Most tested genotypes showed high grain yield and TKW when the CI value was low and vice versa. Ashenafi Gemechu, et al. [2] also reported the same result that stem rust disease resulted a significant reduction in grain yield and thousand kernel weight (TKW) [10].

However, [11] there are few genotypes that revealed high grain yield and TKW under high CI value so these genotypes may be durable rust resistance genotypes which are control by many minor genes. There is Similar report was conducted by Draz, et al. and concluded that durable rust resistance mechanism in wheat is achieved through incorporation of partially resistant minor genes which seems to be more appropriate solution for sustainable wheat production [12].

Performance of the Tested Genotypes across Environments

Polygon ("which-won-where") View of the GGE Biplots grain yield: The polygon view of the GGE biplot explained 91.46% of the genotype plus genotype by environment variation for grain yield (Figure 2). The GGE biplot analysis for grain yield resulted in five and the three locations fell in two of the sectors indicating that the locations are grouped into two [13]. The first group had locations Minjar and Alem Tena while the second had only Dhera. The genotype in the vertex of the polygon the winner genotype. Therefore, genotype entry number 38 was the winner at Minjar and Alem Tena while genotype 10 was the winner genotype at Dhera (Figure 2).

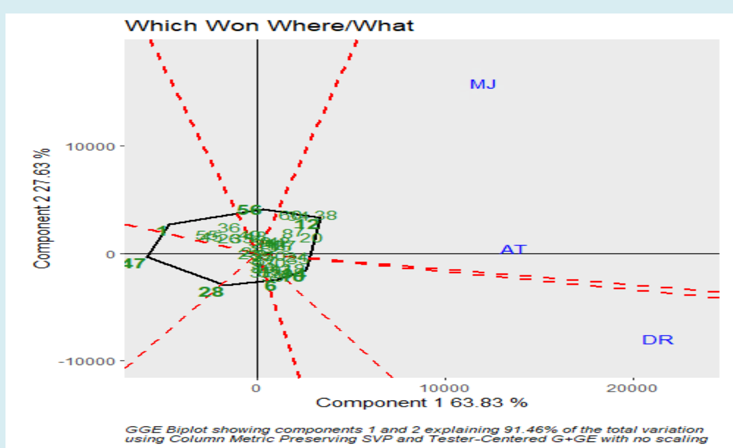

Figure 2: Which-Won-Where View of the GGE Biplot.

Genotype: Omrabi5 which had the longest projection from the AEC x-axis was highly unstable genotype and had low grain yield, while more than 50% the tested genotype is stable. six genotypes (DW193461, DW193563, DW193582, DW193575, Berghisyr and DW193462 which have an entry number 38, 20, 12, 6, 4 and 46 respectively have grain yield the above average mean yield and some genotypes such as Omrabi5, DW193625, DW193592, DW193611 and DW193463 with the entry number 47,1,28,36 and 56 respectively had a grain yield below average mean yield.

The discriminating power versus representativeness view of the GGE biplot as shown in Figure 3 showed that test environments Minjar and Dhera with the longest projection from the biplot origin were found to be the environments with more discriminating power that they provided much information about the differences among genotypes than Alem Tena site which has intermediate projection from the biplot origin. Test environment Alem Tena was found to be more representative of other test environments since it has smaller angles with the Average Environment Axis (AEA) [14]. Minjar therefore identified as an ideal environment that has both discriminating abilities of the genotypes and representative of the other test environments. Thus, environment Minjar and Dhera can be used to effectively select superior genotypes that can perform consistently across environments.

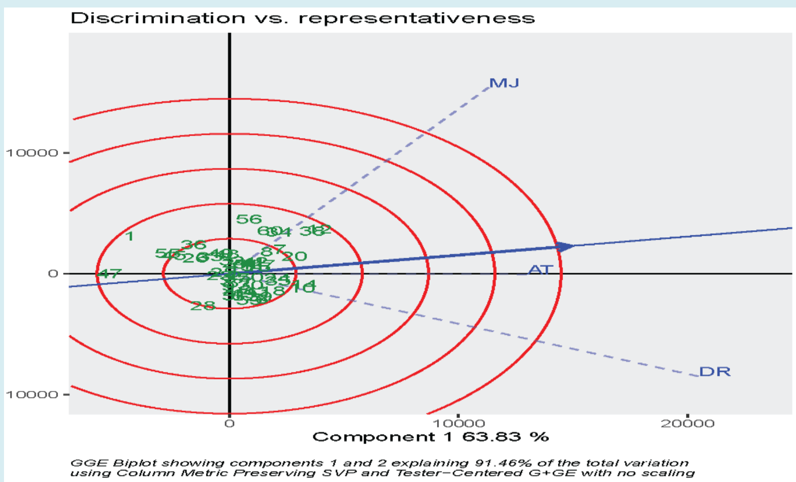

Figure 3: Discrimination verses representativeness Plot.

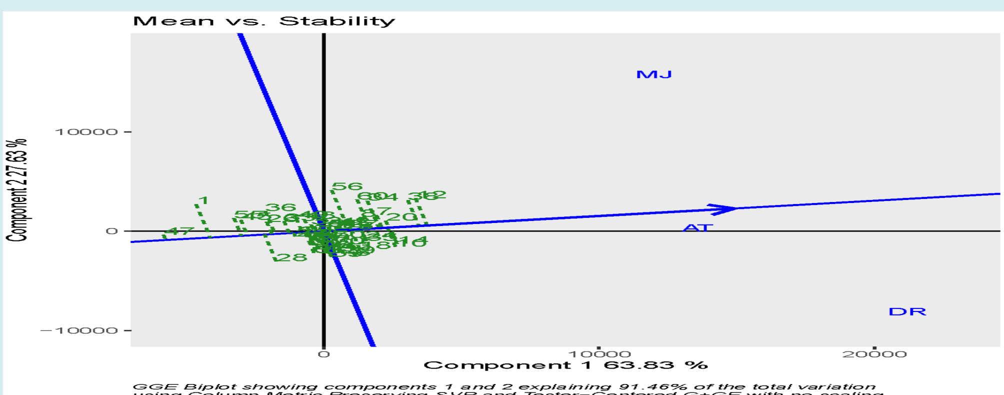

Figure 4: Stability Plot of genotypes across Three Locations.

Mean Performance and Stability of Genotypes: Grain yield performance of the Genotypes trending towards the direction of genotype showed higher grain yield and genotypes trending towards the opposite direction represent the poor performing lines such as genotype Omrabi5 (entry No47), DW193592 (entry No 28) and DW193625 (entry No 1) (Figure 4). Most of the genotypes were the most stable and high yielder as they had near zero projection from the AEC horizontal axis. In agreement with this finding Dennis N, et al. [9] in their finding reported high yielder and stable genotype as well as low yielding and poorly stable genotypes.

S. N	Genotype	Pedigree
G1	DW193625	NA
G2	DW193466	SILVER_14/MOEWE//BISU_1/PATKA_3/3/PORRON_4/YUAN_1/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/TARRO_1/2*YUAN_1//AJAIA_13/YAZI/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/11/ALTAR 84/STINT//SILVER_45/3/GUANAY/4/GREEN_14//Y
G3	Atlhagy	Mgnl3/Aghrass2/4/IcamorTA0462/3/Arislahn7//CI115/Bcrch1/5/Beltagy1/7/Icasyr1//Mrf2/T.dids20123/6/319ADDO/5/D68193A1A//Ruff/Fg/3/Mtl5/4/Lahn
G4	Berghisyr	Ter1//Mrf1/Stj2/3/Icasyr3
G5	Ouhassan	Ouasloukos1/5/Azn1/4/BEZAIZSHF//SD19539/Waha/3/Gdr2/6/Aghrass1/Bezaiz981//Icajihan2
G6	DW193575	NASR99/5/RASCON_33/TISOMA_2/3/CANELO_8//SORA/2*PLATA_12/4/SOMAT_4/INTER_8/6/BCR/GUEROU_1/3/MINIMUS_6/PLATA_16//IMMER
G7	DW193636	LAHNMIKI/7/STORLOM/3/RASCON_37/TARRO_2//RASCON_37/4/D00003A/5/1A.1D 5+106/3*MOJO/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/6/SOOTY_9/RASCON_37//WODUCK/CHAM_3/3/SOMAT_3/PHAX_1//TILO_1/LOTUS_6
G8	DW193517	PLATA_7/ILBOR_1//SOMAT_3/3/CABECA_2/PATKA_4//BEHRANG/10/1A.1D 5+1-06/2*WB881//1A.1D5+106/3*MOJO/3/SOOTY_9/RASCON_37/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/11/CIRNO C 2008/12/CBC 509 CHILE/5/2*AJAIA_16//HORA/JRO/
G9	DW193552	Brigade/4/SOOTY_9/RASCON_37//JUPAREC001/3/SOOTY_9/RASCON_37//GUAYACAN INIA/6/WID22202/4/SORA/2*PLATA_12//SOMAT_3/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/5/CF4-JS 21//TECA96/TILO_2
G10	DW193502	CBC509CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/SOOTY_9/RASCON_37//WODUCK/CHAM_3/13/SOOTY_9/RASCON_37//GUAYACANINIA/11/BOOMER_33/ZAR/3/BRAK_2/AJAIA_2//SOLGA_8/10/PLATA_10/6/MQUE/4/U
G11	DW193560	NA
G12	DW193582	MOHAWK/6/LOTUS_5/F3LOCAL(SEL.ETHIO.135.85)/5/CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FNFOOT/13/SOOTY_9/RASCON_37//GUAYACAN INIA/11/BOOMER_33/ZAR/3/BRAK_2/AJAIA_2//SOLGA_8/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/
13	DW193482	NA
14	DW193465	HUBEI//SOOTY_9/RASCON_37/3/2*SOOTY_9/RASCON_37/4/2*SOOTY_9/RASCON_37/6/SOMAT_3/PHAX_1//TILO_1/LOTUS_4/3/GUANAY/5/NETTA_4/DUKEM_12//RASCON_19/3/SORA/2*PLATA_12/4/GREEN_18/FOCHA_1//AIRON_1/7/ALTAR84/STINT//SILVER_45/3/GUANAY/4/GREEN_14//YAV_10/AUK/5/G
15	DW193639	ZHONGZUO/2*GREEN_3//SORA/2*PLATA_12/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FNFOOT/11/RISSA/GAN//POHO_1/3/PLATA_3//CREX/ALLA/4/JUPARE C 2001/5/ARMENT//SRN_3/NIGRIS_4/3/CA
16	DW193566	DSIAN/11/Mï¿½ALI/6/MUSK_1//ACO89/FNFOOT_2/4/MUSK_4/3/PLATA_3//CREX/ALLA/5/OLUS*2/ILBOR//PATKA_7/YAZI_1/10/SELIM/9/ALTAR84/860137//YAZI_1/4/LIS_8/FILLO_6/3/FUUT//HORA/JOR/8/GEDIZ/FGO//GTA/3/SRN_1/4/TOTUS/5/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO71
17	DW193533	SIMETO/3/SORA/2*PLATA_12//SRN_3/NIGRIS_4/5/TOSKA_26/RASCON_37//SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/7/SOOTY_9/RASCON_37//STORLOM/5/TOSKA_26/RASCON_37//SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/6/RISSA/GAN//POHO_1/3/PLATA_3//CREX/ALLA*2/4/A

18	DW193556	Eurostar/6/ALTAR84/STINT//SILVER_45/3/GUANAY/4/GREEN_14//YAV_10/AUK/5/GUAYACAN INIA/YEBAS_8/3/TOPDY_18/FOCHA_1//ALTAR84/7/WID22202/4/SORA/2*PLATA_12// SOMAT_3/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/5/CF4-JS 21//TECA96/TILO_2
19	DW193580	NA
20	DW193563	CATERVO/12/WID22209/7/AINZEN_1/3/SNTURKMI83-84 503/LOTUS_4//MUSK_4/6/ CMH82A.1062/3/GERARDOVZ394//SBA81/PLC/4/AAZ_1/CREX/5/HUI//CIT71/CII/11/LABUD/ NIGRIS_3//GAN/3/AJAIA_13/YAZI/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/ AVO/HUI/7/PLATA_13/10
21	DW193590	BHA/3/SORA/2*PLATA_12//SRN_3/NIGRIS_4/4/AG 1-22/2*ACO89//2*UC1114
22	DW193476	CF420S/4/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/5/CANELO_9.1// SHAKE_3/2*AJAIA_2/12/MOHAWK/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/ AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/11/ ARMENT//SRN_3/NIGRIS_4/3/
23	DW193621	ODIN_15/WITNEK_1//ISLOM_1/5/TARRO_1/TISOMA_2//TARRO_1/3/COMB DUCK_2/ ALAS//4*COMB DUCK_2/4/SHAG_9/BUTO_17/6/VANRRIKSE_6.2//1A-1D 2+12-5/3*WB881/5/ TARRO_1/TISOMA_2//TARRO_1/3/COMB DUCK_2/ALAS//4*COMB DUCK_2/4/SHAG_9/BUTO_17/7/ PLATA_7/ILBOR_1//SOMAT_3/4
24	DW193509	P91.272.3.1/3*MEXI75//2*JUPAREC 2001/11/BOOMER_33/ZAR/3/BRAK_2/AJAIA_2// SOLGA_8/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/ THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/12/STR/4/JO69/3/JO69/ CRA//CIT71/5/ALTAR 84/
25	DW193608	B0417/7/ZENIT/5/SORA/2*PLATA_12//RASCON_37/4/ARMENT//SRN_3/NIGRIS_4/3/ CANELO_9.1/6/MINIMUS_4/GRO_2/3/PROZANA/ARLIN//MUSK_6/5/SULA/RBCE_2/3/HUI//CIT71/ CII/4/RYPS27_3/SKARV_4
26	DW193545	INRAT102/11/E90040/MFOWL_13//LOTAIL_6/3/PROZANA/ARLIN//MUSK_6/9/USDA595/3/ D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/TOSKA_26/ RASCON_37//SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.3
27	DW193634	RANCO//CIT71/CII/3/COMDK/4/TCHO//SHWA/MALD/3/CREX/5/SNITAN/6/YAZI_1/AKAKI_4// SOMAT_3/3/AUK/GUIL//GREEN/9/CBC509CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/ AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/SOOTY_9/ RASCON_37//WODUCK/CHA
28	DW193592	P91.272.3.1/3*MEXI75//2*JUPAREC2001/11/BOOMER_33/ZAR/3/BRAK_2/AJAIA_2// SOLGA_8/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/ THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/12/STR/4/JO69/3/JO69/ CRA//CIT71/5/ALTAR 84/
29	DW193543	NA
30	DW193615	WID22241/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/TARRO_1/2*YUAN_1//AJAIA_13/ YAZI/3/SOMAT_4/INTER_8/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/6/SORA/2*PLATA_12// SOMAT_3/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/4/1A.1D 5+1-06/3*MOJO// RCOL/3/SNITAN/SO
31	DW193483	NA
32	Polluce	Tpolonicum9/Ch1//IcamorTA0468/3/IcamorTA0459//CandocrossH25/Waha0416/5/CD21760/ Tdic.1Q55132//Ch1/3/Tourus1/4/Sh/6/Ter1//Mrf1/Stj2/7/Bcr/Lks4//Mrf1/Stj2/3/Mrf2/ NormalHamari//Bcr/Lks6
33	DW193499	SOOTY_9/RASCON_37//WODUCK/CHAM_3/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/ YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/12/WID22209/7/AINZEN_1/3/SN TURKMI83-84503/ LOTUS_4//MUSK_4/6/CMH82A.1062/3/GERARDOVZ 94//SBA81/PLC/4/AAZ_1/CREX/5/HUI// CIT71/CII/11/LABUD

34	DW193523	TARRO_1/2*YUAN_1//AJAIA_13/YAZI/3/SOMAT_3/PHAX_1//TILO_1/LOTUS_4/4/CANELO_8//SORA/2*PLATA_12/5/CBC 501 CHILE/GUANAY/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN/7/ALTAR84/BINTEPE85/3/STOT//ALTAR84/ALD/4/POD_11/YAZI_1/5/VANRRIKSE_12/SNITAN/6/SOOTY_9/RASCON_
35	DW193472	CBC509CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/SOOTY_9/RASCON_37//WODUCK/CHAM_3/9/TOPDY_18/FOCHA_1//ALTAR84/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/4/SOMAT_3/GREEN_22/5/VRKS
36	DW193611	TJILKURI/11/E90040/MFOWL_13//LOTAIL_6/3/PROZANA/ARLIN//MUSK_6/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/TOSKA_26/RASCON_37//SNITAN/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.3
37	DW193500	SOOTY_9/RASCON_37//WODUCK/CHAM_3/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/12/WID22209/7/AINZEN_1/3/SN TURK MI83-84 503/LOTUS_4//MUSK_4/6/CMH82A.1062/3/GERARDO VZ 394//SBA81/PLC/4/AAZ_1/CREX/5/HUI//CIT71/CII/11/LABUD
38	DW193461	ADAMAR_15//ALBIA_1/ALTAR84/3/SNITAN/4/SOMAT_4/INTER_8/5/SOOTY_9/RASCON_37/6/BICHENA/AKAKI_7/4/LIS_8/FILLO_6/3/FUUT//HORA/JOR/5/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/7/TOPDY_18/FOCHA_1//ALTAR84/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/4/SO
39	DW193567	NA
40	DW193505	P91.272.3.1/3*MEXI75//2*JUPAREC2001/11/BOOMER_33/ZAR/3/BRAK_2/AJAIA_2//SOLGA_8/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/12/STR/4/JO69/3/JO69/CRA//CIT71/5/ALTAR 84/
41	DW193633	Mï¿½ALI/8/GREEN_2/HIMAN_12//SHIP_1/7/ECO/CMH76A.722//BIT/3/ALTAR 84/4/AJAIA_2/5/KJOVE_1/6/MALMUK_1/SERRATOR_1/9/SELIM/5/SULA/AAZ_5//CHEN/ALTAR84/3/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/10/SARAGOYA/5/GUANAY/
42	DW193501	SOOTY_9/RASCON_37//WODUCK/CHAM_3/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/12/WID22209/7/AINZEN_1/3/SN TURK MI83-84 503/LOTUS_4//MUSK_4/6/CMH82A.1062/3/GERARDOVZ394//SBA81/PLC/4/AAZ_1/CREX/5/HUI//CIT71/CII/11/LABUD
43	DW193486	SELIM/5/BRAK_2/AJAIA_2//SOLGA_8/3/CANELO_8//SORA/2*PLATA_12/4/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/10/NASR99/9/SOMAT_3/PHAX_1//TILO_1/LOTUS_4/7/YEL/BAR/3/GARZA/AFN//CRA/5/DOM//CRA*2/GS/3/SCOT/4/HORA/6/LAP746/GUIL/8/CREX//BOY/YAV_1/3/PLATA_6/4/P
44	DW193561	WOLLAROI/12/LABUD/NIGRIS_3//GAN/3/AJAIA_13/YAZI/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBAD/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/POC//BUB/RUFO/4/FNFOOT/11/SORA/2*PLATA_12//SOMAT_3/4/STORLOM/3/RASCON_37/TARRO_2//RASCON_37/5/CADO/
45	DW193481	CIRNOC2008/4/SOOTY_9/RASCON_37//JUPAREC2001/3/SOOTY_9/RASCON_37//CAMAYO
46	DW193462	PLANETA/PIQUERO//BERGAND/KNIPA/6/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/5/2*NETTA_4/DUKEM_12//RASCON_19/3/SORA/2*PLATA_12/4/GREEN_18/FOCHA_1//AIRON_1/12/ALTAR84/STINT//SILVER_45/3/GUANAY/4/GREEN_14 //YAV_10/AUK/10/CMH79.959/CHEN//SOOTY_9/RASCON_39
47	Omrabi5	Joric69/Hau

48	DW193473	GUAYACANINIA/GUANAY/8/GEDIZ/FGO//GTA/3/SRN_1/4/TOTUS/5/ENTE/MEXI_2//HUI/4/ YAV_1/3/LD357E/2*TC60//JO69/6/SOMBRA_20/7/JUPAREC2001/9/RCOL/ THKNEE_2/3/ SORA/2*PLATA_12//SOMAT_3/10/SOMAT_4/INTER_8/4/GODRIN/GUTROS//DUKEM/3/ THKNEE_11/5/1A.1D 5+1-06/2*WB883
49	DW193536	ODIN_15/WITNEK_1//ISLOM_1/5/TARRO_1/TISOMA_2//TARRO_1/3/COMB DUCK_2/ ALAS//4*COMBDUCK_2/4/SHAG_9/BUTO_17/6/VANRRIKSE_6.2//1A-1D 2+12-5/3*WB881/5/ TARRO_1/TISOMA_2//TARRO_1/3/COMBDUCK_2/ALAS//4*COMB DUCK_2/4/SHAG_9/BUTO_17/7/ SORA/2*PLATA_12//SOMAT_3/5
50	DW193528	ZENIT/5/SORA/2*PLATA_12//RASCON_37/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/6/ MINIMUS_4/GRO_2/3/PROZANA/ARLIN//MUSK_6/5/SULA/RBCE_2/3/HUI//CIT71/CII/4/ RYPS27_3/SKARV_3/7/ZENIT/5/SORA/2*PLATA_12//RASCON_37/4/ARMENT//SRN_3/ NIGRIS_4/3/CANELO_9.1/6/MINIMUS_
51	DW193489	OROBEL//BUSHEN_4/2*GREEN_18/8/GEDIZ/FGO//GTA/3/SRN_1/4/TOTUS/5/ENTE/MEXI_2// HUI/4/YAV_1/3/LD357E/2*TC60//JO69/6/SOMBRA_20/7/JUPARE C 2001/11/CLAUDIO/4/ YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/10/TARRO_1/2*YUAN_1//AJAIA_13/YAZI/9/ USDA595/3/D67.3/RABI
52	DW193568	NA
53	DW193467	SILVER_14/MOEWE//BISU_1/PATKA_3/3/PORRON_4/YUAN_1/9/USDA595/3/D67.3/RABI// CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/TARRO_1/2*YUAN_1// AJAIA_13/YAZI/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/11/GUAYACAN INIA/2*SNITAN
54	DW193541	INRAT102/12/LABUD/NIGRIS_3//GAN/3/AJAIA_13/YAZI/10/PLATA_10/6/MQUE/4/USDA573// QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR 84/3/HUI/POC// BUB/RUFO/4/FNFOOT/11/SORA/2*PLATA_12//SOMAT_3/4/STORLOM/3/RASCON_37/TARRO_2// RASCON_37/5/CADO
55	DW193471	SILVER_14/MOEWE//BISU_1/PATKA_3/3/PORRON_4/YUAN_1/9/USDA595/3/D67.3/RABI// CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/10/TARRO_1/2*YUAN_1// AJAIA_13/YAZI/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/11/ALTAR 84/STINT//SILVER_45/3/ GUANAY/4/GREEN_14//Y
56	DW193463	CIT71/DIPPER_1//ARIZA_2/3/PROZANA/ARLIN//MUSK_6/4/TATLER_1/TARRO_1// HYDRANASSA30/SILVER_5/10/PLATA_3//CREX/ALLA/3/SORA/2*PLATA_12/4/RASCON_37/ GREEN_2/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/ POD_9/11/ALTAR 84/STINT//SILVE
57	DW193573	ALTAR84/STINT//SILVER_45/3/GUANAY/4/GREEN_14//YAV_10/AUK/10/CMH79.959/CHEN// SOOTY_9/RASCON_37/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/ HUI/YAV79/8/POD_11
58	DW193597	PLATA_7/ILBOR_1//SOMAT_3/3/CABECA_2/PATKA_4//BEHRANG/10/1A.1D5+1- 06/2*WB881//1A.1D5+16/3*MOJO/3/SOOTY_9/RASCON_37/9/USDA595/3/D67.3/RABI// CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9/11/CIRNOC 2008/12/CAMAYO// HYDRANASSA30/SILVER_5/3/SOOTY
59	Alemtena	Icasyr-1/3/Gcn//Sti/Mrb3
60	Quamy	CD-75533-A

Table 4: Supplementary Table 1. List of 60 durum wheat genotypes including the two checks evaluated across three locations in 2020/21.

Conclusion

On this study 60 genotypes including the two checks were evaluated for grain yield performance, yield related traits and stem rust resistance. The performance of genotypes for interested traits showed a variation across locations. There are genotypes which revealed high grain yield performance and resistance to stem rust as compared to the standard check. These genotypes are DW193461, DW193563, DW193582, DW193575, Berghisyr and DW193462. So, these genotypes could be advanced to the next step for farther test and recommended as a parent for durum wheat breeding program of durum wheat.

Acknowledgement

The authors would like to thank all projects which supporting this durum wheat research work financially and also would like to express gratitude for staff member of Debre Zeit Agricultural research center durum wheat team and other collaborative research center teams for their tough effort of trial management and data collection.

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