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Phenotypic Selection of Bread Wheat (*Triticum aestivum* L.) Elite Lines for Diseases Resistance and Yield Potential

Tafesse Solomon [a*], Berhanu Sime [a], Rut Duga [a], Negash Geleta [a], Alemu Dabi [a], Gadisa Alemu [a], Abebe Delesa [a], Habtemriam Zegeye [a], Bayisa Asefa [a], Alemu Ayele [a], Getnet Muche [a], Tamirat Negash [a], Daniel Kasa [a], Dawit Asnake [a], Megersa Bayisa [a], Abebe Getamesay [a], Demeke Zewdu [a] and Niguse Degefa [a]

[a] National Wheat Research Program, Ethiopian Institute of Agricultural Research (EIAR), Kulumsa Agricultural Research Center, Asella (P.O. Box -489), Ethiopia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wheat diseases and pests globally threaten wheat production. Wheat rust diseases are the most distractive biotic constraint of wheat in Ethiopia. Therefore, this experiment aimed to select and develop wheat rust resistance bread wheat varieties for the farmers. The result of the study

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**Corresponding author: Email: tafessesolomon@ymail.com;*

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revealed highly significant variation existed among tested genotypes for Plant Height (PHT), Days to Heading (DTH), Days to Maturity (DTM), Thousand Kernel Weight (TKW), Hectoliter Weight (HLW), and Yield (YLD) at (P< 0.001). Out the forty-nine introduced genotypes, five genotypes: EBW222153, EBW222159, EBW222160, EBW222162, and EBW222164, showed resistance to moderately resistance for both yellow rust and stem rust diseases across the two test locations. Also, they delivered high average yield: 5.9 tha-1, 4.46 tha-1, 5.17tha-1,4.15 tha-1, and 4.79tha-1 respectively. Furthermore, all the above-mentioned genotypes, except EBW222162, showed significantly higher yield at (P<0.05) than the check variety, Shaki. Furthermore, EBW222153, EBW222159, EBW222160, EBW222162, EBW222164, and EBW222178 would resistance to moderately resistance for stem rust at Melkasa. Thus, the selection of these genotypes and advancing to the next stage of breeding pipelines enables to release noble bread wheat varieties for the farmers.

Keywords: Wheat; stem rust; yellow rust; resistance; moderately resistant; genotype.

1. INTRODUCTION

Wheat is one of the strategies crops used for food security in the world. It is the second-largest grain in area coverage. In the 2022-2023 marketing season, about 781 million metric tons of wheat were produced worldwide [1]. With this production, it is also in the second place after corn in the world.

There are thousands of wheat species identified on the earth. Of the thousands of species known, the most important are bread or common wheat (*T. aestivum*), used to make most wheat products, such as, for making bread and production confectionary products (like biscuits, cakes, etc), and durum wheat (*T. durum*), used in making pasta such as spaghetti and macaroni [2].

The ongoing effort to balance yield and quality improvements faces significant challenges. Dwindling availability of suitable farmland, climate change, and various unpredictable abiotic and biotic stresses consistently threaten wheat production both locally and globally. Additionally, the reduction in wheat's genetic diversity, driven by the pursuit of elite high-performing cultivars, has created an ideal environment for the emergence of pathogens, leading to diseases that now jeopardize global wheat supplies [3].

World wheat production trend increasing for the past two decays [4]. However, the production is threatened by wheat diseases and pests globally [5-10]. Wheat rust diseases are the most distractive constraint in East Africa, Ethiopia, and Kenya [11]. Wheat is affected by three types of rust diseases. These are: Leaf rust, also known as brown rust, is caused by the fungus *Puccinia triticina*; Stripe rust, also known as yellow rust, is caused by the fungus *Puccinia striiformis* f. sp. tritici; and stem rust, also known as black rust and black stem rust, is caused by the fungus *Puccinia graminis* f. sp. tritici. [12,13].

Among the three wheat rust diseases, stem and yellow rust are the main constraints of wheat production in Ethiopia [14,15]. Due to their wide distribution across wheat-growing regions, the capacity to form new races of fungus that can break previously resistant varieties, spread long distances by wind, and the ability to develop rapidly under optimal conditions make these diseases the most difficult challenge for wheat-producing farmers in the country [16,17].

A stem rust disease is one of the distractive wheat rust diseases. In the epidemic year of this wheat rust disease, and under favorable conditions, it can cause up to 100% yield losses within weeks [18-20]. It frequently occurs at the lowland and mid-altitude of wheat-producing areas in Ethiopia. Yellow rust diseases frequently occurred in the highland wheat-producing areas of the country. It starts at the early stage of crop growth and causes the plant to stunt and weaken. In the epidemic year, it causes up to 100% yield loss on the susceptible varieties [21,22,23,24]. A global cereal rust monitoring system was established to gather geospatial and time-sensitive data on rust prevalence and race structure [25,26].

There are different management approaches to minimize and overcome the loss caused by these diseases: Planting resistance cultivars, planting several cultivars differing in genetic and agronomic characteristics, application of foliar fungicides, and cultural practices such as controlling volunteer wheat and avoiding excessive fertilization and irrigation [27-30].

Deployment of genetic resistance variety is the most effective, environmentally safe, cost-effective, and long-term strategy to control wheat rust disease for reducing yield losses. It is also the best strategy, particularly for resource-poor farmers in the developing world [21,31]. Since the first start of wheat research in Ethiopia, breeding for wheat rust resistance variety has been an ongoing component of the wheat breeding program. Therefore, the objective of this trail was to select and release wheat rust-resistant bread varieties for the farmers.

2. MATERIALS AND METHODS

2.1 Study Material and Experimental Design

The national wheat research program introduced forty-nine genotypes from CIMMYT, Mexico, with a trial name, 42 Elite Spring Wheat Yield Trial (42 ESWYT). Forty-nine introduced genotypes and one standard check (Shaki) were grown in alpha lattice design with two replications in 2023 cropping season. The rep/block had five sub-blocks; each sub-block had ten plots; the experimental unit or plot size was six rows with 1.2 m width by 2.5 m length; the area of the plot was 3 m2.

2.2 Description of the Study Areas

The study was carried out across two locations, Kulumsa Agricultural Research Center (KARC) and Melkasa Agricultural Research Center (MARC), during July to December (2023 G.C.) cropping season. MARC is at 8°24′N 39°12′E latitude and longitude with an Altitude of 550 m.a.s.l. The minimum and maximum temperatures are 14oc and 280c, respectively. The area received an annual rainfall of about 763 mm. KARC is at 8°02′N 39°10′E latitude and longitude with an Altitude of 2200 m.a.s.l., The minimum and maximum temperatures are 10^0c and 22^0c, respectively and annual rainfall at Kulumsa is about 840mm.

2.3 Data Collection and Analysis

Days to heading (DTH), Days to maturity (DTM), Plant Height (PHT), Yellow Rust (YR), and Stem Rust (SR) collected on the field. Post-harvest data such as thousand kernel weight (TKW), Hectoliter weight (HLW), and Grain Yield (GYLD) were taken in the laboratory after harvest.

Yellow and Stem rust diseases score were recorded using modified Cobb scale as suggested by [32,33]. It is a combination of number and English alphabets, where the number stands for the severity, and the letters for host reactions.

Severity is a percentage of rust infection on the plant. It relies upon visual observations. The following intervals commonly used to score severity of yellow rust and stem rust diseases.

Trace, for severity less than 5%;

For 5% and above, 5%, 10%, 20%....100% used

Field response is the type of disease reaction that is recorded using the 0 (zero) and the following letters:

0= No visible infection on the plant;
R= resistant: visible chlorosis or necrosis, no uredia are present;
MR= Moderately Resistant: small uredia are present and surrounded by either chlorotic or necrotic areas;
M=Intermediate: variable sized uredia are present; some with chlorosis, necrosis, or both;
MS= Moderately Susceptible: medium-sized uredia are present and possibly surrounded by chlorotic areas;
S= Susceptible: Large uredia are present, generally with little or no chlorosis and no necrosis;

Severity and field response readings are usually combined.

For example: tR = Trace severity with a resistant field response;
5MR = 5% severity with a moderately resistant.

ALL the analyses computed using R software version 3.6.0 and META-R [34,35].

3. RESULTS AND DISCUSSION

The result of analysis of variance, ANOVA revealed highly significant variation existed among tested genotypes for Plant Height (PHT), Days to Heading (DTH), Days to Maturity (DTM), Thousand Kernel Weight (TKW), Hectoliter

Weight (HLW), and Yield (YLD) at (P<0.05) (Table 1). The observed highly significant variation among the study genotypes may be due to genetic differences among lines, indicating considerable genetic variation in these materials. Therefore, effective selection among the genotypes can be performed for yield [36].

Also, highly significant variation for yield existed among sub blocks within a Rep (Table 1). Probably, it is because of variability found within a replication due to the size, of fifty plots per replication. Thus, the small size of the blocks, ten sub-blocks per replication, could effectively remove the variation. The importance of portioning a large size of block into small size of sub-blocks can capture error variation, as reported by [37-41].

The highest grain yield, 9.19 t/ha, was delivered by genotype EBW222176, whereas the smallest by genotype EBW222178, 1.68 t/ha at Kulumsa. The mean grain yield at this location was 5.3 t/ha (Table 2). The grain yield of the check variety, Shaki, was 7.11 t/ha, less than in 2.08 tones from EBW222176. At Melkasa, the highest, 3.92 t/ha, and the smallest, 0.52 grain yield were delivered by genotypes EBW222164 and Shaki, respectively (Table 2). Furthermore, Genotypes EBW222176 was significantly higher than the check variety, Shaki, in grain yield at (P<0.05) at Kulumsa.

The two wheat rust diseases, primarily used for selection purposes at this stage of the breeding pipeline in the national program, yellow and stem rust disease scores were taken two times on the field. For the stem rust, the first score was at the heading stage of the crop and the second at the milk stage. Since yellow rust usually occurs at the early stage of the crop, the first score was at the stem elongation stage and the second at the boot stage of the plant.

EBW222153, EBW222159, EBW222160, EBW222162, and EBW222164 showed resistance to moderate resistance for both yellow rust and stem rust diseases across the two test locations (Table 2) out of the forty-nine introduced genotypes; also, they delivered high average yields: 5.9 t/ha, 4.46 t/ha, 5.17t/ha,4.15 t/ha, and 4.79t/ha respectively. Furthermore, the above-listed genotypes, except EBW222162, were significantly higher in yield (at P<0.05) than the check variety, Shaki (Table 2).

Genotypes such as EBW222148 with 40S at Kulumsa and 50S at Melkasa; EBW222149 with 60S at Kulumsa and 50S at Melkasa; EBW222154 with 60S at Kulumsa and 50S at Melkasa; EBW222187 with 60S at Kulumsa and 50S at Melkasa were highly susceptible to wheat stem rust diseases across both the test sites. However, these lines were resistant to moderate resistance for yellow rust: EBW222148 KUYR=10M, EBW222149 KUYR=20M, EBW222154 KUYR=5MS, and EBW222187 KUYR=5MR. Therefore, giving a chance for further testing of these genotypes to the next stage of breeding pipelines set to yellow rust-prone areas is needed. EBW222178 was highly susceptible to yellow rust, with a score of KUYR=80S at Kulumsa. But its score was 5MR at Kulumsa and 10M at Melkasa for stem rust. It was the only line susceptible to yellow rust and moderately resistant to stem rust.

Table 1. Analysis of variance (ANOVA) for yield and related traits of fifty bread wheat genotypes tested across two locations

Source of variation	DF	PHT	DTH	DTM	TKW	HLW	YLD
Rep	1	155*	0.8	8	2	0.74	5.91
Environment (E)	1	63582***	8489***	30553.9***	662.48***	283.19***	569.42***
Genotype (G)	49	65***	29.5***	13.6**	45.8***	26.32***	4.12***
Sub block (SB)	4	41	1.5	8.6	8.63	8.78	2.50**
Genotype X	49	44*	6.4***	11.2*	29.3***	20.83***	4.06***
Environment (GXE)	8	46	6.16	3.4	9.19	4.20	1.16*
Residual	90	26	3.5	6.6	5.50	3.70	0.53

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 , Genotype (G) , Environment (SITE) means squares for yield (YLD), days to heading (DTH), days to maturity (DTM), Plant height (PHT), thousand kernel weight (TKW), and hectoliter weight (HLW)*

Table 2. Mean of grain yield, agronomic and diseases data of fifty genotypes tested at Kulumsa And Melkasa

No	GENOTYPE	KUYR	KUSR	MKSR	DTH	DTM	PHT	TKW	HLW	YLD	KUYLD	MKYLD
1	EBW222148	10MR	40S	50S	59.5	108.25	84.5	28.5	62.93	4.32	6.75	1.89
2	EBW222149	20M	60S	50S	60.75	109.5	87	29	61.14	3.42	4.14	2.70
3	EBW222150	50S	5M	70S	58.5	109	88.25	26.5	63.105	3.27	4.14	2.40
4	EBW222151	50S	10MSS	30S	61.5	106.75	79.75	22	59.88	2.42	3.29	1.55
5	EBW222152	30S	30S	50S	60.5	108.5	84.5	26	58.02	2.74	3.74	1.74
6	EBW222153	10M	5M	10M	60.5	109.5	93	33.5	66.625	5.90	8.77	3.03
7	EBW222154	5MS	60S	50S	63	109.5	81.75	26.5	62.08	3.12	5.26	0.98
8	EBW222155	30M	10MSS	50S	62.5	108.5	85	23.5	60.47	3.32	5.46	1.17
9	EBW222156	5M	10M	30S	59.25	107.5	83.25	33.5	64.505	5.02	8.67	1.37
10	EBW222157	40MS	5M	50S	62.25	112.5	80	26	61.6	3.30	5.84	0.75
11	EBW222158	1MR	1MR	30S	60.25	110.5	82.5	32.5	65.8	4.41	8.11	0.71
12	EBW222159	10MR	1MR	10M	65.5	110	83.25	28	62.675	4.46	6.83	2.08
13	EBW222160	5MR	5M	20M	64.25	109.75	89.25	31	64.48	5.17	8.18	2.16
14	EBW222161	5MR	1MR	30S	64.5	110.5	83.75	29	63.92	4.41	6.56	2.26
15	EBW222162	15M	1MR	10M	66.25	111.5	87.5	26.5	62.05	4.15	6.26	2.04
16	EBW222163	20M	5M	30S	67.5	111.5	94.5	28.5	61.55	4.15	5.92	2.39
17	EBW222164	20M	5M	10M	65.75	115.25	90.5	31	63.3	4.79	5.66	3.92
18	EBW222165	40S	40S	50S	65	108.75	83.75	22	57.54	2.49	3.55	1.44
19	EBW222166	30S	20MSS	50S	60	108.5	87.5	29	67.17	4.72	6.32	3.12
20	EBW222167	10MS	20MSS	50S	65	110.75	83.75	27.5	63.68	4.30	6.47	2.12
21	EBW222168	10MR	20MS	70S	63.75	110.25	92	26.5	61.68	4.21	6.44	1.98
22	EBW222169	15M	1MR	50S	63.75	110.5	91.25	28	63.295	3.39	4.51	2.27
23	EBW222170	10MR	1MR	50S	66	109.5	90.75	29	64.55	4.79	7.84	1.75
24	EBW222171	40MSS	20MSS	50S	60.75	107	81.75	24	60.945	2.95	4.39	1.52
25	EBW222172	20M	5M	70S	66.25	111.5	87.5	24	60.765	2.82	4.17	1.48
26	EBW222173	30M	1MR	50S	67.25	111.75	90.5	23.5	60.965	2.72	3.31	2.14
27	EBW222174	5MR	15MSS	50S	63	111.25	84	30	62.59	4.88	7.94	1.81
28	EBW222175	40S	1MR	50S	60	106.25	79	24	60.875	2.78	3.96	1.60
29	EBW222176	0	1MR	30S	58.5	108.5	87	34	66.39	5.70	9.19	2.20
30	EBW222177	50S	20MS	70S	62.75	109	88	22	59.895	2.76	2.38	3.14
31	EBW222178	80S	5MR	10M	61.5	109.25	89.75	24	56.855	1.91	1.68	2.14
32	EBW222179	5MR	5M	30S	60.75	109.5	80.75	26	64.66	3.89	6.04	1.74

No	GENOTYPE	KUYR	KUSR	MKSR	DTH	DTM	PHT	TKW	HLW	YLD	KUYLD	MKYLD
33	EBW222180	30MS	5M	50S	64.25	108.75	82.75	26.5	62.38	3.66	5.40	1.91
34	EBW222181	15MR	20MS	50S	62.5	108.5	90.75	31.5	62.46	4.38	6.45	2.32
35	EBW222182	30MSS	5M	70S	62	108.75	80.5	25	58.885	2.58	3.52	1.64
36	EBW222183	10M	10M	70S	60.5	109	87	25.5	64.89	4.11	6.01	2.21
37	EBW222184	1MR	1MR	40S	63.25	110.5	84.5	28	61.785	4.15	6.74	1.55
38	EBW222185	40S	10M	40S	68	113.75	85	25.5	57.915	2.74	3.18	2.30
39	EBW222186	50S	20MSS	50S	66.25	112.25	90	26	61.27	3.39	4.26	2.52
40	EBW222187	5MR	60S	50S	60.25	110	83.75	29	61.69	4.48	6.56	2.40
41	EBW222188	10M	20MSS	30S	64.5	110.5	83.75	27	62.895	4.36	6.75	1.98
42	EBW222189	30S	5M	30S	60.75	108	86.25	28	60.27	2.52	3.31	1.73
43	EBW222190	50S	20MSS	50S	60.5	108.5	85	25	59.545	2.21	3.25	1.17
44	EBW222191	40MSS	20MSS	50S	57.25	106.25	82.5	27.5	63.64	3.56	5.30	1.83
45	EBW222192	70S	5M	50S	59.75	106.5	89.25	22.5	57.22	2.23	2.59	1.87
46	EBW222193	60S	40S	50S	60.25	107.5	78.25	22.5	60.29	1.97	2.59	1.34
47	EBW222194	80S	1MR	40S	61.75	108.5	79.5	21.5	58.495	1.89	1.89	1.90
48	EBW222195	80S	5M	30S	59.25	107.25	79.25	25.5	61.135	2.47	3.45	1.48
49	EBW222196	40S	30MSS	20MSS	61.5	110.25	84.25	27.5	64.575	4.16	5.51	2.81
50	Shaki	10MS	20MSS	10M	57.75	109.5	88.75	36	70.01	3.81	7.11	0.52
	Mean				62.34	109.50	85.53	27.10	62.02	3.63	5.3	1.94
	LSD				3.21	1.90	5.38	4.68	1.89	0.41	1.8	0.85
	CV				1.62	2.25	6.05	8.63	3.05	19.82	16.6	25.92

Least Significant difference (LSD); Coefficient of variance (CV); DTH=Days to heading; DTM=Days to maturity; PHT=plant height in centimeter; KUYR= yellow rust score at Kulumsa; KUSR= Stem rust score at Kulumsa; TKW= thousand kernel weight; HLW=Hectoliter weight; YLD= average yield across test sites in tone per hectare; KUYLD= Yield at Kulumsa in tone per hectare; MKYLD= Yield at Melkasa tone per hectare

Highly susceptible Lines to stem rust and yellow rust diseases across Kulumsa and Melkasa: EBW222152 scored KUYR=30S, KUSR=30S, and MKSR=50S; EBW222165 scored KUYR=40S, KUSR=40S, and MKSR=50S; EBW222193 KUYR=60S, KUSR=40S, and MKSR=50S were discarded along lines susceptible for yellow rust at Kulumsa and susceptible to stem rust at either of the two locations, Kulumsa or Melkasa (Table 2) Such as, EBW222150, EBW222151, EBW222157, EBW222166, EBW222171, EBW222175, EBW222177, EBW222185, EBW222186, EBW222189, EBW222190, EBW222191, EBW222192, EBW222194, and EBW222195.

EBW222156, EBW222158, EBW222161, EBW222163, EBW222167, EBW222168, EBW222169, EBW222170, EBW222172, EBW222174, EBW222176, EBW222179, EBW222181, EBW222183, EBW222184, and EBW222188 showed resistance to moderately resistance for stem rust and yellow rust diseases at Kulumsa even though highly susceptible for stem rust at Melkasa (Table 2). Besides, EBW222156, EBW222158, EBW222170, EBW222174, and EBW222176 delivered higher yields than the check variety Shaki. Therefore, all these lines advanced to the next stage of breeding pipelines.

In the testing year, yellow rust diseases did not occur at Melkasa. It does not occur in most of the cropping seasons at Melkasa. On the other hand, stem rust disease severely affects the trial. Only seven out of forty-nine lines showed better resistance to stem rust disease at Melkasa. These lines were: EBW222153, EBW222159, EBW222160, EBW222162, EBW222164, EBW222178, and EBW222196 (Table 2). Besides, except EBW222178 and EBW222196, they were resistant to wheat yellow rust disease at Kulumsa. Four lines: EBW222153, EBW222164, EBW222166, and EBW222177 gave above 3 tha-1 yield at Melkasa. Among these lines, EBW222166 and EBW222177 delivered above three tons per hectare, although they were highly susceptible to stem rust diseases, with 50S and 70S scores (Table 2). Lines provide high yield regardless of their susceptibility to wheat rust diseases because of adult plant resistance (APR) genes [42,43]. Therefore, these lines had adult plant resistance genes and then advanced to the next stage of breeding pipelines.

4. CONCLUSION

Genotypes: EBW222153, EBW222159, EBW222160, EBW222162, and EBW222164 were resistant to moderately resistance for yellow and stem rusts. Additionally, they delivered higher grain yield compared to the check variety, Shaki. Thus, selection of these genotypes enables to release noble bread wheat varieties for the farmers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

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CONFLICT OF INTERESTS

Authors have declared that no conflict of interests exist.

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