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Selection and Registration of New Bread Wheat Variety Abay for Low to Mid-Altitude Wheat-Producing Areas of Ethiopia

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Abstract: Wheat production in Ethiopia in the year 2020 was around 5.1 million metric tons (World data Atlas, 2021). Although the country has the potential optimum environment for wheat production, the deficit between wheat grain production and national demand is about 1.7 million tons of wheat per annum. It is about 25% of total consumption. That is mainly due to biotic and abiotic stress threatened production results in low productivity. Wheat rust fungal pathogens are among the production constraints in Ethiopia. The national wheat research program objectively works on the development and release of resistance bread wheat variety for wheat rusts with high grain yield and good quality. In 2018 and 2019, twenty-three advanced genotypes and two checks; as a whole twenty-five entries, set as Bread Wheat National Variety Trial for Moisture Stress Areas set one (BWNVTMSAI) by the National Wheat Research Program and evaluated across different locations. The experiment was conducted in a square lattice design with three replications by the program. The experimental unit had 2.5 m length by 1.2m width was used for this trial with an area of $3m^2$. In 2020 two promising bread wheat candidates, ETBW9396 and ETBW9080, those selected from the National Variety Trial, One standard check Daka, and one local check Kakaba, a total of four materials tested as a Variety Verification Trial (VVT) with no design and replication across four locations. Results showed about twelve genotypes have a greater than 5% grain yield advantage over the best check, Deka (Table 2). ETBW9080, ETBW9172, and ETBW9396 showed better performance for wheat rust disease (Table 3). The National Wheat Research Program selected and proposed ETBW9080 and ETBW9396 as candidate varieties. The National Variety Releasing Committee (NVRC) met its first round at Adiss Ababa in the Ministry of Agriculture in June 2021. The standing committee decided to release ETBW9636. Then. ETBW9636 registered as a new bread wheat variety in 2021 in Ethiopia. Replacement of susceptible bread wheat varieties and availing more alternatives bread wheat varieties to grow for resource-poor farmers is very crucial in the region.

Keywords: Wheat, BWNVTMSAI, VVT, NVRC

1. Introduction

Wheat (Triticum spp.) is one of the most important crops for human Bings that is a staple crop for billions of people in the world. It has been cultivated on around 225.62 million ha with an annual production of over 776.5 million metric tons in 2021/22 [10]. Wheat was brought to cultivation approximately 10,000 years ago by humans, and since it is arguably the most important plant for humans.

Ethiopia is among environmentally gifted countries for crop production; Wheat grows in almost all parts. It is one of the staple food crops for millions of people in Ethiopia. Its production area ranges from lowlands of pastoral and agro-pastoral like Afar, Gambela, and Somali to the highlands of the northern, central, and south-eastern parts of Ethiopia [2]. The first wheat growing season follows the long raining season, “meher” which starts around June and lasts until December in most wheat-growing areas. Wheat is also grown in the preceding short rainy “belg” season, from March or April to June or July.

Wheat production in Ethiopia in the year 2020 was around 5.1 million metric tons [9]. In 2021, USDA forecasted wheat

production projected to be 5.18 [10]. Although the country has the potential optimum environment for wheat production, the deficit between wheat grain production and national demand is about 1.7 million tons of wheat per annum. It is about 25% of total consumption. That is mainly due to biotic and abiotic stress threatened production results in low productivity.

The government of Ethiopia set strategy wheat as the main crop for food security. To be wheat self-sufficient and to offset wheat import, bringing more area under production in lowland areas of the country through irrigation and increasing the average wheat productivity of the nation are the two key activities.

Since the start of wheat research, more than ninety bread wheat varieties released by research centers and universities. Due to high rust pressure in the country, the newly released resistance wheat varieties for rusts on average last about 4-5 years on production without losing their potential for wheat rust disease resistance. The rust pathogens continue to affect the newly released variety through the occurrence of new virulence that has led to breaking the resistance and potential of wheat cultivars under production [4].

High grain yield and quality loss caused by wheat rust fungal pathogens are among the production constraints in Ethiopia [8]. That is because of the high occurrence of pathogens in the country, the development of new races which breaks previous resistance variety, and suitable weather condition for the development of the pathogen [8]. 58% grain yield loss was recorded on susceptible wheat varieties due to yellow rust by researchers [1]. Stem rust caused by Puccinia graminis f.sp. tritici can damage up to 100% yield loss on susceptible bread wheat varieties in the epidemic year [3].

The national wheat research program objectively works on the development and release of resistance bread wheat variety for wheat rusts with high grain yield and good quality. Frequently, susceptible varieties replaced by newly resistance varieties.

2. Material and Method

2.1. Selection of Candidate Varieties

2.1.1. Study Materials and Experimental Design

The national wheat research program sets four experiments. The sets were; Two for optimum areas and two for moisture stress areas as bread wheat national variety trial (NVT) to test advanced lines across different locations For this study, Twenty-three advanced genotypes and two checks, a total of twenty-five entries set as Bread Wheat National Variety Trial for Moisture Stress Areas set one (BWNVTMSAI) in 2018. The checks: Daka, recently released bread variety used as the standard check, and Kakaba a susceptible obsolete variety used as local checks.

The experiment conducted in a square lattice design with three replications. A six-rowed experimental unit of 2.5 m length by 1.2m width used in this trial. The inter-row spacing was 20cm. The path between blocks was 1m and between replications was 1.5m. The seed rate used in the experiment was 150kg/ha. Then, 45g of seed used in the experimental unit of area $3m^2$. Urea fertilizer 150kg/ha, and NPS fertilizers 121kg/ha applied as per recommendation.

2.1.2. Data Collection and Analysis

Date of heading (DH), Date of maturity (DM), and Plant height (PHT) were collected on time from the trial on the field. On other hand Thousand Kernel Weight (TKW), Hectoliter Weight (HLW), and Grain Yield (GYLD) were collected in the laboratory after harvest.

The analysis of variance was done to determine the significance of the differences among the bread wheat genotypes for the various agronomic traits. Mean separation was computed using the least significant differences at (p = 0.05).

The grain yield advantage over best check was calculated using the following formula:

$$GYAg = \frac{GYg - GYC}{GYc} \text{ x } 100$$

GYAg= grain yield advantage of genotype g;

Where GY_g = grain yield of the genotype;

GY_c= grain yield of the best check, Daka.

2.1.3. Disease Score

Yellow Rust (YR) and Stem Rust (SR) scored two times on the field. The first score was taken a week after first appearance of the disease on the experimental plot and the second score (final score) was taken three weeks after first score had been taken.

A modified scab scale which has a combination of numbers and letters the number stand for the severity of the disease and the letters represent the host reaction were used to score both diseases [14].

Where,

Severity is recorded as a percentage of rust infection on the plant. It relies upon visual observations, and it is common to use the following intervals: Trace for severity less than 5% and multiple of 5 for 5 and above 5% to 100%.

Field response is type of disease reaction which is recorded using the 0 (zero) and 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 possible 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 field response.

30S = 30% severity with a susceptible field response.

The wheat rust score used for selection

The experimental design in this study had a three full replication. This means, each experiment had three plots for every genotype. Disease score of stem rust and yellow rust for a genotype was taken from all three plots and the highest score was taken and used to select and advance elite resistance genotype as candidate variety.

2.2. Registration of New Bread Wheat Varieties

Two promising bread wheat candidates, ETBW9396 and ETBW9080; are the germplasms introduced from ICARDA and CIMMYT origin consecutively, One standard check Daka, a recently released bread wheat variety and one local check Kakaba, an obsolete bread wheat variety used by farmers for a long time a total of four materials tested as a variety verification trial with no design and replication in 2020. A proposal was submitted to the Ethiopian Ministry of Agriculture for approval to release and register the candidates as new varieties in the same year by the national wheat research program.

The national program had tested the trials across four locations: Dhara, Alemtena, Arsinegele, and Goro. For each area, three experimental sites had selected: two on a farmer's farm and one on a research station. The team took a supervision frequently.

And the regulatory body from ministry of agriculture assigned Technical Committee (TC) to evaluates the candidate varieties on trial in the field. The TC was from research centers professionally breeders, pathologist, and agronomist and also agronomist from ministry of agriculture. They evaluated the trial at maturity stage on the field for agronomic performance, disease resistance, breeder interest in his candidates, and farmer's preference. TC gathered the farmers on the field and questioned their overall interest in the trials. The farmers respond their choices to the committee their preferences.

The technical committee evaluated the trials compiled their report with their recommendation submitted to the National Variety Releasing Committee (NVRC). The final decision made by NVRC for registration. Then, the regulatory body registered the variety in the Crop Variety Register of Ethiopia, which is published annually.

3. Result and Discussion

3.1. Selection of Candidate Varieties

3.1.1. Grain Yield

Result from combined analysis of variance revealed that the existence of significant differences among the genotypes, Environment, and their interaction for all parameters (Table 1). The presence of the variability among the genotypes for all these parameters is a good opportunity for breeding which used as a tool for selecting and proposing candidate varieties to release new varieties.

Table 1. *Genotype (G), environment (E), and GXE me/ans squares for grain yield (GYLD), date of heading (DTH), date of maturity (DTM), Plant height (PHT), thousand kernel weight (TKW), and hectoliter weight (HLW of twenty five bread wheat genotypes tested at moisture stress area.*

Source of variation	DF	DTH	DTM	PHT	TKW	HLW	GYLD
REP	2	10.1	63***	2.3ns	12.8ns	10.36ns	0.31ns
Genotype (G)	24	78.5*	56***	347.6***	244.6***	50.50***	3.94***
Year	1	0.003ns	33945***	24747.0***	178.7***	67.31***	415.94***
Loc	3	0.12ns	12***	26218.8***	4497.4***	150.81***	605.38***
Environment (E) (Location: Year)	3	0.17ns	3219***	9326.8***	81.2***	107.52***	127.02***
Genotype: Environment (GXE)	72	0.14ns	13***	39.1ns	25.2***	16.61***	1.21***
Pooled error	390	6.51	5	41.0	13.6	3,95	0.61

ns=non-significant; *,**, and *** significant 5%, 1%, and 0.1% level of significance, consecutively.

Of the two checks, variety Daka is a recently released bread wheat variety than bread wheat Variety Ogolcho and showed a good potential in grain yield and disease resistance. Therefore, it was taken as a best check to evaluate the potential of advanced genotypes in the study. About twelve genotypes: ETBW9136, ETBW9139, ETBW9065, ETBW9080, ETBW9172, ETBW9396, ETBW9452, ETBW9641, ETBW9642, ETBW9646, ETBW9647, and ETBW9648 have greater than 5% grain yield advantage over the best check, Deka (Table 2). These genotypes selected based on Grain yield then subjected to other selection characters.

Table 2. *Mean grain yield at each location, gross mean over all locations and grain yield advantage over best check of twenty five advanced bread wheat genotypes tested at moisture stress areas of Ethiopia.*

Genotype	Kulumsa	Dhera	Assasa	Melkasa	Mean	Mean Grain Yield advantage over best check, Daka in %
DAKA	7.16	2.98	6.81	2.69	4.91	0.00
ETBW 9116	6.92	3.38	5.97	2.76	4.75	-3.26
ETBW 9119	6.24	3.01	6.00	2.90	4.54	-7.54
ETBW 9128	7.38	2.80	5.86	2.68	4.68	-4.68
ETBW 9136	7.69	3.92	7.51	3.68	5.70	16.09
ETBW 9139	7.64	3.02	7.36	4.60	5.65	15.07
ETBW 9149	7.67	2.96	6.00	3.18	4.95	0.81
ETBW 9065	6.35	3.39	7.71	3.25	5.17	5.30

Genotype	Kulumsa	Dhera	Assasa	Melkasa	Mean	Mean Grain Yield advantage over best check, Daka in %
ETBW 9077	6.64	3.19	5.99	3.52	4.83	-1.63
ETBW 9078	7.16	3.11	5.86	3.22	4.83	-1.63
ETBW 9080	7.61	3.36	7.53	3.91	5.60	14.05
ETBW 9172	7.41	3.87	6.91	3.78	5.49	11.81
ETBW 9396	7.63	3.21	6.77	3.82	5.36	9.16
ETBW 9452	7.26	3.32	6.34	3.76	5.17	5.30
ETBW 9543	7.00	2.78	6.66	3.09	4.88	-0.61
ETBW 9545	7.85	2.84	6.82	3.04	5.14	4.68
ETBW 9641	7.05	3.46	7.17	3.83	5.38	9.57
ETBW 9642	7.74	3.01	6.48	3.62	5.21	6.11
ETBW 9646	7.65	3.84	6.81	4.17	5.62	14.46
ETBW 9647	7.62	2.96	5.98	4.32	5.22	6.31
ETBW 9648	7.24	4.03	7.13	3.99	5.60	14.05
ETBW 9650	7.43	3.22	5.98	3.42	5.01	2.04
ETBW 9651	6.73	2.37	6.66	3.17	4.73	-3.67
ETBW 9652	7.26	2.96	6.34	3.12	4.92	0.20
OGOLCHO	6.04	2.74	2.82	2.98	3.64	-25.87

ETBW +number = Ethiopian bread wheat; and the number is a unique accession number given for individual genotypes by the national wheat research program.

3.1.2. Wheat Rust Disease

Wheat rust diseases are the major constraint of wheat productivity and production in Ethiopia [5]. A warm humid environment in the mid-altitude of Ethiopia aggravates the wheat rusts, which enable large populations of rust pathogens to persist year-round and favors fast evolution and the spread of new races. Thus, the breeding program mainly targets to release of resistant varieties to major wheat rust diseases. Resistance genotypes for these diseases are high yielders with plumb, vigor, and healthy seed.

Wheat rust occurrences differ year to year at different testing sites. Some years in some testing sites did not occur or exist with little pressure [13]. In this case hard to select among tested materials in which most scored is zero. Most Stem rust score in 2019 at Dhera, yellow rust score in 2018 at Dhera and Melkasa, and yellow rust in 2019 at Melkasa were zero so, not included in Table 3. On the other hand, in some cropping seasons, wheat rust disease pressure is very high hard to select among the genotypes. Stem rust incidence at Kulumsa in 2019 was very high in which most genotypes severely heated.

Table 3. *Yellow rust and stem rust disease score of twenty-five bread wheat advanced genotypes for two consecutive years 2018 and 2019 at fpour locations: Kulumsa, Dera, Assasa, and Melkasa.*

GENOTYPE	YR19KU	SR19KU	YR18KU	SR18KU	YR19DR	SR18DR	YR19AA	SR19AA	YR18AA	SR18AA	SR19ML	SR18ML
DAKA	30MSS	50S	1MRMS	5MSMR	0	30MSMR	15MRMS	10S	5MRMS	15MSMR	1MS	15SMS
ETBW 9116	5MSMR	40S	0	1MS	0	15MSS	1MR	10S	5MRMS	5MSMR	1MS	10SMS
ETBW 9119	60S	50S	5MR	10MSS	0	30MSMR	10MRMS	10S	10MSS	10MR	5MSS	15MSMR
ETBW 9128	50S	50S	5MSMR	5S	0	40S	5MS	30S	10MRMS	60S	20MSS	20S
ETBW 9136	5MSMR	50S	1MR	5S	0	30S	5MRMS	10S	5MSMR	40MSS	10MSS	15SMS
ETBW 9139	60S	50S	5MR	10MSS	0	15MSS	15MS	40S	10MSMR	20MSMR	10MS	15SMS
ETBW 9149	5MSS	40S	5MR	1MS	0	15MSMR	5MR	20S	1MRMS	5MR	1MSS	5SMS
ETBW 9065	60S	30S	1MR	1S	0	30S	1MR	20S	20MSMR	30MS	5MS	15SMS
ETBW 9077	40S	40S	30MS	1MS	1MSMR	20MSMR	10MS	10MS	30MS	20MSMR	1MSMR	10MRMS
ETBW 9078	15MSS	50S	5MRMS	0	5MRMS	5MSMR	15MS	TRMR	10MRMS	10MRMS	0	5MSMR
ETBW 9080	10MSMR	15MSS	1MR	5MS	0	10MSMR	5MSMR	50S	1MSS	10MRMS	1MS	15SMS
ETBW 9172	15MSMR	50S	5MRMS	5MSS	0	15MSMR	1MR	20S	5MSMR	10MRMS	1MSMR	10MSMR
ETBW 9396	1MR	40S	5MSMR	0	0	1MS	5MRMS	TRMS	0	1RMR	1MSMR	1MRMS
ETBW 9452	60S	40S	1MR	0	0	1MR	1MR	TRS	15MRMS	0	1MR	1MRMS
ETBW 9543	50S	30S	15MSMR	0	0	15MSMR	10MSS	5S	20MSS	10MRMS	1MR	5MSMR
ETBW 9545	5MSMR	50S	15MSS	1MR	0	5MSMR	10MS	TRMS	20MSMR	10MS	1MSMR	1MRMS
ETBW 9641	40S	80S	0	20S	0	40S	1MR	40S	5MRMS	60S	15S	20SMS
ETBW 9642	5MSMR	70S	1MR	10MS	0	40S	1MR	70S	5MRMS	60S	10MSS	15SMS
ETBW 9646	10MRMS	70S	1MR	20S	0	40S	1MRMS	30S	5MSMR	40MSS	20S	30S
ETBW 9647	15MSS	50S	1MR	10S	0	50S	1MSMR	80S	1S	70S	50S	30S
ETBW 9648	60S	30MSS	5MRMS	15S	0	10MSMR	15MS	TRMS	10MSMR	10MRR	1MS	1MRMS
ETBW 9650	60S	30S	1MRMS	15S	0	30S	1MR	60S	5MRMS	60S	20MSS	20S
ETBW 9651	60S	30S	5MR	1MSMR	0	5MSMR	5MSMR	15S	5MSMR	20MS	1MR	1MRMS
ETBW 9652	60S	60S	5MRMS	1MS	1MS	10MSMR	10MSMR	5S	5S	10MRMS	20MS	5SMS
OGOLCHO	40S	70S	10MRMS	40S	1MS	20S	80S	20S	20MSMR	50S	30MSS	30S

R=resistance; MR=Moderately Resistance; MS= Moderately susceptible; MS= Moderately Susceptible; S= Susceptible, YR19KU= Yellow rust at Kulumsa in 2019; SR19KU= Stem Rust at Kulumsa; YR18KU=Yelow rust in 2018 at Kulumsa; SR18KU=Stem Rust 2018 in Kulumsa.

From those genotypes selected by the grain yield Table 3 on ETBW9136, stem rust scored 30S in 2018 at dhera and 40MSS in 2018 at Asasa. On ETBW9139, yellow rust scored 60S in 2019, and stem rust scored 40S in 2019 at Asasa. On ETBW9065, yellow rust scored 60S at kulumsa in 2019, and stem rust scored 30S at Dhera in 2018. On ETBW9452, yellow rust scored 60S at Kulumsa in 2019. On ETBW9641, stem rust scored 60S at Asasa and 40S at Dhera in 2018, and Yellow rust scored 40S at Kulumsa in 2019. On ETBW9642, Stem rust scored 40S in 2018 at Dhera, 70S in 2019 at Asasa, and 60S in 2018 at Asasa. On ETBW9646, stem rust scored 40S at Dhera, 40MSS at Asasa, and 30S at Melkasa in 2018; and 30S in 2019 at Asasa. On ETBW9647, stem rust scored 50S at Dhera, 70S at Asasa, and 30S at Melkasa in 2018; and 80S at Asasa in 2019. On ETBW9648, yellow rust scored 60S at Kulumsa in 2019. Therefore, these genotypes were found susceptible to disease rusts.

ETBW9080, ETBW9172, and ETBW9396 showed better performance for wheat rust disease. The national bread wheat breeding team evaluated the seeds of these three genotypes for their size, plumb, color, and vigor visually. Finally, the program selected and proposed ETBW9080 and ETBW9396 as candidate varieties.

3.2. Registration of New Bread Wheat Variety

The two bread wheat candidate varieties ETBW9080 and ETBW9396 with the two checks Daka and Kakaba set as a Variety Verification Trial (VVT) in 2020 and tested across four locations. The application for registration of the candidate varieties with their two years of experimental data was submitted to MoA in 2020. The Ministry of Agriculture accepted the application and assigned the technical committee to evaluate the merits of the candidate varieties under field conditions.

The Technical committee (TC) evaluated the trials in the field at Dhera, Arsinegele, and Alemtena. At each location two trials on Farmers land at different location and one trial on research station seen by the committee. They gathered the farmers and questioned their interest on the candidates. Performance for agronomic, seed per spike, spike length, plant height, seed size, stand, and disease resistance assessed by the TC in the field [12].

Wheat rust disease is a big challenge for wheat growers which suddenly devastated their crop. Unexpectedly, resistance varieties or promising candidates break by new wheat rust races, pathogen and out from registration or production [6, 7]. From the two candidates bread wheat varieties, ETBW9080 break the resistance for stem rust and performed poor compared to the best check Daka. Therefore, the RC decided to don't recommend this candidate variety for registration. Whereas, ETBW9636 performed better than the two checks in wheat rust resistance and agronomic then the committee recommended to NVRC for registration.

The NVRC met its first round at Adiss Ababa in Ministry of Agriculture in June, 2021. The decision was made by the standing committee to release ETBW9636. Then. ETBW9636 registered as a new bread wheat variety in 2021 in Ethiopia.

The name for newly released verities and maintenance of the variety are responsibilities of the research centers which developed and proposed for release. Therefore, Kulumsa Agricultural Research Center (KARK) gave the name Abay to ETBW9636 after a Great Nile river locally named Abay.

4. Conclusion

Wheat rusts are among the main wheat production constraints that continue affecting the economy of wheat growers, especially millions of smallholder farmers in Ethiopia. Popular, wildly adapted bread Wheat Varieties in production broken by rust disease and, frequently out of market or production. Breeders working in an area where wheat rust disease pressure is high shouldn't depend on a few available resistance varieties in production. Replacement of susceptible bread wheat varieties and availing more alternatives bread wheat varieties to grow for resource-poor farmers is very crucial in the region [11]. That is Because of Wheat disease outbreak suddenly destroys their whole crop. Thus, well-organized wheat breading program and a structural seed delivery system are vital. It enables sustainably delivers new resistance varieties with sufficient foundation seed.

Conflict of Interests

All the authors do not have any possible conflicts of interest.

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