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Registration of New Bread Wheat Variety (*Gutu*) for Mid to Highland Altitude Wheat Producing Areas of Ethiopia

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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, a staple crop in Ethiopia, is constrained by biotic and abiotic stresses. Despite efforts to develop high-yielding, disease-resistant varieties, most have short agronomic life spans due to mainly yellow rust and stem rust diseases. Therefore, continuous breeding and selection are

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needed to identify new varieties with high yield potential, resistance to major wheat diseases, and adaptability to different climatic conditions. Thirty advanced bread wheat lines together with standard and local checks were evaluated using row-to-column design in three replications at six and nine locations during the 2021 and 2022 main seasons, respectively. Data such as days to maturity, plant height, yield, TKW, and test weight were taken. The yield data were exposed to statistical analysis. The new variety, *EBW192345* (Kenya sunbird/2*Kachu/3/SWSR22T.B/2* Blouk#1//Wbll1*2/Kuruku) outyielded the standard check (*Boru)* and local check (*Dandaá)* by 25.43% and 51.9%, respectively. The new variety not only outyielded the checks, but it exhibited better resistance to yellow and stem rust diseases and had better performances in 1000 Kernel weight and test weight compared to the other treatments including the checks. Based on two years of multi-location data and performances on research plots and farmers' fields, EBW192345 was released by the national variety release committee for commercial production in mid to highlands in Ethiopia during 2023.

Keywords: Bread wheat; EBW192345; rust resistance; variety; yield.

1. INTRODUCTION

Bread wheat (Triticum aestivum L. Genome BBAADD, 2n = 6x = 42), also known as common wheat, is an annual, predominantly autogamous species belonging to the Triticeae tribe of the grasses (Poaceae) family. This cereal is naturally polyploidy and domestically grown worldwide and plays an important role in agriculture [1, 2, and 3]. Wheat is a basic food for both the rich and the poor. Accounting for over half of the food calories consumed globally wheat is a primary source of nutrition for 36% of the world's population and is grown in 70% of the world's farmed areas [3]. This is likely because of wheat's agronomic adaptability, ease of grain storage, and ease of converting grain into flour for making many different foods [4]. Bread wheat (Triticum aestivum, 2n = 6x = 42, AABBDD) is an introduced crop to Ethiopia but it is the dominant wheat type covering more than 90% of the total wheat production area in Ethiopia [5, 6].

It is essential to accurately identify the cultivars grown by farmers for crop management, food security, and cultivar development and dissemination, among other things [7]. An understanding of the effects of environment, genotype, and GEI is important at all stages of crop improvement as they have crucial effects on selection and cultivar adaptation in the sets of environments. So far, several varieties of bread wheat have been released for large-scale production in Ethiopia [6, 8]. However, most of these are abandoned from production, due to susceptibility to new races of stem and yellow rust diseases [9, 10]. Several factors such as varieties, low agricultural input utilization, environments, wheat rust, management practices, and their interactions affect bread wheat production. Wheat production is on the rise, despite facing significant challenges such as ongoing disease epidemics, particularly rust and septoria [11, 12]. Increasing yield is often considered a crucial factor in ensuring food security [13]. Wheat breeding plays a crucial role in developing high-yielding varieties that are resistant or tolerant to pests and diseases at both international and national levels [14]. Ethiopian wheat breeding programs use techniques such as introductions and selection, hybridizations, and selection to improve wheat plants. Developing and identifying high-yielding genotypes with broad adaptation and resistance to biotic and abiotic stress is a top priority for these programs.

Advancements in wheat cultivation techniques have led to increased yields, resulting in a steady increase in worldwide wheat production without the need for expanding arable land [15]. Population growth and changing consumer demands are driving the agricultural production systems. To meet the growing demand for food, especially in developing countries, wheat productivity must be increased over the next few decades as arable land area will not increase beyond current levels [16]. To overcome the obstacles that hinder the wheat sector and increase output and productivity, it is crucial to improve possibilities and reduce obstacles [17]. In Ethiopia, bread wheat improvement can be achieved by evaluating wheat germplasm for high-yield and rust-resistance in multi-environment trials [18]. To enhance farm profitability by using improved bread wheat technologies in Ethiopia, there is a need to develop climate smart varieties which are high yielding, rust resistant, and adaptable to low moisture areas in the country. The national wheat research program at Kulumsa Agricultural Research Center, Ethiopia works with other collaborating centers in developing and releasing bread wheat variety with wheat rust resistance, high grain yield, and satisfactory wheat quality. Therefore, the objective of this paper is to describe and characterize the newly released bread wheat variety “Gutu” for commercial production for Midland to Highland areas in the country.

2. MATERIALS AND METHODS

2.1 Study Materials and Experimental Sites

In 2021, a total of 30 advanced bread wheat genotypes along with standard checks underwent evaluation at multiple locations including Debre-Markos, Holeta, Arsi-Robe, Sinana, Bekoji, and Kofale. The evaluation process continued in 2022 during the main cropping season at Bekoji, Kofale, Arsi-Robe, Chafe Donsa, Debre-Markos, Enawari, Holeta, Kulumsa, and Gonder. The experimental setup involved a row-column design with three replications. Following the evaluations, two candidate genotypes were selected from the initial 30 and subjected to variety verification trials, including testing against two check varieties. These verification trials took place at the specified locations, encompassing both on-station and on-farm trials (two on-farm trials at each location). The National Variety Verification Technical Committee meticulously assessed the trials and subsequently granted Gutu the committee's clearance for release.

2.2 Data Collection and Analysis

Data were collected for days to 50% heading (DTH), days to 90% maturity (DTM), plant height (PHT), thousand kernel weight (TKW), hectoliter weight (HLW), and grain yield (GY). The analysis of variance was done to determine the significance of the differences among the bread wheat genotypes for the various agronomic traits.

2.3 Breeding Material

The Gutu line, which was obtained from CIMMYT in Mexico for the 2019 cropping season, was carefully selected for national variety trials due to its exceptional potential for grain yield. Over two years, from 2021 to 2022, Gutu was evaluated alongside 30 other candidate wheat lines and two checks 'Danda'a and Boru'. A comprehensive assessment of various agronomic features was conducted on Gutu, including screening for multiple wheat diseases, with a particular focus on rust resistance in hotspot locations of Ethiopia. This evaluation also encompassed testing for yield potential, agronomic traits, and genotype suitability under different climatic conditions in the Crop Protection Research's key location disease screening nursery trials.

Following the rigorous assessment, Gutu emerged as the top bread wheat genotype and is scheduled for release in 2023. Notably, Gutu demonstrated distinctness, uniformity, and stability (DUS) qualities, and was found to be a high-producing, lodging-resistant, and disease-tolerant cultivar. As a result, it has been approved for widespread cultivation throughout the province of Ethiopia. Another high-performing genotype from the trials is also being advanced to undergo a variety of verification trials.

3. RESULTS AND DISCUSSION

3.1 Varietal Evaluations and Yield Performance

The mean yields of the genotypes are presented in Table 1. The results indicated that the mean yields across the Ten environments ranged from 3.0 t/ha (Danda’a) to 4.70 t/ha EBW182767 The second-high yielder genotypes were Gutu (4.60 t/ha). The grand mean for all genotypes across the Ten environments was 3.5 t/ha. Due to high wheat rust pressure in Ethiopia, commercial varieties lose their performance within a few years of commercial cultivation [19]. Furthermore, a wheat rust epidemic occurs in both the main season and off-season in the country. Therefore, providing farmers with new varieties of different backgrounds is crucial. The new high-yielding variety (Gutu) was developed from CIMMYT germplasms through several stages of evaluations and testing. Therefore, the results of multi-location trials showed that Gutu had above-average grain yield across tested locations and years. The performance of 'Gutu’ was assessed in a national variety trial of the national bread wheat research program during 2021-2022 wherein this line was tested as ' Gutu’. Based upon its superiority over checks the genotype along with other test entries and check varieties were evaluated for two years i.e. 2021 and 2022. The outcome showed that there were significant differences in grain yield amongst bread wheat genotypes across test environments, suggesting that it may be possible to choose a genotype or genotype that performs effectively. The new variety EBW182767 has a significant yield advantage over the check, at various locations, including KF20BWOL, KU20BWOL, KU20BWPL, RA20BWPL, SN20BWPL, DM21BWNL, HL21BWNL, RA21BWNL, SN21BWNL, BE21BWNL, BE21BWPL, KF21BWPL, and KF22BWNL. The newly released variety Gutu has a 25.43% and 51.90% yield advantage over the standard checks Boru and Danda'a, respectively (Table 2). The relative instability of the genotypes acts the different environments. GEI effect was due to the differences in test locations and years. This indicates that there is a need to test genotypes across sites and years to find relatively stable genotypes across environments. It is a stable and adaptable wheat variety for different bread wheat-growing midland to highland agroecologies of Ethiopia (Table 1). The recently released variety ' **Gutu** 'surpassed standard checks in terms of grain yield, proving the broad adaptability of the genotypes.

3.2 Morphological Descriptions of the New bread Wheat variety

The Variety Gutu took approximately 69.3 days to head and 121.3 days to mature (Table 3). The number of days to flowering was earlier than Boru and local check Danda'a by one and six days respectively. The Variety Gutu was relatively Shorter than the standard varieties in Boru and local check Danda'a. When compared to the other two varieties, the seeds of this new variety were bigger. Comparing the Gutu to checks Boru (37.6 g), and Danda'a (32.7 g), the GUTU has more thousand kernels weight (39.6 g). Gutu had a 5.05%, and 17.42%, TKW advantage over Boru, and Danda'a, respectively. Additionally, it had higher HLW than Boru and Danda'a (Table 3). Instead of checks, the Gutu variety had bold seeds. It outperformed Boru and Danda'a, in terms of HLW by 2.6%, and 6.95%, respectively. It possesses a high plant stand, good tillering ability, resistance to lodging, an erect growth habit, large ears, amber seeds that are deep green at the vegetative stage, and other desirable traits.

3.3 Agronomic and Morphological Characteristics of the Advanced Genotype Gutu

The high-yielding variety **Gutu** was adapted to midland to highland agroecologies of Ethiopia, which ranges from 1900-2780 m.a.s.l. It gives a better yield under 640-1290 mm of rainfall. Annually. It took 69.3 days to head and 121.3 days to maturity (Table 4). **Gutu** was the best-adapted variety with a stable yield in Ethiopia.

3.4 Major Diseases Reaction

The mean reactions of advanced genotypes and checks to rust diseases of wheat are presented in Table 5. Stem and yellow rusts caused by Puccinia sp. are major production constraints which could cause total yield losses in Ethiopia [20]. The resistance level of the newly released bread wheat variety was better than the standard and the local checks. The incidences of wheat rust disease differ from year to year and testing sites [21] and favorable conditions for the disease pressure [22]. This study recorded high yellow and stem rust rates for most of the genotypes at each experimental site. The findings indicate that the disease pressure at each location influenced the yield potential of the genotypes. Hence emphasis should be given to resistance to these diseases during wheat genotype selection or screening for yield at the respective location. Genotypes **Gutu** relatively showed lower severity rates at each testing environment.

The standard check, Boru variety showed moderately susceptible to stem, yellow rust, and Septoria disease while the local check Danda'a showed susceptible reaction to yellow, Stem rust, and Septoria disease (Table 5). The recently developed bread wheat varieties are comparable to the Danda'a and Boru in terms of leaf rust disease. The candidate variety **Gutu** was moderately resistant to stem, yellow rust, Leaf rust, and Septoria diseases (Table 5). Therefore, the development of new rust-resistant varieties will provide an excellent chance for producers of wheat in areas with limited resources.

Table 1. Mean grain yield (t/ha) performance of 10 genotypes and 2 checks tested from 2020 to 2022 cropping seasons

SN	Genotype	KF20BWOL	KU20BWOL	KU20BWPL	RB20BWPL	SN20BWPL	DM21BWNL	HL21BWNL	RB21BWNL	SN21BWNL	BE21BWNL	BE21BWPL	KF21BWPL	BE22BWNL	KF22BWNL	RB22BWNL	CD22BWNL	DM22BWNL	EW22BWNL	GD22BWNL	HL22BWNL	KU22BWNL	Mean
1	**Gutu**	**2.3**	**2.9**	**4**	**2.6**	**3.2**	**4.4**	**3.3**	**4.2**	**5.4**	**4.7**	**4.4**	**5.2**	**4.4**	**6.9**	**6.7**	**5.2**	**4.6**	**7.1**	**5.2**	**3.1**	**5.9**	**4.6**
2	**EBW182767**	3.5	4	4.5	2.4	2	5	3.8	4	4.3	4.3	4.2	4.2	5.2	6.6	6.7	5.5	5.9	7.6	5.3	4.4	6.2	4.7
3	EBW192022	1.5	2.5	2.7	2.1	1.6	4	2.4	3.5	4	2.9	3.3	3.3	3.3	1.6	4.6	5.2	4.2	6.6	4.3	2.2	3.9	3.3
4	EBW192387	2.2	2.9	2.8	2	2.3	3.6	1.7	3.5	4.2	2.4	2.5	2.9	3	2.3	5.1	5	3.5	6.5	4.3	1.8	4.1	3.3
5	EBW182981	2.7	3.2	3.6	2.1	3	3.9	2	3.7	4.3	2.3	2	2.2	2.8	2.6	5.5	4.8	3.4	6.8	4.5	2.1	4.7	3.4
6	EBW192874	1.5	2.6	3.9	2.1	1.5	4.9	2.6	3.3	3.4	2.5	2.4	2	3.6	1.6	5.1	5.3	5	7.2	5.2	3.3	5.2	3.5
7	**Boru**	**2.3**	**3.3**	**3.9**	**1.9**	**1.1**	**4.9**	**2.6**	**3.2**	**3**	**2.4**	**2.4**	**1.9**	**3.7**	**1.3**	**5.3**	**5.4**	**5.8**	**7.4**	**5.2**	**3.8**	**5.5**	**3.6**
8	EBW192873	0.5	1.8	3.8	2.4	1.7	4.4	2.3	3.4	3.7	2.4	2.2	2	3	1.7	5.3	5.2	3.6	6.9	5.2	2.5	5.1	3.3
9	EBW192140	2.3	3.2	4	2	2.4	4.8	2.4	3.3	3.7	2.3	2	1.8	3.2	2	5.1	5	4.6	7.3	5	3.2	5.4	3.6
10	EBW183001	0.8	2.3	3.7	1.3	3	5	2.5	2.5	3.5	2.8	2.4	2.3	3.6	1.7	3.1	4.7	5	6.5	5.3	3.7	5.5	3.4
11	EBW182999	1.9	2.9	3.4	1.3	3.4	4.5	2.2	2.8	3.8	2.4	2.1	2.2	3.1	1.7	3.2	4.5	4.5	6.4	4.7	3	4.9	3.3
12	**Danda'a**	**3.5**	**3.9**	**2.4**	**1.7**	**1.3**	**4**	**1.8**	**3.2**	**3.2**	**1.3**	**1.8**	**1.6**	**3.1**	**1.3**	**4**	**5**	**4.9**	**6.6**	**3.5**	**2.1**	**2.8**	**3.0**
Mean		2.2	3.1	3	1.5	1.7	4.4	2.3	3.3	3.8	2.5	2.2	2.3	3.7	3.2	5.2	5.2	4.7	7	4.9	3	5	3.5
Genetic Variance		0.8	0.4	0.9	0.3	1	0.5	1.3	0.4	0.8	1.2	1.1	1.7	0.8	4	1	0.1	1	0.2	0.3	0.8	0.9	0.9
Error Variance		0.9	0.5	0.2	0.2	0.1	0.4	0.2	0.5	0.3	0.1	0.1	0.8	0.4	0.3	0.2	0.5	0.5	0.3	0.5	0.2	0.4	0.4

20BWPLRB= Robe Arsi 2020; 21BWNLRB= Robe Arsi 2021; and 22BWNLRB = Robe Arsi 2022; 20BWOLKU=Kulumsa 2020; 20BWPLKU=Kulumsa 2021; and 22BWNLKU= Kulumsa 2022; 21BWNLHL=Holeta 2021; 22BWNLHL= Holeta 2022, 22BWNLGD= Gonder 2022; 22BWNLEW=Enawary 2022; 22BWNLCD= Chefe donsa 2022, 21BWNLBE= Bekoji 2021; 22BWNLBE= Bekoji 2022; 20BWOLKF=Kofele 2020; 21BWPLKF = Kofele 2021; 20BWPLSN = Sinana 2020

Table 2. Relative yield advantages of the candidate varieties over the standard checks

SN	Environment	GUTU	YLD adv. to Boru	YLD adv. to Danda'a
1	KF20BWOL	2.3	0.00	-34.29
2	KU20BWOL	2.9	-12.12	-25.64
3	KU20BWPL	4.0	2.56	66.67
4	RB20BWPL	2.6	36.84	52.94
5	SN20BWPL	3.2	190.91	146.15
6	DM21BWNL	4.4	-10.20	10.00
7	HL21BWNL	3.3	26.92	83.33
8	RB21BWNL	4.2	31.25	31.25
9	SN21BWNL	5.4	80.00	68.75
10	BE21BWNL	4.7	95.83	261.54
11	BE21BWPL	4.4	83.33	144.44
12	KF21BWPL	5.2	173.68	225.00
13	BE22BWNL	4.4	18.92	41.94
14	KF22BWNL	6.9	430.77	430.77
15	RB22BWNL	6.7	26.42	67.50
16	CD22BWNL	5.2	-3.70	4.00
17	DM22BWNL	4.6	-20.69	-6.12
18	EW22BWNL	7.1	-4.05	7.58
19	GD22BWNL	5.2	0.00	48.57
20	HL22BWNL	3.1	-18.42	47.62
21	KU22BWNL	5.9	7.27	110.71
	Overall mean	4.6	25.43	51.90

20BWPLRB, 21BWNLRB and 22BWNLRB = Robe Arsi, 20BWOLKU, 20BWPLKU and 22BWNLKU= Kulumsa, 21BWNLHL, 22BWNLHL= Holeta, 22BWNLGD= Gonder, 2BWNLEW=Enawary, 22BWNLCD= Chefe Donsa, 21BWNLBE, 22BWNLBE= Bekoji, 20BWOLKF, 21BWPLKF = Kofele, 20BWPLSN = Sinana

Table 3. Mean performance of some important agronomic traits of 10 genotypes and 2 checks tested from 2020 to 2022 trial seasons

SN	Genotype	DTH (days)	DTM (days)	HLW (kg/hl)	PHT (cm)	TKW (gm)
1	**Gutu**	**69.3**	121.3	**69.1**	**84.2**	**39.9**
2	**EBW182767**	72.2	122.3	71.7	93.7	39.9
3	EBW192022	73.1	118.7	67.9	84.1	34.4
4	EBW192387	72.1	116.7	66.6	86.3	33.3
5	EBW182981	68.2	116.0	70.0	87.5	32.9
6	EBW192874	67.1	120.7	68.9	82.5	36.7
7	Boru	70.6	122.3	67.3	92.1	37.6
8	EBW192873	67.5	116.0	67.5	85.7	35.7
9	EBW192140	70.6	120.7	70.5	86.2	37.8
10	EBW183001	65.0	115.7	70.3	82.5	34.9
11	EBW182999	66.4	116.3	70.9	84.7	36.1
12	Danda'a	75.4	119.0	64.3	98.9	32.7
	Mean	**69.8**	**118.8**	**68.7**	**87.4**	**36.0**
	SEM (+/-)	**3.1**	**2.6**	**2.1**	**5.0**	**2.5**

DTH=Days to heading; DTM=Days to maturity; PHT=Plant height; TKW=Thousand kernel weight; HLW=Hectoliter weight; YLD=Grain Yield

3.5 Variety Maintenance

The goal of seed maintenance is to create new breeder seed lots with the same genetic makeup. Once the variety has been released to the public, it is the breeder's responsibility to preserve it. In ear-rows, wheat plants that represent the variety are grown under careful supervision. Row plots, or small plots, are where plants from particular rows are collected and grown. Consequently, it is the responsibility of the wheat breeder at the Kulumsa Agriculture Research Institute to maintain the variety.

Table 4. Morphological and descriptions of candidate bread wheat genotype Gutu

SN	Morphological Description Types	Types
1	Growth habit	Intermediate
2	Auricle color	White
3	Leaf waxiness	Weak
4	Ear density	Dense
5	Ear color	White
6	Ear shape	Slightly clavate
7	Glume hairiness	Absent
8	Spike length	Long
9	Seed color	White
10	TKW (g)	39.9
11	HLW (kg/hl)	69.1
12	GY (t/ha)	4.60

Table 5. Disease summary for newly released variety and checks

Diseases/insects and other hazard	Gutu	Boru (St. Check)	Danda'a (St. Check)
Stem rust (%+ reaction)	10MRMS	40MS	50MS
Yellow rust (%+reaction)	5RMR-5MR	30MSS	40MRMS
Leaf rust (%+ reaction)	0	0	0
Septoria (0-9)	3	5	5

Fig. 1. The seed of the new variety Gutu

4. CONCLUSION

To tackle food shortages and malnutrition in developing countries, especially in the face of rapid population growth, it is essential to boost food production. This can be accomplished by improving crop yields through innovative practices, such as developing superior crop varieties that are well-suited to different environments and socioeconomic conditions. Plant breeders focus on creating cultivars that perform well in both optimal and less favorable conditions. Therefore, it is important to consider both yield potential and stability together to effectively refine the selection of varieties. Gutu was the best-yielding bread wheat variety. It is stable in grain yield performance over locations and years. It was resistant to major wheat rust diseases that prevailed in the growing areas. Farmers also preferred the variety for its superior performance over the existing local variety, which is manifested by better grain yield, and disease resistance. Likewise, the variety has a white grain color and it has good general acceptance for bread with high quality. Hence, Gutu was verified and officially released for midlands wheat-growing areas of Ethiopia in 2024.

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 writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kizilgeci F, Yildirim M, Islam MS, Ratnasekera D, Iqbal MA, Sabagh AE, Normalized difference vegetation index and chlorophyll content for precision nitrogen management in durum wheat cultivars under semi-arid conditions. Sustainability. 2021;13(7):3725. DOI: 10.3390/su13073725
2. Khalid A, Hameed A, Shamim S, Ahmad J. Divergence in single kernel characteristics and grain nutritional profiles of wheat genetic resource and association among traits. Frontiers in Nutrition. 2022;8:805446. DOI: 10.3389/fnut.2021.805446
3. Khalid A, Hameed A, Tahir MF. Wheat quality: A review on chemical composition, nutritional attributes, grain anatomy, types, classification, and function of seed storage proteins in bread making quality. Frontiers in Nutrition. 2023;10,1053196. Available:https://doi.org/10.3389/fnut.2023.1053196
4. Curtis BC. Wheat in the World; 2019. Available:http://www.fao.org/3/y4011e/y4011e04.htm
5. Yirga C, Mohammad A, Kassie M, Groote HD, Mebratu T, Jaleta M, Shiferaw B. Analysis of adoption and diffusion of improved wheat technologies in Ethiopia. Research Report No. 1. EIAR and CIMMYT; 2013.
6. Hodson DP, Jaleta M, Tesfaye K, Yirga C, Beyene H, Kilian A, Carling J, Disasa T, Alemu SK, Daba T, Alemayehu Y, Badebo A, Abeyo B, Erenstein O. Ethiopia's transforming wheat landscape: tracking variety use through DNA fingerprinting. 2020;10:18532. Available:https://doi.org/10.1038/s41598 020-75181-8
7. Jaleta M, Tesfaye K, Kilian A, Yirga C, Habte E, Beyene H. Misidentification by farmers of the crop varieties they grow: Lessons from DNA fingerprinting of wheat in Ethiopia. PLoS ONE. 2020;15(7):e0235484. Available:https://doi.org/10.1371/journal.pone.023548
8. MoANR (Ministry of Agriculture and Natural Resources) Plant variety release, protection, and quality control directorate. Crop Variety Register, Addis Ababa, Ethiopia; 2016.
9. Olivera P, Newcomb M, Szabo LJ, Rouse M, Johnson J, Gale S, Jin Y. Phenotypic and genotypic characterization of race TKTTF of Puccinia graminis f. sp. tritici that caused a wheat stem rust epidemic in southern Ethiopia in 2013–14. Phytopathology. 2015;105(7):917-928.
10. Alemu T, Moti J, David H, Yoseph A, Chilot Y, Bekele A. Wheat varietal change and adoption of rust-resistant wheat varieties in Ethiopia from 2009/10 to 2013/14. Socioeconomics Program Working Paper 12. Mexico, CDMX: CIMMYT; 2018.
11. Singh RP, Hodson DP, Huerta-Espino J, Jin Y, Njau P, Wanyera R, Herrera-Foessel SA, Ward RW. Will stem rust destroy the world's wheat crop? Advances in Agronomy. 2008;98:271–309.
12. Teferi TA, Gebreslassie ZS. Occurrence and intensity of wheat Septoria tritici blotch and host response in Tigray, Ethiopia. Crop Protection. 2015;68:67–71.
13. Bekele A, Viljoen MF, Ayele G, Ali S. Effect of farm size on efficiency of wheat production in Moretna-Jirru district in Central Ethiopia. Indian Journal of Agricultural Economics. 2009;64(1): 1–11.

14. Tadesse W, Bishaw Z, Assefa S, Wheat production and breeding in Sub-Saharan Africa: Challenges and opportunities in the face of climate change. International Journal of Climate Change Strategies and Management. 2018;11(5):696–715.
15. Erenstein O, Jaleta M, Mottaleb KA, Sonder K, Donovan J, Braun HJ. Global trends in wheat production, consumption, and trade. In *Wheat* improvement: food security in a changing climate (pp. 47-66). Cham: Springer International Publishing; 2022.
16. Crespo-Herrera LA, Crossa J, Huerta-Espino J, Vargas M, Mondal S, Velu G, Singh RP. Genetic gains for grain yield in CIMMYT's semi-arid wheat yield trials grown in suboptimal environments. Crop Science. 2018;58(5):1890-1898.
DOI: 10.2135/cropsci2018.01.0017
17. Adugnaw Anteneh, Dagninet Asrat. Wheat production and marketing in Ethiopia: Review study. Cogent Food & Agriculture. 2020;6(1):1778893.
DOI: 10.1080/23311932.2020.1778893
18. Mizan TA, Hussien Sh, Teka S, Azeb H. Genotype-by-environment interaction and selection of elite wheat genotypes under variable rainfall conditions in northern Ethiopia, Journal of Crop Improvement; 2019.
Available:https://doi.org/10.1080/15427528.2019.1662531.
19. Sime B, Solomon T, Alemu G, Dabi A, Geleta N, Duga R, Delasa A, Zegaye H, Asnake D, Asefa B, Kasahun C, Getamesay A, Zawad D, Tadesse Z, Abeyo B and Badebo A. Registration of New Bread Wheat Variety (Biftu) for Low to Mid-Altitude Wheat-Producing Areas of Ethiopia. Journal of Global Agriculture and Ecology. 2023;15(4):1-9.
20. Hei, N, Shimelis HA, Laing M. Appraisal of farmers' wheat production constraints and breeding priorities in rust-prone agroecologies of Ethiopia. African Journal of Agricultural Research. 2017;12(12):944-952.
21. Tenge BN, Ojwang PPO, Otaye D, Oyoo ME. Wheat stem rust disease incidence and severity associated with farming practices in the Central Rift Valley of Kenya. African Journal of Agricultural Research. 2016;11(29):2640-2649.
22. Dabi A, Alemu G, Sime B, Duga R, Geleta N, Delasa A, Solomon T, Zegaye H, Kasahun C, Asnake D, Asefa B. Mult environments evaluation of Zn and Fe enhanced bread wheat genotypes in optimum areas of Ethiopia. International Journal of Bio-resource and Stress Management. 2024;15(6);01-11.
Available:Https://DOI.ORG/10.23910/1.2024.5375

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