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Identification of Climate-smart Bread Wheat (*Triticum aestivum* L.) Germplasm for Highland Wheat Growing 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 is one of the most widely cultivated and successful crop species worldwide and is pivotal in the global food system. This study aims to determine high-yielding advanced bread wheat genotypes and releases best-performing genotypes across different wheat-growing areas of

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Ethiopia as a new variety for end users. The BLUP analysis shows Enawari had the highest grain yield followed by Robe Arsi, ChefeDonsa, Kulumsa, in 2022, and Debre Markos in 2023. Holeta genotypes had the lowest yield in 2021. In 2021, the genotypes in Holeta had the lowest yield, with an average yield of 2.6 t/ha. The study revealed high heritability for all traits, ranging from 71.6% for grain yield t/ha to 98.87% for days to heading. All traits had a broad sense of heritability at all locations, except for thousand kernel weight at 23KU and grain yield at 22CD, 22EW, and 23KU. The study reveals yield, yield component, and disease resistance variations for yellow and stem rusts. The genotypes with the best performance were promoted to the next breeding stage National Performance Trials (NPT) for further study and released as new varieties after further testing. The EBW212574 and EBW202087 genotypes, exhibiting moderate resistance to stem rust, were chosen for national performance trials in 2024 based on their response to yield, yellow rust, and other agronomic traits.

Keywords: BLUP; disease resistance; high yielding; NPT; rust.

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) holds the position of the most significant cereal crop globally. Wheat plays a crucial role in global food security, providing a vital source of carbohydrates and nutrients. It is a significant source of nutrition [1,2,3]. It is the main source of calories and protein for human consumption, especially in developing countries [4], and accounts for nearly 20% of the world's calories and daily proteins to 4.5 billion people globally [5,6], these crop plants are essential for global food security [7]. Additionally, it is an industrial crop because the grain, along with stalk and chaff, serves as industrial raw materials, which are also used as mulch, construction material, and animal bedding. In terms of food security, it is the second most important food crop in the developing world after rice, because an estimated 80 million farmers rely on wheat for their livelihoods [8]. Wheat, with over 218 million hectares, is the most widely grown crop globally, with a greater world trade than all other crops combined.

Bread wheat and durum wheat stand out as the most extensively cultivated among the various wheat species. Wheat production has grown significantly over the past two decades following several government programs and initiatives implemented to drive the country's agricultural growth and food security. Wheat, a highly adaptable crop due to its complex genome, can thrive in various climates and soil types worldwide [9]. Wheat, a significant crop in Ethiopia, is primarily grown in rain-fed environments [10]. And that can grow in highlands at altitudes ranging from 1500 to 3000 m.a.s.l [11]. The most suitable elevation zones of wheat lie between 1900 and 2700 m.a.s.l. [12]. Ethiopia's main wheat-producing regions are Bale and Arsi, Hadiya and Kenbata, East Gojam, and North Shoa [13]. Such wide adaptation and cultivation of wheat across all continents led to the harvest of wheat in each month of the year at least in a given area in the world.

The growing global population and climate change are major concerns in agriculture. Food production and security are crucial issues, as food output may double by 2050, and innovative approaches are needed to increase agricultural productivity and meet the rising demand for food, as the food output may need to double by 2050 [14]. Global wheat production increased by 4% in the first decade post-revolution, with 8% growth in South Asia, East Asia, Mexico, and Central America [15]. Climate change and related stresses necessitate efforts to include resilience while improving production and quality to secure food security for the fast-rising global population. Bread wheat germplasm has wide genetic diversity, which means it can withstand a biotic-many biotic and abiotic stresses [16]. New crop cultivars, particularly those resistant to biotic and abiotic factors and adaptable to climatic variations, are crucial for addressing climate change [17].

Grain yield is one of the traits of importance and breeders often seek to identify genotypes with high and stable yield across environments [18]. Wheat genotypes should be tested in multi-environment yield trials to determine grain yield, stability, GEI, and adaptability, and to identify a potential candidate to release for commercial cultivation [19]. Multi-location trials are essential for assessing genotype adaptation to various environments and identifying the optimal genotype for commercialization. Statistical approaches are crucial for assessing wheat breeding trials to choose reliable types that contribute to agricultural productivity. High genetic variation is necessary for stable variants to emerge, and understanding how genotype and environment interact is essential for identifying genotypes with high environmental stability. Genotype by environment interaction (GEI) is a phenomenon that impacts genotype performance under different conditions, reducing varietal recommendation accuracy and selection efficiency [20]. Plant breeding initiatives aim to increase stability and crop productivity across various environments. The best techniques involve finding cultivars with high genetic potential and assessing adaptation using multi-condition tests in target locales.

Crop improvement activities rely on identifying superior genotypes for cultivation and assessing their stability in performance amidst environmental changes and factors over time. Wheat genotype development for disease resistance, adaptability, and high yield has been ongoing through research institutes and universities. However, most cultivars are out of production due to rust disease susceptibility. To alleviate wheat production constraints, Ethiopia has developed various bread wheat varieties through breeding research programs. This study aims to determine high-yielding advanced bread wheat genotypes and release best-performing genotypes across different wheat-growing areas of Ethiopia as a variety for end users.

2. MATERIALS AND METHODS

A study was undertaken using germplasm of different genetic backgrounds to determine their level of GE in their biological yield responses. Eighteen bread wheat advanced breeding genotypes including three check varieties were evaluated from 2021 to 2023 at 10 locations resulting in 19 environments. The test genotypes were derived from the National Variety Trial (NVT) tested at potential environments. Three replications were used in a row-column experiment design. Experimental units consisted of plots of 2.5 m in length and 1.2 m in width with six rows. Replications were separated by 1.5 meters while plots were separated by 1 meter. It utilized 150 kg/ha of seed (45g/plot). Production was all under rain-fed conditions. We gathered information on several traits including days to heading (DTH), days to maturity (DTM), plant height (PHT), grain yield per plot (GYLD), hectoliter weight (HLW), and thousand kernel weight (TKW). To evaluate these genotypes for yellow and stem rust diseases, they have been planted at two hot spot areas Meraro and Debreziet for yellow and stem rust respectively. The data for yellow rust from the Meraro site and stem rust from Debreziet were collected from hot spot areas by observing the spore severity on the leaf surfaces of each genotype. A 0-9 scale was used to take notes on the rust diseases. The geographic information of testing sites is presented in Table 1.

Statistical analysis: The study used R software for statistical analysis, applying a mixed linear model to multi-environment trial data analysis. Similar to the AMMI model, the factor analytic model was used to capture heterogeneous variance-covariance structures. Spatial field trends were fitted first for each environment and tested for potential field trends between neighbor plots. Global variability and extraneous variation were checked and included in the standard linear mixed model. Trials across environments were combined with specific trial information, including spatial field trends. The BLUP predictors were used to compare the means of each genotype with the general mean, as described by [21]. The BLUP pair grain yields were ranked descending to identify genotypes or superior lines, allowing comparison of environmental effects' free genetic values for improved genetic gain in subsequent selection cycles.

Table 1. The geographic information of testing sites

Geographic information	Testing site							
	Robe Arsi	Bekoji	Debre Markos	Debre Birhan (EN)	Chefe Donsa	Sinana	Holeta	Kulumsa
Latitude	07º53'02"N	07º32'37"N	10° 19′59″N	9°41′N	8°44′N	7°7’N	09°03′41″N	08º01'10"N
Longitude	39º37'40"E	39º15'21"E	37°44′53″E	39°32′E	39°95′E	39°49'E	38°30′44″E	39º09'11"E
Altitude	2420	2780	2450	2840	2450	2450	2400	2200

Table 2. List of materials tested in the experiment

Genotype	Pedigree
Alidoro	HK-14-R251
Danda'a	Kiritati//2*PBW65/2*Seri.1B
EBW182767	MANKU/3/MUU/FRNCLN//FRANCOLIN #1
EBW192154	CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/AE.SQUARROSA (213)//PGO*2/5/KUTZ
EBW192156	PREMIO//PI 610750/PIFED*2/3/KSW/SAUAL//SAUAL
EBW192255	VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/5/BAVIS/6/BORL14
EBW192345	KENYA SUNBIRD/2*KACHU/3/SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU
EBW192387	KACHU/DANPHE/3/KACHU//KIRITATI/2*TRCH
EBW192470	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/4/T.DICOCCON PI94625/AE.SQUARROSA (372) //SHA4/CHIL/5/WHEAR/KUKUNA/3 /C80.1/3*BATAVIA//2*WBLL1/6/MUU/FRNCLN//FRANCOLIN #1
EBW192493	SHORTENED SR26 TRANSLOCATION//2*WBLL1*2/KKTS/3/BECARD
EBW192800	CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/AE.SQUARROSA (213) //PGO/5/BORL14
EBW202087	CROC_1/AE.SQUARROSA (205) //BORL95/3/PRL/SARA//TSI/VEE#5/ 4/FRET2/5/WHEAR/SOKOLL/6/KACHU/3/WHEAR//2*PRL/2*PASTOR
EBW202117	MUTUS*2/MUU/6/ATTILA/3*BCN//BAV92/3/PASTOR/4/TACUPETO F2001*2/BRAMBLING/5/PAURAQ/7/MUCUY
EBW212532	PRL/2*PASTOR//WAXWING*2/KRONSTAD F2004/4/PBW343*2/KUKUNA// KRONSTAD F2004/3/PBW343*2/KUKUNA/7/2*WBLL1*2/4/YACO/PBW65/3/ KAUZ*2/TRAP//KAUZ/5/KACHU #1/6/PBW343*2/KUKUNA*2//FRTL/PIFED
EBW212574	SR47/5/3*SHORTENED SR26 TRANSLOCATION/4/3*CHIBIA// PRLII/CM65531/3/MISR 2
EBW212985	MUCUY*2//SUP152/BAJ #1
Shaki	BABAX/LR42// BABAX/3/ER2000/4/BAVIS
Lemu	WAXWING*2/HEILO

3. RESULTS AND DISCUSSION

Table 3 displays the genotypes' average grain yield performances. The BLUP analysis shows Enawari had the largest grain yield in the 2022 cropping season (7 t/ha), followed by Robe Arsi (5.4 t/ha), Chefe Donsa (5.2 t/ha), and Kulumsa (5 t/ha) in 2022 cropping season, and Debre Markos (5 t/ha) in 2023 cropping season, with an average mean yield of 4.3 t/ha. The genotypes in Holeta generated an average grain yield of 2.6 t/ha in 2021, the lowest yield recorded (Table 3). The selection and evaluation phases are essential yet different components of the breeding program. Selection is best performed using tools or environments that separate lines for the traits of interest. Since there is not a single environment that represents all the current and future environments where a line may be grown (often referred to as a target population of environments) [22], selection usually occurs in multiple environments, and G×E or G×E×M must be considered [23,24]. For additional confirmation, testing of the studied traits was undergone in 2022, only two genotypes that were tested from 2021-2023 were selected. These two genotypes (EBW212574 and EBW202087) were advanced to the national performance trials to evaluate the performance of the genotypes in various locations (Table 3). Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from EBW182767 (5.2 t/ha) followed by EBW192800 (5 t/ha), EBW192156 (4.9t/ha), and EBW192345 (4.9 t/ha). In contrast, minimum grain yield was observed in Danda'a (3.3 t/ha) (Table 3). The result showed that varieties released for mid to high land were ranked first based on overall environment mean grain yield followed by the candidate varieties EBW192800 and EBW192156. Therefore, these candidate genotypes were selected for the crossing block.

Estimates ranged from 0.07 to 3.45 for genetic variance, 0.07 to 0.63 for error variance, and 71.6 to 98.477 for heritability for grain yield (Table 4). The study found high heritability for all traits, ranging from 71.6% for grain yield t/ha to 98.87% for days to heading. Heritability values above 80% were considered very high, while values between 60-79% were moderately high, 40-59%medium, and less than 40% low. All traits had a very high broad sense of heritability at all locations, except for TKW at 23KU, and grain yield at 22CD, 22EW, and 23KU. The study found moderate broad sense heritability values for traits such as TKW (77.66% at 23KU), and grain yield (71.60% at 22CD, 74.07% at 22EW, and 77.18% at 23KU) (Table 4).

Table 3. BLUPs for genotypes mean values across environments

Genotype	21BE	21DM	21HL	21RB	21SN	22BE	22CD	22DM	22EW	22GD	22HL	22KF	22KU	22RB	23BE	23DM	23HL	23RB	23KU	Mean
Alidoro	2.0	5.2	1.4	2.3	2.6	2.0	4.9	5.3	6.6	4.7	3.1	0.5	4.5	2.5	1.8	4.8	4.4	1.7	2.2	3.3
Danda'a	1.4	3.8	1.7	3.2	3.1	3.1	4.9	4.9	6.7	3.6	2.1	1.2	2.8	4.1	3.5	3.8	4.8	1.1	2.6	3.3
EBW182767	4.3	4.8	3.7	4.1	4.4	5.3	5.5	5.9	7.5	5.5	4.4	6.7	5.8	6.7	5.7	5.5	5.3	3.3	4.6	5.2
EBW192154	4.2	4.7	2.5	3.5	3.8	4.1	5.5	5.6	7.0	5.0	3.0	5.6	4.9	5.3	5.1	5.5	5.0	3.3	3.3	4.6
EBW192156	5.4	4.5	4.8	4.3	5.5	5.7	4.9	5.2	7.1	4.7	3.8	4.2	5.7	5.6	4.2	5.3	4.6	2.4	4.8	4.9
EBW192255	3.9	4.4	3.0	3.9	4.4	4.2	5.4	4.7	7.0	5.0	2.8	5.8	5.2	6.0	4.4	5.2	4.5	3.2	4.6	4.6
EBW192345	4.8	4.5	3.0	4.2	5.3	4.1	5.1	4.7	7.0	5.2	3.1	7.0	6.2	6.7	5.1	5.6	4.2	4.1	4.0	4.9
EBW192387	2.4	3.5	1.7	3.5	4.2	3.0	4.8	3.6	6.5	4.1	1.8	2.4	4.0	5.1	3.8	4.3	4.0	2.5	3.4	3.6
EBW192470	2.8	4.0	2.6	4.2	5.0	3.7	4.8	4.2	6.8	4.8	2.7	4.6	5.5	6.7	4.6	4.7	4.3	3.1	4.0	4.4
EBW192493	2.2	3.9	0.8	3.2	3.5	2.5	5.3	3.7	7.0	5.0	1.9	5.5	4.6	5.6	4.6	5.0	4.1	3.6	3.4	4.0
EBW192800	4.8	4.7	3.5	4.2	4.5	4.8	5.6	5.6	7.2	4.9	3.0	5.9	5.2	6.6	5.3	5.4	5.0	3.6	4.3	5.0
EBW202087	3.7	3.8	2.3	4.0	4.5	3.9	5.5	3.9	7.0	4.9	2.2	5.1	4.9	6.7	5.3	5.1	4.3	3.8	4.6	4.5
EBW202117	4.2	5.3	3.8	3.8	4.1	4.4	5.4	5.9	7.3	5.0	3.5	3.2	5.5	5.3	3.4	5.3	4.8	2.7	4.5	4.6
EBW212532	4.5	6.1	4.3	3.8	3.8	4.4	5.5	7.0	7.3	5.3	4.7	2.6	6.0	5.1	3.1	5.6	5.2	2.6	4.2	4.8
EBW212574	4.3	3.3	1.8	3.8	4.4	3.8	5.4	3.7	6.6	4.2	1.7	7.1	3.7	5.8	5.8	5.0	4.2	3.6	3.4	4.3
EBW212985	2.2	4.2	2.1	3.5	3.9	3.2	5.1	3.9	6.9	4.9	2.5	1.9	5.0	5.5	3.3	4.6	4.1	2.7	4.6	3.9
Shaki	3.9	4.6	3.2	3.3	4.3	4.4	5.0	4.7	6.9	5.1	2.9	3.3	5.4	4.6	3.5	5.3	4.4	2.3	4.4	4.3
Lemu	1.8	5.2	1.4	2.5	2.6	2.3	5.0	5.6	6.9	5.0	3.9	2.6	4.7	3.4	2.9	5.0	4.8	2.0	2.2	3.7
Mean	**3.5**	**4.5**	**2.6**	**3.6**	**4.1**	**3.8**	**5.2**	**4.9**	**7.0**	**4.8**	**3.0**	**4.2**	**5.0**	**5.4**	**4.2**	**5.0**	**4.6**	**2.9**	**3.8**	**4.3**

Where: 21BE= 2021 Bekoji, 21DM: 2021 DebreMarkos, 21HL; 2021 Holeta, 21RB; 2021 Robe Arsi, 21SN: 2021 Sinana, 22BE= 2022 Bekoji, 22DM: 2022 Debre Markos, 22HL; 2022 Holeta, 22RB; 2022 Robe Arsi, 21CD: 2022Chafe Donsa,22GD; 2022 Gonder, 22EW: 2022 Enawari, 22KF: 2022 Kofale, 22KU: 2022 Kulumsa, 23BE= 2023 Bekoji, 23DM: 2023 Debre Markos, 23HL; 2023 Holeta, 23RB; 2023 Robe Arsi and 23KU: 2023 Kulumsa

Table 4. Variation for individual environment variance components and grain yield means for grain yield and genetic variance and broad-sense heritability for all traits, in 19 environments

	Grain yield (t/ha)			Hectoliter weight (kg/hl)		Plant height (cm)		Thousand Kernel weight (g)		Days To Headings (days)	
Environments	**Genetic Variance**	**Error Variance**	**Heritability**	**Genetic Variance**	**Heritability**	**Genetic Variance**	**Heritability**	**Genetic Variance**	**Heritability**	**Genetic Variance**	**Heritability**
21BE	1.25	0.07	98.77	11.14	96.54	13.46	90.03	25.27	96.98	5.99	97.32
21DM	0.38	0.35	91.17	-	-	16.58	86.16	-	-	13.43	95.07
21LHL	0.85	0.25	96.03	28.64	97.06	12.92	89.69	36.45	96.83	11.43	94.77
21RB	0.26	0.53	93.7	2.76	93.11	22.04	89.95	10.36	91.84	13.05	97.68
21SN	0.59	0.24	96.68	3.03	92.15	8.44	83.05	-	-	-	-
22BE	0.64	0.38	92.09	-	-	19.22	94.02	24.2	93.45	7.98	96.46
22CD	0.07	0.52	71.6	0.34	86.43	19.06	86.27	14.95	94.19	14.63	97.93
22DM	0.84	0.51	93.35	-	-	17.42	96.8	-	-	14.93	98.87
22EW	0.14	0.34	74.07	1.4	91.11	14.42	91.45	11.7	91.4	8.58	95.25
22GD	0.26	0.47	87.27	-	-	9.73	96.21	24.04	95.39	20.91	97.67
22HL	0.61	0.19	93.61	21.01	96.24	17.07	96.54	36.91	96.9	29.97	98.31
22KF	3.45	0.23	97.89	43.65	97.25	16.39	88.63	-	-	-	-
22KU	0.8	0.41	92.59	8.14	92.11	19.84	92.86	14.52	93.12	14.12	97.71
22RA	1.05	0.24	95.45	3.6	93.81	20.33	95.06	24.09	95.35	33.36	96.88
22KU	1.52	0.29	92.68	14.17	87.79	19.06	83.42	29.42	91.03	20.15	97.08
23BE	0.93	0.22	95.66	11.42	97.06	32.55	94.44	27.41	95.05	2.57	97.03
23DM	0.21	0.59	91.52	-	-	10.91	84.89	-	-	2.27	92.63
23HL	0.21	0.21	92.03	-	-	33.96	97.13	9.76	92.74	13.16	98.78
23RA	0.44	0.21	93.15	21.66	95.79	21.66	93.57	34.51	94.43	17.62	98.15
23KU	0.8	0.63	77.18	6.2	83.66	61.93	85.32	16.09	77.66	55.75	96.54

Where: 21BE= 2021 Bekoji, 21DM: 2021 Debre Markos, 21HL; 2021 Holeta, 21RB; 2021 Robe Arsi, 21SN: 2021 Sinana, 22BE= 2022 Bekoji, 22DM: 2022 Debre Markos, 22HL; 2022 Holeta, 22RB; 2022 Robe Arsi, 21CD: 2022 Chafe Donsa, 22GD; 2022 Gonder, 22EW: 2022 Enawari, 22KF: 2022 Kofale, 22KU: 2022 Kulumsa, 23BE= 2023 Bekoji, 23DM: 2023 Debre Markos, 23HL; 2023 Holeta, 23RB; 2023 Robe Arsi and 23KU: 2023 Kulumsa

Table 5. Mean performance of some important agronomic traits of 18 genotypes

Genotype	Days To Heading (Days)	Plant height (cm)	Thousand Kernel Weight (g)	Hectoliter weight (kg/hl)
Alidoro	74.62	99.19	31.70	66.01
Danda'a	76.50	99.77	34.60	63.96
EBW182767	71.77	94.38	42.03	71.99
EBW192154	68.86	92.07	45.17	74.07
EBW192156	65.18	80.53	39.74	71.95
EBW192255	64.25	86.05	41.01	71.39
EBW192345	69.15	85.12	42.36	70.26
EBW192387	72.57	86.83	34.89	68.02
EBW192470	69.19	93.88	39.10	72.01
EBW192493	66.17	87.33	39.63	71.44
EBW192800	65.44	88.19	42.42	73.08
EBW202087	68.18	83.35	35.43	70.51
EBW202117	72.40	90.90	39.94	72.85
EBW212532	74.10	89.52	44.09	71.59
EBW212574	74.10	90.21	37.14	69.38
EBW212985	70.11	86.91	37.01	67.84
ETBW9089	68.59	92.61	42.86	70.46
Lemu	76.25	92.63	32.28	68.78
Mean	70.41	89.97	38.97	70.31

Table 6. Selection based on wheat rust (Yellow and Stem Rust)

Genotypes	YR2 Meraro	YR3 Meraro	SR1DZ	SR2 DZ	Decision
Alidoro	6.679	6.913	3.429	4.796	
Danda'a	5.370	6.432	6.856	7.392	
EBW182767	3.038	3.258	5.105	6.416	
EBW192154	3.426	3.612	5.871	6.740	
EBW192156	5.588	6.525	5.347	6.038	
EBW192255	3.614	3.758	5.752	6.610	
EBW192345	3.230	3.300	1.927	4.322	
EBW192387	4.914	5.701	6.298	6.923	
EBW192470	3.337	3.429	6.439	6.943	
EBW192493	1.107	1.868	5.815	6.701	
EBW192800	3.213	3.690	6.16	6.853	
EBW202087	3.233	3.329	5.199	5.948	NPT
EBW202117	6.431	7.014	5.795	6.675	
EBW212532	4.341	5.153	4.871	6.356	
EBW212574	1.600	2.909	3.374	5.500	NPT
EBW212985	6.230	6.839	6.376	6.885	
Shaki	6.566	7.009	2.668	4.370	
Lemu	6.540	7.073	6.381	6.905	

Where: 0=Immune,1= Resistance, 2= Resistant-Moderately Resistant, 3= Moderately Resistance, 4=Moderately Resistant-Moderately Susceptible, 5= Moderately Susceptible, 6=Moderately Susceptible-Susceptible, 7= Susceptible, 8-9= Very Susceptible

Mean performance of some important agronomic traits: The mean grain yield was observed from 18 bread wheat genotypes across nineteen environments and ranged from 3.30 t/ha to 5.20 t/ha and the highest grain yield was obtained from the check EBW182767while the lowest grain yield was obtained from genotype Alidoro (Table 3). Days to heading ranged from 64.25 days to 76.50 days. Genotype EBW192255 gets headed early within 64.25 days, while genotype Danda'a is headed late within 76.50 days. Variety Danda'a was the tallest (99.7 cm) followed by genotype Alidoro (99.19 cm) and EBW182767 (94.38 cm). On the other hand, genotype EBW192156 (80.53 cm) was the shortest among all. Genotype EBW192154 had high thousand kernel weight (45.17 g) followed by EBW212532 (44.09g), ETBW9089 (42.86g), and EBW192800 (42.42g). The local check Alidoro (31.70g) had a lower thousand kernel weight than other genotypes. Genotype EBW192154 had a high hectoliter weight (74.07 kg/hl) followed by EBW212532 (44.09g), and EBW192800 (73.08 kg/hl). The local check Danda'a (63.96 kg/hl) had a lower hectoliter weight than other genotypes (Table 5).

Reaction to the foremost wheat diseases: The genotypes were planted in hot spot areas Meraro and Debreziet to assess yellow and stem rust diseases. Data was collected from these areas by observing spore severity on leaf surfaces of each genotype for yellow rust and stem rust, respectively. The severity of yellow rust and stem rust was evaluated using the 0-9 scale at Merero and Debreziet hotspots respectively. The genotype's response to field infection was scored twice for stem rust and three times for yellow rust. The study found phenotypic variation in infection types, severity, and reaction response for both yellow rust and stem rust diseases in 14 elite bread wheat genotypes and four standard checks, with response responses ranging from moderately resistant to susceptible for yellow rust and moderately resistant - moderately susceptible to susceptible for stem rust (Table 4). Most of the evaluated genotypes exhibited moderate resistance (MR) to moderately susceptible (MS) reactions. Wheat improvement programs in Ethiopia will use genotypes with high resistance to both rust diseases as disease sources. High-yielding, resistant genotypes will be released as new varieties. Only two genotypes are considered new sources of resistance. The best-performed genotypes with good disease resistance will be released as a new variety. Understanding the genetic basis of rust resistance is crucial for incorporating resistance genes into high-yielding, locally adapted bread wheat cultivars and releasing new rust-resistant varieties for large-scale production.

Among 18 wheat genotypes, three wheat genotypes, EBW192493 was found resistant moderately resistant to yellow rust. EBW212574, EBW202087, EBW192800, EBW192470, EBW192345, EBW192255, EBW192154, and EBW182767 were found to be moderately resistant to moderately resistant- moderately susceptible (MRMS) for yellow rust based on last scoring (Table 4). The final stem rust severity levels were recorded for each genotype when the check was severely rusted and the disease rate reached its maximum level. Only genotypes EBW192345, exhibited moderately resistant-moderately susceptible (MRMS) reactions according to second disease scoring. The EBW212574and EBW202087, genotypes showed moderately susceptiblereactions to stem rust. Finally based on their response to yield, yellow rust, stem rust, and other agronomic traits two genotypes were selected for national performance trials in 2024 (Table 5).

4. CONCLUSION AND RECOMMENDATIONS

Ethiopia is characterized by diverse climatic factors; lowland, midland, and highland wheat growing areas. The country's wheat breeding program prioritizes developing bread wheat varieties adapted to various agro ecologies, aiming for high grain yield, disease resistance, abiotic stress tolerance, and desirable quality. A well-developed new variety should be stable, adaptable, and high-yielding, ensuring its success across diverse environments. Improved crop varieties for commercial cultivation, screening, and testing in various environments are crucial for identifying specific and broad adaptations of potential genotypes. Improving crop varieties' adaptability to changing environments, supported by appropriate management strategies, ensures global crop productivity. So far, several varieties of bread wheat have been released for large-scale production in Ethiopia. The study reveals variations in yield, yield component, and disease resistance for both rusts. The genotypes with the best performance were promoted to the next breeding stage (NPT) for further study and released as new varieties after further testing. The EBW212574 and EBW202087 genotypes, exhibiting moderate resistance to stem rust, were chosen for national performance trials in 2024 based on their response to yield, yellow rust, and other agronomic traits.

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.

DATA AVAILABILITY

Available from the first author upon request.

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COMPETING INTERESTS

The authors have declared that no competing interests exist

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