OPEN ACCESS
Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 04 | Issue 03 | May-June | 2024
Journal homepage: https://gjrpublication.com/gjrals/

Research Article

Registration of bread wheat variety *Kulumsa* for the midlands of Ethiopia

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DOI: 10.5281/zenodo.11412708 **Submission Date:** 18 April 2024 | **Published Date:** 02 June 2024

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Abstract

Bread wheat (*Triticum aestivum L.)* is a crucial crop in Ethiopia, and breeders test newly developed elite lines for superiority to existing cultivars to boost national productivity. Recently, commercial wheat varieties with higher genetic gain for economic traits have been released, which outperform older varieties. One such variety is Kulumsa, which has the pedigree "PFAU/MILAN/5/CHEN/AEGILOPSSQUARROSA(TAUS)/BCN/3/VEE#7/BOW/4/PASTOR/6/2*BAVIS#1/7/BORL14" and selection history "CMSS13B00513S-099M-099NJ-099NJ-15Y-0WGY". It was developed and released by Kulumsa Agricultural Research Center for mid to high altitudes of wheat-growing agroecology of Ethiopia. Kulumsa has higher grain yield performance than the check and has good agronomic characteristics and medium maturing type compared to the current varieties. It consistently out-yielded other tested bread wheat genotypes over two years. Compared to Wane, Danda'a, and Lemu checks, Kulumsa demonstrated significant improvement in agronomic characteristics and enhanced yield by 60%, 62%, and 68%, respectively. Wane (30.2g), Lemu (29.6g), and Danda'a (32.7g) have lower thousand kernel weights than Kulumsa (39.6g). Kulumsa had a 31%, 21%, and 34% thousand kernel weight advantage over Wane, Danda'a, and Lemu, respectively. The new variety has a better hectoliter weight than Wane, Lemu, and Danda'a by 18%, 13%, and 11%, respectively. The newly released bread wheat varieties are moderately resistant to stem rust, and yellow rust, and comparable for leaf rust disease and Septoria with the checks Wane, Danda'a, and Lemu. Kulumsa proved to be more resistant to stem yellow and leaf rust than all currently produced varieties in the mid to high-land part of wheat-growing agroecology. It offers new hope for farmers of Ethiopia and has a white grain color with good general acceptance for bread with high quality.

Keywords: Enhanced yield, Hectoliter weight, Kulumsa variety, Newly released, Moderately resistance.

1. Introductions

Bread wheat (Triticum aestivum L.) is a crucial crop for global food security, as it can be grown in different climates and soil types around the world [1]. It is the most widely produced crop on the planet [2, 3], the most critical food source [3-6], and is consumed by more than one-third of the world's population [7]. Wheat provides almost 20% of the world's calories [8], and daily proteins to 4.5 billion people worldwide [9-11]. Wheat provides more food worldwide compared to other food crops [12, 13]. Its popularity is attributed to the vast range of culinary products it can be used in, which has led to its cultivation in non-traditional areas where it was not previously grown [12, 14]. It is also the most traded grain in the world, but there is a significant imbalance between supply and demand [3].

Due to the complexity of its genome, wheat can adapt to a wide range of environmental conditions, making it an incredibly adaptable crop [15]. Wheat is an important crop in Ethiopia due to its potential and diverse agroecologies for cultivation [16, 17]. Wheat can grow in the highlands of Ethiopia at altitudes ranging from 1500 to 3000 m.a.s.l. [17, 19].

The most suitable elevation zones of wheat lie between 1900 and 2700 m.a.s.l. [17, 20-22]. Bale and Arsi, Hadiya and Kenbata, East Gojam, and North Shoa are the main wheat-producing regions of Ethiopia [23, 24].

Breeders are constantly working to improve the yield and quality of grains. They focus on aspects such as bread-making quality, seed color, seed size, protein content, and resistance to biotic and abiotic stresses. When breeders develop a new variety, they test it for yield performance at multiple locations. The success of releasing new wheat varieties depends on their grain quantity and quality, as well as their adaptation potential in the target areas. Continuous improvement of new varieties that are heat- and drought-tolerant, as well as biotic resistant, presents an interesting opportunity to address issues related to climate change and water crisis [25-27]. However, biological stressors like wheat rust pose a significant challenge, as they are continually evolving and evading the protective features of the plants. Ultimately, cultivars with high and stable yields are preferred by farmers and breeders alike.

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 [3]. The growth of the population and changing consumer demands are driving the agricultural production systems [28]. To meet the growing demand for food, especially in developing countries, wheat yields must continue to increase over the next few decades as arable land area will not increase beyond current levels [29]. Therefore, progress in wheat yields is essential. In Ethiopia, bread wheat improvement can be achieved by evaluating high-yielding and rust-resistant genotypes in multi-environment trials [30]. To overcome the obstacles that hinder the wheat sector and increase output and productivity, it is crucial to improve possibilities and reduce obstacles [19]. This study examines the overall performance of the newly developed bread wheat variety Kulumsa, which has the potential to play a key role in fulfilling the country's wheat production needs and meet the growing demand for wheat.

2. Materials and Methods

Breeding Material

In 2019, a new variety of bread wheat was chosen from the germplasm obtained from CIMMYT in Mexico. This variety was named 'Kulumsa' and was found to have excellent grain yield potential. It was promoted to national variety trials and evaluated alongside 87 other wheat lines and three checks: 'Danda'a', 'Wane', and 'Lemu' for two consecutive years in 2020 and 2021. During this time, 'Kulumsa' was screened for multiple wheat diseases, including rust resistance, at hotspot locations in Ethiopia, and was found to be highly resistant to these diseases.

After being tested for yield potential, agronomic traits, and ideal genotype under various climatic conditions, 'Kulumsa' was selected as the best genotype evaluated under national variety trials. It was then advanced to the variety verification trial in 2022, and ultimately released for wide cultivation as a high-yielding, lodging-resistant, and disease-tolerant cultivar based on its distinctness, uniformity, and stability (DUS) characteristics in Ethiopia.

Experimental sites, design, and layout

The testing locations, include Kulumsa, Asasa, Bekoji, Arsi-Robe, Sinana, Holeta, Debra Markos, and Debre Zeit (Table 1) used for two consecutive years, 2020 and 2021. The trial was carried out using a randomized complete block design (RCBD) laid out in a rectangular (row x column) array of plots with two replications. In row-column designs the experimental units were grouped in two directions, i.e., two blocking factors were used with one factor representing the rows and the other factor representing the columns of the design. Each genotype was planted on six rows of 2.5m long in 20cm between rows spacing. The trial included in this study with the respective row, column, and genotypes in each trial (Table 1).

Two candidate genotypes were chosen and put in a variety verification trial, with two checks at the locations indicated under Table 1, both on-station and on farmer fields. The trial was carried out at two on-farm sites at each location. The National Variety Verification Technical Committee evaluated the trials and granted *Kulumsa* (BW192346) the committee's approval for release.

Table 1: List of Test Environments, number of genotyped used, and Geographic information of the testing sites.

Sites	Environment	No Genotypes	Row	Column	No Rep	Latitude	Longitude	Altitude (m asl)
Arsi Robe	20BWNL1RA	90	18	10	2	07º53'02"N	39º37'40"E	2420
Arsi Robe	20BWNL2RA	90	18	10	2	07º53'02"N	39º37'40"E	2420
Asasa	20BWNL1AA	90	18	10	2	07º07'09"N	39º11'50"E	2340
Asasa	20BWNL2AA	90	18	10	2	07º07'09"N	39º11'50"E	2340
Bekoji	20BWNL2BE	90	18	10	2	07º32'37"N	39º15'21"E	2780
Bekoji	20BWNL1BE	90	18	10	2	07º32'37"N	39º15'21"E	2780
Dabre Markos	20BWNL1DM	90	18	10	2	10° 19′59″N	37°44′53″E	2450

Dabre Markos	20BWNL2DM	90	18	10	2	10° 19′59″N	37°44′53″E	2450
Dabre Zeit	20BWNL1DZ	90	18	10	2	08°38'N	38°30'E	1900
Dabre Zeit	20BWNL2DZ	90	18	10	2	08°38'N	38°30'E	1900
Holeta	20BWNL1HL	90	18	10	2	09°03′41″N	38°30′44″E	2400
Holeta	20BWNL2HL	90	18	10	2	09°03′41″N	38°30′44″E	2400
Kulumsa	20BWNL1KU	90	18	10	2	08º01'10"N	39º09'11"E	2200
Kulumsa	20BWNL2KU	90	18	10	2	08º01'10"N	39º09'11"E	2200
Sinana	20BWNL1SN	90	18	10	2	7°7’N	39°49'E	2450
Sinana	20BWNL2SN	90	18	10	2	7°7’N	39°49'E	2450

Statistical analysis

In multi-environment trial (MET) data analysis, there are many possible forms of genetic variance matrix structures using linear mixed model and the standard structure. This implies that all environments have constant genetic variance, and all pair of environments have the same genetic covariance [31]. because of inefficient estimation, consider an alternative variance structure model which is known as Factor Analytic model which is analogous of AMMI model. In addition, this model captures the nature of heterogeneous variance covariance structures. While fitting linear mixed model in this study, spatial field trend fitted first for each environment and tested for the potential existence of field trend between the neighbor plots. Trial across environments is combined keeping their specific trial information like spatial field trend and included in a linear mixed model through factor analytic model. The comparison of means was carried out using the BLUP predictors (best linear unbiased prediction) that represent the predicted value for each genotype with respect to the general mean [32]. The BLUP pair grain yields were ordered in descending order to identify superior genotypes. This methodology allowed comparing free genetic values of environmental effects and not the phenotypic means to improve genetic gain in the subsequent selection cycle.

3. RESULT SUMMARY

3.1 Varietal Evaluations and Yield Performance

There were significant differences in grain yield among different types of bread wheat that were tested in various conditions. This suggests that there may be some genotypes that perform better than others. The average grain yield of 'Kulumsa' was 4.45 t/ha across 16 environments, while the lowest yield was EBW120052 at 1.29 t/ha (as shown in (Fig 1). 'Kulumsa' proved to have superior and stable yield under recommended planting conditions in various locations throughout Ethiopia over two years (as shown in Fig 2). Except for 2020 Bekoji, 2020 Debre Markos, 2020 Kulumsa, and 2021 Debre Markos, 'Kulumsa' outperformed standard checks in grain yield and had broad adaptation (as shown in Fig 2). The improved yield advantage of new varieties over old cultivars is a result of breeding research. It's important to increase crop yields to ensure food security for the growing population. Achieving significant genetic gains through breeding is crucial in accomplishing this.

A new variety called Kulumsa has been released. Its pedigree includes PFAU/MILAN/5/CHEN/AEGILOPS SQUARROSA (TAUS)/BCN/3/VEE#7/ BOW/4/ PASTOR/6/2*BAVIS #1/7/BORL14 and it was developed using germplasm from CIMMYT. During the 2020-2021 national variety trial, Kulumsa was tested alongside other varieties such as Wane, Danda'a, and Lemu. Kulumsa demonstrated significantly better agronomic characteristics and yielded 60%, 62%, and 68% more than Wane, Danda'a, and Lemu, respectively (see Fig 3).

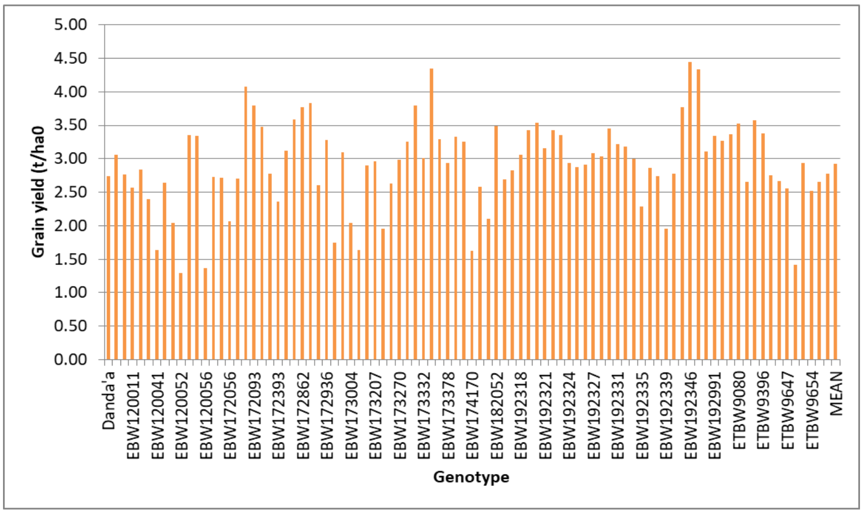

Figure 1: Mean grain yield of tested genotypes

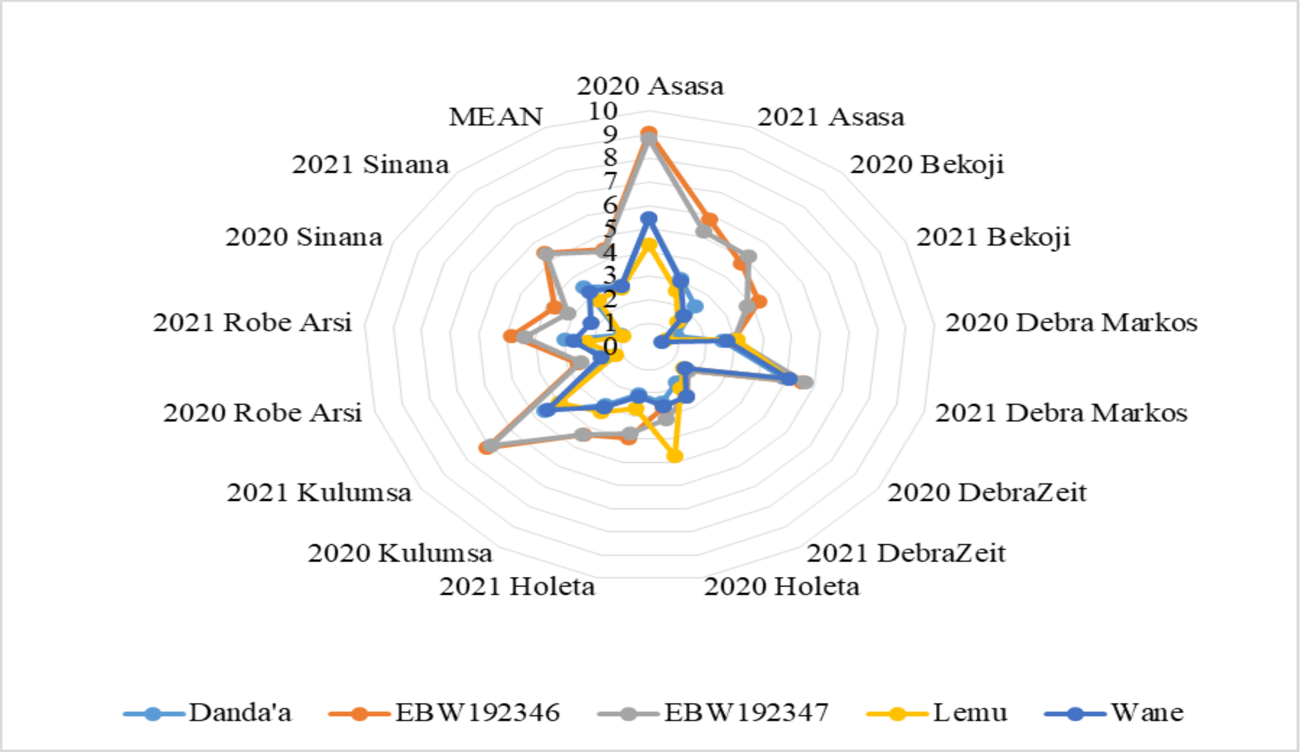

Figure 2: Mean performance of *Kulumsa*, EBW192347, Wane, Lemu, and Danda'a in tested environments

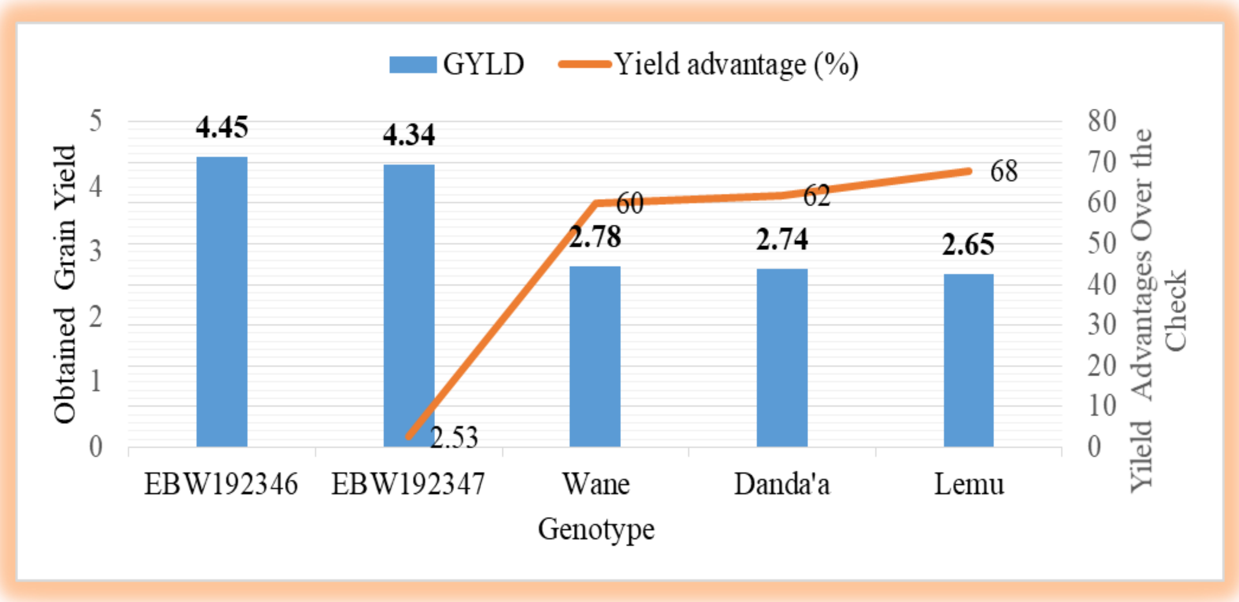

Figure 3: Yield advantages of Kulumsa (EBW192346) over the checks and the other candidate

3.2 Stability Analysis

Table 2 presents the parameter estimates for the genetic variance component, ranging from 0.013 to 3.024, and for the error variance, ranging from 0.072 to 0.37. Apart from five trials, genetic variance in yield was higher in all other trials. This suggests that the test sites had a strong genotype discrimination. Specifically, in five of the sixteen experiments, namely 20BWNL1AA, 20BWNL1BE, 20BWNL1HL, 20BWNL2SN, and 20BWNL2KU, the genetic variance in yield was notably higher.

The component analysis revealed the clustering of studies based on genetic relatedness using dendrogram, as shown in Figure 4. Three clusters of related environments were identified, influencing the selection of important wheat genotypes in each cluster. Genotype selection was done independently for each cluster, using mean BLUP values as a selection indicator. Correlations between environments ranged between -1 and 1. A correlation of +1 meant a perfect correlation between the two environments. The heatmap showed that most experiments were well connected (Figure 5). Genotype selection could be done by calculating genotype averages in almost all experiments of the first red cluster.

Table 2: Variance component results MET analysis using spatial and FA models

Environments	Mean GYLD	Genetic Variance	Error Variance
20BWNL1AA	5.64	3.024	0.294
20BWNL1BE	2.131	1.327	0.266
20BWNL1DM	2.77	0.133	0.37
20BWNL1DZ	1.58	0.013	0.109
20BWNL1HL	2.541	1.057	0.167
20BWNL1KU	3.176	0.502	0.213
20BWNL1RA	1.557	0.299	0.105
20BWNL1SN	1.768	0.783	0.118
20BWNL2AA	3.424	0.811	0.122
20BWNL2BE	1.268	0.801	0.072
20BWNL2DM	5.16	0.116	0.223
20BWNL2DZ	2.187	0.127	0.175
20BWNL2HL	2.4	0.772	0.11
20BWNL2KU	4.76	1.493	0.186
20BWNL2RA	3.006	0.848	0.245
20BWNL2SN	3.411	1.322	0.173

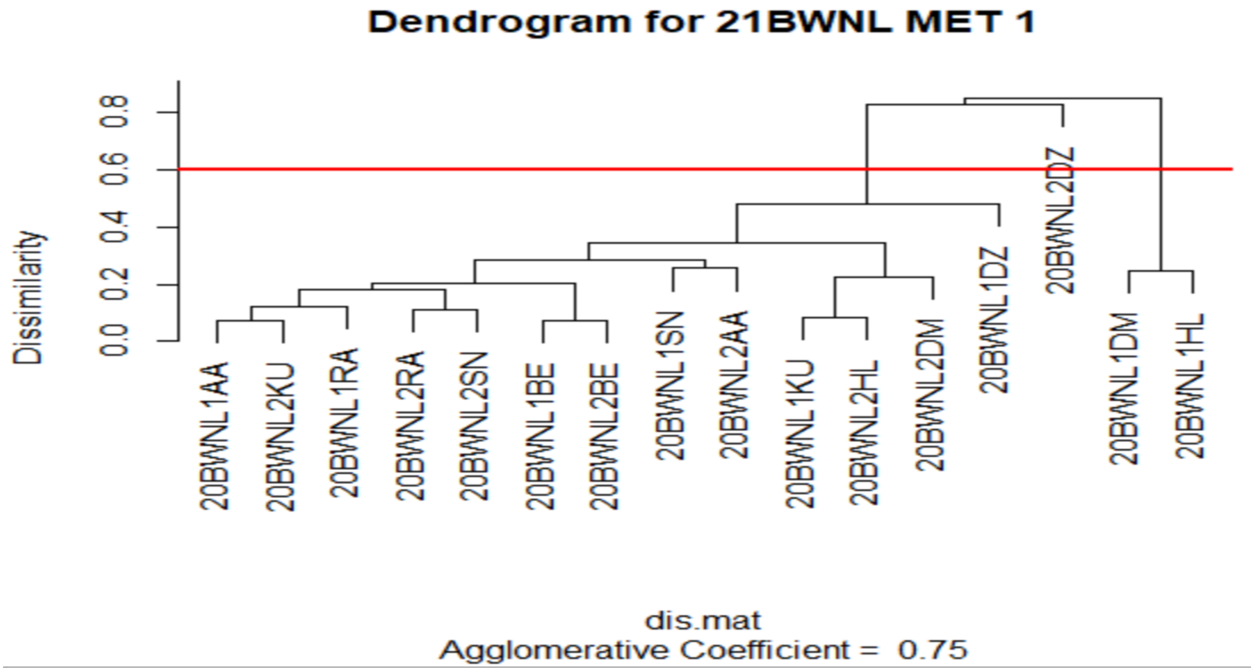

Figure 4. Dendrogram of the dissimilarity matrix

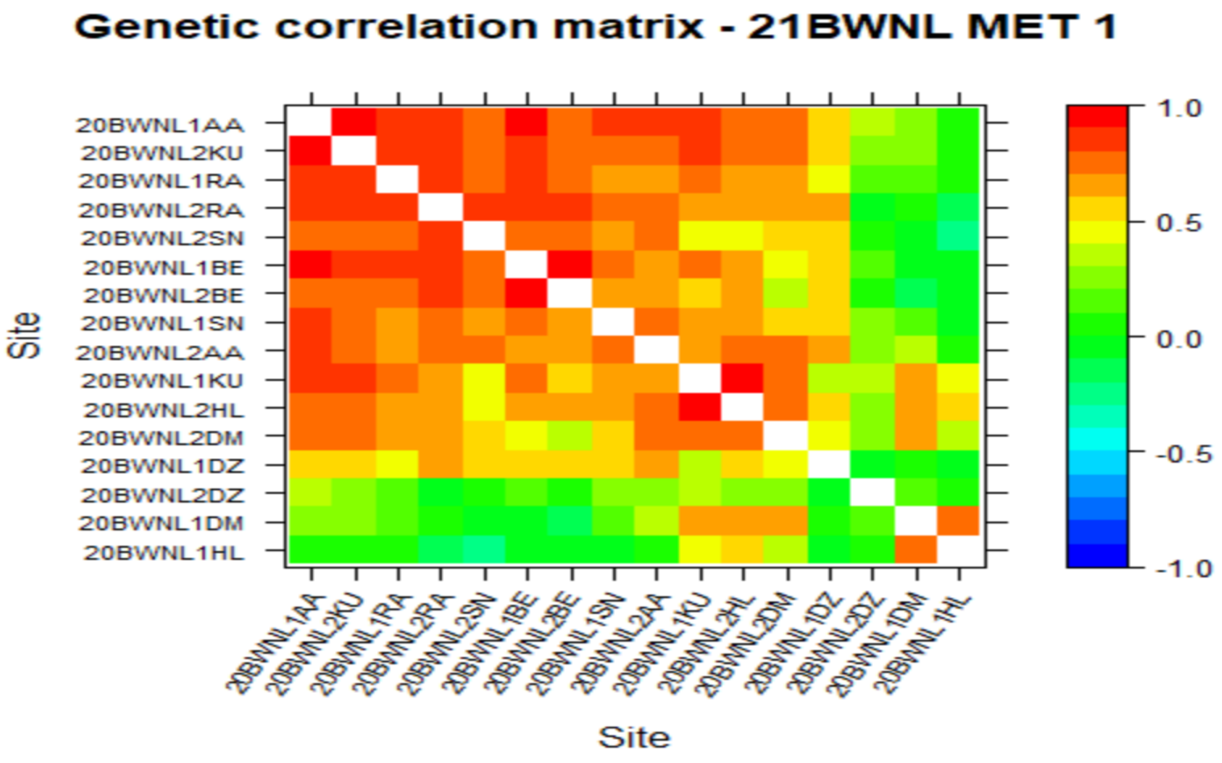

Figure 5. Heat map representation of the genetic correlation matrix

3.3 Agronomic and Morphological Characteristics of *Kulumsa* variety

The Kulumsa variety stands out from the other three checks due to its larger grains. The thousand kernel weight (TKW) for Wane, Lemu, and Danda'a were lower than that of Kulumsa (Table 3). Kulumsa had a significant advantage over the other varieties, with a 31%, 21%, and 34% advantage in TKW over Wane (G90), Danda’a (G1), and Lemu (G89), respectively. Additionally, Kulumsa had higher hectoliter weight (HLW) than the other varieties, including Wane (G90), Danda’a (G1), and Lemu (G89), as shown in Table 3. In comparison to the other varieties, Kulumsa had plump seeds that outperformed Wane (G90), Lemu (G89), and Danda’a (G1) in terms of HLW by 18%, 13%, and 11%, respectively.

The Kulumsa variety also has desirable plant architecture, with an average plant height of 86.6 cm, 66 days to heading, and 129 days to maturity. It has a high plant density, good tillering ability, resistance to lodging, an erect growth habit, large ears, amber seeds, deep green color at the vegetative stage, and other desirable traits.

Table 3: **Mean performance of some important agronomic traits of genotypes tested across 8 locations in 2020 and 2021 cropping season**

SN	**Entry**	**Genotype**	**Days to heading (days)**	**Days to maturity (days)**	**Plant height (cm)**	**Thousand kernel weight (g)**	**Hectoliter weight (kg/hl)**
1	G1	Danda'a	**71.00**	**133.00**	**92.00**	**32.70**	**72.40**
2	G2	EBW120002	69.00	130.00	88.00	30.00	73.10
3	G3	EBW120004	70.00	130.00	94.00	28.10	73.40
4	G4	EBW120011	70.00	128.00	88.00	27.60	70.70
5	G5	EBW120014	63.00	125.00	85.00	34.40	73.60
6	G6	EBW120039	69.00	128.00	87.00	26.70	69.30
7	G7	EBW120041	71.00	135.00	91.00	22.60	58.90
8	G8	EBW120042	73.00	139.00	98.00	32.10	71.60
9	G9	EBW120044	66.00	138.00	92.00	30.50	67.40
10	G10	EBW120052	68.00	127.00	87.00	22.90	59.70
11	G11	EBW120053	68.00	130.00	90.00	35.00	72.50
12	G12	EBW120054	70.00	132.00	91.00	37.50	74.40
13	G13	EBW120056	78.00	133.00	87.00	25.00	60.30

14	G14	EBW120060	67.00	135.00	93.00	28.90	69.00
15	G15	EBW120063	64.00	128.00	94.00	33.70	77.70
16	G16	EBW172056	60.00	124.00	83.00	26.00	65.40
17	G17	EBW172082	66.00	127.00	85.00	30.20	75.70
18	G18	EBW172088	66.00	124.00	84.00	36.50	79.70
19	G19	EBW172093	65.00	125.00	86.00	38.40	80.30
20	G20	EBW172105	65.00	125.00	90.00	36.40	75.30
21	G21	EBW172319	63.00	127.00	81.00	30.70	67.80
22	G22	EBW172393	67.00	129.00	84.00	29.50	75.90
23	G23	EBW172440	68.00	128.00	88.00	34.40	77.20
24	G24	EBW172474	67.00	127.00	81.00	30.50	75.80
25	G25	EBW172862	66.00	125.00	86.00	39.50	80.00
26	G26	EBW172864	68.00	127.00	87.00	39.10	80.00
27	G27	EBW172872	69.00	129.00	85.00	29.20	73.10
28	G28	EBW172936	69.00	126.00	87.00	35.20	79.60
29	G29	EBW172996	69.00	126.00	87.00	24.60	65.00
30	G30	EBW173001	65.00	128.00	87.00	33.30	76.90
31	G31	EBW173004	68.00	127.00	86.00	28.00	78.10
32	G32	EBW173006	68.00	125.00	85.00	26.70	72.50
33	G33	EBW173031	69.00	126.00	90.00	29.90	78.00
34	G34	EBW173207	65.00	126.00	85.00	31.10	76.70
35	G35	EBW173261	65.00	123.00	80.00	26.30	69.70
36	G36	EBW173263	65.00	125.00	86.00	31.40	81.70
37	G37	EBW173270	67.00	129.00	85.00	33.80	73.60
38	G38	EBW173288	64.00	128.00	86.00	33.50	71.80
39	G39	EBW173292	68.00	132.00	86.00	35.80	74.70
40	G40	EBW173332	65.00	125.00	85.00	30.70	76.80
41	G41	EBW173353	64.00	126.00	87.00	39.10	81.90
42	G42	EBW173366	66.00	130.00	86.00	31.00	71.20
43	G43	EBW173378	65.00	125.00	84.00	34.50	72.70
44	G44	EBW173380	67.00	127.00	89.00	33.30	72.40
45	G45	EBW174116	64.00	123.00	82.00	30.20	74.60
46	G46	EBW174170	68.00	124.00	80.00	26.10	72.70
47	G47	EBW174187	64.00	126.00	83.00	31.70	77.40
48	G48	EBW174456	65.00	125.00	83.00	27.60	74.70
49	G49	EBW182052	65.00	123.00	85.00	37.20	83.40
50	G50	EBW182122	67.00	127.00	86.00	30.60	76.60
51	G51	EBW182146	68.00	124.00	90.00	29.10	76.20
52	G52	EBW192318	62.00	125.00	82.00	34.20	78.80
53	G53	EBW192319	67.00	129.00	84.00	33.70	73.90
54	G54	EBW192320	68.00	132.00	87.00	30.90	72.50
55	G55	EBW192321	67.00	129.00	85.00	33.50	75.70
56	G56	EBW192322	68.00	129.00	87.00	35.10	79.10
57	G57	EBW192323	69.00	131.00	87.00	35.10	82.00
58	G58	EBW192324	70.00	129.00	82.00	34.60	77.70
59	G59	EBW192325	70.00	129.00	82.00	31.50	79.20
60	G60	EBW192326	70.00	128.00	82.00	30.90	78.70
61	G61	EBW192327	68.00	128.00	83.00	35.10	81.80
62	G62	EBW192328	67.00	128.00	83.00	32.80	78.80
63	G63	EBW192330	66.00	130.00	86.00	32.90	73.20
64	G64	EBW192331	70.00	127.00	81.00	35.50	80.00
65	G65	EBW192332	67.00	128.00	83.00	34.90	78.50
66	G66	EBW192333	69.00	127.00	82.00	36.10	76.50
67	G67	EBW192335	68.00	125.00	79.00	27.90	71.30
68	G68	EBW192336	65.00	126.00	84.00	28.80	66.30
69	G69	EBW192337	65.00	126.00	85.00	27.80	68.90
70	G70	EBW192339	67.00	128.00	84.00	26.20	64.50
71	G71	EBW192341	65.00	127.00	87.00	30.80	70.00

72	G72	EBW192343	68.00	125.00	88.00	40.70	79.60
73	G73	EBW192346	66.00	129.00	87.00	39.60	80.10
74	G74	EBW192347	68.00	129.00	83.00	39.00	78.70
75	G75	EBW192348	66.00	127.00	83.00	33.90	81.20
76	G76	EBW192991	66.00	127.00	85.00	38.10	75.30
77	G77	EBW192992	65.00	125.00	83.00	33.60	72.20
78	G78	ETBW9077	65.00	123.00	84.00	36.70	86.20
79	G79	ETBW9080	66.00	125.00	91.00	39.20	74.40
80	G80	ETBW9128	67.00	128.00	84.00	30.00	74.20
81	G81	ETBW9136	67.00	126.00	88.00	36.40	78.70
82	G82	ETBW9396	66.00	126.00	84.00	29.20	79.20
83	G83	ETBW9452	66.00	126.00	84.00	33.40	75.10
84	G84	ETBW9642	66.00	127.00	87.00	31.60	68.80
85	G85	ETBW9647	67.00	126.00	87.00	33.20	70.40
86	G86	ETBW9648	67.00	128.00	84.00	21.70	55.50
87	G87	ETBW9650	67.00	127.00	86.00	32.60	73.30
88	G88	ETBW9654	68.00	125.00	85.00	29.20	73.50
89	G89	Lemu	72.00	133.00	86.00	29.60	71.10
90	G90	Wane	64.00	126.00	88.00	30.20	68.00
		Mean	**67.00**	**128.00**	**86.00**	**32.10**	**74.90**

3.4 Quality of *Kulumsa* Variety

Improving the quality of wheat has always been a top priority in wheat breeding, in addition to achieving higher yields [33]. Wheat breeders evaluate various quality parameters such as protein content, grain weight, grain hardness, grain wetness, grain hardiness index, and grain diameter for advanced wheat genotypes. The recently released Kulumsa variety has a protein content that is comparable to that of Lemu and higher than that of Danda'a and Wane. Kulumsa's grain weight, grain hardness, and grain diameter were measured to be 39.18, 68.07, and 2.83 respectively, as shown in Table 4.

Table 3. Some quality traits for newly released variety and checks

Parameter	Danda'a	Kulumsa	EBW192347	Wane	Lemu
Grain Weight (mg)	28.26	39.18	37.34	31.4	26.03
Grain Hardiness Index %	71.31	68.07	69.39	60.48	64.6
Grain Moisture %	8.65	10.44	10.47	10.65	9.11
Grain Diameter %	2.58	2.83	2.77	2.55	2.44
Grain Hardiness Class	Hard	Hard	Hard	Hard	Hard
Protein Contents %	13.69	14.07	14.08	13.6	14.07

3.5 Disease Resistance of the Kulumsa variety

Pests can cause significant yield losses, which is a major obstacle to achieving higher crop yields [8]. There are around 200 known diseases and pests that affect wheat, but only about 50 of them are relevant in the world's major wheat-growing regions. Fungal diseases are the most damaging to wheat, and they can seriously hinder wheat production. Disease resistance is one of the key factors that can be improved to maintain wheat yield potential on farms. Recently developed bread wheat varieties have shown comparable resistance to leaf rust and Septoria as Danda'a, but only moderate resistance to stem rust and yellow rust (Table 5). The current commercial bread wheat cultivars in the highlands are susceptible to yellow rust, but the newly released Kulumsa has shown high levels of yellow rust resistance and moderate resistance to stem rust. Therefore, the development of new rust-resistant varieties will provide excellent opportunities for wheat producers in areas with limited resources.

Table 4: Disease summary for newly released variety and checks

Diseases	Kulumsa	EBW192347	Wane	Danda'a	Lemu
Stem rust (%+ reaction)	5MR	5R	50S	40S	50S
Yellow rust (%+reaction)	10MR	20MRMS	40S	50S	80S
Leaf rust (%+ reaction)	0	0	0	0	0
Septoria (00-99)	54	78	77	56	73

3.6 Variety maintenance

Seed maintenance involves creating new lots of breeder seeds with the same genetic makeup as the original variety. Once a variety is released to the public, it is the breeder's responsibility to preserve it. This is done by growing wheat plants that accurately represent the variety in ear-rows under close supervision. Plants from specific rows are collected and grown in small plots known as row plots. Therefore, it is the responsibility of the wheat breeder at Kulumsa Agriculture Research Center to maintain the variety.

4. Conclusion

Ensuring sufficient food production in developing countries, amidst rapid population growth, extensive food scarcity, malnutrition, and depletion of natural resources, remains a crucial challenge for the future. To address this, it is necessary to intensify crop production by adopting innovative methods, such as developing better crop varieties that are suited to varying agroecological conditions and socioeconomic contexts. In a crop improvement program, the ultimate goal of plant breeders is to create cultivars or varieties that can adapt to a diverse range of environments. The adaptability of a variety is typically tested by analyzing its interaction with different environments. A variety or genotype is considered to be more stable and adaptive if it has a high average yield and low levels of fluctuation in yield when grown across diverse environments. Farmers need reliable wheat varieties that can provide good yields and withstand climate shocks, diseases, and stress. The most challenging wheat diseases are stem, yellow, and leaf rust. Kulumsa is a new variety that offers hope to farmers in Ethiopia's rust-prone regions and is expected to replace susceptible cultivars in highland and midland agroecological zones.

Acknowledgments

For financial assistance, we are grateful to the Kulumsa Agricultural Research Center (KARC) of Ethiopian Institutes of Agricultural Research (EIAR), specifically the Bread wheat breeding program and AGGW for financial support.

5. Reference

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CITATION

Gadisa Alemu, Negash G., Alemu D., Berhanu S., Ruth D., Abebe D., Demeke Z., Cherinet K., Tafesse S., Habtemariam Z., Abebe G., Dawit A., Bayisa A., Bekele A., Ayele B., & Tilahun B. (2024). Registration of bread wheat variety Kulumsa for the midlands of Ethiopia. In Global Journal of Research in Agriculture & Life Sciences (Vol. 4, Number 3, pp. 15–24). https://doi.org/10.5281/zenodo.11412708