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Original Research Article

Bread Wheat (*Triticum aestivum* L.) Variety Development, Release and Registration for Rainfed Areas of Ethiopia

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Abstract

A strong variety development is the backbone of a well-established national seed program and identification of high-yielding genotypes with wide adaptation and resistance to biotic and abiotic stresses remain the top priorities of the wheat breeding programs. Over the years of research on bread wheat, commendable achievements have been made in the generation of technologies and information useful for boosting the productivity and production of wheat in Ethiopia. Five improved bread wheat varieties; Deka, Balcha, Boru, Dursa, Shaki, Biftu and kulumsa were developed from CIMMYT materials and released in 2018, 2019, 2020, 2020, 2021, 2022 and 2023 respectively for wheat growing areas of Ethiopia. In addition, one improved bread wheat variety (Abay) has been released in 2021 from ICARDA materials for low-midland agro-ecologies. In these varietal development two breeding components (germplasm enhancements (hybridization and selection, introduction, evaluation, and selection) and varietal development (ON, PVT, NVT, and VVT) were considered. The new variety Deka was tested along with three checks (Ogolcho, Hawi, and Kingbird) in eight environments from 2015-2016 and Balcha from 2016-2017 with Ogolcho and Kakaba in eight environments. During the 2017-2018 main cropping season newly released bread wheat varieties Boru (with Wane and Hidasse) and Dursa (with Ogolcho and Kakaba) were tested at eleven locations and four locations respectively. Also, Abay was tested with Deka and Ogolcho as a check, and Shaki was tested with Wane and Lemu during the 2018-2019 cropping season. The two years of data of NVT combined over locations and years provide the newly released varieties showed superior grain yield performance, stability, and wide adaptation. The six newly released varieties have been demonstrated and are being cultivated by farmers for production purposes. Hence, the cultivation of newly released improved bread wheat varieties Balcha, Dursa, and Abay in the low- midland agro-ecologies, Deka in the midland while, Boru and Shaki in mid-highland wheat-growing agro-ecologies.

Keywords: *Agro-ecologies, Bread wheat, Improved, moderately resistant, newly released, Variety development.*

1. Introduction

Bread wheat (*Triticum aestivum* L.) is widely cultivated all over the world as a staple food (Huerta-Espino et al.,2020, Admikew and Afework, 2021). Annually about 772.6 million tons of bread wheat, were produced in the world (Statista., 2021). Globally, China, India, and Russia are the three largest individual wheat producers in the world, accounting for about 41% of the world's total wheat production while, in Sub-Saharan Africa, Ethiopia is the primary wheat producer owing to the suitable agro-ecological conditions (Nigus et al., 2022). Currently, in Ethiopia wheat is produced on a total area of 2.1 mha of land with a total production of 6.7 mt with average productivity of 3 t ha-1 and 4 t ha-1 under rain-fed and irrigation conditions, respectively (Hodson et al., 2020, CSA, 2022, Tadesse et al., 2022) which is relatively lower than the attainable yield of the crop, reaching up to 5 t ha−1 (Zegeye et al., 2020). On the other hand, the Ethiopian government is determined to fill the demand gap through the production of wheat during the off-season in existing

environments by using irrigation and expansion of wheat production in nontraditional wheat growing areas especially in lowlands (Abebe et al., 2023).

Wheat is one of the three most consumed cereal crops in the world, along with rice and corn (Belete et al., 2020), and a relevant source of nutrients for the population (Hazard et al., 2020, Hossain et al., 2021). It is a staple source of nutrients for around 40% of the world's population (Acevedo et al., 2018, Giraldo et al., 2019; Kheseli et al., 2021, Aliyi et al.,2022) and it occupies a central place in human nutrition providing 20% of the daily protein and food calories (Braun et al., 2010; Shiferaw et al.,2013, Enghiad et al., 2017). Wheat is also rich in fiber, vitamins, and minerals (Kumar et al., 2011, Shewry and Hey, 2015, Biel et al., 2020). It is also a source of cash for smallholder farmers (Bergh et al., 2012).

In Ethiopia, wheat production and productivity are affected by complex and interactive effects of biotic and abiotic factors and socio-economic challenges. Wheat rust diseases, notably stem and stripe rust, are the most important biotic constraints to wheat production in Ethiopia (Ayele et al., 2008, Singh et al., 2016), a lack of backward agronomic practices, use of marginal agricultural land, and terminal drought stress, among others (Belay and Araya 2015, Hei et al., 2017, Semahegn et al., 2021) and erratic rainfall pattern, low soil fertility, high temperature are some of the abiotic yield-limiting factors in wheat (Husnu et al., 2010, Kılıc et al., 2010). The occurrence and relative importance of these constraints vary in different agroecologies, and farmers may perceive them differently, which affects the wheat breeding goals and hence varietal choices and adoption. The national wheat research program continued to support countries by releasing new high-yield and resistant wheat varieties in Ethiopia to help overcome the increasing threat of recurring rust epidemic in the country and help rehabilitate the agricultural sector. Of course, the program is able to release more than 100 wheat varieties for different agro-ecologies of Ethiopia in five decades of concerted research efforts & endeavors (Tadesse et al., 2022). However, majority of these varieties are becoming susceptible to rust diseases and put out of production in a few years of their release. Because, yellow and stem rusts epidemics have frequently occurred in Ethiopia (Solh et al., 2012, Singh et al., 2015, Hei et al., 2018, Tolemariam et al., 2018, Meyer et al., 2021). Thus, the target of this research was to evaluate, develop, and release of best-adapted wheat varieties for rainfed areas of Ethiopia.

2. Material and Method

Breeding Material, Experimental Site, and Field Experiment

The national wheat research coordinating center requests international wheat nurseries from CIMMYT and ICARDA to undertake their crossing programs and subsequent evaluation of the segregating generations (F2-F6) and grows the nurseries for further evaluation and selection either direct release or parental purposes. Fixed germplasm obtained from the international centers or the national programs was evaluated across locations in observation nursery (ON) and preliminary yield trial (PYT) for one year followed by national variety trials (NVT) across locations for two years and finally best genotypes were evaluated in VVT for release. So initially, more than 2000 bread wheat genotypes were received from CIMMYT and ICARDA and evaluated under field conditions in augmented and alpha lattice design under a quarantine site. The best promising genotypes were selected based on maturity, and diseases and advanced to preliminary yield trials for further test.

In 2015-2016 twenty-four genotypes and 2016-2017 fifteen genotypes selected from preliminary yield trials were evaluated using alpha lattice design and RCBD respectively at eight locations for two years. During this time, agronomic data was collected on a plot base. Out of 24 bread wheat tested, two promising bread wheat genotypes were selected and promoted to a variety of verification trials trial and also from fifteen bread wheat genotypes two best promising bread wheat candidates were identified for a variety of verification trials for the final release. Similarly, sixty bread wheat genotypes were tested under national variety trials for low land wheat growing areas (30 genotypes) and for mid to high land wheat growing areas (30 genotypes) of Ethiopia for two years (2017-2018). Out of these genotypes, four bread wheat genotypes were selected and advanced to variety verification trials (two for early set and two for mid to high land). Additionally, 25 bread wheat genotypes were tested at four locations for early set and 25 genotypes for mid to high land agro-ecologies for two consecutive years (2018 - 2019) using alpha lattice design with three replications. Out of these genotypes, four bread wheat genotypes were selected and advanced to variety verification trials (two for early set and two for mid to high land). Finally, the most promising candidate varieties were evaluated along with standard checks on 10 m x 10 m (1002) plots by the National Variety Releasing Committee at their respective locations in 2017, 2018, 2019, and 2020, respectively at the grain-filling stage for resistance to diseases, maturity, yield potential, and farmers' preference. After the technical committee reports its assessment to the national variety release committee which decides to release tested genotypes under variety verification trials were been released fully six improved bread wheat varieties for the lowland, highland, and mid-altitude areas of wheat growing regions of Ethiopia.

Table 1. Testing location for national variety trials and Variety Verifications trials 2015/2016-2020/2021 under different sets

Location	Geographic position		Altitude	Rainfall (mm)
	Latitude	Longitude		
A.Nagele	7°21′N	38°42′E	2043	750
A.Robe	07º53'02"N	39º37'40"E	2420	890
A.Tena	08°.30N	38°.95E	1611	728
Adet	11° 16’ N	37° 29’ E	2216	1250
Areka	7°3′25" N	37°40'52" E	2230	1290
Asasa	07º07'09"N	39º11'50"E	2340	644
Bekoji	07º32'37"N	39º15'21"E	2780	1020
Debre Zeit	08° 44’ N	38° 58’ E	1900	851
Dhera	08º19'10"N	39º19'13"E	1650	680
Enawari	9°53'00.0"N	39°09'00.0"E	2650	878
Halaba	7.4933° N	38.1900° E	1726	900
Haramaya Un.	9.4083° N	42.0345° E	2047	800.9
Holeta	09°03′41″N	38°30′44″E	2400	1044
Kulumsa	08º01'10"N	39º09'11"E	2200	820
Melkasa	08°.24'N	39°.12'E	1550	763
Shambu	9° 34′ 0″ N	37° 6′ 0″ E	2503	-

3. Result and Discussion

After the technical committee reports its assessment to the national variety release committee which decides to release tested genotypes under variety verification trials from twelve candidate genotypes six genotypes were released as new varieties. As Laidig et al., (2017) reported before the new variety release evaluation of advanced lines across locations and over the year is important to access its adaptability and stability performance for important traits of yield and yield components as supported (Friedrich et al., 2017).

3.1. Varietal Characteristics

3.1.1. Deka

Deka is a commercial name given for a newly released bread wheat variety with the pedigree name ATTILA/3*BCN*2//BAV92/3/KIRITATI/WBLL1/4/DANPHE which originated from CIMMTY. It was evaluated and released by the Kulumsa Agricultural Research Center for low to mid-altitude wheat-growing agroecology in Ethiopia. The variety showed higher grain yield performance than the check and it has good agronomic characteristics. These newly-released bread wheat varieties are moderately resistant to stem rust, and yellow rust and comparable for leaf rust disease and Septoria with the standard checks Kingbird and Ogolcho) and local check Hawi. Deka was released for low – midland agro-ecologies but, it shows the best performance and gives high yield potential in midland areas of wheat growing. In an attempt to develop Deka, higher yield, and resistance to major bread wheat diseases were important traits of consideration. The Deka is relatively shorter in height than the standard varieties than Ogolcho and taller than Kingbird and local check Hawi. Also, Deka has better thousand kernel weight and grain yield than the standard check and local check. Deka has white grain color (Figure 2) and it has good general acceptance for bread with high quality.

Table 2. Morphological characteristics of Deka	
Growth habit	Semi Erect
Auricle color	White
Leaf waxiness	Strong
Ear density	Dense
Ear color	White
Ear shape	Tapering
Hairiness of ear	Absent
Ear length	Medium
Seed color	White

Figure 1A. The head and uricle color of Deka variety

Figure 1B. The seed of Deka Variety

3.1.2. Balcha

Balcha (ETBW8260) is a new variety that was released in 2019 with the pedigree name CROC_1/AE.SQUARROSA (213) //PGO/10/ ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA which originated from CIMMTY. It was developed and released by the Kulumsa Agricultural Research Center for low to mid-altitude wheat-growing agroecology in Ethiopia. The New variety Balcha (ETBW8260) was giving the highest yield over year and testing locations at the time of release. The variety "Balcha" is moderately resistant to stem rust, and yellow rust and comparable for leaf rust and Septoria disease with the checks Kakaba and Ogolcho. Balcha was adapted from low to mid-agro-ecologies of Ethiopia.

Table 3. The mean grain yield of 15 bread wheat genotypes was tested for two years across twelve locations (year by location) (2016-2017)

Table 3. The mean grain yield of 15 bread wheat genotypes was tested for two years across twelve locations (year by location) (2016-2017)

Genotype	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-10	E-11	E-12	Mean
Ogolcho	5.05	3.01	5.72	2.68	1.80	1.38	2.37	3.13	3.34	4.89	5.77	3.91	3.59
ETBW8303	3.69	2.33	3.85	3.16	2.30	1.64	2.15	3.41	3.32	4.62	6.05	4.48	3.42
ETBW8310	3.62	2.10	4.62	3.20	2.00	1.57	2.22	2.98	3.73	6.44	7.59	3.72	3.65

ETBW8260	6.36	3.11	7.09	2.71	2.20	1.48	1.70	3.61	3.90	6.63	7.19	4.27	4.18
ETBW8261	5.11	2.89	5.11	3.27	2.00	1.52	2.69	3.07	2.99	6.73	7.28	3.86	3.88
ETBW8076	1.87	2.65	1.67	2.15	2.00	1.70	1.75	4.06	2.80	1.13	2.78	2.89	2.29
ETBW8085	1.53	2.30	1.87	1.56	2.10	0.64	1.74	1.34	3.54	0.86	2.25	4.45	2.02
ETBW8289	3.52	2.48	2.73	2.38	2.20	1.34	2.30	3.52	3.68	1.50	3.38	4.29	2.77
ETBW8348	4.12	2.74	3.59	3.47	1.50	1.38	1.51	2.90	2.86	3.41	5.84	3.64	3.08
ETBW8406	5.51	3.25	5.38	2.71	2.10	0.95	1.94	2.38	4.09	6.22	7.02	4.41	3.83
ETBW8437	5.16	2.65	4.98	3.7	1.80	1.13	2.28	2.05	2.75	6.21	7.23	4.22	3.68
ETBW8454	4.46	3.89	5.22	3.24	1.90	1.37	2.11	3.18	2.49	6.20	6.48	4.34	3.74
ETBW8387	3.99	2.38	4.43	2.48	2.20	1.23	1.81	2.21	2.94	6.25	5.90	4.45	3.35
ETBW8394	4.24	2.24	4.94	2.56	1.90	1.23	1.96	1.85	3.71	6.57	6.14	4.14	3.45
Kakaba	3.89	3.14	3.18	3.13	2.20	1.10	2.38	2.66	2.64	3.72	5.52	4.21	3.14
Mean	4.14	4.76	2.74	4.29	2.83	2.00	1.31	2.06	2.82	3.25	5.76	4.09	3.34

Where E-1: Kulumsa 2016, E-2: Dhera 2016, E-3: Asasa 2016, E-4: Melkasa 2016, E-5: Arsi Nagele 2016, E-6: Alem Tena 2016, E-7: Halaba 2016, E-8: Melkasa 2017, E-9: Dhera 2017, E-10: Asasa 2017, E-11: Kulumsa 2017 and E-12: Haramaya 2016

Table 4. Morphological characteristics of Balcha

Growth habit	Erect
Auricle color	White
Leaf waxiness	Weak
Ear density	Medium
Ear color	Slightly Colored
Ear shape	Tapering
Hairiness of ear	Absent
Ear length	Short
Seed color	White

Figure 2A. The head and uricle color of Balcha variety

Figure 2B. The Seed of Balcha variety

3.1.3. Boru

Boru is a commercial name given for a newly released variety with the pedigree name SAUAL/MUTUS/6/ CNO79// PF7 0354/MUS/3/PASTOR/4/BAV92*2/5/FH6-17/7/CNO79//P F70354/MUS/3/ PASTOR /4/BAV92*2/5/FH6-1-7 which originated from CIMMYT. Boru showed superior overall agronomic performances over the standard check Wane and Hidasse and it had a 9% and 14% yield advantage respectively. This new variety had a bold seed size than the two checks. Boru variety showed relative resistance to stem, yellow and leaf rust as compared to wheat varieties under production at the medium to high land wheat-growing agro-ecologies. It shows the best performance and gives high yield potential at midland than highland. Boru offers new hope for resource-poor farmers in rust-prone areas of Ethiopia. It's expected to replace the rust susceptible variety both in midland and highland agro ecology areas of Ethiopia. In addition, the Boru variety is known for its higher protein content (14.37%) than standard check Wane (12.14%) and local check Hidasse (12.3%). In an attempt to develop Boru, higher yield, and resistance to major bread wheat diseases were important traits of consideration. The Boru is comparatively taller than the standard varieties of Wane and local check Hidasse and has better thousand kernel weight (42.70 g) and grain yield than standard check Wane (38.3 g), and local check Hidasse (38.10 g) and 71.4 hl/kg (Table 5). Likewise, the Boru variety had bold seeds than checks. It possessed a 5.2% and 5.5% TKW advantage over Wane and Hidasse, respectively.

Figure 3A. The head and uricle color of Boru variety

Figure 3B. The seed of the Boru variety

Table 5. Mean performance of some important agronomic traits of 28 genotypes and 2 checks tested in the 2017 and 2018 cropping season

Entry	Genotype	DH	DM	PHT	TKW	HLW	GYLD
1	Wane	66.00	123.00	89.00	38.30	71.20	4.61
2	ETBW 8751	65.00	123.00	89.00	39.60	73.20	5.12
3	ETBW 8858	67.00	124.00	91.00	39.30	73.10	4.77
4	ETBW 8870	67.00	126.00	94.00	37.90	72.80	4.87
5	ETBW 8802	68.00	129.00	90.00	33.00	71.80	4.36
6	ETBW 8991	65.00	123.00	85.00	37.40	72.70	5.04
7	ETBW 8862	69.00	127.00	100.00	40.20	73.80	4.88
8	ETBW 8804	65.00	123.00	80.00	34.00	72.10	3.67
9	ETBW 8996	64.00	124.00	93.00	39.80	73.40	4.99
10	ETBW 8583	68.00	127.00	89.00	38.70	73.40	4.77
11	ETBW 8668	65.00	125.00	95.00	43.30	74.80	5.00
12	ETBW 8595	65.00	126.00	95.00	42.80	74.30	4.88
13	ETBW 8684	64.00	125.00	90.00	40.50	74.10	4.60
14	ETBW 9486	66.00	123.00	87.00	41.10	73.80	4.37
15	ETBW 9547	72.00	128.00	87.00	43.40	73.40	4.91
16	ETBW 9548	72.00	128.00	87.00	40.00	73.40	4.49
17	ETBW 9549	70.00	129.00	88.00	39.20	73.10	4.31
18	ETBW 9550	68.00	126.00	85.00	36.50	73.90	4.17
19	ETBW 9551	67.00	127.00	87.00	38.70	71.50	4.24
20	ETBW 9552	69.00	128.00	89.00	42.70	72.70	3.91
21	ETBW 9553	74.00	131.00	92.00	40.40	72.30	4.90
22	ETBW 9554 (Boru)	70.00	128.00	94.00	42.70	71.40	5.10
23	ETBW 9555	67.00	127.00	88.00	36.90	71.60	4.14
24	ETBW 9556	68.00	125.00	91.00	39.80	73.50	4.63
25	ETBW 9557	68.00	126.00	90.00	37.30	69.70	4.87
26	ETBW 9558	67.00	126.00	91.00	40.50	73.90	4.79
27	ETBW 9559	69.00	126.00	92.00	40.20	72.60	4.49
28	ETBW 9560	66.00	125.00	89.00	37.80	72.00	4.75
29	ETBW 9561	72.00	130.00	90.00	39.80	74.40	4.59
30	Hidasse	66.00	124.00	92.00	38.10	70.80	4.42
Grand mean		68.00	126.00	90.00	39.30	72.80	4.62

Table 6. Morphological characteristics of Boru	
Growth habit	Erect
Auricle color	White
Leaf waxiness	Weak
Ear density	Medium
Ear color	White
Ear shape	Parallel Side
Hairiness of ear	Absent
Ear length	Long
Seed color	White

3.1.4. Dursa

Dursa is a commercial name given for a newly released variety with the pedigree name NAVJ07/ SHORTENEDSR26 TRANSLOCATION/3/ATTILA/BAV92//PASTOR which originated from CIMMYT. Dursa is adapted from low to midland wheat-growing areas. Dursa (ETBW9578) varieties produced a 12% TKW advantage over the Ogolcho variety, similarly, a 20% TKW advantage over the Kakaba variety, implying their better seed plumpness over checks. Moreover, Dursa (ETBW9578) varieties produced a 39.5% grain yield advantage over the Ogolcho variety and a 36% grain yield advantage over the Kakaba variety. Dursa was taken 59 days for heading and 106 days for maturing at the time of release. The Dursa is relatively shorter in height than the varieties Ogolcho and taller than Kakaba and it has better thousand kernel weight and grain yield than the check. Dursa is resistant to stem, yellow and leaf rusts as compared to all currently released varieties in the low to mid-altitude areas of wheat growing agro-ecologies at the time of release.

Table 7. Mean performance of important agronomic traits of 28 bread wheat genotypes and 2 checks tested across 6 locations in 2017/18 and 2018/19 cropping season

Entry	Genotypes	DH	DM	PHT	TKW	HLW	GYLD
1	ETBW 9562	58	105	83	31.1	69.2	4.1
2	ETBW 9563	57	105	81	31.8	68.6	4.4
3	ETBW 9564	59	106	88	31.3	69.9	4.4
4	ETBW 9565	60	107	83	34.9	70.4	5.1
5	ETBW 9566	59	105	84	31.2	72.7	4.9
6	ETBW 9567	61	105	87	31.2	70.5	4.2
7	ETBW 9568	58	105	84	33.0	70.3	4.9
8	ETBW 9569	65	109	90	27.9	69.0	4.6
9	ETBW 9570	58	106	88	37.5	69.2	5.0
10	ETBW 9571	59	106	86	35.6	70.4	5.1
11	ETBW 9572	60	106	83	31.7	71.8	4.5
12	ETBW 9573	59	107	85	33.9	69.5	5.0
13	ETBW 9574	61	106	84	32.4	70.0	4.6
14	ETBW 9575	58	104	83	31.0	71.5	4.7
15	ETBW 9576	57	105	87	32.6	70.6	5.1
16	ETBW 9577	59	105	82	30.5	71.5	4.5
17	ETBW 9578 (Dursa)	59	106	84	33.5	70.9	5.3
18	ETBW 9579	58	105	86	35.7	71.2	4.8
19	ETBW 9580	59	108	82	33.0	71.9	4.1
20	ETBW 9581	62	107	80	34.3	70.4	4.9
21	ETBW 9582	60	107	84	31.4	71.7	4.8
22	ETBW 9583	63	108	78	31.3	68.2	4.4
23	ETBW 9584	63	108	83	31.1	70.8	4.6
24	ETBW 9585	58	105	82	34.6	71.7	4.7
25	ETBW 9586	60	106	82	31.3	72.0	4.6
26	ETBW 9587	61	107	83	32.2	69.1	4.7
27	ETBW 9588	61	107	81	30.0	70.3	4.1
28	ETBW 9589	58	102	80	34.0	67.7	3.5
29	Kakaba	59	106	80	27.9	67.9	3.9
30	Ogolcho	63	108	92	29.9	67.9	3.8
GRAND MEAN		60	106	84	32.3	70.2	4.6

Figure 4A. The head and uricle color of Dursa variety

Figure 4B. The seed of the Dursa variety

3.1.5. Abay

Abay is a commercial name given for a newly released variety in 2021 with the pedigree name BOUSHODA-1/4/CROC-1/AE.SQUARROSA(205)//KAUZ/3/SASIA which originated from ICARDA. Abay is adapted within the range of altitude 1550 m.a.s.l. to 2340 m.a.s.with annual rainfall amount receiving from 620–900 mm. Abay showed superior overall agronomic performances over the standard check Deka and Ogolcho and it had a 7% and 36% yield advantage respectively. Abay (ETBW 9396) varieties produced a 3% HLW advantage over the Deka variety, similarly, a 6% HLW advantage over the Ogolcho variety Abay was taken 59 days for heading and 107 days for maturing at the time of release. Abay is resistant to stem, yellow and leaf rusts as compared to all currently released varieties in the low to mid-altitude areas of wheat growing agro-ecologies.

Table 8: Combined mean performance of bread wheat for some important agronomic traits tested across 9 environments from 2018 to 2019 cropping seasons.

SN	Genotype	DTH	DTM	PHT (cm)	TKW (g)	HLW (kg/hl)	GYLD
1	Deka	62	110	89	31	66	5.067
2	ETBW 9116	65	110	86	31	67	5.006
3	ETBW 9119	63	110	86	29	67	4.835
4	ETBW 9128	61	110	85	30	66	4.793
5	ETBW 9136	60	107	91	35	69	5.732
6	ETBW 9139	58	107	85	34	68	5.845
7	ETBW 9149	60	108	85	35	67	5.049

8	ETBW 9065	58	108	90	32	68	5.378
9	ETBW 9077	60	109	83	31	68	5.135
10	ETBW 9078	60	108	84	30	68	4.978
11	ETBW 9080	59	108	87	37	69	5.545
12	ETBW 9172	61	108	86	32	68	5.634
13	Abay (ETBW 9396)	59	107	83	28	68	5.467
14	ETBW 9452	59	108	84	36	68	5.376
15	ETBW 9543	59	110	83	32	67	5.199
16	ETBW 9545	57	107	83	38	68	5.165
17	ETBW 9641	60	108	91	36	67	5.550
18	ETBW 9642	60	108	89	35	68	5.386
19	ETBW 9646	60	109	93	36	69	5.754
20	ETBW 9647	60	109	89	37	68	5.387
21	ETBW 9648	59	109	90	32	68	5.712
22	ETBW 9650	60	108	89	34	68	5.310
23	ETBW 9651	58	107	82	31	69	4.855
24	ETBW 9652	61	110	86	29	67	5.123
25	OGOLCHO	62	109	92	28	64	4.018
Mean		60.11	108.43	86.89	32.75	67.63	5.252
LSD (5 %)		1.81	1.98	3.50	2.81	2.00	1.495
CV (%)		4.10	2.07	6.78	9.69	2.57	

Note: DH=Days to 75% heading; DM=Days to 95 % maturity; PHT=Plant height (cm); TKW=Thousand kernel weight (g); HLW=Hectoliter weight; YLD=Grain Yield (t/h

Table 9: Morphological characteristics of Abay

Growth habit	Erect
Auricle color	White
Leaf waxiness	Weak
Ear density	Dense
Ear color	White
Ear shape	Parallel Side
Hairiness of ear	Absent
Ear length	Medium
Seed color	White

Figure 5A. The head and uricle color of Abay variety

3.1.6. Shaki

Shaki is a commercial name given for a newly released variety in 2021 with the pedigree name BABAX/LR42//BABAX/3/ER2000/4/BAVIS which originated from CIMMYT. Shaki is adapted within the range of altitude 1900–2780 masl with annual rainfall amount receiving from 640–1290 mm. Shaki showed superior overall agronomic performances over the standard check Wane and Lemu and it had a 13.3% and 12.68% yield advantage respectively. The new variety had a read seed color and bold seed size than the two checks. Shaki variety showed relative resistance to stem, yellow and leaf rust as compared to wheat varieties under production at the medium to high land wheat-growing agro-ecologies. Shaki offers new hope for resource-poor farmers in rust-prone areas of Ethiopia. It's expected to replace the variety disease susceptible varieties in medium and 'high land areas of Ethiopia. In an attempt to develop Shaki, higher yield, and resistance to major bread wheat diseases were important traits of consideration.

Table 10: Morphological characteristics of Shaki

Growth habit	Erect
Auricle color	White
Leaf waxiness	Weak
Ear density	Medium
Ear color	Slightly Colored
Ear shape	Tapering
hairiness of ear	Hairy
Ear length	long
Seed color	Red

Figure 6A. The head and uricle color of Abay variety

Figure 6B. The seed of the Shaki variety

Table 11. Adjusted mean grain yield (t ha-1) of 25 genotypes tested across eleven locations in 2018 and 2019

Genotype	A.Robe -2018	Bekoji-2018	Kulumsa-2018	Adet-2018	Areka-2018	Holeta-2018	Holeta-2019	Asasa-2019	Bekoji-2019	Kulumsa-2019	A.Robe -2019	GYLD
Wane	3.16	4.32	7.57	5.03	2.30	6.24	2.10	8.55	2.74	7.56	4.82	4.94
ETBW 9185	4.40	5.73	7.15	4.81	3.18	4.89	2.56	6.04	3.70	7.84	4.50	4.98
ETBW 9193	3.67	4.73	7.71	5.35	2.60	5.92	2.45	6.70	3.30	7.35	5.49	5.02
ETBW 9086	3.61	4.74	7.90	5.01	2.59	6.65	2.79	7.54	4.76	7.22	5.47	5.30
ETBW 9087	4.19	4.98	7.76	4.29	2.88	5.17	2.22	6.57	3.99	7.77	4.75	4.96
ETBW 9089	2.37	5.66	8.01	6.08	2.98	6.15	2.85	8.37	6.20	9.03	3.93	5.60
ETBW 9109	3.07	4.22	7.47	5.77	3.26	6.57	3.05	6.36	3.39	6.84	3.75	4.89
ETBW 9284	2.74	4.52	7.69	5.85	2.88	7.55	3.58	7.28	1.08	7.62	3.43	4.93
ETBW 9299	2.85	4.98	7.26	5.13	2.90	4.07	2.06	5.70	4.52	7.59	4.55	4.69
ETBW 9304	3.24	5.08	7.42	5.51	2.80	7.23	2.42	7.87	5.85	7.80	4.72	5.45
ETBW 9313	1.65	3.12	7.09	4.58	2.92	7.72	2.87	6.63	0.52	7.14	3.26	4.32
ETBW 9094	2.90	4.59	7.52	4.87	2.11	5.59	3.33	7.87	4.94	8.02	5.01	5.16
ETBW 9066	2.89	5.11	6.13	5.09	2.81	4.92	3.42	6.86	2.64	6.99	4.20	4.64
ETBW 9102	3.88	5.26	7.41	5.82	2.63	5.69	4.18	7.80	6.05	7.91	4.13	5.52
ETBW 9315	3.85	4.41	6.60	5.79	2.27	7.41	2.73	7.47	4.57	7.16	5.52	5.25
BW174459	3.98	3.82	8.03	4.81	2.84	6.76	3.20	6.81	2.57	7.79	5.51	5.10
BW174460	3.80	4.36	7.88	5.10	2.64	6.67	2.64	7.17	5.31	7.92	5.08	5.32
BW174461	3.49	4.95	8.13	5.13	2.10	4.91	2.56	7.50	5.97	7.46	4.43	5.15
BW174462	3.11	4.91	7.89	4.96	2.18	5.42	2.11	7.76	4.78	7.42	5.24	5.07
BW174463	3.93	4.53	7.58	5.43	2.81	5.61	3.50	7.31	4.17	8.41	4.45	5.25
BW174464	3.10	4.59	7.94	5.95	1.85	4.31	3.35	8.83	5.79	7.82	5.67	5.38
BW174465	3.31	3.32	6.28	4.03	2.69	4.11	2.64	5.01	3.52	7.41	3.81	4.19
BW174466	2.76	3.75	7.28	5.32	2.17	7.03	2.89	7.94	4.34	7.44	4.29	5.02
BW174467	1.85	3.36	7.27	5.42	1.51	5.10	2.80	8.27	5.22	6.85	3.57	4.66
Lemu	3.27	4.09	6.44	5.08	3.13	7.54	3.67	6.05	3.20	7.85	4.36	4.97
Env. Mean	3.24	4.53	7.42	5.21	2.60	5.97	2.88	7.21	4.13	7.61	4.56	5.03
CV (%)	20.30	18.82	7.85	12.85	19.32	12.68	21.15	13.32	17.50	15.16	15.97	14.73
LSD (5%)	1.08	1.40	0.96	1.10	0.82	1.24	1.00	1.58	1.19	1.52	1.20	-
R2	0.64	0.52	0.58	0.47	0.65	0.77	0.55	0.62	0.87	0.39	0.61	0.91

3.1.7. Kulumsa

Kulumsa is a commercial name given for a newly released bread wheat variety with the pedigree name PFAU/MILAN/5/CHEN/ AEGILOPS SQUARROSA (TAUS)/BCN/3/ VEE#7/ BOW/4/ PASTOR/6/2*BAVIS #1/7/BORL14 which originated from CIMMTY. It was evaluated and released by the 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.

3.1.8. Biftu

Biftu is a commercial name given for a newly released bread wheat variety with the pedigree name CHIPAK*2/3/KSW/SAUAL//SAUAL which originated from CIMMTY. It was evaluated and released by the Kulumsa Agricultural Research Center for low to mid altitudes of wheat-growing agro-ecology of Ethiopia. Biftu was adapted to low to midland agro-ecologies of Ethiopia, which ranges from 1500-2200 m.a.s.l. It gives better yield under 500-800 mm rainfall annually. It took 60.50 days to head and 103.60 days to maturity (Table 4). The genotype had 8.24%, 19.09% and 27.68 % TKW advantage and 4.68%, 5.61% and 6.72 % HLW advantage over Deka, Kakaba and Kingbird variety, respectively. Biftu is the, best adapted variety with stable yield in Ethiopia. The mean yields across the nine environments ranged from 3.40 t/ha (ETBW9119) to 5.60 t/ha (Biftu (BW173528)). The new high yielding variety Biftu was developed from CIMMYT germplasms through several stages of evaluations and testing. Therefore, the results of multi-location trials showed that Biftu had above-average grain yield across tested locations and years. The genotype also gave 16.7%, 27.3% and 36.6% yield advantage over the standard checks Deka, Kakaba and Kingbird, consecutively. It also had better seed quality in terms of size, color, and texture; and diseases resistance across years and locations.

Table 12: Morphological and quality descriptions of Biftu

SN	Morphological description	Types
1	Growth habit	Erect
2	Auricle color	White
3	Leaf waxiness	Weak
4	Ear density	medium
5	Ear color	White
6	Ear shape	Parallel side
7	Glume hairiness	Absent
8	Spike length	Long
9	Seed color	White
10	Protein (%)	14.62
11	wet gluten (%)	38.50
12	TKW (g)	37
13	HLW (kg/hl)	71
14	GY (t/ha)	5.60

4. Variety Maintenance

The purpose of seed maintenance is to produce new lots of breeder seed with the same genetic composition. It is the task of breeder to maintain the variety once it has been released. For wheat, plants representing the variety are grown in ear-rows and carefully observed. Plants from selected rows are harvested and grown in small plots; row-plots. Breeder seed is produced from plots with the best wheat crop and highest crop purity. The initial small amount of breeder seed is initially multiplied to produce Pre basic seed which is further multiplied to large quantities of basic seed or certified seed to satisfy farmers' requirements. In 2021 the nucleus seed were produced for these six improved bread wheat varieties for purification (Fig.7A) and these improved varieties were produced at KARC based on their demands in 2021 (Fig 7B). To reach the farmer in short period of time these produce seed were distributed to Oromia Sees Enterprise, Amhara Seed Enterprise, SNNPR, Ethiopia Seed Enterprise, Amhara Regional Agricultural Research Institute, EIAR Technology Multiplication, KARC Extension, ISVCDO-Extention, CIMMYT, EIAR demonstration, Holeta Agriculture Research Center, Farmer Training Center and some model farmer. The variety is maintained at the Klumsa agriculture research center (KARC).

5. Conclusion

Over the years of research on bread wheat, commendable achievements have been made in the generation of technologies and information useful for boosting the productivity and production of wheat in Ethiopia. Deka, Balcha, Boru, Dursa,

Abay, Shaki, Kulumsa and Biftu are the best released varieties and they have better agronomic performance with disease resistanc compared to the standard checks. Therefore, these varieties were recommended in major wheat-growing areas of the country having similar agro-ecologies with the testing environments.

Figure 7A. Nucleus seed of improved bread wheat varieties.

Figure 7B . Field of breeder seed at KARC.

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