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Bread Wheat Varietal Development and Release in Southeastern Highlands of Ethiopia

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Abstract: Four improved bread wheat varieties; Mandoyu (WORRAKATTA/PASTOR), Sanate (14F/HAR1685), Obora (UTIQUE96/FLAG-1) and Dambel (AGUILAL/3/PYN/BAU//MILAN) are developed from ICARDA materials and released in 2014 and 2015, respectively for highland and mid altitude areas of Bale and similar agro-ecologies. The new varieties were tested along with three standard checks (Madawalabu, Sofumer and Tusie) and one local check (Hollandi) at three environments in 2011 to 2012 and 2012 to 2013, respectively during main cropping seasons. The two years data of regional variety trial combined over locations and years provide the newly released varieties showed that superior in grain yield performance, stability, and wide adaptation. The four newly released varieties have good protein content, good physical grain quality, resistant to stem rust, moderately susceptible to yellow rust, moderately resistant to septoria leaf blotch and comparable for leaf rust disease with the checks. The variety Mandoyu, Sanate, Obora and Dambal have been demonstrated and are being cultivated by farmers for production purpose. Hence, the cultivation of these newly released improved bread wheat varieties in the highland and mid altitude areas of major wheat growing environments of the country is highly recommended. This new variety given local name Mandoyu, Sanate, Obora and Dambel, respectively.

Keywords: Wheat Variety, Grain Yield, Grain Quality, Protein Content, Wheat Diseases

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important crops in the world in production and nutrition. Annually, wheat is produced on 224.53 million hectares of land and 672.2 million metric tons of wheat is produced in the world [10]. In Ethiopia, wheat is one of the most important cereal crops widely cultivated. It is cultivated both in bi-modal and uni-modal rain fall areas. Bread wheat (*Triticum aestivum* L.) and durum wheat (*T. turgidum* L. var. durum) are the two species which are mainly cultivated by small scale farmers in Ethiopia. It ranks fourth in area coverage next to teff, maize and sorghum, respectively [7]. It is the main staple food for about 36% of the Ethiopian population [4], [5]. Arsi and Bale highlands are the major wheat producing regions of Ethiopia [2] and are deemed to be the wheat belts of East Africa. The area under wheat production is estimated to be about 1.6 million hectares, which makes the country the largest wheat producer in sub-Saharan Africa [6], [8]. Wheat production constrained by various biotic and abiotic factors. Among the biotic factors, fungal diseases are one of the most important biotic constraints threatening wheat production in Ethiopia [1], [9]. Recently, rusts (stem, yellow and leaf rust) and

septoria leaf blotch and fusarium head blight are significantly threatening wheat production in most of wheat producing agro-ecologies [3]. To alleviate these constraints confronting wheat production, wheat breeding program at Sinana has been working on development of wheat varieties with high yield potential and resistance to major wheat diseases. Development of high yielding varieties requires a thorough knowledge of the existing genetic variation for yield and its components. The successful process of wheat breeding is based on the knowledge of characteristics of genotypes, environment and its interaction. The ideal cultivar for high grain yield or for any other desirable traits needs to express genetic potential with low value of variance in different environmental factors of growing. Therefore, generating more new improved production technologies on wheat must be continues to contribute in food self-sufficiency and sustainable agriculture and could be source of income generation for the local farmers. The objective of the present study was to develop high yielding and disease resistant bread wheat varieties suitable for optimum environments.

2. Materials and Methods

2.1. Breeding Material and Its Background

Initially more than 2000 bread wheat genotypes received from ICARDA and evaluated under field conditions in augmented design. The best promising genotypes were selected on the basis of maturity, diseases and advanced to preliminary yield trial for further test.

2.2. Experimental Site and Field Experiment

The experiment was conducted at three locations for two years (2011 to 2012) and the other experiment was also carried out at the same locations for two consecutive years (2012 to 2013) during main cropping seasons. One of the experiment was conducted at the research farm of Sinana Agricultural Research Center, and the other three sites in the farmer's fields; Robe, Goba and Agarfa. The experiment was conducted from regional variety trial till to the verification trial in 2011 to 2012 and 2012 to 2013, respectively at each locations on vertisol clay-loam soil under rain fed conditions during meher seasons (August-January). Sinana Research Center (7°N latitude and 40°E longitude; and 2400 m a.s.l) is located 463 km southeast of Addis Ababa and east of Robe town of Bale zone. Robe is located 33 km from Sinana in the southeast direction. Goba is located 37 km from Sinana and about 14 km from Robe in the south west direction, and Agarfa is located 63 km from Sinana and 30 km from Robe town in the Northeast direction.

Sixty-four bread wheat genotypes selected from ICARDA materials and promoted to preliminary yield trial for further evaluation. Sixty-four wheat genotypes were evaluated along with standard and local checks using simple lattice design at Sinana research center in 2010 main cropping season for one year. During this time, agronomic data was collected in plot basis. Out of sixty-four bread wheat tested, fifteen promising bread wheat genotypes were selected and promoted to regional variety trial. Eighteen bread wheat genotypes were evaluated including one standard (Madawalabu) check and one local check (Hollandi) under field condition for two consecutive years (2011 to 2012) at three locations (Sinana, Robe and Goba) using simple lattice design with three replications. Finally, two best promising bread wheat candidates (WORRAKATTA/PASTOR) and (14F/HAR 1685) were identified for final release (Table 1).

Similarly, forty-nine bread wheat lines selected from ICARDA materials and best lines advanced to preliminary yield trial. In the preliminary yield trial, bread wheat lines were tested along with standard and local checks at Sinana research center in 2011 main cropping season for one year. Out of forty-nine, twenty-three bread wheat lines were selected and advanced to regional variety trial. In multi-location trial, twenty-five bread wheat lines were tested including two standard checks (Sofumer and Tusie) and one local check (Hollandi) at three locations (Sinana, Goba and Agarfa) for two consecutive years (2012 to 2013) using simple lattice design with three replications. All agronomic practices were done as recommended for wheat. Agronomic and yield data collected and subjected to statistical analysis to identify the best promising bread wheat genotypes among the evaluated genotypes. Finally, two best candidate varieties (UTIQUE 96 /FLAG-1) and (AGUILAL / 3 / PYN / BAU // MILAN) were identified for possible release (Table 2).

Finally, the most promising candidate varieties evaluated along with standard checks on 10 m x 10 m plots by the National Variety Releasing Committee at their respective locations in 2013 and 2014, respectively and was been released fully four improved bread wheat varieties for the highland and mid altitude areas of Bale and similar agro-ecologies.

3. Results and Discussion

3.1. Varietal Characteristics

Mandoyu (WORRAKATTA/PASTOR) is the improved bread wheat variety released in 2014 for mid and highlands of Bale and similar agro-ecologies. This variety is characterized by an erect growth habit and compact ear types. It has white seed color. On average this variety required 68 days for heading, 139 days need to reach physiological maturity and the average plant height is 85 cm (Table 1). The average weight of thousand kernel is 36.2 and test weight is 81 kg/hl (Table 1). This variety is resistant to stem rust and moderately susceptible to yellow rust.

Sanate (14F/HAR 1685) is the newly released bread wheat variety in 2014 for highlands of Bale and similar agro-ecologies. The variety has compact ear types and erect growth habit. It has amber seed color. On average the variety needs 71 days to heading and 141 days requires to reach physiological maturity, with the average plant height is 102 cm (Table 1). The average weight of thousand kernel of this new variety is 39.5 and test weight is 80 kg/hl (Table 1). The variety is resistant to stem rust and moderately susceptible to yellow rust.

Table 1. *Mean grain yield, other agronomic traits and diseases reaction of Mandoyu, Sanate and the checks in multi-location test during 2011-2012.*

SN	Genotypes	Dh	Dm	Plh	Tkw	Tw	Gy	Yr	Sr	Lr	Sep
1	WORRAKATTA/PASTOR (Mandoyu)	68	139	85	36.2	81.5	4275.5	10ms	Tr	5ms	82
2	14F/HAR 1685 (Sanate)	71	141	102	39.5	80	4238.6	5ms	5ms	5ms	81
3	Sofumer (*Standard check*)	67	136	97	39.8	72	3571.5	5ms	30s	5ms	82
4	Tusie (*Standard check*)	68	139	98	34.6	73	3684	10ms	50s	5ms	82
5	Hollandi (*Local check*)	66	138	119	40.4	72	3126.2	60s	30s	5ms	84

Dh= days to heading, Dm= days to maturity, Plh= plant height (cm), Tkw= thousand kernel weight (g), Tw= test weight (kg/hl), Gy= grain yield (kg/ha), Yr= yellow rust, Sr= stem rust, Lr= leaf rust, Sep= Septoria.

Obora (UTIQUE96/FLAG-1) is the newly released bread wheat variety in 2015 for mid and highlands of Bale and similar agro-ecologies. The variety is characterized by having an erect growth habit and compact ear types. It has white seed color. Obora variety on average needs 73 days to heading and 144 days to reach physiological maturity, with the average plant height is 94 cm (Table 2). The average weight of thousand kernel of this new variety is 39gram and test weight is 82.1 kg/hl (Table 2). This variety is resistant to major wheat diseases.

Dambal (AGUILAL/3/PYN/BAU//MILAN) is the improved bread wheat variety released in 2015 for highland of Bale and similar agro-ecologies. This variety is characterized by having slightly red to amber seed color. It has an erect growth habit and compact ear types. The variety requires 69 days to heading and 142 days needs to reach physiological maturity and with the average plant height being 101 cm (Table 2). The average weight of thousand kernel is 41.2 and test weight is 81.7 kg/hl (Table 2). This variety is resistant to major wheat diseases.

Table 2. *Mean grain yield, other agronomic traits and diseases reaction of Obora, Dambal and the checks in multi-location test during 2012-2013.*

SN	Genotypes	Dh	Dm	Plh	Tkw	Tw	Gy	Yr	Sr	Lr	Sep
1	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopa)-107 (Obora)	73	144	94	39	82.1	4253.8	Trmr	5ms	10ms	81
2	AGUILAL/3/PYN/BAU//MILAN (Dambal)	69	142	101	41.2	81.7	4578.7	5mr	10ms	10ms	81
3	Madawalabu (*Standard check*)	69	143	101	42	78.8	3797.1	5mr	40s	15ms	94
4	Hollandi (*Local check*)	65	140	116	38	79.4	3239.8	Trmr	40s	10ms	87

Dh= days to heading, Dm= days to maturity, Ph= plant height (cm), Tkw= thousand kernel weight (g), Tw= test weight (kg/hl), Gy= grain yield (kg/ha), Yr= yellow rust, Sr= stem rust, Lr= leaf rust, Sep= Septoria.

3.2. Grain Yield Performance

Mandoyu (WORRAKATTA/PASTOR) is characterized by having higher seed grain than the standard check so far released. It has better grain yield advantage of 20%, 16% and 36% over standard check Sofumer, Tusie and local check Hollandi, respectively (Table 1). The variety gives grain yield of 4.9 to 5.8 t ha^{-1} on the research field whereas it gives 2.7 to 4.2 t ha^{-1} on farmers' field (Table 3).

Sanate (14F/HAR 1685) variety has high seed grain than the standard check. It has better grain yield advantage of 18.6%, 15% and 35.5% over standard check Sofumer, Tusie and local check Hollandi, respectively (Table 1). This variety gives grain yield of 5.28 to 6.69 t/ha^{-1} on the research field whereas it gives 3.25 to 4.29 t ha^{-1} on farmers' field (Table 3).

Table 3. *Combined mean grain yield and other agronomic traits of bread wheat regional variety trial over years (2011-2012) and over locations (Sinana, Robe and Goba).*

SN	Genotypes	Dh^{++}	Dm^{++}	Plh^{++}	Tkw^{++}	Tw	Gy^{++}
1	SAKER/5/RBS/ANZA/KVZ/HYS//YMH/TOB/4/ BOW'S/PEWIT3/7/ANTA-1	69.33cdef	137.11gh	82.78i	36.12h	68.3	3767.1defg
2	SAMAR-8/KAUZ'S//CHAM-4/SHUHA'S/	67.11fg	137.78efg	92.50fgh	34.22i	68.9	3747.2defg
3	EALME4SA-167	67.22fg	135.22i	89.61h	37.71fg	68.2	3720.9efg
4	SKAUZ/BAV92	70.28bcd	138.89de	99.67d	37.13gh	69.0	3814.9def
5	WORRAKATTA/PASTOR (Mandoyu)	68.39defg	138.83def	85.33i	36.22h	70.6	4275.5a
6	UTQUE96/3/PYN/BAU//MILLAN	74.78a	139.39d	91.61fgh	39.68cde	71.5	3966.3bcd
7	UTQUE96/3/PYN/BAU//MILLAN	70.94bc	139.00de	93.89efg	40.55abc	71.8	4276.3a
8	AGUILAL/3/PYN/BAU//MILLAN	66.72g	137.94efg	91.28gh	41.24ab	71.1	4104.5abc
9	ETBW5570	68.06defg	135.11i	91.00gh	41.13ab	70.1	4283.4a
10	ETBW5572	67.50efg	137.89efg	99.67d	39.09def	69.3	4183.0ab
11	NS732/HER//MILAN/SHA7	69.83bcde	141.50c	94.89ef	41.58a	71.2	4074.8abc
12	VEE/PJN//2*TUI/3/2*MILAN/KAUZ	68.56cdefg	137.61fg	94.22efg	40.28abcde	72.3	4155.9abc
13	15F/HAR710	70.44bcd	141.94bc	112.67b	38.92ef	72.0	3931.5cde
14	14F/HAR1685 (Sanate)	75.11a	142.94ab	103.83de	36.02h	71.5	4238.6a
15	F6-MR-CA-ETH-SRR	72.22b	143.22a	93.50efg	36.91gh	72.4	3769.3defg
16	Sofumer (*standard check*)	67.22fg	135.94hi	96.83de	39.87bcde	72.0	3571.5g
17	Tusie (*standard check*)	68.44defg	139.22d	98.78d	34.58i	73.0	3684.0fg

SN	Genotypes	Dh^{++}	Dm^{++}	Plh^{++}	Tkw^{++}	Tw	Gy^{++}
18	Hollandi (*local check*)	66.39g	138.22defg	119.89a	40.39abcd	71.9	3126.2h
Mean		69.36	138.77	96.22	38.43	70.8	3927.3
CV (%)		5.3	1.4	5.6	5.5		91
SE		0.858	0.453	1.265	0.498		81.983
LSD (5%)		2.364	1.263	3.527	1.389		234.17

*Dh: days for heading, Dm: days to maturity, Plh: plant height (cm), TKW: thousand kernel weight (gm), TW: test weight (kg/hl), Gy: grain yield (kg/ha), Sr: stem rust (%), Yr: yellow rust (%), Lr: leaf rust (%), S: susceptible, MS: moderately susceptible, MR: moderately resistant, Tr: trace, Trms: trace with moderately susceptible, Trmr: trace with moderately resistant, R: resistant, CV (%): coefficient of variations, SE: standard error of the mean, LSD: least significant differences, ++ Means within each column followed by the same letter are not significantly different from each other based on the 0.05 probability level of LSD.

Obora (UTIQUE96/FLAG-1) has high grain yield than the standard check so far released. It has better grain yield advantage of 12% over standard check Madawalabu and 31.3% over local check Hollandi (Table 2). This variety gives grain yield of 4.68 to 6.31 t ha^{-1} on the research field whereas it gives 3.3 to 3.75 t ha^{-1} on farmers' field (Table 4).

Dambal (AGUILAL/3/PYN/BAU//MILAN) has high grain yield as compared to standard check. It has better grain yield advantage of 20.58% over standard check Madawalabu and 41.32% over local check Hollandi (Table 2). This variety gives grain yield of 5.63 to 6.37 t ha^{-1} on the research field whereas it gives 3.38 to 4.19 t ha^{-1} on farmers' field (Table 4).

Table 4. *Combined mean grain yield and other agronomic traits of bread wheat regional variety trial over years (2012-2013) and over locations (Sinana, Goba and Agarfa).*

SN	Genotypes	Dh^{++}	Dm^{++}	Plh^{++}	Tkw^{++}	Tw	Gy^{++}
1	ICARDA ELITE SRR-ON Summer 09-257	69.39^{cde}	143.44^{bcd}	91.72^{hij}	35.49^{h}	81.9	3900.3^{defghi}
2	ICARDA ELITE SRR-ON Summer 09-258	69.44^{cd}	143.61^{bcd}	94.00^{ghi}	35.26^{h}	80.7	4046.1^{cdef}
3	ICARDA ELITE SRR-ON Summer 09-263	66.56^{ij}	142.50^{def}	98.94^{cde}	36.93^{fg}	80.3	3525.3^{jklm}
4	ICARDA ELITE SRR-ON Summer 09-308	70.39^{b}	143.44^{bcd}	77.28^{k}	37.32^{ef}	80.1	3865.7^{efghi}
5	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-4	66.72^{ij}	143.11^{cde}	112.06^{ab}	39.20^{d}	81.4	4052.4^{cdef}
6	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-98	67.94^{gh}	139.67^{i}	91.11^{ij}	29.97^{jk}	79.9	3597.9^{ijkl}
7	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-103	68.28^{fg}	139.78^{hi}	91.44^{ij}	31.22^{j}	80.1	3851.5^{efghi}
8	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-107	72.67a	144.44b	93.94ghi	39.03d	82.1	4253.8c
9	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-114	66.39^{ijk}	140.78^{ghi}	92.33^{hij}	41.63^{bc}	81.2	4088.1^{cde}
10	ICARDA ELITE SRR-ON Summer 09 (Kenya+Ethiopia)-115	66.11^{jk}	140.72^{ghi}	97.61^{cdefg}	43.89^{a}	80.9	4196.3^{cd}
11	CHIL-1//VEE'S/SAKER'S'	67.17^{hi}	142.72^{def}	97.39^{cdefg}	36.52^{fgh}	80.6	3410.8^{lm}
12	LOUOU-3	66.56^{ij}	144.17^{bc}	97.00^{defg}	38.54^{de}	79.5	3439.6^{klm}
13	ICBW206974 (Sr35)	69.44^{cd}	140.33^{hi}	89.44^{j}	32.66^{i}	81.1	3633.7^{hijkl}
14	PBW343 (Sr24)	72.67^{a}	145.61^{a}	95.94^{efgh}	35.53^{h}	80.1	4206.2^{cd}
15	CHIL-1/ICARDA-SRRL-7	68.50^{efg}	142.78^{def}	96.83^{defg}	36.26^{fgh}	80.9	3688.1^{ghijkl}
16	15F/HAR 1522	67.78^{gh}	142.67^{def}	110.67^{b}	41.45^{bc}	81.9	4253.3^{c}
17	ETBW 5565	69.89^{bc}	139.67^{i}	96.17^{efgh}	36.01^{gh}	80.2	4650.6^{a}
18	ETBW 5586	68.22^{fg}	140.83^{gh}	98.67^{cdef}	38.51^{de}	80.3	3972.3^{cdefg}
19	AGUILAL/3/PYN/BAU//MILAN	69.11^{cdef}	141.78^{fg}	101.50^{c}	41.19^{c}	81.7	4578.7^{ab}
20	UTQUE96/3/PYN/BAU//MILAN	68.67^{defg}	143.11^{cde}	100.17^{cde}	42.00^{bc}	81.6	4257.0^{bc}
21	SABA/3/PYN/BAU//MILAN	69.39^{cde}	139.89^{hi}	94.33^{fghi}	29.24^{k}	78.5	3739.6^{fghijk}
22	ETBW 5517	68.22^{fg}	142.28^{ef}	79.78^{k}	38.60^{d}	80.1	4059.0^{cdef}
23	ETBW 5519	69.94^{bc}	143.00^{de}	91.94^{hij}	37.19^{fg}	80.6	3926.7^{defgh}
24	Madawalabu (*Standard check*)	68.61^{defg}	142.67^{def}	100.72^{cd}	42.59^{b}	78.8	3797.1^{efghij}
25	Hollandi (*Local check*)	65.56^{k}	140.22^{hi}	116.39^{a}	38.55^{de}	79.4	3239.8^{m}
Mean		68.5	142.1	96.3	37.4	80.6	3929.2
CV (%)		2.1	1.2	7.1	5.2	1.6	12.6
SE		0.33	0.42	1.61	0.46	0.52	116.262
LSD (5%)		0.93	1.16	4.48	1.27	1.47	323.58

*Dh: days for heading, Dm: days to maturity, Plh: plant height (cm), Tkw: thousand kernel weight (cm), Tw: test weight (kg/hl), Gy: grain yield (kg/ha), Sr: stem rust (%), Yr: yellow rust (%), Lr: leaf rust (%), S: susceptible, MS: moderately susceptible, MR: moderately resistant, Trmr: trace with moderately resistant, Tr: trace, Trr: trace with resistant, R: resistant, CV (%): coefficient of variations, SE: standard error of the mean, LSD: least significant differences, ++ Means within each column followed by the same letter are not significantly different from each other based on the 0.05 probability level of LSD.

3.3. Reaction to the Major Wheat Diseases and Quality Traits

The newly released bread wheat varieties resistance / tolerance to stem rust, moderately susceptible to yellow rust, moderately resistance to septoria leaf blotch and comparable for leaf rust disease with the checks (Table 1 and 2). The quality parameters indicates that the newly released variety Obora, Sanate, Mandoyu and Dambal have good percentage of protein content and gluten content, which ranges from 12.1 to 15.9% and 25.9 to 37.4%, respectively (Table 5).

Table 5. *Quality parameters of improved bread wheat varieties recently released from SARC.*

SN	Variety	Quality parameters					
		TKW* (g)	HLW* (kghl^{-1})	Gluten (%)	Moisture content (%)	Protein (%)	Zeleny index (ml)
1	Senate (14F/HAR1685)	39.1	75.2	29.6	12.7	13.9	58.9
2	Mandoyu (WORRAKATTA/PASTOR	32.5	80.0	31.1	11.5	13.7	63.6
3	Obora (UTIQUE96/FLAG-1)	37.2	80.0	37.4	11.0	15.9	79.3
4	Dambal (AGUILAL/3/PYN/BAU//MILAN)	46.3	83.6	25.9	11.7	12.1	48.1

*TKW= thousand kernel weight, HLW= hectoliter weight, SN= serial number.

3.4. Adaptation

Mandoyu variety released for mid and high altitude areas of Bale whereas Sanate variety released for highlands of Bale and similar agro-ecologies. These two improved bread wheat varieties perform very well in area having an altitude 2200 to 2500 and 2300 to 2600 m a.s.l, respectively with the annual rainfall of 750-1500 mm. The two improved bread wheat varieties are better if planting is done from mid-June to late August based on the agro-ecology of the area.

Obora and Dambal varieties are released for highlands of Bale and similar agro-ecologies. These two improved bread wheat varieties perform very well in area having an altitude 2000 to 2400 m a.s.l with the annual rainfall of 750-1500 mm. Both two improved bread wheat varieties are better if planting is done from mid-June to early September based on the agro-ecology of the area.

4. Conclusions

Mandoyu, Sanate, Obora and Dambal are the best varieties identified and verified along with standard checks and local check in multi-location trials across the testing environments with superior in grain yield performance, yield stability and wide adaptation. They have better agronomic performance with resistance to stem rust disease compared to the standard checks. Hence, cultivation of the new varieties are recommended in major wheat growing regions of the country having similar agro-ecologies with the testing environments.

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