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Enhancing Sustainable Wheat Productivity and Production through Development of Wheat Varieties Best Adapted to Irrigated Lowland Areas of Ethiopia

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***Abstract* – Seven breeding activities that showed the variety development processes such as germplasm introduction, Observation Nursery Trial (ONT), Preliminary Variety Trial (PVT), National Variety Trial (NVT) and Variety Verification Trial (VVT) were considered in this paper. The trials were conducted during the cool season at Werer Agricultural Research Center (WARC) and On-farms from 2010 to 2015 using the appropriate experimental designs for each type of activities with the objectives of selecting best performing lines and candidate varieties for the next stages of evaluation and release, respectively. The number of genotypes evaluated under ONT, PVTs, NVTS and VVT were 146, 49, 31 and 9, respectively. The recommended agronomic and crop protection practices were applied equally for all trials. All the required agronomic data for the trials were collected and analyzed using the appropriate software. Based on the results of statistical analysis, 56 genotypes from ONT, 20 best performing lines from PVT and 9 candidate varieties from NVT were selected. The first three candidate varieties selected for verification in 2012/13 were Adel-6, Nejemah-14 and Halal-44 and the other three candidate varieties selected in 2014/15 were Moontiji-3, Saamid-3 and Doukkala-4. Among the six candidate varieties verified, four were accepted and released by the standing committee of the national variety release in 2013 and 2015, respectively. The remaining three candidate varieties selected in 2016/17 were SERI 82/SHUHA'S'//PASTOR-2, QAFZAH-2/FERRIUG-2 and REYNA-28 are evaluated by the national variety releasing committee. The quality characteristics of the released and candidates varieties were better than the standard.**

***Keywords* – Environment; Genotypes; Quality; Yield.**

I. Introduction

Wheat is one of the most important crops and it is common diet for more than one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops. The wheat consumption in Sub-Saharan African countries has also become increased. According to Negassa, et al (2013), Africa produced 23 million tons of wheat and imported nearly 36 million tons of wheat grain during the periods of 2009 to 2011, creating a huge food gap between supply and demand. Wheat in Ethiopia is one of the most important cereal crops both in terms of production and use. It has been widely cultivated in mid and high altitude rainfed areas of Ethiopia by five million households on 1.6 million ha with current annual total grain production of nearly 4 million metric tons (ATA, unpublished data). Wheat is an important staple food for Ethiopian people and its straw has been used as sources of feed for animals and thatching the house. In Ethiopia, expansion of urbanization and rising incomes created big gap between wheat grain production and its consumption. To fill the gap, the country has been importing about 1.0 Million MT of wheat grain annually since 2008 at a cost of 500 Million USD (Personal communication, 2016), resulted in losing of huge foreign currency. Nutrient self-sufficiency for semi-arid dwelling community of Ethiopia is the great issue as in addition to the yield, the grain quality is becoming a widely concerned in crop sciences (Lingan Kong et al., 2013). The research work result by Werer Agricultural Research Center (WARC) from 1969/70 up to 1986/87 clearly showed that the yield of wheat genotypes could reach up to 4400 kg/ha (Jemal, 1994) indicating the suitability of lowland irrigated areas for wheat production. Thus, the wheat varieties development works have been implemented fully by government money and later on with financial and technical support of Support to Agricultural Research for Development of Strategic Crops (SARD-SC) wheat project. The variety development activities were started with adaptation trials using rainfed varieties of both bread and durum wheat for two seasons and concluded with the recommendation of 3 bread wheat and 2 durum wheat varieties. Side by side, the variety development activities have been implemented using the introduced wheat germplasms from ICARDA at different locations (Werer, Amibera, Gewane and later on Fentale and Mehoni). As a result, five bread wheat varieties have been officially released by the national variety releasing committee for irrigated lowland areas of Ethiopia based on the results of multi-locations data. Both the recommended and released bread and durum wheat varieties were demonstrated on agro-pastorals fields both in Middle- and Lower-Awash areas (Afar Region) and in Fentale District (Oromiya Region) followed by demonstration and pre-scaling up activities. Therefore, the objective of this paper is to present the findings of the variety development works undertaken so far in irrigated lowland areas of Ethiopia.

II. Material and Method

Observation Nursery Trials (ONT) comprising of 120 genotypes were conducted at WARC for one season using augmented design in 2013/14 cool season. Preliminary Variety Trials (PVT) was conducted using lattice design and national Variety Trials (NVTs) were conducted in a randomized complete block design with three replications on a plot size of $9m^2$ (ten rows of 3m length and 0.3m between rows. The trials were conducted across several locations for two to three years and promising varieties were identified and promoted to VVT. Three candidate wheat varieties each in 2012 and 2014 cropping seasons were selected based on their multi-location performance. Then after, the breeders applied to the National Variety Release Committee, the Variety Verification Trial (VVT) were conducted in 2012/13 cropping seasons for the first VVT and in 2014/15 for the second at three sites in each location using the standard plot size of $100m^2$ (10m x 10m) without replications for one season. The candidate varieties were evaluated by the technical committee at maturity stage of the candidate varieties. For all types of trials, sowing was done every year from Mid-October to Mid-November by hand drilling at a seed rate of 80 kg/ha. Irrigation interval was every 10 days using furrow method. UREA and DAP fertilizers were applied at the rate of 100 and 50 kg/ha, respectively. UREA fertilizer was applied in split, half at seedling stage and at booting stage while DAP whole at sowing time. Data were collected on days to heading, days to maturity, plant height, spike length, number of spikelet per spike, number of kernel per spike, 1000 kernel weight and grain yield. The collected data from ONT, PVTs and NVTs were compiled and subjected to statistical analysis using the appropriate software (SAS version 9.0).

III. Results and Discussion

3.1. *Advanced Observation Nurseries*

Based on field evaluation and statistical analysis of the collected data, 42 best performing lines among the 119 BW genotypes and 14 Promising DW genotypes based on their heat tolerance level and yielding potential were selected. The lists of top ten selected lines and their agronomic performances with their minimum, mean and maximum values are shown in table 1 and 2. These results revealed that there was high genetic variability among the selected genotypes for most traits studied. Hence, there is high chance to select best performing genotypes for the next stage of evaluation (table 1 and table 2).

Table 1. Mean performance of the BW genotypes for the traits at Werer (2013/14)

S.N	Genotypes	DH	DA M	PH (cm	SL (cm	NPS	NKS	TKW (g)	YLD (kg/ha
1	DEBEIRA(check)	51	83	69	8	12	43	36	4944
2	BOHAINE	51	80	63	6	14	33	36	5406
3	KAUZ/RAYON/3/N5732/HER//CASKOR	59	93	79	8	17	15	26	4183
12	IMAM	57	90	72	9	15	46	32	3967
20	KACHU/WBLL1*2/BRAMBLING	57	89	75	9	17	59	32	3944
21	STLN/MUNAL#1	58	93	72	9	17	45	36	4200
26	TACUPETOF2001*2/BRAMBLING//	57	90	77	8	15	37	42	3978
27	WAXWING/4/BL 1496/MILAN/3/	60	91	70	9	16	40	34	4728
32	ATTILA*2PBW65*2/4/BOW/NKT//	65	90	73	8	14	40	34	4056
35	UP2338*2/4/SNI/TRAP?1/3/KAUZ*2/	61	93	74	9	19	34	40	4194
36	ATTILA*2/PBW65*2/4/BOW/NKT//	65	93	75	9	17	50	32	4244
39	SERI-1B//KAUZ/HEVO/3/AMAD/4/	47	77	70	9	16	47	38	4183
	Mean	55	86	70	8	16	43	34	3611
	Maximum	65	95	82	10	21	60	42	5406
	Minimum	46	75	54	5	12	15	24	3228

Table 2. Mean performance of the HTDW genotypes for the traits at Werer (2015/16)

En No	Designation	PLH (cm)	Total tillers	Effective tillers	Spike length (cm)	spikelet /spike	kernel /spikelet	Yld (kg/ha)
1		56	4	4	6	14	22	2264
2		58	4	4	6	13	28	3037
3		67	4	4	5	15	29	2792
5		69	5	5	5	16	32	1371
6		57	3	3	5	14	30	1446
12		64	4	4	5	12	31	1319
14		53	5	5	6	14	31	1372
15		53	3	3	5	14	29	1200
17		54	3	3	5	14	25	1353
18		47	4	4	6	14	28	1293
21		55	3	3	6	12	38	1360
22		50	3	3	5	11	29	1286
24		55	4	4	5	12	24	1681
	Mean	56	4	4	5	13	27	1139
	Max	69	5	5	7	16	41	3037
	Min	46	3	3	4	11	16	321

3.2. *Preliminary Variety Trials*

The analysis of variance for the first preliminary variety trial showed that there were significant difference (alpha = 0.05) among the treatments (genotypes and standard check) for all parameters studied. Eleven genotypes were reached to 50% heading before the mean value 52 days. Among the twenty-four genotypes evaluated, eight lines attained physiological maturity before the mean value 82 day maturity revealing the presence of early maturing genotypes in the materials studied. Eight genotypes were taller than the mean height (66 cm) spike length of the genotypes ranged from 6 to 8 cm with the mean value of 7.2 cm. The number of spikelet per spike ranged from 13 to 15 with mean value of 14. The 1000 seed weight ranged from 24 gm to 33 gm with the average weight of 27.4 gm (Table3). Most of the out yielded germplasms showed a better thousand kernel weight as compared to the low yielders. (table 3). The yield of the genotypes reached 3184 kg/ha with the mean of 2481 kg/ha. This result showed that the lines are genetically variable in their yielding potential. Nine genotypes gave higher grain yield than the mean values (2481 kg/ha) and the standard check (2366 kg/ha). Based on the results, Nine genotypes were selected for national variety trials. (table 3).

Table 3. Mean performance of the genotypes for the traits studied

S.N.	Genotypes	DH	DMA	PH (cm)	SL (cm)	NSS	NKS	TKW	YLD (kg/ha)
2	HIDDAB/ATTILA-7	50	80	66	7	15	40	28	2751
10	ATRIS-10/4/PASTOR/3/	49	79	68	7	13	41	31	2642
15	HUBARA-5/ANGI-1	50	81	63	7	14	38	25	2650
16	HUBARA-5/PASTOR-2	49	81	67	7	14	37	29	3184
17	PASTOR-2/HUBARA-5	50	81	66	6	14	29	33	3003
18	DEBEIRA(CHECK)	49	79	64	7	13	34	29	2671
19	ANGI-2/HUBARA-3	51	82	70	8	14	33	29	2671
20	BJY/COC//PRL/BOW/3/	51	82	66	8	14	38	27	2959
24	KAUZ'S'/FLORKWA-1//	48	84	63	6	14	36	29	3030
	Mean	52	82	66	7.2	14	36	27	2481
	CV	8.3	5.5	7.9	10	7.5	13.5	13	25
	LSD	7	7.5	8.5	1.2	1.7	8.0	5.6	1034
	P<0.05	*	*	*	*	*	*	*	*

The analysis of variance in the second preliminary variety trial showed that there were significant differences (alpha = 0.05) among the treatments (genotypes and standard checks) for all parameters studied showing the presence of genetic variability among the genotypes for those traits. Days to heading ranged from 45 to 64 of which 12 genotypes were reached to 50% heading before 53 days (the mean value). Days to maturity varied from 76 to 93 days with the ten genotypes reached to physiological maturity stage before mean value 85 days as there were early maturing types and high yielding genotypes among the materials evaluated in this activity. Nine genotypes were taller than the mean plant height (65.5 cm) and twelve genotypes possessed longer spike length than mean value 7.3 cm. The number of spikelet per spike and number of kernel per spike varied from 12 to 15 with mean value of 14 and from 26 to 43 with mean value of 34, respectively (table 4). The 1000 kernel weight differed from 27 to 40 gm with the average weight of 33 gm showing high genetic variability among the genotypes (table 4). The yielding potential value of the lines varied from 2538 to 5467 kg/ha with the mean yield value of 3332 kg/ha. Nineteen genotypes gave higher grain yield compared to check variety and ten lines had better yielder than the mean value of all the genotypes (table 4). Thus, based on the results, high performing genotypes over the mean value were selected for national variety trial (table 4).

Table. 4. Mean performance of the genotypes

SN	Genotypes	DHE	DM	PLH	SPL	NSP	NKS	TKW (g)	YLD Kg/ha
1	ATTILA-7	57	89	72	8	14	33	31	4050
3	REYNA-19	53	85	65	8	15	43	32	5467
5	REYNA-29	57	89	64	7	14	33	31	3579
8	UTIQUE 96/FLAG-1	64	93	66	8	15	39	27	3741
9	TEMERIND-8	46	77	66	8	14	35	38	3652
12	NABUQ-6	51	81	57	6	14	32	32	3336
13	GIZA-168//SHUHA'S'/	52	82	68	8	13	30	37	3482
15	BOW#1/FENGKANG	60	89	72	8	14	32	32	4146
17	SOMAMA-9//SERI 82/	58	93	64	8	14	33	38	4159
20	KADAR1/4/VAN'S'/3/C	59	90	65	8	15	35	34	3477
	Mean	53.4	85.4	65.5	7.3	13.8	33.7	33.1	3332
	CV%	1.3	4.9	4.9	6.7	6.4	9.2	6.5	23
	LSD(0.05)	1.2	7	5.3	0.8	1.45	5.1	3.53	1268
	Sig (P<(0.05)	*	*	*	*	*	*	*	*

3.3. *National Variety Trials*

Prior to new variety release evaluation of advanced lines across location and over year is important to access its adaptability and stability performance for important traits of yield and yield components as supported by (Friedrich *et al*., 2017). Varity development under lowland stressful irrigated areas of the Ethiopia is the key to utilize the potential of the Agro-ecology untouched resources. As per other scientific findings a cost effective and environmentally sound means of meeting global demand for grain is through the genetic improvement of wheat (Skovmand B. *et al*., 2001). Combined analysis of variance for the first national variety trial showed that the effect of year and location were highly significant (P<0.01) for most of the parameters studied and significant (P<0.05) for TKW and grain yield. Highly significant differences (P<0.01) were observed among the genotypes for most parameters studied and significant difference (P<0.05) for yield but non-significant for spike length. The combined analysis of variance showed that genotype x year and Genotype x location were highly significant (P<0.01) for all traits studied and significantly different (P<0.05) for grain yield (Table 5). Combined analysis of variance for the second national variety trial showed that the effect of location was highly significant (P<0.01) for all parameters studied. Highly significant differences (P<0.01) were observed among the genotypes for almost all parameters studied. The combined analysis of variance showed that Genotype x Location were highly significant (P<0.01) for most traits studied (table 6). Combined analysis of variances for the third national variety trial showed that the effects of environments, Genotypes and Environment x Genotype were highly significant (P<0.01) for parameters studied (table 7). The most important is the genotypic variance, environmental variation. Year by location interaction, Environmental variation, due to years, locations are important to check stability of lines. For the most traits and quality, genotypic variation accounts for more total variability to explain variation (Friedrich *et al*., 2017, Darya Khan Akbarzai et al., 2017).

Table 5. Combined Variances (ANOVA (2010/11 - 2011/12) (1st NVT)

.Source of variation	df	DH	DM	PH	SL	NKPS	GY	TKW
		Mean squares for the parameters						
Year (Y)	2	*	**	**	**	**	**	ns
Location(L)	2	**	**	**	**	**	*	*
Treatment(G)	8	**	**	**	ns	**	*	**
YG	14	**	**	**	**	**	*	**
LG	14	**	**	**	**	**	*	**

DH = Days to heading, **DM** = Days to Maturity, **PH** = Plant Height, **SL** = Spike Length, **NKPS** = Number of Seeds per Spike, TKW = Thousand Kernel Weight and **YLD** = Grain Yield

Table 6. Combined analysis of variance (ANOVA) (2011/12 – 2014/15) (2nd NVT)

Sources of variation	Parameters MS							
	Days to heading	Days to Maturity	Plant height	Spike length	spikelet number /spike	kernel number /spike	1000 kernel weight	Yield
Location	**	**	**	**	**	**	**	**
Treatment	**	**	**	**	**	**	**	**
L x T	NS	**	**	**	**	*	NS	**
Error	76	6	19	0.4	1.3	13.9	7.9	417691

Table 7. Combined ANOVA over years and location from (2012 to 2016) EMBW

Sources of variation	df	Parameters MS							
		Days to heading	Days to Maturity	Plant height	Spike length	Spikelet number	kernel /spike	1000 weight	Yield
E	7	**	**	**	**	**	**	**	**
G	13	**	**	**	**	**	**	**	**
E x G	91	**	**	*	**	**	**	**	**
Error	207	9.51	8.99	36.8	0.45	1.02	145.3	7.35	298599

E = Environment, G = Genotypes

The mean performance of the genotypes studied in the first national variety trial ranged from 49 to 57 days for DH, 81 to 90 days for DM, 63 to 72 cm for PH, 6-7 cm for SL, 30-38 for NKPS, 26-35 g for TKW and 1894 – 2977 kg/ha for grain yield. The highest yielding genotypes were NEJEMAH-14 (2977 kg/ha), ADEL-6 (2931 kg/ha) and HAALLA-44 (2724 kg/ha); were also early maturing with maturity date of 81, 82 and 81 days, respectively (table 8). The yield performances of these three genotypes were high across locations and over years (Table 8).

The significant difference observed for most of the trait showed the existence of sufficient genetic variability among the genotypes evaluated under the lowland irrigated areas. This variability could be utilized for future breeding works. Similar finding was reported by Mihratu (unpublished data 2014). Earliness, which is the phenological traits, such as DH and DM was observed in the three promising genotypes revealed the possibility of using these materials in the breeding program for improving earliness without affecting the yield. Similar result was reported by Saulescu *et al* (1998). The high environmental stresses of the testing sites such as high mean temperature ranged from 24.8 to 25.1 ^{0}C), low RH (47.3 to 50.8 %), high evapo-transpiration (207.6 to 232.1%) and high soil temperature (30.1 ^{0}C to

33.2 ^{0}C) could affect the yielding potentials of the genotypes. The findings of Reynolds *et al* (2012) supported the present results. The soil PH was relatively high for Werer site (8.1) as compared to Gewane site (7.62) but the mean temperature of Gewane during the growing period was 27.2 ^{o} C, which is higher than Werer site (24.95 ^{0} C) (Werer and Gewane unpublished weather data). Generally, the combined effects of these all stresses greatly affected the yield performances of the genotypes. Despite these environmental stresses, the mean yield performances of the three promising genotypes across locations and over years were higher than the other genotypes showing their potential to adapt wide ranges of environmental conditions (table 8).

In the second national variety trial, four genotypes were reached to 50% heading earlier than the mean value (56 days of sowing) and the check variety (table 9) and six genotypes including the check variety attained the physiological maturity stage earlier than the mean value (86 days of sowing). Four genotypes were taller than the mean height (70.5 cm) of the range is 64 cm to 74 cm. The range of spike length was 6.5 to 8.1 cm with mean values of 7.2 cm. The number of spikelet per spike and number of kernels per spike varied from 13 to 15 with mean value of 14 and from 29 to 38 with mean value of 33.1, respectively. The yield value of the lines evaluated were varied from 2322 to 3487 kg/ha with the mean yield value of 2975 kg/ha. Based on the mean performances of the genotypes evaluated for the past four years across three locations, three promising lines (Moontiji-3, Doukkala-4 and Saamid-3) were selected as candidate varieties for verification. The 1000 seed weight ranged from 29 to 36 g with the average weight of 32.4 g. Among the three candidate varieties, Doukkala-4 possessed higher 1000 KW (35 g) as compared to the other two candidate varieties and the standard check (table 9).

In the third national variety trial, five genotypes were reached to 50% heading earlier than the mean value (50.6 days of sowing) and the check variety (table 10). For days to maturity among the genotypes eight genotypes including the check variety attained the physiological maturity stage earlier than the mean value (85.3 days of sowing). Among all the genotypes studied, the highest yielding candidate variety (SERI 82/SHUHA'S'//PASTOR-2) was found to be early maturing type (table 10) which is very desirable character for irrigated areas of Ethiopia where double cropping (cotton and wheat) is becoming a common practice. The plant heights ranges of 63 cm to 78 cm six genotypes were taller than the mean height (69.1 cm). The spike length of the lines ranged from 7 to 8 cm with mean values of 7.6 cm. The number of spikelet per spike, number of kernels per spike and total kernel weight varied from 12 to 14 with mean value of 13, 33 to 60 with mean value of 45.2 and 29 to 40 g with mean value of 33.2g respectively with existence high genetic variability among the genotypes for these traits as per (Reynolds et al., 2001). Among all the genotypes; QAFZAH-2/FERRIUG-2 possessed higher 1000 KW (40 g) (table 10). The yield value of the lines evaluated were varied from 2901 to 4011 kg/ha with the mean yield value of 3404 kg/ha. The highest grain yields obtained from SERI 82/SHUHA'S'//PASTOR-2 (4011 kg/ha) followed by REYNA-28 (3718 kg/ha) and QAFZAH-2/FERRIUG-2 (3681 kg/ha). Based on the mean performances of the genotypes evaluated for the past five years across three locations, three promising lines (SERI 82/SHUHA'S'//PASTOR-2, QAFZAH-2/FERRIUG-2 and REYNA-28) were selected as candidate varieties for verification trial implemented in 2016/17. The improved varieties developed though wheat breeding is important catalysts for increasing crop performance at the farm level, where a range of biotic and abiotic stresses impinge on yields (Reynolds et al., 2001). Also choose a variety that has a higher yield to be planted and utilized by end-users (http://www.nvtonline.com.au/wp).

Table 8. Mean performance of wheat genotypes (2010/11- 2012/13) (1st NVT)

S.N.	Genotypes	DH	DM	PH (cm)	SL (cm)	NKPS	GY (kg/ha)	TKW (g)
1	ADEL-6	51	82	65	6	31	2931	33
2	MORSUD-22	55	88	70	7	34	2224	31
3	HAALLA-44	49	81	63	7	34	2724	35
4	NADIA-15	57	90	71	7	30	1894	28
5	NEJMAH-6	53	81	65	7	32	2279	30
6	PRINIA-2/2* KAR-2	56	86	65	7	38	2046	26
7	PAVON-76 (ck)	54	83	71	7	35	2191	31
8	NEJMAH-14	52	81	72	6	35	2977	31
9	SOLAJAN-1	52	87	69	7	32	2409	33
	Mean	53	84	68	7	33	2408	31
	CV	5.71	3.67	7.98	10.34	12.37	11.89	9.29
	LSD	2.53	3.26	4.52	0.62	2.92	465.04	1.98

DH = Days to heading, **DM** = Days to Maturity, **PH** = Plant Height, **SL** = Spike Length,
NKPS = Number of Seeds per Spike, TKW = Thousand Kernel Weight and **YLD** = Grain Yield

Table 9. Mean performance of the genotypes (2011/12 – 2014/15) (2nd NVT)

S.N.	Genotypes	DHE	DMA	PLH (cm)	SPL (cm)	NSS	NKS	TKW (g)	YLD (kg/ha)
1	GA'AAMBOO (CK)	56	83	74	7.6	15	35	34	3119
2	SAAMID-3	56	84	72	7.2	14	34	32	3157
3	WERRDAH-1	65	92	64	6.8	15	34	30	2322
4	DOUKKALA-4	57	90	70	7.2	15	29	35	3257
5	SISBAN-3	63	91	67	7.5	15	35	31	2630
6	ZAIN-6	47	82	70	7.2	15	32	32	2996
7	MOONTIJ-3	51	82	74	8.1	15	38	32	3487
8	DOUKKALA-35	61	90	72	7.0	15	30	29	2573
9	SHIBILL-2	53	84	70	7.5	15	32	33	3195
10	NOUHA-4	48	81	71	6.5	13	33	36	3006
	Mean	55.6	86	70.5	7.2	14	33	32.4	2975
	CV%	15.6	3	6	8.6	7.9	11.3	8.7	21.7
	LSD	5.3	1.2	2.6	0.4	0.7	2.3	1.7	394

DH = Days to heading, **DM** = Days to Maturity, **PH** = Plant Height, **SL** = Spike Length, **NKPS** = Number of Seeds per Spike, TKW = Thousand Kernel Weight and **YLD** = Grain Yield

Table.10. Mean performance of the genotypes under irrigated environments (2012 – 2015)

SN	Genotypes	DH	DM	PH (cm	SL (cm)	SPS	NKS	TKW (g)	YLD (kg/ha
1	TEVEE-3/SHUHA-20//SERI 82/SHUHA'S'	53	86	72	8	14	46	32	3499
2	SERI 82/SHUAHA'S'//DOVIN-2	54	86	68	8	13	45	35	3236
3	PAVON 76/HAMAM-4/4/YACO/PWW65/3/KUAZ*2	52	87	68	7	13	40	33	3226
4	CHECK (Fentale/Moontij-3)	53	85	77	8	13	53	34	3657
5	FERRROG-3/4/NAI60/HN7//SX/3/JUN'S'	46	82	68	8	12	39	32	3336
6	QAFZAH-2/FERRIUG-2	45	81	72	8	12	39	40	3681
7	SERI 82/SHUHA'S'//PASTOR-2	53	85	66	8	13	44	33	4011
8	QAFZAH-33/FLORKWA-2	55	88	68	8	13	53	37	3413
9	REYNA-28	47	83	70	7	13	60	31	3718
10	SANDALL-3	50	84	78	8	13	54	38	3546
11	NABUR-6	52	86	63	7	13	44	29	3287
12	GONGLASE-4	45	82	63	7	13	40	31	2980
13	CROW'S'/BOW'S'-3-1994/95//	53	85	71	8	14	43	29	2901
14	PBW 343	51	94	63	7	13	33	31	3170
	Mean	51	85	69	7.6	13	45.2	33.2	3404
	CV	6.1	3.5	8.8	8.85	7.7	26.5	8.15	15.99
	LSD	3.1	3.0	6.1	0.7	1.0	12.1	2.7	546.4

3.4. *Variety Verification Trials*

Based on the results of multi-environments test, six wide adaptable candidate varieties (Adel-6, Halal-44 and Nejemah-14 from the first NVT and Sammid-3, Doukkala-4 and Moontiji-3 from the second NVT) were identified and promoted to VVT and verified in 2012/13 and 2014/15, respectively. Among the six candidate varieties, Adel-6 and Nejemah-14 from the first NVT and Moontiji-3 and Doukkala-4 from the second NVT were accepted by the national variety releasing committee and released for commercial production in 2013 and 2015, respectively. The performances of the released varieties under research and agro-pastorals fields with their very promising quality characteristics are indicated in table 11 and table 12. A protein content of 12 percent and above is most desirable. Hard red wheats with a high percentage of yellow berry usually have a lower protein content (D. R. McAllister and R. S. Roberts, 1995). Genetic quality traits and also environmental variables affect wheat grain protein accumulation and processing quality (Lingan Kong *et al.*, 2013). The yield gap of the varieties at research center and on-farm is narrow as the varieties scale-out to agro-pastorals with their full production packages.

Table 11. The performances of the released varieties on research station and farmers' fields

Name of varieties	Year of release	Response to stress; Moderately	Yield (ton/ha)	
			On- station	On-farm
Werer-2 (Adel-6)	2013	tolerant to heat & salinity	3.5-4.0	3.0
Lucy (Nejemah-14)	2013	tolerant to salinity	3.5-4.0	3.0
Fentale (Moontiji-3)	2015	tolerant to heat	5.0-5.7	4.0-4.5
Amibera (Doukkala-4)	2015	tolerant to heat	5.0-5.1	4.0-4.5

Table 12. Quality characteristics of released BW Varieties

Varieties	Seed color	1000 Kernel wt.(g)	HLW (kg/hl)	Protein (%)	Gluten (%)	Zeleny index(ml)
Werer-2	White	33.5	79.2	16.89	44.1	78.5
Lucy	Red	34.8	74.4	14.5	64.3	-
Fentale	White	34.6	71.0	17.46	45.6	85.5
Amibera	White	38.1	71.3	16.63	44.7	86

IV. Conclusions and Recommendation

By Introduction of appropriate wheat germplasms using internationally set breeding procedures, out of 518 genotypes introduced from ICARDA, 114 promising lines were selected and promoted to PVTs, NVTs and VVT during the project period. Four bread wheat varieties were released and 3 promising lines are at pipelines. The released varieties were demonstrated on agro-pastoral fields at various locations since 2013. In their quality characteristics; released and candidate varieties were very promising which can be utilized for local factories as raw materials. Varieties were under production by agro-pastorals in six districts of the Afar Region and one district of Oromiya Region. In addition to this, the Ethiopian Sugar Corporation started to produce these varieties at three farms (Kuraz, Beles and Dubti sites) after signing agreement with EIAR in 2016. Released varieties and those at pipelines were evaluated at specific places of the Afar and Oromiya Regions despite the presence of wide lowland areas at the different parts of the country with their own specific environmental conditions. Therefore, the wheat variety evaluation trials have to be conducted in all lowland areas of the country to develop and release wide and location specific adaptable varieties having world standard grain quality.

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