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Yield Potential and Stability of Irrigated Spring Bread Wheat Genotypes in Central Rift Valley of Ethiopia

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Abstract

The available potential resources under arid and semi-arid lowland irrigated areas of Ethiopia could be more exploited by irrigated wheat technology generation on progress and production to fill the gap of national wheat demand. Bread wheat genotypes evaluated in different locations of the Amibara district in the Afar Region and Fentale district of Oromia Region for three consecutive years 2015/16-2017/18 were considered in the study. The 25 bread wheat genotypes were evaluated in the triple lattice with three replications on 9 m^2 plot area. The study was targeted to identify and select high yielding potential and stable candidate varieties for release and also further breeding purposes. The analysis of variances of bread wheat genotypes evaluated revealed a highly significant difference ($p \leq 0.01$) among genotypes for all traits and the genotypes by environment interactions. The overall mean performance of genotypes evaluated across different environments the two genotypes (HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH) 3877 kg/ha and (MUU/FRNC LN//FRANCO LIN #1) with 3655 kg/ha were better out yielded with 12% and 5% than check respectively. The third promising genotype (GLADIUS/2* BAVIS) is most stable genotype and it is better in early maturing (12%), 2nd best plant height (13%) next to MUU/FRNCLN// FRANCOLIN #1, and it has the maximum thousand kernel weight (8%) and related quality traits comparing to check. The out yielded genotypes and performed well in their important traits were selected as candidate varieties and submitted for variety releasing committee and out of which the HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH and GLADIUS/2*BAVIS were officially released. Therefore from the current results, it has been observed better yield potential than the check variety and showing stability among the studied genotypes and this could be exploited in future large scale seed production and breeding purposes.

Keywords: ***Environment; Genotypes; Stability; Yield***

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Introduction

Wheat is one of the major cereals grown for use as food and industrial raw materials in Ethiopia. It is an important staple food in the diets of many Ethiopians, providing an estimated 12% of the daily per capita caloric intake for the country's over 90 million population [1]. It is the important staple crop in Ethiopia and ranked 4th in the area (13.38%) and grain production (15.17%) of total grain crops which has resulted in an increase in production mainly by smallholder farmers using rain-fed based production system [2]. Ethiopia is still importing about 1.6 ml tons of wheat which estimated to 25% in deficit to fulfill domestic wheat demand by foreign currency [3]. Several Bread wheat (*Triticum aestivum L.*) varieties have been released for rain fed production targeted for different midland and highland area agro-ecologies. Although there is a potential for irrigated wheat production in the lowlands, the capacity to produce at a commercial scale is at its very initial stage in the country. Main wheat production constraints are biotic and abiotic stresses across rain-fed and irrigated environments which accentuated by the increasing incidence of climate change heat and drought [4]. So the climate change effect abiotic and biotic stress tolerant high yielding variety development is vital in continuous as per Tadesse et al., [4]. Irrigated Lowland area wheat production has limitations in the high yielding and stability of released wheat varieties and their seed system. It is very important to increase the irrigated lowland wheat varieties as a choice for variety development as well as for production and also for irrigable areas with better seed supply. The Irrigated wheat Research and development works done in the last decade achieved better in continuous variety development and pre-scaling up which utilized by policymakers and get attention for irrigated wheat production and diversification in lowland areas of Ethiopia. The progress and promising irrigated wheat Research results to be sustainable in technology generation to supply the required varieties and related packages to feed the irrigated wheat development works and diversification throughout the Ethiopian lowland areas. The high yielding and stable varieties are very crucial to attain the required production gain. Hence, evaluation of the extent and performance of available high yielding genotypes present under lowland areas are essential for effective crop production in an extensive way for local consumption. Thus, the aim of the study is to identify high yielding and stable genotypes in different environments for various development works then to release and access related merits for further breeding activities.

Materials and Methods

1. Experimental material, sites, and Agronomic practice

The experiments were conducted in Awash River basins at Amibara district Werer Agricultural Research Centre (WARC) under the Ethiopian Institute of Agricultural Research (EIAR). The WARC is located at 740 m a.s.l (9°16'8"N, 40°09'41" É). In Oromia regional state the trials were done at Saru-weeba Fentale district. The 25 bread wheat Genotypes in a triple lattice with three replications were planted under irrigated lowland area on 3 m × 3 m=9 m^2 plot area. The trials were planted at the relatively cool season of the middle awash from mid-October to November per consecutive years.

The fertilizers (UREA=100N Kg/ha, DAP=50 P_2O_5 kg/ha) were applied based on previous practice in the irrigable areas. UREA Fertilizer application was on split basis; 1/2 at 25-30 days after planting and 1/2 at booting stage and DAP applied all at planting. All experimental plots irrigated uniformly using furrow irrigation methods in 10 days interval until the wheat crop reached physiological maturity. Other management practices performed as per previous recommendations. Data were recorded for Days to 50% heading, Days to 75% Maturity, Spike length, Spikelet number per spike, Plant height (cm), Number of kernel per spike, Thousand kernel weight (g) and Grain yield (kg ha^{-1}).

2. Statistical analysis of data

The recorded all yield components and average yield across locations data was subjected to Analysis of Variance (ANOVA) and Varieties by environment interaction (GGE) biplot analysis using appropriate software GenStat statistical package18th Edition [5]. A comparison of treatment means was done using Fischer's Least Significant Difference (LSD) test at 5% probability levels. The combined analysis of variance was carried out to estimate the effects of the environment (E), Genotypes (G) and Genotype by Environment interaction.

Results and Discussion

1. Analysis of variance

The Analysis of variances across the location from 25 bread wheat genotypes evaluated revealed that highly significant ($p \leq 0.01$) difference among genotypes for all traits and the genotypes by environment interaction was a highly significant difference ($p \leq 0.01$) for all traits **(TABLE 1)**. This indicated that the measured traits of bread wheat genotypes were highly influenced by environmental factors. Significant genotype 'X' environment interaction found for all traits studied would mean that evaluation of bread wheat genotype on several environments would give a more accurate estimate of different traits. These results agreed with the study that indicated that bread wheat genotypes responded deferentially to environments with significant genotype 'X' environment interaction [6].

TABLE 1. **Analysis of Variance (ANOVA) of irrigated wheat genotypes.**

Source of Variation	**Mean square of Traits**								
	d.f.	DH	DAM	PLH	SL	NSPS	NKSP	GY	TKW
G	24	114^{**}	72.4^{**}	125^{**}	8^{***}	16^{***}	174^{**}	1551795^{**}	133^{**}
G × En	125	30^{**}	107^{**}	366^{**}	3.1^{**}	4.7^{**}	83^{**}	1258917^{**}	27^{**}
Residual	200	8	15	34	2.1	3.2	31	753892	15

G: Genotype; E: Environment; DH: Days to heading; DM: Days to Maturity; PH: Plant Height; SL: Spike Length; NSPS: Number of Spikeletes per Spike; NKPS: Number of Kernels per Spike GY: Grain Yield; TKW: Thousand Kernel Weight

2. Mean performance of genotypes

The mean performance of yield in specific environments (year and location) were described in **TABLE 2** that clearly showing the performance genotypes across environments. The two candidates HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH and MUU/FRNCLN//FRANCOLIN #1 were among the superior genotypes almost in all environments and similarly the third candidate GLADIUS/2*BAVIS is average yielder in addition to its extra earliness except for the first environment **(TABLES 2 and 3).** The combined mean performance of the evaluated genotypes different traits across different environment were illustrated in **TABLE 3.** From all the genotypes evaluated in different environments the two genotypes (HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH) with a mean yield of 3877 kg/ha followed by (MUU/FRNCLN//FRANCOLIN #1) the second most genotype with 3655 kg/ha mean performance out yielded by 12% and 5% than the standard check respectively. The third promising genotype (GLADIUS/2*BAVIS) is characterized by its extra early maturing (12%), it is second-best in plant height (13%) next to MUU/FRNCLN//FRANCOLIN #1, the best in its thousand kernel weight (8%) and related quality traits mean performance than check **(TABLE 3)**. For the yield-related traits, spike length and number of spikelets per spike BAJ #1/KIS KADEE#1 and PFAU/MILAN/5/CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/3/VEE#7/BOW/4/PASTOR/6/2*BAVIS#1 genotypes have the best mean performance followed by HEILO//MILAN/MU NIA/3/KIRITATI/2*TRCH **(TABLE 3)**. The high yielding genotypes and their promising yield-related traits help to use them in large scale production and also further breeding similar to the findings of Punia SS [7]. In addition to high yielding, genotypes that are characterized by an early maturity could be promising because these adaptation mechanisms are associated with an escape strategy for stress conditions. These studies were very important in arid areas with respect to the existing stresses for a different purpose which is supported by M. Afzal Arain et al. results [8].

TABLE 2. **Mean performance of yield (kg/ha) of wheat trial in lowland irrigated areas over different environments.**

S. No.	Genotypes	2015-16 Werer	2015-16 Fentale	2015-16 WARC	2015-16 FWCF	2015-16 FHF	2016-17 WARC	2017-18 WARC	Mean Yield
1	KIRITATI//HUW234+LR34/PRINIA/3/BAJ #1	3161	2503	3797	3067	3718	2596	2549	3064
2	BAJ #1/KISKADEE #1	2893	2708	3713	2951	2787	3605	2926	3145
3	QUAIU//2*BRBT1*2/KIRITATI	2984	1991	3545	2642	3839	2584	3020	2929
4	ND643/2*WBLL1//2*KACHU	2896	2382	3908	2230	4542	3783	3155	3243
5	BAVIS//ATTILA*2/PBW65	3691	2045	3849	2107	3972	4312	3088	3331
6	BAJ #1/KISKADEE #1	2824	2646	3385	3804	4153	3640	3056	3287
7	GLADIUS/2*BAVIS	1424	3088	3272	3286	3527	3003	2813	2706
8	Gaambo	3318	2395	4143	3777	3161	4066	3117	3469
9	HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH	3958	3168	3812	4512	4089	4526	3297	3877
10	WHEAR/VIVITSI//WHEAR/3/FRNCLN	2844	3087	4328	3377	2788	3594	3020	3329
11	MUU/FRNCLN//FRANCOLIN #1	2716	3274	4574	4072	4062	3651	3217	3655
12	DANPHE #1//ND643/2*WBLL1/3/DANPHE	2146	2263	4082	2723	3334	3419	2517	2916
13	PFAU/MILAN/5/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/VEE#7/BOW/4/PASTOR/6/2*BAVIS #1	2735	3469	4408	3160	2133	2896	3325	3222
14	BAVIS/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	1888	3300	4095	3112	4828	4113	3043	3455
15	MUTUS//ND643/2*WBLL1	1810	2736	4357	1871	3677	3129	3113	3039
16	KIRITATI//HUW234+LR34/PRINIA/3/FRANCOLIN #1	2516	1739	3611	2646	3589	3644	3540	2952
17	VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/5/BAVIS	1692	2866	3318	3125	4369	4486	3209	3233
18	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	2186	3194	2287	3377	1420	3946	2740	2876
19	DANPHE #1*2/CHYAK	2879	2973	3478	3684	2036	3945	3169	3280
20	MINO/898.97/4/PFAU/SERI.1B//AMAD/3/KRONSTAD F2004	2783	2716	2500	2912	2143	3547	2605	2838
21	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1*2/4/ND643/2*WBLL1	2995	2233	2818	2826	1626	3506	2707	2751
22	TACUPETO F2001*2/BRAMBLING//KIRITATI/2*TRCH	2664	2771	3081	1838	2358	3541	2995	2849
23	PRL/2*PASTOR//WHEAR/SOKOLL	2275	1696	2571	1963	3461	3657	3045	2600
24	DANPHE #1*2/CHYAK	3223	2894	3114	2359	3722	3866	3286	3205

25	W15.92/4/PASTOR//HXL757 3/2*BAU/3/WBLL1/5/MUU	3116	2434	3543	1704	4553	3798	3285	3181
Mean		2705	2656	3584	2748	3485	3634	3029	3137
CV%		30.6	27	26	29.25	25.06	17.3	19.4	32.7
LSD		1368	1471	1563	43.33	1922	1163	1191	673

TABLE 3. **Combined analysis of bread wheat genotypes mean performance across different locations (Amibara district at Afar region and Fentale district at Oromia region) 2015-16 to 2018-19.**

Trt	Genotypes	DH	DAM	PLH	SL	NSPS	NKPS	Yld_kg/ha	TKW
1	KIRITATI//HUW234+LR34/PRINIA/3/BAJ #1	53^{b-e}	85^{bc}	72^{abc}	8^{fgh}	14^{c-f}	36^{d-g}	3064^{b-e}	35^{d-j}
2	BAJ #1/KISKADEE #1	54^{cde}	86^{c}	75^{abc}	10^{a}	16^{ab}	37^{d-g}	3145^{b-e}	38^{bcd}
3	QUAIU//2*BRBT1*2/KIRITATI	53^{b-e}	84^{bc}	77^{bc}	9^{a-d}	15^{abc}	43^{b-g}	2929^{cde}	35^{d-i}
4	ND643/2*WBLL1//2*KACHU	53^{b-e}	85^{bc}	72^{abc}	8.1^{d-g}	15^{abc}	37^{d-g}	3243^{a-e}	30^{m}
5	BAVIS//ATTILA*2/PBW65	54^{cde}	86^{c}	73^{abc}	8.1^{d-g}	13.3^{fg}	34^{fg}	3331^{a-d}	34^{f-k}
6	BAJ #1/KISKADEE #1	54^{cde}	86^{c}	72^{abc}	9.4^{ab}	14^{c-f}	34^{fg}	3287^{a-d}	31^{lm}
7	GLADIUS/2*BAVIS	41^{a}	76^{a}	69^{ab}	7^{h}	12^{g}	32^{g}	2706^{de}	42^{a}
8	Gaambo	55^{de}	86^{c}	79^{c}	9.3^{abc}	16^{ab}	38^{d-g}	3469^{abc}	39^{bc}
9	HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH	54^{cde}	86^{c}	76^{abc}	9.4^{ab}	16^{ab}	41^{c-g}	3877^{a}	40^{ab}
10	WHEAR/VIVITSI//WHEAR/3/FRNCLN	54^{cde}	87^{c}	72^{abc}	8.7^{a-f}	15^{abc}	39^{c-g}	3329^{a-d}	35^{d-i}
11	MUU/FRNCLN//FRANCOLIN #1	53^{bcd}	86^{c}	68^{a}	8.2^{d-g}	14^{c-f}	34^{fg}	3655^{ab}	37^{b-f}
12	DANPHE #1//ND643/2*WBLL1/3/DANPHE	54^{cde}	85^{bc}	79^{c}	8.4^{b-g}	14.7^{b-e}	38^{d-g}	2916^{cde}	35^{d-i}
13	PFAU/MILAN/5/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/VEE#7/BOW/4/PASTOR/6/2*BAVIS #1	52^{bcd}	87^{c}	75^{abc}	8.1^{d-g}	16.2^{a}	39^{c-g}	3222^{a-e}	36^{ch}
14	BAVIS/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	52^{bcd}	85^{bc}	75^{abc}	8.8^{a-e}	14^{c-f}	35^{efg}	3455^{abc}	35^{d-i}
15	MUTUS//ND643/2*WBLL1	52^{bcd}	85^{bc}	71^{abc}	8.4^{b-g}	14.8^{bcd}	36^{d-g}	3039^{b-e}	34^{f-k}
16	KIRITATI//HUW234+LR34/PRINIA/3/FRANCOLIN #1	54^{cde}	85^{bc}	70^{ab}	8.3^{d-g}	14^{c-f}	37^{d-g}	2952^{cde}	33^{i-m}
17	VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/5/BAVIS	51^{bc}	85^{bc}	73^{abc}	7.7^{fgh}	13.7^{def}	35^{efg}	3233^{a-e}	36^{b-g}
18	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79	52^{bcd}	85^{bc}	72^{abc}	7.6^{gh}	13.5^{ef}	47^{a-d}	2876^{cde}	33^{i-m}

	//2*SERI								
19	DANPHE #1*2/CHYAK	52^{bcd}	84^{bc}	72^{abc}	8.09^{efg}	14.8^{bcd}	55^{ab}	3280^{a-e}	34^{e-j}
20	MINO/898.97/4/PFAU/SERI.1B//AMAD/3/KRONSTAD F2004	53^{bcd}	87^{c}	73^{abc}	7.6^{fgh}	13.97^{c-f}	51^{abc}	2838^{cde}	32^{j-m}
21	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1*2/4/ND643/2*WBLL1	51^{b}	84^{bc}	73^{abc}	8.09^{efg}	14.5^{b-f}	46^{b-e}	2751de	34^{g-l}
22	TACUPETO F2001*2/BRAMBLING//KIRITATI/2*TRCH	56^{e}	86^{c}	73^{abc}	8.2^{d-g}	14.3^{c-f}	44^{b-f}	2849^{cde}	37^{b-e}
23	PRL/2*PASTOR//WHEAR/SOKOLL	52^{bcd}	85^{bc}	71^{abc}	7.5^{gh}	14.2^{c-f}	50^{abc}	2600^{e}	31^{klm}
24	DANPHE #1*2/CHYAK	51^{b}	81^{ab}	71^{abc}	8.3^{c-g}	16^{ab}	59^{a}	3205^{a-e}	33^{h-m}
25	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1/5/MUU	53	86^{bc}	74^{abc}	7.7^{fgh}	14^{c-f}	54^{ab}	3181^{b-e}	36^{d-i}
Mean		53	85	73	8	15	41	3137	35
CV		7.3	8.3	17.5	19.3	13.7	44.6	32.7	13
LSD		2.8	5.1	8.4	1.04	1.3	12	673.3	3

** DH: Days to Heading; DM: Days to Maturity; PH: Plant Height; SL: Spike Length; NSPS: Number of Spikelets per Spike; NKPS: Number of Kernels per Spike; GY: Grain Yield; TKW: Thousand Kernel Weight; a-m: Used as Mean Separation

3. GGbiplot analysis

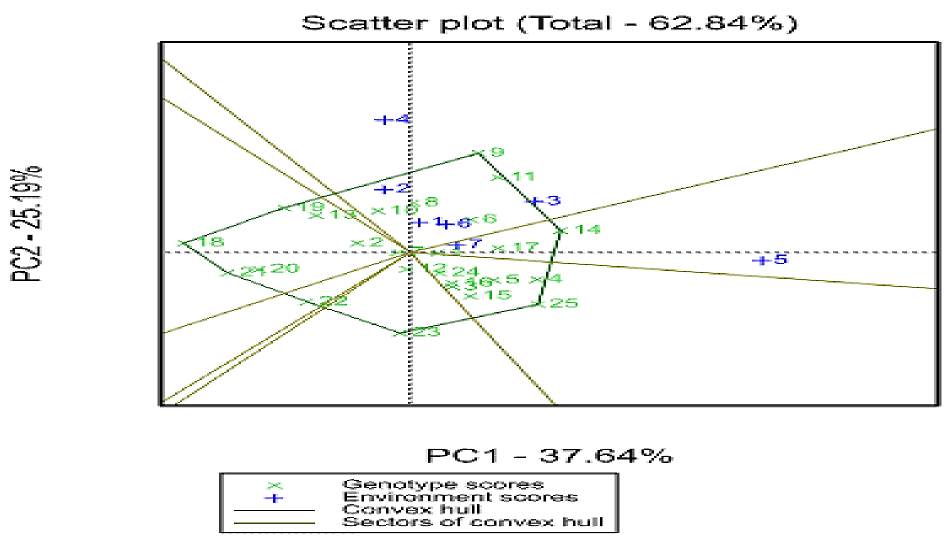

FIG. 1. **GGbiplot analysis of the genotypes across different locations and years.**

The GGbiplot analysis showed that overall performance of the Genotypes across different environments (locations/years) and cumulative mean performance as per Anputhas et al. [9] and Yan W et al. [10]. Genotypes assigned on treatment 9 (HEILO//MILAN/MUNIA/3/KIRIT ATI/2*TRCH) and 11 (MUU/FRNCLN//FRAN COLIN #1) out yielded in overall mean and more stable on environments except for environment-5. Early maturing Genotype assigned on treatment 7 (GLADIUS/2*BAVIS) is the most stable genotype in its yield on overall environments **(FIG. 1)**.

Conclusion

The variability among genotypes for different traits was well recognized and stability of promising genotypes in yield also well discriminated. Based on the study results three candidate varieties for yield potential and different agronomic merits were identified. Generally, the outperformed candidate varieties were potential yielder across all the six environments exception to the fifth environment and the best stable, early maturing and superior quality. The two candidate varieties; HEILO//MILAN/MUNIA/3/KIRITATI/2*TRCH and GLADIUS/2*BAVIS were officially released for production under irrigated lowland agro-ecology. The out yielded genotypes were promising in their most traits that could be utilized for further breeding purposes. More locations and area-based better package utilization could express more the potential which requires attention in future to broaden the study.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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