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RESEARCH ARTICLE

Augmentation of conventional bread wheat breeding technique with farmers' participatory variety selection

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Abstract

Farmers in Amhara regional state, Wollo, were reluctant to adopt improved bread wheat varieties due to their low participation during varietal development. Thus, participatory variety selection was conducted at six locations of Wollo with the objective of examining farmers preferred traits and evaluating varieties based on them. There were significant variations among varieties for the traits examined. G1, G9 and G16 scored maximum grain yield. G15, G21, G19 were specifically adapted genotypes. Farmers identified and weighted key selection criteria ; frost and disease resistance (20%), seed color (12%) and size (11%), kernels per spike (10%), earliness (10%), tillering (6%), spike length (4%) and plant height (3%). Each of the varieties was evaluated against the traits as per direct matrix ranking method. Farmers considered; G9, G5 and G1 were the most preferred varieties. These varieties may prove worthy for general wheat cultivation in this area.

Key words: Bread wheat, farmers’ traits, grain yield, participatory variety selection

Introduction

Amhara National Regional State (ANRS) is one of the major wheat growing regions of the country which shared about 32.8% (545,106.1 ha.) and 28.96 % (1.22 million tons) of the total wheat growing area and production of the country, respectively (CSA, 2016). Of the total wheat production areas covered in the Amhara region, 25.8% is found in Wollo administrative zones from which about 0.27 million tons wheat grain produced (CSA, 2016). Several wheat varieties were released in the region. However, farmers were reluctant to adopt varieties due to the low participation during varietal development. Some breeders have familiarized participatory plant breeding (PPB) program in which selection and evaluation of breeding materials starting from the early generation with the participation of farmers (Ceccarelli *et. al.*, 1997; 1998; 2000 and Ceccarelli and Grando, 2007). Participatory varietal selection (PVS) is also parts of PPB by which farmers start to evaluate and select varieties in their own fields (Muchow *et. al.*, 1994). PVS helps to increase the speed and rate of the adoption of new varieties much faster through farmer to farmer seed exchange system than under the formal crop improvement (Bellon and Reeves, 2002). PVS has been conducted in crops like rice (Sthapit *et. al.*, 1996) and barley (Ceccarelli and Grando, 2007). Hence, the objective of this study was to identify the farmers’ key desirable traits for bread wheat selection and evaluate varieties based on the criteria.

Materials and methods

Twenty two released bread wheat varieties (Table 2) were evaluated at six different locations of Wollo in 2015/16 cropping season. The testing environments are diverse in soil type, annual rainfall and positional information (Table 1). Generally, rainfall starts at June and extends to ends of November and maximum rainfall was received from July to August. Among the six testing environments E2 and E4 are located in North Wollo while E1, E3, E5 and E6 are located in South Wollo Administrative Zone.

Table 1: Description of the testing locations

Location			Geographical positions			Annual rainfall (mm)	Mean temperature (°C)
Name	Code	Soil type	Latitude	Longitude	Altitude(m.a.s.l)		
Borena	E1	Litosol	10⁰46′01″N	38⁰49′55″E	2555	617	16
Geregera	E2	Litosol	11⁰45′02″N	38⁰44′57″E	2872	931	na
Jamma	E3	Vertisol	10⁰27′18″N	39⁰16′01″E	2622	725	16
Kon	E4	Litosol	11⁰37′34″N	38⁰55′05″E	2872	1368	14
Mekdela	E5	Vertisol	11⁰57′21″N	39⁰02′56″E	2765	775	15
Woreilu	E6	Vertisol	10⁰34′42″N	39⁰24′20″E	2628	831	16

Table 2: Description of experimental materials

Code	Variety	Year of released	Code	Variety	Year of released
G1	Madawalabu	2000	G12	Tsehay	2011
G2	Sofumar	2000	G13	Hoganna	2011
G3	Tay	2005	G14	Huluuka	2012
G4	Digalu	2006	G15	Ogolcho	2012
G5	Alidoro	2007	G16	Hidase	2012
G6	Gasay	2007	G17	Mekelle-3	2012
G7	Menze	2007	G18	Sorra	2013
G8	Bolo	2009	G19	Mekelle-4	2013
G9	Danda'a	2010	G20	Biqa	2013
G10	Kakaba	2010	G21	King bird	2014
G11	Shorima	2011	G22	Honkollo	2014

Experimental design and procedure

The experiment was laid-out using Randomized Complete Block (RCB) design with three replications. A plot size of 6 rows of 2.5 meters length with a row spacing of 20 cm was used. Land preparation was done and then planting was carried out at all locations in the mid-week of July. Nitrogen and phosphorous fertilizers were applied uniformly for all experimental plots at the recommend rate of 69 and 46 Kg ha^{-1}, respectively. Half of the recommendation nitrogen fertilizer was applied at planting and the remaining was applied at tillering while full dosage of the recommendation phosphorus fertilizer was applied at planting. Seed rate of 125 Kg ha^{-1} was used for each location. Weeding and other important wheat management practices were applied for each of the experimental plots. After varieties were fully matured, it was harvested and postharvest data were measured at laboratory.

Agronomic data collected

Data were collected from the central four rows, of leaving border rows. Days to 90% maturity (DM) were measured on the whole plot basis.

Five randomly plants were tagged from the central four rows ahead of heading and agronomic traits viz; plant height (cm), number of kernels per spike (KPS) were measured. Biological yield (g plot^{-1}); at harvesting above-ground plant parts from central four rows was sun-dried and weighed using spring balance, and converted into ton ha^{-1} for analysis. Grain yield (g plot^{-1}) obtained from the central four rows was weighed using analytical balance. The result was adjusted for the standard moisture content (12.5%), and converted into ton ha^{-1} for analysis. Thousand-kernels were counted randomly from each plot and were weighted in gram. The result was adjusted to 12.5% moisture content for analysis.

Farmers' participatory varietal selection (PVS)

All trials were conducted in the farmers' fields and evaluations were made by the farmers. A total of 60 (male =40, female =20) farmers were participated in the experimentation. Participant farmers were selected based on their willingness to identify the best bread wheat varieties for the testing communities. PVS were conducted using direct- matrix and pair-wise ranking methods on tested bread wheat varieties at final growth stages of wheat. Farmers were allowed to set key selection criteria. They were jointly agreed and select the most desirable traits during the selection processes; disease resistance, frost (cold) resistance, earliness, seed size and color, number of seeds per spike, straw yield, plant height, and spike length. All criteria were tabulated in a matrix table and then were compared each other in a pair-wise ranking method. Rank was assigned for each criterion based on the scored value of each. Then, farmers were invited to observe each experimental unit cautiously and scored value based on the criteria set.

Direct matrix tables were prepared to evaluate testing bread wheat varieties against traits listed by farmers. Depending on the criteria; scoring to each of the varieties were taken in all locations (1= very good, 2 = good, 3= average, 4 = poor and 5 =very poor). The values were multiplied by the relative weight of a given trait (criteria set). To determine the scoring value of a variety to a trait, value of each of the locations were added together. At last the overall performances of each of the varieties were determined. Then, values were arranged from the smallest to the largest; the smallest value ranked first and vise versa.

Data analysis

Analyses of variance (ANOVA) were performed using Genstat software for yield and yield related traits. Duncan's Multiple Range Test (DMRT) was used to compare means among varieties (Steel and Torrie, 1980). Homogeneity of error variance among environments was tested before combining the data over environments (Steel and Torrie, 1980). Farmers' selection traits were displayed over locations using a graphical tool called genotype plus genotype by environment (GGE) bi-plot analysis (Yan *et. al.*, 2000; Yan and Kang, 2002). The bi-plot was constructed using the first two principal components (PC1 and PC2), subjecting farmers' traits to singular value decomposition. To statistically compare farmers' preferred varieties, using their selection criteria, with grain yield; spearman's rank correlation coefficients were determined (Steel and Torrie, 1980) using the formula, $\gamma_{s=1-}\frac{6\sum d^2}{n(n^2-1)}$

Where

d = difference in the ranks assigned to the same bread wheat variety and n = number of tested bread wheat genotypes.

The minimum (127 days) and maximum (150 days) environmental mean for maturity were recorded at E6 and E4 respectively (Table 5). The occurrence of cold and wind severity at E6 forcing wheat varieties triggered to maturity. On the contrary, low temperature at E4 delayed maturity, implying the presence of genetic elasticity of wheat varieties to make genetic adjustment to tolerate adverse environmental stresses. The maximum (97 cm) and minimum (70 cm) environmental mean of plant height of wheat varieties were scored at E1 and E6, respectively. E1 was the highest yielding location in terms of above ground biomass yield (15.4 tha^{-1}) and the lowest was recorded at E6 (6.5 tha^{-1}) (Table 3). The varieties mean of number of kernels per spike ranged from 38 at E5 to 48 at E1 (Table 3).

Table 3. Mean and range values of yield related traits of 22 wheat varieties in each location

Location		Days to maturity	Plant height (cm)	Kernels /spike	Biomass yield (ton ha^{-1})	1000 kernels weight (g)
Geregera	Mean	137	83	46	7	36
	Range	129-147	76-91	30-55	6-10	29-43
Kon	Mean	150	84	45	8	39
	Range	144-159	73-95	34-61	7-11	32-47
Jamma	Mean	147	79	40	9	49
	Range	142-159	72-96	31-50	8-11	44-56
Mekdela	Mean	137	76	38	67	42
	Range	130-151	71-89	25-54	5-10	37-46
Borena	Mean	133	97	48	15.4	44
	Range	124-140	87-106	36-64	12-19	39-52
Woreilu	Mean	127	70	39	6.5	38
	Range	121-140	51-81	28-50	5-7	31-43

Farmers' preferred traits to select potential wheat variety

Farmers identified 9 preferred traits that could be helping them during bread wheat varieties selection. Depending on the farmers perceptions to the traits each of them was weighted (Fig.1) frost (FR) and disease resistance (DR) =22%, seed color (SC) =12%, kernel size (KS) = 11%, number of kernels per spike (NKPS) =10%, maturity (MD) =10%, tillering capacity (TC) =6%, spike length (SL) =4% and plant height (PHT) =3%. GGE bi-plot technique was employed to compare farmers' preferred traits in testing environments by which the centre of the concentric circles is where an ideal trait should be (Fig. 2). FR and DR traits were displayed closest to the concentric circle indicating there most importance during variety selection. Three traits (SC, NKPS and KS) were laid near to the testing locations in the bi-plot indicated their consistency across tested environments. NKPS and KS are yield component traits that directly affect the improvement of yield and SC is a qualitative trait which helps farmers to identified marketable wheat varieties based on their color. Even though the areas received high amount of annual rainfall, the distribution was variable which mainly terminated at the time of grain filling period. Therefore, the areas were characterized as a terminal moisture stressed areas and the problem was high in litosol (E1, E2 and E4) relative to vertisol areas (E2 and E6). Accordingly, the bi-plot analysis revealed that earliness was more preferred farmers' trait at E1, E2 and E4 than at E2 and E6. PHT, SL and TC were the least preferred farmers' traits in most of the testing environments. In agreement with this finding, Netsanet *et. al.,* (2017) reported that disease resistance (27.8 %) was the major farmers' preferred traits.

Fig 1: Over all weighted values of farmers' bread wheat variety selection criteria

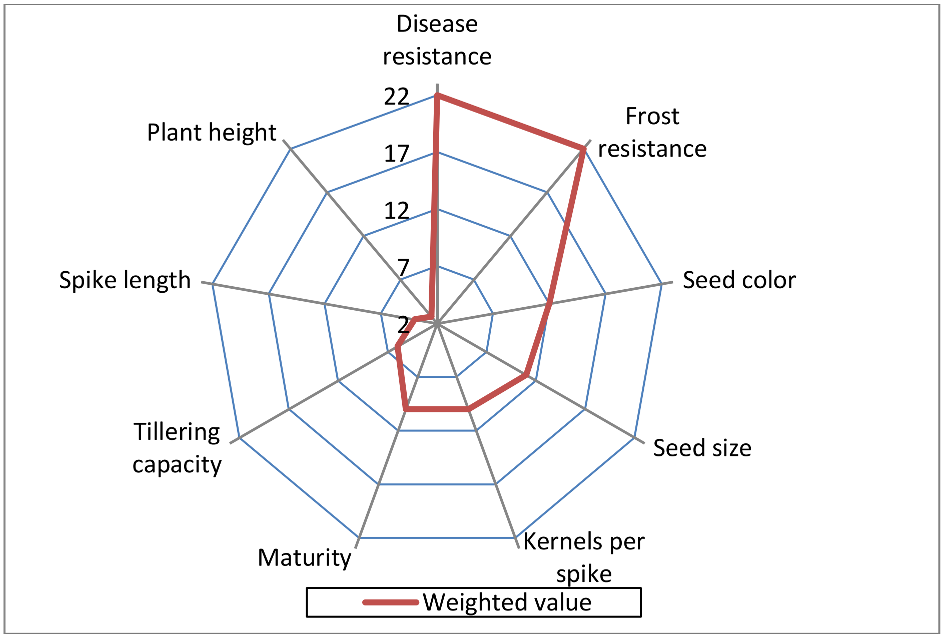
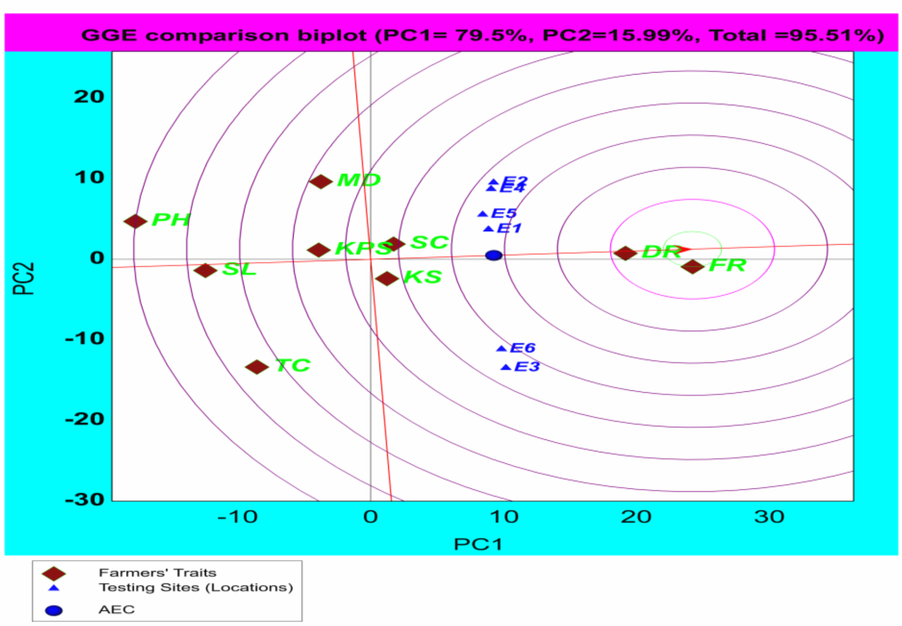


Fig:2 Bi-plot analysis of farmers' wheat preference traits. Disease Resistance (DR), Frost Resistance (FR), Days to Maturity (MD), Seed Color (SC), Kernels per Spike (KPS), Kernel Size (KS), Plant Height (PH), Spike Length (SL) and Tillering Capacity (TC). Borena (E1), Geregera (E2), Jamma (E3), Kon (E4), Mekdela (E5) and Woreilu (E6)



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Varieties performance against farmers' traits

Wheat varieties performance varied in scores and ranking based on individual farmers' traits (Table 4). Farmers perceived that G4, G7, G8, G18 and G12 were good disease resistant wheat varieties while G13, G22, G3 and G14 were less resistant varieties. When considering maturity; G21, G20, G17, G19, G15, G12, G16 were early matured and G4, G8 and G13 and G3 were late matured bread wheat varieties. G5, G9, G1, G4 and G19 were the most preferred while G13, G11, G14, G2 and G20 were the least preferred bread wheat varieties when considered kernels per spike trait. White kernelled varieties (G4, G7, G8, G9 and G21) were more preferred than brown kernelled varieties (G18, G17, G13, G5 and G12) because in relative white kernelled varieties have good market price. G1, G7, G8, G18 and G19 have possessed large kernel size and G13, G2, G14, G17 and G11 possessed small kernel size. Based on tillering capacity trait; G21, G1, G17, G8 and G9 have best tillering capacity while G13, G10, G19, G2, G11 and G6 have low tilliering capacity. With regarding frost tolerance trait; G4, G18, G8, G16, G15, and G19 were the best frost tolerant wheat varieties preferred by farmers on contrary G13, G14, G2, G3, G11, and G22 were the least frost tolerant farmers preferred varieties. In overall performance; G9, G5, G1 were the best farmers' preferred varieties. Similar researches were reported by different researchers on different crops as: wheat (Demelash *et. al.*, 2013) and maize (Sugiharto *et. al.*, 2017) respectively.

Table 4: Direct-matrix ranking (in parentheses) and scoring value by farmers' over six locations for tested wheat varieties

Variety	DR	MD	KPS	PH	SC	KS	SL	TC	FR	Overall
G1	$14^{(6)}$	$23^{(13)}$	$15^{(3)}$	$25^{(6)}$	$28^{(12)}$	$12^{(1)}$	$29^{(5)}$	$28^{(2)}$	$14^{(5)}$	$\underline{188^{(3)}}$
G2	$21^{(17)}$	$17^{(8)}$	$32^{(13)}$	$33^{(11)}$	$29^{(13)}$	$43^{(19)}$	$46^{(13)}$	$49^{(13)}$	$24^{(13)}$	$294^{(19)}$
G3	$23^{(20)}$	$26^{(14)}$	$29^{(10)}$	$15^{(2)}$	$22^{(9)}$	$36^{(16)}$	$26^{(4)}$	$39^{(9)}$	$24^{(13)}$	$240^{(12)}$
G4	$11^{(2)}$	$34^{(17)}$	$19^{(4)}$	$27^{(8)}$	$5^{(1)}$	$22^{(7)}$	$56^{(18)}$	$31^{(5)}$	$6^{(1)}$	$211^{(9)}$
G5	$18^{(12)}$	$22^{(11)}$	$9^{(1)}$	$10^{(1)}$	$32^{(15)}$	$24^{(8)}$	$7^{(1)}$	$29^{(3)}$	$17^{(7)}$	$\underline{168^{(2)}}$
G6	$22^{(18)}$	$20^{(10)}$	$26^{(8)}$	$40^{(15)}$	$23^{(10)}$	$27^{(10)}$	$35^{(8)}$	$47^{(12)}$	$19^{(9)}$	$259^{(15)}$
G7	$7^{(1)}$	$33^{(16)}$	$21^{(5)}$	$19^{(4)}$	$9^{(3)}$	$13^{(2)}$	$53^{(15)}$	$32^{(6)}$	$8^{(2)}$	$195^{(5)}$
G8	$12^{(3)}$	$33^{(16)}$	$26^{(8)}$	$16^{(3)}$	$7^{(2)}$	$14^{(3)}$	$43^{(11)}$	$28^{(2)}$	$10^{(3)}$	$189^{(4)}$
G9	$18^{(13)}$	$18^{(9)}$	$11^{(2)}$	$20^{(5)}$	$9^{(3)}$	$25^{(9)}$	$17^{(2)}$	$29^{(3)}$	$19^{(9)}$	$\underline{166^{(1)}}$
G10	$20^{(16)}$	$23^{(13)}$	$30^{(11)}$	$34^{(12)}$	$26^{(11)}$	$33^{(15)}$	$42^{(10)}$	$49^{(13)}$	$13^{(4)}$	$270^{(17)}$
G11	$19^{(15)}$	$15^{(6)}$	$32^{(13)}$	$32^{(10)}$	$14^{(5)}$	$36^{(16)}$	$56^{(17)}$	$45^{(11)}$	$22^{(12)}$	$271^{(18)}$
G12	$14^{(5)}$	$12^{(4)}$	$30^{(11)}$	$29^{(9)}$	$31^{(14)}$	$30^{(13)}$	$51^{(14)}$	$40^{(10)}$	$20^{(10)}$	$257^{(14)}$
G13	$29^{(22)}$	$32^{(15)}$	$38^{(15)}$	$50^{(19)}$	$33^{(16)}$	$46^{(20)}$	$66^{(20)}$	$54^{(14)}$	$28^{(14)}$	$376^{(21)}$
G14	$23^{(19)}$	$23^{(12)}$	$37^{(14)}$	$42^{(17)}$	$16^{(7)}$	$39^{(18)}$	$57^{(19)}$	$39^{(9)}$	$24^{(13)}$	$300^{(20)}$
G15	$17^{(11)}$	$11^{(3)}$	$31^{(12)}$	$26^{(7)}$	$14^{(5)}$	$21^{(6)}$	$42^{(10)}$	$34^{(7)}$	$14^{(5)}$	$210^{(8)}$
G16	$16^{(10)}$	$13^{(5)}$	$31^{(12)}$	$33^{(11)}$	$29^{(13)}$	$32^{(14)}$	$34^{(7)}$	$31^{(5)}$	$13^{(4)}$	$232^{(10)}$
G17	$15^{(8)}$	$10^{(2)}$	$25^{(7)}$	$26^{(7)}$	$35^{(17)}$	$38^{(17)}$	$55^{(16)}$	$28^{(2)}$	$16^{(6)}$	$248^{(13)}$
G18	$14^{(4)}$	$10^{(2)}$	$25^{(7)}$	$20^{(5)}$	$36^{(18)}$	$15^{(4)}$	$32^{(6)}$	$38^{(8)}$	$8^{(2)}$	$198^{(6)}$
G19	$19^{(14)}$	$10^{(2)}$	$21^{(5)}$	$38^{(14)}$	$14^{(5)}$	$20^{(5)}$	$23^{(3)}$	$49^{(13)}$	$14^{(5)}$	$208^{(7)}$
G20	$15^{(7)}$	$10^{(2)}$	$32^{(13)}$	$36^{(13)}$	$23^{(10)}$	$28^{(11)}$	$43^{(11)}$	$30^{(4)}$	$19^{(9)}$	$236^{(11)}$
G21	$16^{(9)}$	$7^{(1)}$	$28^{(9)}$	$41^{(16)}$	$12^{(4)}$	$25^{(9)}$	$40^{(9)}$	$24^{(1)}$	$18^{(8)}$	$211^{(9)}$
G22	$23^{(21)}$	$16^{(7)}$	$24^{(6)}$	$48^{(18)}$	$17^{(8)}$	$29^{(12)}$	$44^{(12)}$	$39^{(9)}$	$21^{(11)}$	$261^{(16)}$

Where, DR=Disease Resistance, DM= Days to Maturity, KPS= Kernels/Spike, PH= Plant Height, SC= Seed Color, KS= Kernel Size, SL= Spike Length, TC= Tillering Capacity, FR= Frost Resistance

Farmers' preferred varieties compared with grain yield performances of the varieties in each environment

Farmers in each specific locations identified common or specific wheat varieties to growing in the testing areas (Table 5). At E2; G1, G5, G15, G16, G18 were the top five ranked bread wheat varieties preferred by farmers (Table 5). In this location; G15, G16, G18, G19 were out-smarted in grain yield and providing 3.2 t ha^{-1} to 3.4 t ha^{-1}. According to Mohammadi and Amri (2008), grain yield is the key parameter for evaluation of varieties, thus, almost best performed varieties in grain yield were selected by farmers. In the four locations (E2, E4, E5 and E6), G9 was the top ranked farmers' preferred bread wheat variety. G9 has good tillering capacity, plant height, and spike length, kernels per spike, seed size and color. The four bread wheat varieties (G1, G9, G15 and G16) were the best varieties which recorded potential yield (3.3 ton ha^{-1} to 4.7 ton ha^{-1}) at E3, E4, E5 and E6. In all locations the minimum yield was recorded by variety G13. At E1; G5, G15, G7, G8 and G18 varieties were the most farmers' preferred varieties which ranked in the top five. Among these; G5 and G15 were possessed the longest spike length and plant height attributes which easily attracted farmers' attention. Even though G18 has brown seed color, farmers were preferred it by its seed size. G4, G7 and G8 were best in there seed color, kernels number per spike and kernel size, however, it affected by stem rust. At E1; almost all bread wheat varieties were expressed their genetic potential which recorded grain yield in the range of 3.2 ton ha^{-1}(G13) to 6.4 ton ha^{-1} (G17) which may prove worthy.

Correlation of farmers' visual selections with measured trait (grain yield)

Spearman's rank correlation coefficients were calculated among farmers' selections and grain yield of varieties at six locations (Table 6). As the result showed that grain yield and farmers' preference has significant and positive with the correlation coefficients (r) ranging from 0.3 ($p \leq 0.05$) to 0.48 ($p \leq 0.01$). The correlation of grain yield with maturity (r=0.48), number of kernels per spike (r=0.29), kernel size (r=0.3), spike length (r=0.37), and tillering capacity (0.36), respectively. The relationship revealed that farmers were capable to identified high yielding varieties by visual selection. Selecting wheat varieties depend on quantitative and qualitative traits advances the opportunity to select the best varieties. The mean grain yield performance of tested bread wheat varieties over locations revealed that G1, G9 and G16 were recorded maximum grain yield performance (Table 5). By farmers' visual selection; G9, G5 and G1 were the most preferred varieties to the testing areas (Table 4). In addition, G15 and G21 varieties were providing mean grain yield of over the grand mean. Thus, most of the high yielding varieties were selected by farmers. Ceccarelli *et. al.,* (2000), Fufa *et. al.,* (2010) and Sthapit *et. al.,* (1996) reported that; farmers were successfully identifying the highest yielding varieties that were in agreement with this research finding. Thus, farmers' participation during varietal selection is very vital in plant breeding to select the best varieties using their untouched indigenous knowledge. It also helps to increase the confidence of breeders to recommend appropriate varieties to the testing environments. In future during varietal development, participating farmers will be vital to easily disseminate and adopt the release technologies by growers.

Table 5: Varieties yield performances and their rank based on farmers selection criteria

Variety	Grain yield (ton ha^{-1}) in each tested location							Farmers total score and rank of each variety (in parentheses)					
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**Mean**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
G1	5.5^{abc}	2.5^{b}	4.3^{ab}	3.0^{abc}	2.9^{ab}	3.3^{abc}	$\underline{3.6}^{a}$	$248^{(6)}$	$263^{(2)}$	$112^{(10)}$	$191^{(16)}$	$158^{(10)}$	$133^{(10)}$
G2	3.8^{hij}	2.3^{b}	3.2^{g}	2.6^{cde}	2.2^{bcd}	2.9^{bcd}	2.8^{gh}	$384^{(19)}$	$690^{(20)}$	$126^{(15)}$	$141^{(11)}$	$169^{(11)}$	$160^{(21)}$
G3	4.6^{efg}	2.5^{b}	4.0^{bcd}	$\underline{3.5}^{a}$	1.3^{e}	2.9^{bcd}	3.1^{cde}	$299^{(13)}$	$420^{(8)}$	$107^{(6)}$	$101^{(4)}$	$312^{(20)}$	$143^{(13)}$
G4	4.9^{cde}	2.3^{b}	3.6^{cde}	3.1^{abc}	2.3^{bcd}	2.5^{def}	3.1^{cde}	$262^{(8)}$	$411^{(7)}$	$102^{(3)}$	$107^{(5)}$	$201^{(15)}$	$122^{(5)}$
G5	4.3^{ghi}	2.4^{b}	3.3^{fg}	2.7^{bcd}	1.6^{de}	2.8^{bcd}	2.9^{gh}	$98^{(1)}$	$276^{(4)}$	$116^{(12)}$	$133^{(10)}$	$237^{(16)}$	$134^{(11)}$
G6	4.6^{efg}	2.4^{b}	3.9^{bcd}	3.0^{abc}	2.4^{bc}	2.7^{cde}	3.2^{bcd}	$423^{(21)}$	$542^{(18)}$	$103^{(5)}$	$111^{(6)}$	$156^{(9)}$	$140^{(12)}$
G7	4.6^{efg}	2.2^{b}	3.8^{bcd}	2.9^{bcd}	1.8^{cde}	3.2^{bcd}	3.1^{cde}	$226^{(5)}$	$412^{(6)}$	$101^{(4)}$	$99^{(3)}$	$152^{(8)}$	$125^{(6)}$
G8	4.3^{ghi}	2.0^{bc}	4.3^{ab}	2.5^{ef}	2.2^{bcd}	2.5^{def}	3.0^{efg}	$223^{(4)}$	$410^{(9)}$	$110^{(9)}$	$129^{(8)}$	$93^{(2)}$	$127^{(7)}$
G9	4.1^{ghi}	2.6^{b}	$\underline{4.7}^{a}$	3.0^{abc}	$\underline{3.6}^{a}$	3.4^{ab}	$\underline{3.6}^{a}$	$274^{(11)}$	$419^{(12)}$	$90^{(1)}$	$81^{(1)}$	$41^{(1)}$	$85^{(1)}$
G10	3.7^{hij}	2.6^{b}	3.4^{efg}	2.5^{ef}	1.8^{cde}	2.9^{bcd}	2.8^{gh}	$302^{(14)}$	$408^{(11)}$	$119^{(13)}$	$319^{(22)}$	$248^{(17)}$	$131^{(9)}$
G11	4.5^{fgh}	2.6^{b}	4.2^{abc}	2.4^{f}	2.2^{bcd}	2.8^{bcd}	3.1^{cde}	$365^{(17)}$	$523^{(17)}$	$141^{(19)}$	$265^{(19)}$	$106^{(3)}$	$154^{(19)}$
G12	4.7^{def}	2.5^{b}	4.1^{abc}	3.2^{abc}	2.2^{bcd}	3.1^{bcd}	3.3^{abc}	$274^{(11)}$	$462^{(14)}$	$135^{(17)}$	$179^{(15)}$	$274^{(19)}$	$153^{(18)}$
G13	3.2^{j}	1.5^{c}	3.3^{fg}	2.4^{f}	1.9^{cde}	2.0^{ef}	2.4^{h}	$371^{(18)}$	$820^{(22)}$	$210^{(22)}$	$221^{(17)}$	$324^{(21)}$	$200^{(22)}$
G14	5.5^{abc}	2.3^{b}	4.3^{ab}	3.3^{ab}	2.2^{bcd}	2.9^{bcd}	3.4^{abc}	$265^{(10)}$	$719^{(21)}$	$147^{(20)}$	$314^{(21)}$	$107^{(4)}$	$151^{(17)}$
G15	5.5^{abc}	$\underline{3.2}^{a}$	3.5^{def}	3.3^{ab}	2.4^{bc}	2.9^{bcd}	3.5^{ab}	$172^{(2)}$	$392^{(5)}$	$96^{(2)}$	$162^{(12)}$	$256^{(18)}$	$120^{(4)}$
G16	4.5^{fgh}	$\underline{3.4}^{a}$	4.3^{ab}	2.6^{cef}	$\underline{3.4}^{a}$	3.2^{bcd}	$\underline{3.6}^{a}$	$353^{(16)}$	$287^{(3)}$	$108^{(7)}$	$294^{(20)}$	$151^{(7)}$	$110^{(2)}$
G17	$\underline{6.4}^{a}$	2.3^{b}	4.0^{bcd}	2.6^{cde}	2.3^{bcd}	3.0^{bcd}	3.4^{abc}	$264^{(9)}$	$523^{(16)}$	$138^{(18)}$	$170^{(13)}$	$188^{(12)}$	$145^{(4)}$
G18	5.3^{bcd}	$\underline{3.4}^{a}$	3.6^{cde}	3.2^{abc}	2.3^{bcd}	2.7^{cde}	3.4^{abc}	$203^{(3)}$	$244^{(1)}$	$150^{(21)}$	$225^{(18)}$	$200^{(14)}$	$154^{(19)}$
G19	4.9^{cde}	$\underline{3.3}^{a}$	3.9^{bcd}	2.5^{ef}	2.5^{bc}	$\underline{3.9}^{a}$	3.5^{ab}	$252^{(7)}$	$440^{(10)}$	$113^{(11)}$	$130^{(9)}$	$136^{(5)}$	$115^{(3)}$
G20	3.7^{hij}	2.6^{b}	3.9^{bcd}	2.6^{cef}	2.1^{cd}	3.5^{ab}	3.1^{cde}	$279^{(12)}$	$555^{(19)}$	$132^{(16)}$	$124^{(7)}$	$138^{(6)}$	$150^{(16)}$
G21	5.8^{ab}	2.2^{b}	3.6^{cde}	3.0^{abc}	$\underline{3.4}^{a}$	2.5^{def}	3.4^{abc}	$318^{(15)}$	$489^{(15)}$	$109^{(8)}$	$86^{(2)}$	$93^{(2)}$	$130^{(8)}$
G22	5.6^{abc}	2.6^{b}	3.9^{bcd}	2.8^{bcd}	2.6^{bc}	3.0^{bcd}	3.4^{abc}	$405^{(20)}$	$505^{(13)}$	$120^{(14)}$	$172^{(14)}$	$190^{(13)}$	$148^{(15)}$
Mean	4.7	2.5	3.9	2.9	2.3	2.9	3.2						
CV(%)	10.0	13.4	8.8	11.9	17.0	12.4	11.8						

Table 6: Spearman's rank correlation coefficient between farmers' scores with grain yield for tested bread wheat at six tested environments

Traits	**GY**	**KS**	**MD**	**KPS**	**PH**	**SL**
Grain_yield (GY), Metric						
Kernel_size (KS)	0.30^{*}					
Days to Maturity (MD)	0.48^{**}	-0.05				
Kernels/Spike (KPS)	0.29^{*}	0.66^{**}	-0.14			
Plant_height (PH)	-0.02	0.44^{**}	-0.26	0.51^{**}		
Spike_length (SL)	0.37^{*}	0.44^{**}	0.22	0.52^{**}	0.39^{**}	
Tillering capacity (TC)	0.36^{*}	0.47^{**}	0.10	0.47^{**}	0.47^{**}	0.25

*Significant at 0.05 probability level, **Significant at 0.01 probability level

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