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Participatory variety selection of bread wheat (*Triticum aestivum* L.) in highland areas of North Gondar, Ethiopia

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Abstract
Wheat is one of Ethiopia's most important crops, serving as a source of food security, import-substitution, and raw material for the agro-processing industry. Farmers use Participatory Variety Selection (PVS) to recognize and pick improved varieties in a reasonable time frame, thus overcoming the constraints that force farmers to grow old or obsolete varieties. Eleven bread wheat varieties including the local check were tested at Debark and Dabat districts during 2016 main cropping season. The objective of this experiment was to select best adaptive and high yielder variety with the participation of farmers. The experiment was conducted as mother and baby trial fashion. The Mother trial was laid on randomized complete block design with three replications. The combined analysis of variance across locations indicated that there was highly significant difference (p<0.01) among the varieties for plant height, days to heading, days to maturity, spike length, number of spikelet per spike, number of seeds per spike, grain yield and there was significant difference among the varieties in biomass yield. The grain yield was ranged from 3685 kg ha-1 (local check) to 5102 kg ha-1 (Alidoro). Alidoro was the highest in grain yield and other yield related parameters and had a grain yield advantage of 38.4% over the local check. Farmers were also invited and evaluated the varieties based on their selection criteria during maturity time in both districts (Woredas). Based on their selection criteria, Alidoro was selected as first by farmers during field evaluation. Therefore, based on the analysis and farmers preference, Alidoro was recommended for production with its full production packages in highland areas of North Gondar and other similar agro ecologies. In addition to this, Milan and Shorima can be recommended as a 2nd and 3rd option for Debark district.

Keywords: bread wheat variety, grain yield, highland areas, participatory selection

Introduction

Wheat is one of the most important cereal crops grown worldwide, with 750 million tons (MT) generated on 220 million hectares (Mha) of land in 2017 (Tadesse *et al.*, 2019) [13]. More than 25 million tons of wheat are grown on 10 million hectares in Africa, with 7.5 million tons produced on 2.9 million hectares in Sub-Saharan Africa (SSA), accounting for 40 and 1.4 percent of wheat production in Africa and the world, respectively (FAO, 2017) [5].

Wheat is one of Ethiopia's most important crops, serving as a source of food security, import-substitution, and raw material for the agro-processing industry. Ethiopia is the continent's third-largest wheat producer. Wheat is one of the main cereal crops grown by 4.6 million smallholder farmers on 1.8 million hectares of land, with an estimated annual output of 5.0 million tons at average productivity of 2.8 t/ha, which has been steadily growing over the last 25 years but is still well below the global average of 3.3 t/ha. Despite recent increases in demand, Ethiopia is still a net importer of around 1.7 million tons of wheat, draining the country's coffers (EIAR, 2020) [1].

In Ethiopia, wheat is one of the strategic crops contributing for food security, import substitution, and supply of raw material for agro-processing industry. The crop covers an area of 1.89 million ha and production of 5.32 million tons (CSA, 2020) [4]. Amhara Region accounts 32.7% of land area coverage and 30.3% of volume of wheat production in the country (CSA, 2020) [4]. However, average wheat productivity in the Amhara region is 25.3 quintal per hectare which is below the national average 29.7 quintal per hectare and far below the potential productivity (75qt/ha) which can be obtained by using available improved varieties with associated improved production package. Low wheat productivity is mainly attributed to lack of improved seed supply, agronomic practices, integrated diseases and pest management strategy, farm mechanization and low level of awareness of farmers to available wheat production technologies.

Smallholder farmers control the majority of Africa's agricultural system (Lowder *et al*., 2014) [16]. Smallholder farmers account for 90% of Ethiopia's 80 million farmers (Bigsten *et al*., 2003) [3]; (Salami *et al*., 2010) [11]. In subsistence systems, farmers pick varieties from their fields to support the following year's harvest. Their selection of varieties is based on conventional knowledge and previous field experience, as well as their knowledge of weather conditions. End-users of all breeding program outputs should have their preferences for better cultivar adaptation taken into account. However, due to the diverse nature of different agro-ecologies and the diverse interests held by small-scale farmers, incorporating traits of interest to newly established varieties in centralized breeding programs is difficult.

Due to the wide range of temperatures, soil characteristics, disease prevalence, and other factors, a variety's adaptability to a particular low-input environment is reduced. From the viewpoint of a smallholder farmer, the traits of interest are diverse and cannot be easily captured by the existing breeding strategy. Recent developments in genomics and statistics, on the other hand, have opened the door to integrating farmers' preferences into rigorous, quantitative methods aimed at identifying breeding goals that are directly responsive to small farmers' conventional information. Farmers' participation in the breeding process should be reconsidered to speed up the identification of better adapted/preferred varieties that could be distributed to farmers right away, as well as the identification of traits of interest to be included in new genetic material that could meet smallholder agriculture needs (Kidane, 2016) [8].

Participatory varietal selection (PVS) is the selection of finished or near-finished products from plant breeding programs by farmers on their own lands. Released cultivars, varieties in advanced stages of development, and well-characterized material, such as advanced non-segregating lines in inbreeding crops or advanced populations in outbreeding crops.

Farmers use Participatory Variety Selection (PVS) to recognize and pick improved varieties in a reasonable time frame, thus overcoming the constraints that force farmers to grow old or obsolete varieties (Joshi, A., & Witcombe, 1996) [7]. Furthermore, participatory research operation improves scientists' and researchers' work effectiveness (Bellon, 2001) [2], as well as farmers' information retention from year to year (Grisley, W., & Shamambo, 1993) [6]. Farmers who are required to engage in a variety of testing and selection will minimize research costs and increase adoption rates (Joshi, A., & Witcombe, 1996) [7]. Furthermore, as farmers adopt new varieties discovered through participatory research, production rises (Witcombe *et al*., 1996) [14].

Currently Ethiopia's wheat production is insufficient to meet domestic demand, forcing the country to import more than 1.6 million metric tons per year. By the year 2025, Ethiopian government plans to save 3 billion USDs of foreign currency that would have been used to import wheat for domestic consumption. To boost wheat productivity and production, the government of Ethiopia has been striving to produce wheat under different agro ecologies of the country there by remarkable achievements are recorded in the way to substitute wheat importation. As a result, introducing new varieties that are best adaptive and high yielder is very crucial to maximize the productivity of the crop. To do this, there are a number of varieties developed by the research centers of Ethiopia, and most of them were not evaluated in the area and farmers were not participated in varietal selection and evaluation process. Therefore, the objective of this study was to select best adaptive and high yielder variety in the highland areas of North Gondar with the participation of farmers.

Materials and Methods

The study area is located in the northwest part of Amhara National Regional State; North Gondar Administrative zone at Debark and Dabat districts. Debark site is located at 13.13166 N and 37.899121 E with an altitude of 2885 m.a.s.l. The experimental site has annual average rain fall of 974 mm most of which falling between April and September having peaks in July and August. The temperature ranges from 8.6°c to 19.8°c and the soil type is classified as cambisol. Dabat site is located at 12.93178 N and 37.74412 E with an altitude of 2628 m.a.s.l. The experimental site has the annual average rain fall of 758mm most of which falling between April and September having peaks in July and August. The average temperature is 16.6°c and the soil type is classified as cambisol.

The experiment was carried out during 2016/2017 main cropping season at Debark and Dabat districts. Ten improved bread wheat varieties namely Honkolo (ETBW5879), Biqa (ETBW6095), Milan, Worrakatta/Pastor, Ogolcho, Shorima, Gambo, Danda'a, Alidoro, Mada-Wolabu and one local variety were tested (see Table-1 for more information about the varieties). The experiment was conducted as mother and baby trial fashions.

The experiment was laid on randomized complete block design (RCBD) with three replications for mother trials, and single replication for baby trials. The gross and net plot sizes were 6.4 m2 (1.6 m * 4 m) and 5.6 m2 (1.4 m*4 m), respectively for both mother and baby trials. Planting was done by row planting with a spacing of 0.2 m at seed rate of 150 kg ha-1. Spacing between blocks and plots was 1 m and 0.4 m, respectively. Fertilizer was applied at the rate of 92/46 kg ha-1 nitrogen and P2O5 in the form of urea and NPS, respectively. Half of the total nitrogen and all phosphorus were applied at the time of planting while the remaining nitrogen was applied at the time of tillering. All necessary data were taken from the net plot of mother trials. Weeding and other appropriate management practices were done as per the recommendations.

Data on Plant Height: (average height of five plants measured from the ground to the tip of the spike excluding the owns (cm)), Spike Length: (average length of five spikes containing grains (cm)), Number of Spikelet Per Spike: (average number of spikelet counted on five randomly selected plants), Number of Seeds Per Spike: (the average number of seeds counted per spike from five randomly selected plants), Days to Heading: (when the spikes of 50% of the plants are fully visible), Days to Maturity: (the date by which 90% of the plot is ready for harvest), Above Ground Dry Biomass: (gm/plot), and Grain Yield: (gm/plot) were collected from harvestable rows of each plot of the mother trials.

The collected data were analyzed using SAS software (SAS version 9.0, 2002) [12]. Farmers were invited to evaluate and select best variety/varieties based on their selection criteria from the baby trials. The farmers' main selection criteria were spike length, lodging resistance, frost resistance, biomass, disease resistance (septoria), and plant height. They used 1-5 scoring scale (1=very poor, 2=poor, 3= good, 4=very good, 5=excellent) to rank the varieties based on their selection criteria

Table 1: list of bread wheat varieties and background information

Variety	Released Center	Year of release	Productivity Qt/ha		Disease reaction
			Research field	Farmers field	
ETBW5879	Kulumsa	2014	50-60	-	Moderately resistance to rusts and septoria
ETBW6095	Kulumsa	2014	35-50	-	Moderately resistance to rusts and septoria
Milan	Sinana	2014	60-65	45-55	-
Pastor	Sinana	2014	50-57	28-43	Moderately resistance to rusts and septoria
Ogolcho	Kulumsa	2012	28-40	22-35	Resistance to major rusts
Shorima	Kulumsa	2011	29-71	23-43	Resistance to rusts and septoria
Ga'ambo	Kulumsa	2011	45-57	35-50	Moderately resistance to stem rust
Danda'a	Kulumsa	2010	35-55	25-50	Moderately resistance to stem rust
Alidoro	Holetta	2007	27-53	22-42	YR=5(ms), resistance to septoria
Mada-wolabo	Sinana	1999	-	-	-

Results and Discussions

At Debark district, the analysis of variance revealed that there was highly significant difference ($p<0.01$) among the varieties in plant height, days to heading, days to maturity, spike length, number of spikelet per spike and grain yield, and there was also significant difference ($p<0.05$) among the varieties in number of seeds per spike and biomass (Table-2). Alidoro was the highest in all parameters taken among the tested varieties. At Dabat district, the analysis of variance indicated that there was highly significant difference ($p<0.01$) among the varieties in plant height, days to heading, days to maturity, spike length, number of spikelet per spike and number of seeds per spike, and there was also significant difference ($p<0.05$) among the varieties in grain yield, and no significant difference was observed among the varieties in biomass yield (Table-3).

Table 2: Mean performance of 11 bread wheat varieties including local check tested in highland areas of North Gondar during 2016/2017 main cropping season at Debark district.

Variety	PH	DH	DM	SPL	SPS	KPS	GY	BY
ETBW5879	84.50	76.30	145.3	7.27	17.67	55.7	4335.13	11.27
ETBW6095	91.40	69.7	143.3	8.27	18.33	47.87	4975.07	11.9
Milan	96.70	77.3	145.7	8.3	16.8	49.27	5048.77	12.57
Pastor	82.90	75.0	144.7	7.47	16.53	50.47	4261.20	11.47
Ogolcho	100.40	75.0	136.7	8.3	16.6	43.93	2934.77	10.53
Shorima	96.73	75.3	144	8.27	17.73	56.43	5127.97	12.43
Ga'ambo	96.67	75.3	143	8.27	15.93	48.27	4344.40	12.63
Danda'a	102.90	78.0	145.7	7.93	18.13	56.87	3718.50	12.23
Alidoro	112.10	79.7	150.3	10.4	20.33	57.67	5168.20	14.47
Mada-wolabo	104.80	79.0	150.7	10.27	19.27	54.93	3769.03	11.73
Local	103.60	76.3	147.00	7.80	18.20	54.83	3131.50	11.63
CV (%)	2.70	1.7	1.20	5.08	3.48	8.73	15.85	9.41
LSD	4.51**	2.2**	3.10**	0.73**	1.05**	7.79*	1148.8**	1.94*

PH=plant height, DH=days to heading, DM=days to maturity, SPL=Spike Length, SPS=spikelet per spike, KPS=kernels per spike, GY=grain yield, BY=Biological Yield,* =Significant at 5% probability level, **=Significant at 1% probability level,

The overall combined analysis of variance indicated that there was highly significant difference ($p<0.01$) among the varieties in plant height, days to heading, days to maturity, spike length, number of spikelet per spike, number of seeds per spike, grain yield and there was significant difference among the varieties in biomass yield (Table-4). Ogolcho was the earliest for days to maturity (130.5 days) whereas Alidoro was the latest (142.67 days). The longest and the shortest plant height were recorded from Alidoro (106.47 cm) and Pastor (77.1 cm), respectively. The highest and the shortest spike length were recorded from Alidoro (9.9 cm) and ETBW5879 (7.3 cm), respectively. The highest biomass was recorded from Alidoro (13.55 ton ha-1) and the lowest biomass was recorded from Pastor (11.07-ton ha-1).

The highest grain yield was recorded from Alidoro (5102.4 kg ha-1) and the lowest yield was recorded from the local variety (3685.5 kg ha-1. The varieties also showed highly significant difference across the tested locations in all parameters except spike length and biomass yield. This indicated that the varieties expressed their genetic potential differently at different locations. This may be due to different weather conditions and soil factors. But, Alidoro showed consistent and best performance across locations in mean grain yield and other yield related traits. The same result was reported by (Mehari *et al*., 2015) [10] for the best consistence and stable higher grain yield of Alidoro across locations. Similarly, (Zerga *et al*., 2016) [15] reported that Alidoro showed good performance in grain yield and other yield related traits. Farmers were invited to select the varieties based on their selection criteria at maturity time in both districts (Woredas).

Table 3: Mean performance of 11 bread wheat varieties tested in highland areas of North Gondar during 2016/2027 main cropping season at Dabat district

Variety	PH	DH	DM	SPL	SPS	KPS	GY	BY
ETBW5879	85.7	69	124.7	7.3	16.1	42.73	4751.7	11.7
ETBW6095	82.2	59	122.7	8.47	16.8	42	4627.7	10.83
Milan	86.4	68.6	124	8.8	17.87	44.27	4412	11.1
Pastor	71.3	65	123	7.267	16.133	46	5161.2	10.67
Ogolcho	95.3	68	124.3	8.2	16.6	45.8	5523.2	12.37
Shorima	88.8	65.3	123.3	8.6	16.73	46.73	4351.5	10.83
Ga'ambo	89.1	66.3	123.7	8	16.53	44.53	4822.1	12.43
Danda'a	93.3	69.3	129.3	8.2	17.4	50.2	5017.2	11.67
Alidoro	100.8	71	135	9.4	20.27	53.6	5036.5	12.63
Mada-wolabo	97.3	67	127	9	16.73	44.33	4752.7	11.8
Local	92.2	68.6	130.3	7.87	17.53	47.73	4239.5	11.67
CV (%)	4.4	1.4	1.3	5.6	4.8	9.14	7.72	7.08
LSD	6.6**	1.6**	2.8**	0.79**	1.41**	ns	629.8*	ns

PH=plant height, DH=days to heading, DM=days to maturity, SPL=Spike Length, SPS=spikelet per spike, KPS=kernels per spike, GY=grain yield, BY=Biological Yield,* =Significant at 5% probability level, **=Significant at 1% probability level,

Table 4: Mean performance of 11 bread wheat varieties tested in highland areas of North Gondar during 2016/2027 main cropping season at Debark and Dabat districts (combined data of the two locations)

Variety	PH	DH	DM	SPL	SPS	KPS	GY	BY
ETBW5879	85.13	72.67	135	7.3	16.88	49.2	4543.5	11.48
ETBW6095	86.8	64.3	133	8.37	17.57	44.9	4801.4	11.37
Milan	91.57	73	134.83	8.57	17.33	46.8	4730.4	11.83
Pastor	77.1	70	133.83	7.37	16.33	48.2	4711.2	11.07
Ogolcho	97.87	71.5	130.5	8.27	16.6d	44.9	4229	11.45
Shorima	92.8	70.3	133.67	8.43	17.23	51.6	4739.7	11.63
Ga'ambo	92.9	70.83	133.33	8.13	16.23	46.4	4583.3	12.53
Danda'a	98.13	73.67	137.5	8.07	17.77	53.5	4367.9	11.95
Alidoro	106.47	75	142.67	9.9	20.3	55.6	5102.4	13.55
Madawolabo	101.067	73	138.83	9.63	18	49.6	4260.9	11.77
Local	97.9	72.5	138.67	7.83	17.87	51.3	3685.5	11.65
CV (%)	4.78	1.62	1.33	5.89	4.48	9.03	11.74	8.56
LSD (Trt)	5.21**	1.35**	2.11**	0.57**	0.91**	5.19**	618.48**	1.18*
Loc	**	**	**	ns	**	**	**	ns

PH=plant height, DH=days to heading, DM=days to maturity, SPL=Spike Length, SPS=spikelet per spike, KPS=kernels per spike, GY=grain yield, BY=Biological Yield,* =Significant at 5% probability level, **=Significant at 1% probability level, ns=Non-significant, Loc= location, and Trt=treatment

Most of the farmers' selection criteria were similar in both districts. The main selection criteria were spike length, lodging resistance, frost resistance, biomass, disease resistance (septoria), and plant height. Based on the farmers' selection criteria at Debark district, Alidoro, Milan, and Shorima were selected as1st, 2nd and 3rd rank, respectively whereas at Dabat district, Alidoro, Ogolcho and Danda'a were selected as1st, 2nd and 3rd rank, respectively (Table-5).

Table 5: Farmers' Selection Criteria and Their Score for the Varieties at Debark and Dabat Districts

Farmers selection criteria and their scores in both locations															
	Debark								Dabat						
Verities	DR	FR	LR	SL	BM	sum	mean	rank	DR	LR	SL	BM	PH	sum	mean	rank
ETBW5879	5	3	4	3	3	18	3.6	8	2	2	2	2	2	10	2.0	8
ETBW6095	5	2	5	4	4	20	4.0	4	1	1	2	1	1	6	1.2	9
Milan	5	5	4	5	4	23	4.6	2	2	2	3	3	2	12	2.4	7
Pastor	1	1	1	3	4	10	2.0	11	1	1	1	1	1	5	1.0	11
Ogolcho	5	1	1	3	3	13	2.6	10	4	4	4	3	4	19	3.8	2
Shorima	5	5	4	3	4	21	4.2	3	1	1	2	1	1	6	1.2	9
Ga'ambo	5	3	3	4	3	18	3.6	7	2	2	3	3	3	13	2.6	6
Danda'a	1	2	3	4	5	15	3.0	9	3	3	4	5	3	18	3.6	3
Alidoro	5	5	4	5	5	24	4.8	1	5	5	5	4	4	23	4.6	1
Madawolabo	5	3	3	4	4	19	3.8	6	2	3	3	3	2	14	2.8	4
Local	5	4	3	4	4	20	4.0	4	3	3	3	2	3	14	2.8	4

Where: DR=Disease resistance, FR=frost resistance, SL=spike length, BM=biomass, PH=plant height, LR=lodging resistance; 1=very poor, 2=poor, 3= good, 4=very good, 5=excellent/highly preferable

The participant farmers did have similar and strong preferences on the varietal selection. The varietal selection criteria's were set by the participant farmers to evaluate eleven bread wheat verities on the three sites of baby trials. Figure 1 indicates that the average values and their ranks of verities in both sites. A variety that has scored large average value is the best, while a variety with lowest average value is the poorest as stated in the methodology part. Accordingly variety Alidoro was scored large average value and ranked lowest value in both tested sites that meant that was highly preferred by the participant farmers. Whereas, a variety pastor was scored lowest average value and ranked highest value that did not preferred by the participant farmers in both tested locations.

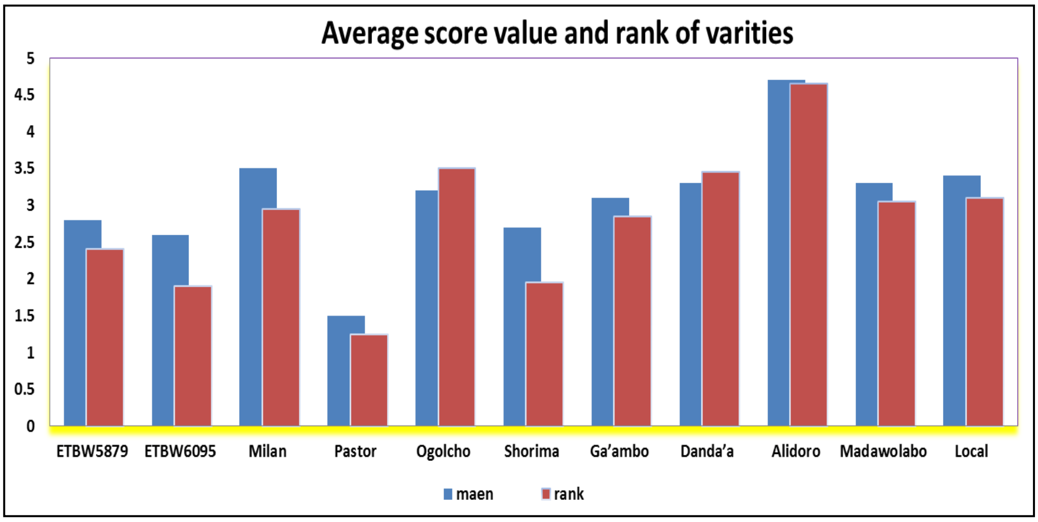

Fig 1: Histogram of the average score values and ranks of the tested verities in both locations

Conclusions and Recommendations

The overall combined analysis of variance indicated that there was highly significant difference ($p<0.01$) among the varieties in all parameters measured. Alidoro was the outstanding variety in all parameters and had grain yield advantage of 38.4% over the local check. It also showed consistent and best performance across locations in mean grain yield and other yield related traits. Farmers also selected Alidoro as first from both locations during field evaluation. Therefore, based on the analysis and farmers preference, Alidoro was recommended for production with its full packages in highland areas of North Gondar and similar agro ecologies. In addition to this, Milan and Shorima varieties can be recommended as 2nd and 3rd option for Debark district.

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