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Performance and farmers selection criteria Evaluation of Improved Bread Wheat Varieties

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Bread wheat is one of the most important cereal crops of the world and a staple food for about one third of the world's population and is a major cereal crop in Ethiopia. One of the major challenges in improving food security is to develop varieties that are adapted to specific environment and farmers' needs. Field trials were conducted at two locations, Hitosa (Sero-Anketo kebele) and Limu Bilbilo (Bekoji-Negesso kebele) districts, in Arsi zone of Oromiya regional state, Ethiopia in 2015. The objectives were to identify farmers' and traders' preferences and selection criteria and acceptable varieties among the tasted twenty-five bread wheat varieties through farmers' participation. The experiment was laid out in lattice design with three replications in which farmers participated only in one of the replication for ranking. Farmers and traders identified top seven criteria that are the same at both locations (that is, disease and insect resistance, grain yield, spike size, seed color, tillering capacity, market demand and seed size, except seed weight instead of seed size at Seru-Anketo) for rating of varieties from 1 to 5 scale (1=very poor and 5=excellent). Data analysis was done using SAS and Microsoft Excel. All varieties showed resistant type of infection for the three rusts (Stem, Yellow and Leaf) at Bekoji-Negesso: As all varieties scored <20 ACI. Similarly, at Sero-Anketo, *Kakaba, Digelu* and *Jefferson* ranged under MS to S whereas *Gassay, Hiddasse*, and *Mekelle-02* ranged under MS and MR types of infection for SR, respectively. Grain protein was analyzed and *Hoggana* (14.27%) was found to be the highest. Based on measured trait (rusts resistance) and farmers' and traders preferences ranking; *Bika, Bulluk* and *TAY* for *Bekoji-Negeso* and *Mekelle-4*, *Ogolcho* and *TAY* for Sero-Anketo were recommended with their full production packages. Therefore, participation of farmers in early breeding program could be one of the approaches as to identify the best variety for specific location.

Key words: Direct matrix ranking, grain protein, pairwise ranking matrix, participatory varietal selection (PVS), rust.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is grown on more land area worldwide than any other crop. In 2013, world production of wheat was 713 million tons, making it third most-produced cereal after maize (1,016 mill t) and rice (745 million tons) (FAOStat, 2015). According to Central Statistical Agency (CSA, 2015) report of Ethiopia, wheat is fourth both in area (1,663,838 ha) and in production (4,231,589 t) after Maize, *tef* and sorghum with an average national yield of 2.54 t ha^{-1}, which is far to global average wheat productivity of 3.33 t ha^{-1} (FAOStat, 2014).

Although useful as a livestock feed, wheat is used mainly as a human food. Wheat provides 21% of the food calories and 20% of the protein for more than 4.5 billion people in 94 developing countries (Von Braun et al., 2010). It has been realized since long that gluten protein largely determines the bread making performance of wheat flour. In Ethiopia, wheat grain is used in the preparation of a range of products such as the traditional stable pancake ("*injera*"), bread ("*dabo*"), local beer ("*tella*"), and several others local food items (that is, "*dabokolo*", "*genfo", "kinche*"). Besides, wheat straw is commonly used as roof thatching material, and as a feed for animals. Wheat contributes approximately 200 kcal/day in urban areas, compared to about 310 kcal/day in rural areas. It accounts for about 11% of the national calorie intake (Guush, 2011).

However, development of appropriate crop production technologies for site-specific have been major problem. It is known that there could be many genetic and environmental factors on plant products (Yazici and Bilir, 2017). Agricultural researchers must know farmers' production constraints. Such a client-driven approach is rather new in many developing countries like Ethiopia (Zewdie, 2004). Participatory research is defined in general as that type of research in which users are involved in the design and not merely in the final testing of a new technology. Participatory plant breeding (PPB), in particular, is that type of plant breeding in which farmers, as well as other partners, such as extension staff, seed producers, traders and NGOs, participate and collaborate in the development of a new variety (Ceccarelli, 2012). Participatory varietal selection (PVS) is the selection by farmers on their own fields of finished or near-finished products from plant breeding programmes. These include released cultivars, varieties in advanced stages of testing, and well-characterized material such as advanced non-segregating lines in inbreeding crops, or advanced populations in out-breeding crops. Witcombe et al. (1996) discussed the contrasting impacts of PVS and PPB on biodiversity.

Rigid release requirements and unrepresentative testing conditions lead to mismatches between what breeders offer and what farmers desire (Witcombe and Virk, 1997). A high incidence of genotype by environment (GxE) interactions also complicates the testing picture in cropping systems cultivated in marginal environments (Ceccarelli et al., 1996).

Breeding and cultivar introduction programs produce and evaluate many varieties. These varieties may produce high yield in trials on the research station, but sometimes do not perform well in farmers' fields, or may lack a quality trait that is important to farmers. Participatory variety selection is a simple way for breeders and agronomists to learn which varieties perform well on-farm and preferred by farmers (Ceccarelli, 2012).

Participatory varietal selection to identify preferred cultivars has three phases: Identifying farmers' needs; searching for suitable material to test with farmers; and experimentation on farmers' fields. PVS can be effectively used to identify farmers acceptable varieties that are better than old and obsolete varieties with which farmers stick for long period (Joshi and Witcombe, 1996). A very important advantage of PVS is that the adoption of new cultivars is much faster than under the formal crop improvement and also the spread of varieties from farmer-to-farmer through the local seed system can be very fast, thus guaranteeing a further good adoption (Bellon and Reeves, 2002). The targeted beneficiaries from participatory crop improvement may be resource poor farmers in marginal areas where solely local varieties or landraces cultivated, or farmers in potential areas who were dependent on old improved varieties (Boef and Ogliari, 2008). There is an opportunity to extract much greater value from agro-ecology based breeding, as opposed to the "broadly-adapted" (but not really well adapted) varieties currently available (Dawit, 2010).

Ceccarelli (2012) identified three common characteristics of most agricultural research programmes that might help explain its limited impact in marginal areas: (i) The research agenda is usually decided unilaterally by the scientists and is not discussed with the user, (ii) Agricultural research is typically organized in compartments, that is, disciplines and/or commodities (for example breeding and agronomy, or breeding programmes of specific crops), and seldom uses an integrated approach; this contrasts with the integration existing at farm level and, (iii) There is a disproportional development between the large number of technologies generated by the agricultural scientists and the relatively small number of them actually adopted and used by the farmers. In Ethiopia, for example, over 122 varieties of cereals, legumes and vegetables have been released, but only 12 varieties had been adopted by farmers (Mekbib, 1997), and similar examples are known in many countries.

Researchers may not be aware of some of the important characters that are preferred by farmers. Instead they focuses on agronomic performance (trial like yield, lodging, duration, and disease resistance), but farmers consider many other features of new variety when deciding whether to adopt or not. For example in Ethiopia, farmers identified high yield, resistance to sprouting and lodging, seed color and size, and baking

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quality as important agronomic characters and their perceptions about some of these characteristics positively influenced their adoption of modern wheat varieties (Bekele et al., 2000). Farmers may concern straw quantity and palatability, harvestability, threshability and storability. These factors are very hard to evaluate in conventional variety testing programs, but may be strongly related to farmer's decision on adoption. However, in PVS trials farmers express their opinion and preference about varieties under evaluation (IRRI, 2006).

Improved bean varieties in East Africa are probably the best-known example of the successful application of PVS, which has catalyzed bean crop improvement in several countries including Rwanda, Tanzania, and Malawi (Weltzien et al., 2003). In their use of the PPB and PVS approaches, the Debre Zeit and Melkassa research centers of the EIAR showed the increased participation of farmers in tef and haricot bean seed production, respectively, along with the increased adoption of the accepted varieties (Assefa et al., 2005; Belay et al., 2006). Similarly, various researchers from Ethiopia have made investigations on PVS in different crops such as common bean (Mekbib, 1997; Asrat and Fitsum, 2008; Mekonen, 2011; Fekadu, 2013), barley (Zerihun et al., 2012), maize (Mulatu and Zeleke, 2002; Daniel et al., 2014), faba bean (Tafere et al., 2012), bread wheat (Kassa et al., 2003; Alebachew, 2012; Molla and Tsedalu, 2012; Assefa et al., 2014), sorghum (Mulatu and Belete, 2001), and tef (Belay et al., 2006). Therefore, the main goal of experimenting with farmers, through PVS, is important to address their information needs about new and released technologies and solutions to problems in a way that is relevant, cheap, systematic, and has low risk for them. So, through PVS, a broader choice of varieties was offered (a basket of choices) that matched their needs in adaptation and quality traits.

MATERIALS AND METHODS

Description of the experimental sites

The field trials were conducted at two locations in the southwest part of Ethiopia in Arsi zone of Oromiya regional state during 2015 main cropping season at Sero-Anketo kebele (=peasant association) of Hitosa district (=woreda) and at Bekoji-Negesso kebele of Limu-bilbilo district as indicated in Figure 1.

Sero-Anketo is located about 22 km north of KARC and 140 km southeast of Addis Ababa and Bekoji-Negesso is located about 65 km south of KARC and 140 km southeast of Addis Ababa, within bread wheat belt districts in the region. Bekoji-Negesso is located at latitude of 7°32′ 37″ N and longitude of 39°15′ 21″ E and the site have Clay (Nitosols) type of soil. The area is located at higher altitude of 2780 m a.s.l. having 1020 mm annual rainfall and 7.9 and 18.6°C minimum and maximum average annual temperature, representing highland and high rainfall types of agro-ecology. Sero-Anketo is located at mid-altitude of 2250 m.a.s.l. and geographically lay at 8°07′ 31″ N and 39° 16′ 31″ E with loam soil type. The cropping systems in these districts have dominated by diversified field crop production and some horticultural crops. Major field crop grown in these areas were; wheat, barley, faba bean, field pea, oil seed, potato, etc. in rain fed condition.

Experimental materials

Twenty-five improved bread wheat varieties (released and new) were evaluated for their performance in the two sites (Table 1). The varieties have been recently released at federal and regional level from different research institutes or centers but not all tested on those study areas of the districts.

Treatments and experimental design

The trials were conducted using an incomplete block design (partially balanced lattice design) with three replications, each consisting of five incomplete. Randomization was done following the basic plan for 5×5 partially balanced lattice design of triple lattice and twenty-five varieties randomly assigned to each five incomplete blocks in each replications. Every plot has a size of 1.2 m × 2.5 m (3 m^2). The spacing between replications, blocks and plots were 1, 1 and 0.4 m, respectively with 0.2 m row spacing. Planting was done in rows at seed rate of 150 kg ha^{-1}.

Field management and practices

All the recommended agronomic practices have applied throughout the growing season. The land was ploughed three times starting from June, 2015 till planting and after leveling, rows were made by using row marker; planting was carried out in 25 June and 7 July, 2015 at Bekoji station and Sero-Anketo, respectively. Nitrogen and phosphorus fertilizers were applied as per recommendation in the form of Urea (46% N) and diammonium phosphate (18% N and 46% P_2O_5) each at the rate of 100 kg/ha. Harvesting and threshing was done manually.

Data collected

Composite soil samples at 15 cm depth were collected from each trial site just before planting, for soil analysis. Grain yield was determined after its MC was determined and adjusted to 12.5%.

The soil physical and chemical properties of the experimental areas

Composite soil sample of the study sites collected just before planting and analyzed for soil physical and chemical properties (Table 2). The optimal pH range for most plants is between 5.5 and 7.0. The result of soil analysis showed that soil pH of 6.7 and 5.2 were determined at Sero-Anketo and Bekoji-Negesso sites, respectively. The result approaches with the optimum soil pH range of 5.5 to 6.5 for wheat production (http://www.cropnutrition.com/efu-soil-ph#soil-acidity accessed 11/4/2016).

Weather condition during the experimental period

The amount of rainfall for main season (June, July, August and September) of 2015 was low as compared to thirteen years mean rainfall of each month in both locations. A total seasonal RF of 396 and 534 mm was received in four growing months (June, July, August and September) of 2015 at Bekoji and Iteya stations, respectively (Figures 2 and 3). Wheat is cultivated in the region

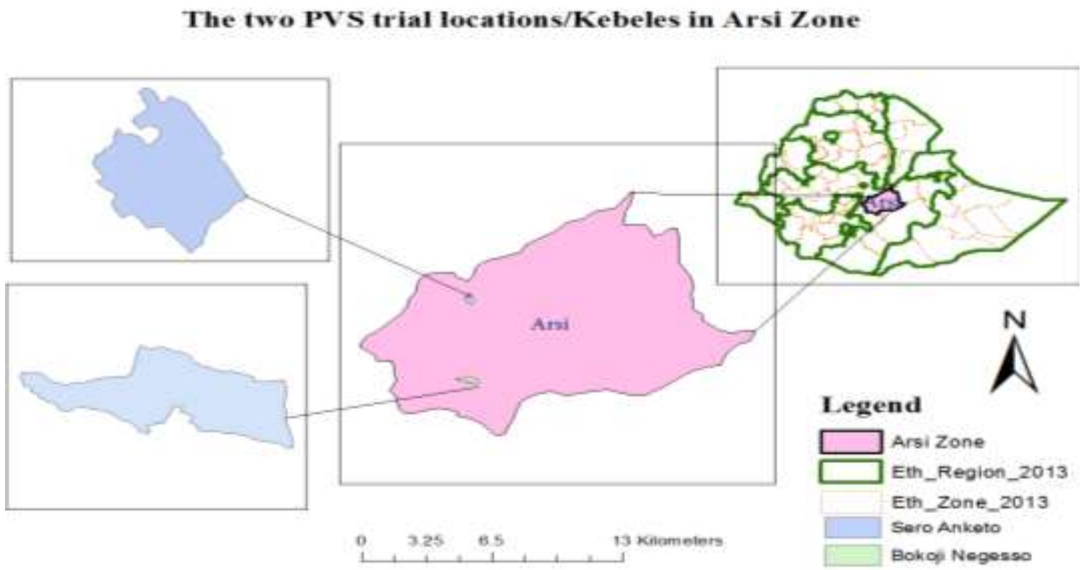

Figure 1. Map of study areas.

Table 1. Description of bread wheat varieties evaluated.

S/N	Varieties/genotype	Institution	Year of release	Adaptation zone	
				Altitude	Rainfall
1	*Honqolo*/ETBW 5879	KARC/EIAR	2014	2200-2600	750-1500
2	*Bika*/ETBW 6095	KARC/EIAR	2014	2200-2600	750-1500
3	*Mandoyu*/Worrakatta/Pastor	SARC/OARC	2014	2200-2500	750-1500
4	*Bulluk/*UTQE96/3/PYN/BAU//MILLAN	BARC/ EIAR	2015	-	-
5	*Hiddasse*/ETBW5795	KARC/EIAR	2012	2100-2800	>600
6	*Ogolcho*/ETBW5520	KARC/EIAR	2012	1500-2100	500-800
7	*Hoggana*/ETBW5780	KARC/EIAR		2200-2800	800-1200
8	*Hulluka*/ ETBW5496	KARC/EIAR	2012	2200-2800	>600
9	*Mekelle-03*/M17SAWSN-79	TARI/TARI	2012	1980-2500	300-500
10	*Mekelle-4*/FRTI-1	TARI/TARI	2013	1980-2500	300-500
11	*Shorima*/ ETBW 5483	KARC/EIAR	2011	2100-2700	700-1100
12	*Mekelle-01*/HUW-468	KARC/EIAR	2011	1980-2500	300-500
13	*Mekelle-02*/HI-1418	MeARC/TARI	2011	1980-2500	300-500
14	*Ga'ambo/ QUIAU#2*	WARC/EIAR	2011	650-2400	Irrigation
15	*Kakaba*/Picaflor#1	KARC/EIAR	2010	1500-2200	500-800
16	*Danda'a*/Danphe#1	KARC/EIAR	2010	2000-2600	>600
17	*Gassay*/ HAR-3730	AdARC/AARI	2007	1500-2200	500-800
18	*Alidoro*/ HK-14-R251	HoARC/EIAR	2007	2200-2900	≥500
19	*Digelu*/SHA 7/KAUZ or HAR3116	KARC/EIAR	2005	2000-2600	>600
20	TAY/ ET-12 D4/HAR 604 (1)	AdARC/AARI	2005	750-2500	>500
21	*Sofumar*/ HAR-1889	SARC/OARI	2000	2000-2600	>600
22	*Mada-Wolabu*/ HAR-1480	SARC/OARI	2000	2200-2900	≥500
23	Pavon-76	KARC/EIAR	1982	750-2500	>500
24	Jefferson	OARI/MORREL	2012	1500-2200	500-800
25	Kingbird	KARC/EIAR	2014	1500-2200	500-800

KARC, Kulumsa Agricultural Research Center; AlamARC, Alamata Agricultural Research Center; AdARC , Adet Agricultural Research Center; SARC, Sinana Agricultural Research Center; MeARC, Mekelle Agricultural Research Center; HoARC, Holleta Agricultural Research Center; OARI, Oromiya Agricultural Research Institute; WARC, Werer Agricultural Research Center; BARC, Bako Agricultural Research Center; AARI, Amara Agricultural Research Institute; TARI, Tigray Agricultural Research Institute; EIAR, Ethiopian Institute of Agricultural Research.

Table 2. Soil physical and chemical properties of the experimental areas, in Arsi zone.

Location	Soil pH(1:2) soil distilled water ratio	Available P (ppm)	Nitrogen (%)	OC (%)	OM (%)
Sero-Anketo	6.7	273.31[¥]	0.25	3.39	5.84 or (OCx1.724)
Bekoji-Negesso	5.2	7.05	0.23	2.73	4.71

Source: Agricultural chemistry laboratory, KARC, EIAR (2016); *OM=organic matter, OC=Organic Carbon, ppm=parts per million; = [¥] value is more than expected.

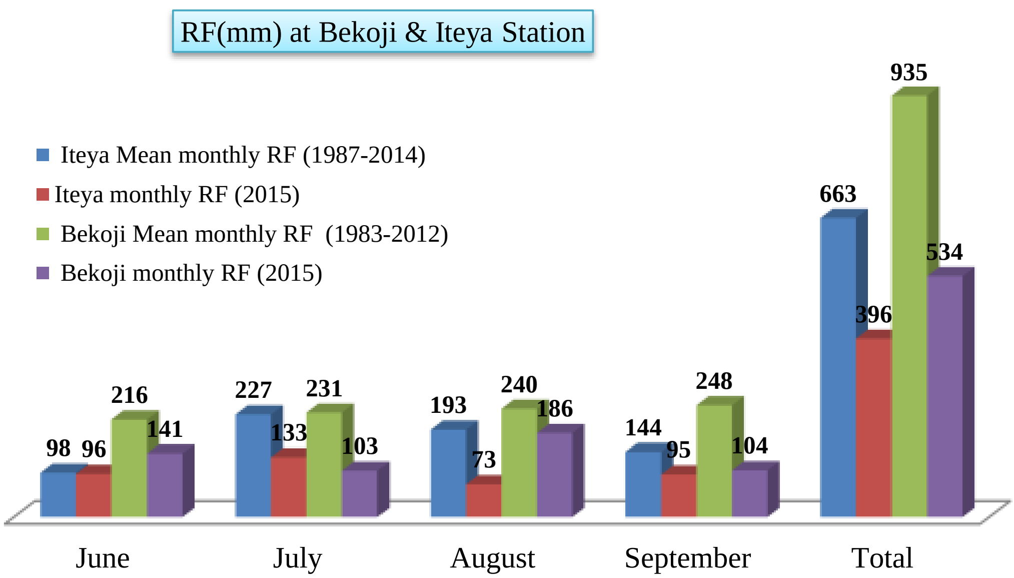

Figure 2. Mean monthly rainfall (RF) for more than twenty-eight years and monthly RF of the growing season (2015) (Bekoji station) and (Iteya stations) districts.
Source*:* KARC Meteorology Research Division.

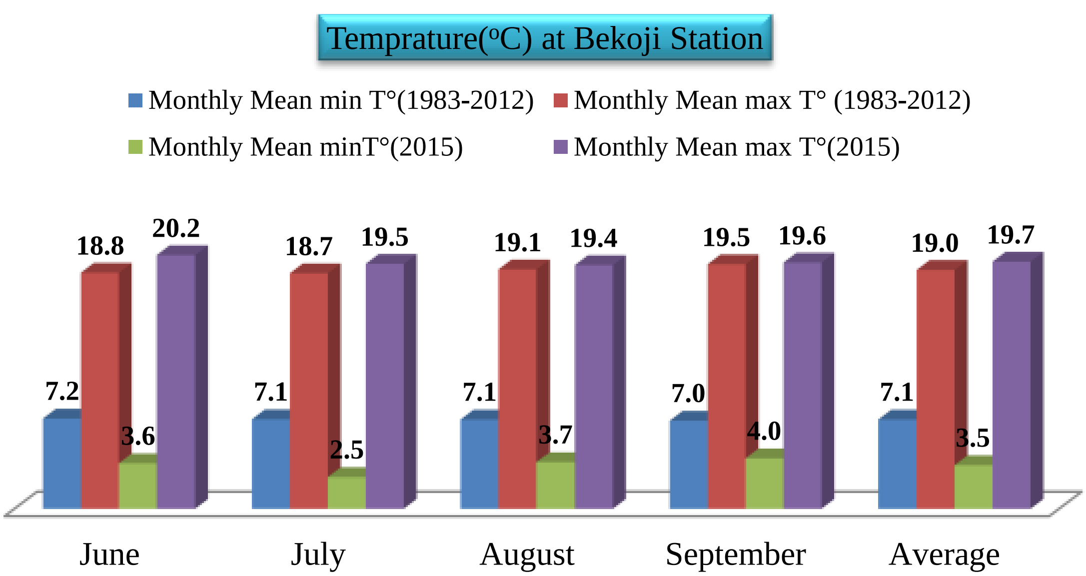

Figure 3. Monthly mean minimum and maximum temperature for thirteen years and growing season (2015) at Limu-Bilbilo (Bekoji station).
Source*:* KARC Meteorology Research Division.

Table 3. Field responses or infection types and assigned constant values.

Field response	Symbol	Constant value
Immune	I	0
Resistant	R	0.2
Moderately resistant	MR	0.4
Intermediate or M	M	0.6
Moderately susceptible	MS	0.8
Susceptible	S	1

where annual precipitation occurs from 250 to 1750 mm, though 75% wheat area falls where annual rainfall precipitation occurs between 375 to 875 mm. Region with 625.4 to 870 mm rainfall are most suitable for wheat cultivation (Jaiswal, 2009).

Rust diseases reaction

The reaction of experimental bread wheat varieties against rusts was scored using visual assessment at random samples of each varieties of wheat by observing the spore severity on the leaves for both leaf and yellow rust and additionally on stem in case of stem rust. Field response was recorded two times; when the crop growth stage was on average between the medium milk and early maturity stages according to Zodaks et al. (1974). Rusts intensities was recorded according to modified Cobb scale as proposed by Peterson et al. (1948) based upon severity as percentage of the plant infected as scale: Trace (<5), 5, 10, 20, 40, 60 and 100% infection and plant response (type of disease reaction) or infection type using the method of Roelf et al. (1992) as shown in Table 3. Severity and response readings were combined; the three rusts (stem, leaf and yellow) were recorded in the classical manner, giving the severity on the modified Cobb scale, along with the field response. After the last disease score when the disease progress ceased, the field severity data were converted to coefficient of infection (CI) by multiplying constant values of field response according to Stubbs et al. (1986) to rank or rate the varieties. Then the average CI (ACI) was determined by adding the CI of replications and divided by the number of replications. Varieties with coefficient of infections ranging from 0 to 20 was considered as resistant (R) while 20 to 30, 30 to 40, 40 to 60 and 60 to 100 were moderately resistance (MR), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible (S), respectively.

Participatory varietal selection

In PVS work, the participating farmers were bread wheat growers with strong interest in participating and some representatives of the main ethnic and social groups in the community. Consequently, the researchers together with the district agricultural worker identified and selected farmers and fields for the trials. More than forty farmers of both sexes participated and each site has about twenty evaluators of both female and male.

Before starting evaluation of the varieties, a clear-cut explanation, including objectives, was given to the farmers. One randomly assigned replication was selected for evaluation at each site. Farmers observed and evaluated the varieties in three developmental stages: At vegetative, flowering and maturation stages. The overall performances of the varieties, for field preferences, were evaluated at maturation stage. Before the final selection was made, farmers were invited to evaluate the test varieties at vegetative and flowering stages by allowing farmers to identify reasons/criteria of selections and rate each variety, while observing.

The bread wheat varieties were evaluated using farmers' selection criteria. Farmers were exposed to identify a set of characteristics that they find important in their wheat varieties. Even though they identified many selection criteria, they agreed to use seven characteristics (selection criteria) in common (that is, disease and insect resistance, grain yield, spike size, seed color, tillering capacity, market demand and seed size/weight) for final selection on both sites. This is in agreement with Bekele et al. (2000), Kassa et al. (2003) and Alebachew (2012) where farmers identified high yield, tillering capacity, disease resistance, seed color and size, and baking quality as important agronomic characters and their perceptions about some of these characteristics positively influenced their adoption of modern wheat varieties. Similarly, Asaye et al. (2014) reported farmers employed seven different parameters to select their preferred varieties including plant stand, number of tillers, seed coat color, seed size, spike length, number of kernels and disease resistance.

Both direct matrix ranking and pair wise ranking methods were used to rank the tested varieties. In matrix ranking, farmers were advised to rate the performance of each variety with respect to each selection criteria as: (1 = very poor, 2 = poor, 3 = good, 4 = very good and 5 = excellent). In addition, they also gave rating of importance (a relative weight) for each selection criteria as: (3 = very important, 2 = important and 1 = less important) based on consensus where differences were solved by discussion (Boef and Thijssen, 2006). Scoring was done by major vote/hand by group of farmers participated in the selection. Scores of each variety were multiplied by the relative weight of a given character to get the result and then added with the results of other characters/criteria to find out the total score of a given variety and their ranks (Tables 7 and 8). A matrix was prepared as per the selection criteria; wheat varieties were listed in the column and criteria in the row. The performance of the wheat varieties were evaluated and compared among each other and among the study sites.

The pair wise ranking method consists ranking of varieties based on pair wise comparisons of the variety according to attributes: e.g., seed size, seed color, disease free seed, plumpness and uniform sized seed, based on the seed, as these contributes to high market demand/premium price and for other needs. Pair wise ranking has been a useful tool whenever it is important to explore and discuss the criteria for decision making between and among attributes/ alternatives.

Determination of grain protein content

A major quality attribute of wheat is its protein content. The importance for protein content stems from its reputation for being an indicator of gluten content and dough quality. When wheat grain or flour is analyzed for protein content, the material is completely digested to ammonia (in the Kjeldahl method) or to nitrogen (by Dumas analysis). As a result, there is complete destruction of

Table 4. Each location mean values of grain protein of the tested bread wheat varieties.

Variety	Mean value			
	S/Anketo		B/Negeso	
	Protein (%)	GYLD (kg/ha)	Protein (%)	GYLD (kg/ha)
Honqolo	14.07^{bcd}	5027.3^{bc}	11.10^{bcd}	6348.30^{defgh}
Bika	15.03^{abcd}	4996.7^{bcd}	12.23^{abc}	7109.0^{abcd}
Mandoyu	15.13^{abcd}	4451.7^{cde}	12.33^{abc}	6395.3^{defgh}
Bulluk	15.27^{abc}	4525.3^{cde}	12.40^{ab}	7783^{a}
Hiddasse	14.9^{abcd}	4590.3^{bcde}	11.80^{abcd}	5859.7^{ghij}
Ogolcho	13.50^{d}	5227.7^{ab}	12.17^{abc}	5270.3^{jk}
Hoggana	16.37^{a}	3259.3^{f}	12.17^{abc}	7070.7^{abcd}
Hulluka	14.53^{bcd}	4638.0^{bcde}	11.90^{abcd}	6665.0^{cdef}
Mekelle-3	14.57^{bcd}	4689.3^{bcde}	11.10^{bcd}	6656.0^{cdef}
Mekelle-4	13.80^{bcd}	5894.0^{a}	11.90^{abcd}	4999.7^{k}
Shorima	14.80^{abcd}	4981.0^{bcd}	11.87^{abcd}	7718.3^{a}
Mekelle-1	13.83^{bcd}	4982.3^{bcd}	12.03^{abcd}	5760.0^{ghijk}
Mekelle-2	13.80^{bcd}	4602.7^{bcde}	12.10^{abc}	6506.7^{cdefg}
Ga'ambo	14.07^{bcd}	5096.7^{abc}	11.23^{bcd}	7260.7^{abc}
Kakaba	14.20^{bcd}	4530.7^{bcde}	11.13^{bcd}	6449.7^{defgh}
Danda'a	13.60^{cd}	5358.7^{ab}	11.10^{bcd}	5717.7^{hijk}
Gassay	13.77^{cd}	4746.3^{bcde}	11.00^{cd}	6344.0^{defgh}
Alidoro	15.47^{ab}	4178.3^{de}	11.40^{abcd}	6894.3^{bcde}
Digelu	14.07^{bcd}	3919.3^{ef}	10.70d	5760.3^{ghij}
TAY	14.73^{abcd}	5203.0^{abc}	12.23^{abc}	7632.7^{ab}
Sofumar	14.63^{bcd}	4016.0^{ef}	11.27^{bcd}	6473.3^{defgh}
Mada-Wolabu	14.37^{bcd}	4591.7^{bcde}	12.33^{abc}	6015.7^{fghij}
Pavon-76	14.47^{bcd}	5149.7^{abc}	11.83^{abcd}	6196.7^{efghi}
Jefferson	14.93^{abcd}	4636.7^{bcde}	12.77^{a}	5513.3^{ijk}
Kingbird	14.97^{abcd}	4508.3^{cde}	11.97^{abcd}	6260.0^{efghi}
Mean	14.52	4712.04	11.76	6426.41
LSD(0.05)	1.68	832.05	1.40	784.58
CV (%)	3.63	5.55	3.73	3.83

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to tukey's studentized range (HSD) test for Protein % = Grain protein (%) and GYLD = grain yield(kg/ha) at S/Anketo-Sero-Anketo and B/Negeso-Bekoji-Negesso.

information about protein structure and function (Wrigley and Bekes, 2001). Therefore, in this study the routine practice today for determination of protein content that not actually involve digestion but rather a correlative procedure near-infrared spectroscopy was used.

The grains of each variety at each location were tested for their total grain protein percentage by using near-infrared spectroscopy (Infratec^{TM} 1241 Grain Analyzer). Three hundred grams (300 g) of grain was used for the analysis of protein from each plot. The machine was adjusted to analyze the average grain protein percentage of ten sub samples per sample (300 g) or per plot in each replication for each location.

Data analysis

The data were subjected to ANOVA for significance test. Error variance of the individual location was tested for homogeneity; and the combined analysis of variance over the two locations was performed as per the formula given by Gomez and Gomez (1984). Data analysis was done using the SAS computer program, version 9.0 (SAS, 2002). The ANOVA was performed to determine the significances of differences between varieties and between variety-location combinations. Mean separations were conducted using Tukey's Studentized Range (HSD) test at 0.05 probability level. Microsoft Excel was used for the descriptive analysis preference ranking.

RESULTS AND DISCUSSION

Total grain protein content and grain yield of bread wheat

The individual location analysis of variance showed highly significant ($P \leq 0.01$) differences at each location for grain protein content and grain yield (Appendix Tables 1). The analysis of variance over locations revealed highly significant ($P \leq 0.01$) difference among varieties, locations and their interactions for grain protein content and grain yield (Appendix Table 2). The individual location mean values are presented in Table 4.

Table 5. Pair wise ranking of farmers' selection criteria for bread wheat varieties at Bekoji-Negesso.

No.	Criteria	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size	Total score	Rank
1	Disease and insect resistance	X							6	1
2	Grain yield	Disease and insect resistance	X						5	2
3	Spike size	Disease and insect resistance	Grain yield	X					1	5
4	Seed color	Disease and insect resistance	Grain yield	Seed color	X				1	5
5	Tillering capacity	Disease and insect resistance	Grain yield	Tillering capacity	Tillering capacity	X			4	3
6	Market demand	Disease and insect resistance	Grain yield	Market demand	Market demand	Tillering capacity	X		3	4
7	Seed size	Disease and insect resistance	Grain yield	Spike size	Seed size	Tillering capacity	Market demand	X	1	5

The major emphasis in wheat has been high protein content for nutritional enhancement and improved processing performance. The total protein contents varied from 13.5% (*Ogolcho*) to 16.4% (*Hoggana*) and from 10.7% (*Digelu*) to 12.8% (Jefferson) at Sero-Anketo and Bekoji-Negesso, respectively. Because grains were collected from plants grown under different conditions in field trait at each location during the same growing season, the influence of environmental factors and/or varietal variation could be the factors for such variation of the total grain protein. Vogel et al. (1978) reported that protein content of 12,600 wheat lines from the USDA World Wheat Collection ranged from about 7 to 22% protein content with the genetic component accounting for about a third of the variation (that is, about 5%). The greater part of the variation was due to non-genetic factors and this strong environmental impact has made breeding for high protein difficult (Shewry, 2007). In addition, it should be noted that rainfall from anthesis to maturity, and soil physical and chemical characteristics (Figure 2 and Table 2) could be the cause for significant difference between the two locations (Appendix Table 2). The mean total proteins within each location did not vary much among tested bread wheat varieties (2.87% at Sero-Anketo and 2.07% at Bekoji-Negesso), but relatively higher variation was found between locations (5.67%).

Generally, higher protein contents were recorded at Sero-Anketo than Bekoji-Negesso. This may be probably due to environmental factors including rainfall, growing temperature, and soil fertility, while genetic differences existed in wheat varieties. Relatively excessive rainfall at Bekoji-Negesso than Sero-Anketo may result to available nitrogen to be leached. The final protein concentration depends on the nitrogen availability during the crop cycle (Stone and Savin, 1999). In addition, as wheat is a cool season plant, relatively higher temperature at Sero-Anketo that occurred after heading and during grain fill affected wheat plant to store fewer carbohydrates (yield) and conversely stored more protein. Water stress can also accelerate leaf senescence, which can impact assimilate supply for seed fill. Longevity of the green tissue in the parent plant during grain development may be a factor in yield. In wheat the leaves become yellow (that is, senesce) before the ear does, and the latter may be the more important in providing photosynthetate at the late stages of maturity. At this time, however, respiration by the grain may exceed the net import of sugars and other substrates, resulting in a small loss in grain weight (Bewley et al., 2013).

Farmers' participatory evaluation and selection criteria for the tested varieties

Participatory variety selection clearly showed which criteria (Table 5 and 6) and which varieties (Tables 7 and 8) the farmers preferred. Farmers' needed a good number of characters in their wheat varieties during discussions. They cited many selection criteria at different stages in both locations: broad leaf, green leaf, good tiller and uniform stand, rust (yellow rust) and insect resistance (shoofly) were among the best criteria chosen at early tillering stage. At flowering stage, criteria like tillering capacity, rusts and insect resistance (aphids), uniform flowering, thick stock, and medium height were preferred. At physiological maturity to harvesting stage: medium and uniform maturity, cool wind resistance (even if it is not a frequent problem), spike size, seeds per spike, spike density, seed color, seed weight, disease resistance, grain yield, tillering capacity, shattering and viviparous resistance were mentioned as selection criteria. However, farmers' in both locations suggested seven same criteria as final selection criteria and ranked using pair-wise ranking as shown in Table 5 and 6. Similarly, Mulatu and Zeleke (2002) and Mekonen (2011) stated that, in a refinement exercise using pairwise comparison the excessive criteria list was

Table 6. Pair wise ranking of farmers' selection criteria for bread wheat varieties in Sero-Anketo.

No.	Criteria	Disease and pest resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed weight	Total score	Rank
1	Disease and pest resistance	X							3	4
2	Grain yield	Grain yield	X						6	1
3	Spike size	Disease and pest resistance	Grain yield	X					2	5
4	Seed color	Disease and pest resistance	Grain yield	Spike size	X				0	7
5	Tillering capacity	Tillering capacity	Grain yield	Tillering capacity	Tillering capacity	X			4	3
6	Market demand	Disease and pest resistance	Grain yield	Spike size	Market demand	Tillering capacity	X		1	6
7	Seed weight	Disease and pest resistance	Grain yield	Seed weight	Seed weight	Seed weight	Seed weight	X	5	2

reduced to the trait, which the majority of the respective village farmers want a crop to have. Such targeted selection efforts have a much higher rate of success and of progress from selection than programs that have to consider multiple traits, for multiple systems as selection criteria.

Top seven criteria were prioritized according to total scores and ranked through pair wise system at Sero-Anketo (Table 6). High yield had the highest score and ranked 1st followed by seed weight and market demand; seed color were the least ranked according to pair wise ranking of top seven criteria, as market availability for farmers in this area has not been such a problem although white colored seed fetch high price. Generally, this indicated that the main target of farmers in this area was getting high yielding variety with good quality grain (Table 6). At Bekoji-Negesso, disease and insect resistance was ranked first and grain yield were ranked second as such altitude have been favorable for rusts development. Earliness was not such important criteria at both locations since seasonal rainfall shortage was not a problem but farmers have preferred medium maturing varieties. However, in some cropping seasons like 2015, e.g. shortage of rainfall at Sero-Anketo is alarming that breeders should develop early to medium maturing varieties in the future. However, high yield with better quality grain were the main criteria at both locations.

Farmers' evaluation of tested bread wheat varieties

The evaluators ranked the varieties in each location based on total score of the suggested selection criteria. Ranking of the varieties for each selection criteria was done based on evaluators common score agreement/ consensus and women's vote were equally considered as men's during scoring. Farmers' evaluations of bread wheat varieties using direct matrix ranking on the field are shown in Tables 7 and 8 and pair wise ranking scores on seed are given in Appendix Tables 3 and 4.

Direct matrix scoring of varieties based on selected criteria in the field at Bekoji-Negesso showed that varieties *Danda'a*, *Shorima*, TAY, *Mada-Wolabu, Hiddasse*, *Sofumar*, *Gassay*, *Bulluk* and *Bika* were ranked first to nine, respectively. In contrast, *Hulluka*, Jeffersson, *Mekelle-4* and the most dominating variety *Kakaba* were the least scored (Table 7). Disease and insect resistance was the most important criteria among others for field ranking of varieties; as rust diseases have been the most important criteria since the higher altitudes are suitable for the development of rusts, causing high yield lose. Besides, grain yield, tillering capacity and spike size were also important. Similarly, Kassa et al. (2003) and Alebachew (2012) identified grain yield and spike size as farmers' important criteria.

The first nine varieties ranked based on farmers scoring at Sero Anketo, from first to nine, were *Mekelle-4*, *Danda'a*, *Hiddasse*, *Ogolcho*, *Honqolo*, *Bika, Shorima*, *Mekelle-01* and TAY(Table 8). The newly adapted variety for this location was *Mekelle-4, which* ranked first at Sero-Anketo. Variety *Danda'a* was preferred at both locations although it showed up to 40S severity reaction for stem rust at Sero-Anketo. Grain yield and tillering capacity were the most important selection criteria in this area; which is in agreement with Alebachew (2012) for bread wheat. Besides, market demand and seed size were also among the very important criteria in which plump seed with white seed color have high demand in market with premium price.

Marketability evaluation of bread wheat varieties

Majority of the farmers have sold their wheat

Table 7. Direct matrix ranking evaluation of bread wheat varieties by group of farmers' (on field) at Bekoji-Negoso (n=22)[Ω].

Variety \ Relative Weight	Ranking of selection criteria for each variety								
	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size	Total scores	Rank
	3	3	2	2	3	2	3		
Honqolo	4(12)	4(12)	3(6)	4(8)	5(15)	4(8)	3(9)	70	14
Bika	4(12)	4(12)	5(10)	5(10)	2(6)	5(10)	5(15)	75	9
Mandoyu	4(12)	3(9)	3(6)	4(8)	4(12)	4(8)	4(12)	67	17
Bulluk	5(15)	2(6)	3(6)	5(10)	5(15)	5(10)	5(15)	77	7
Hiddasse	2(6)	4(12)	5(10)	5(10)	5(15)	5(10)	5(15)	78	5
Ogolcho	4(12)	4(12)	5(10)	3(6)	3(9)	4(8)	4(12)	69	16
Hoggana	4(12)	4(12)	3(6)	1(2)	5(15)	1(2)	3(9)	58	19
Hulluka	3(9)	2(6)	2(4)	2(4)	2(6)	2(4)	3(9)	42	25
Mekelle-3	4(12)	4(12)	3(6)	1(2)	5(15)	2(4)	4(12)	63	18
Mekelle-4	1(3)	1(3)	4(8)	4(8)	2(6)	4(8)	4(12)	48	23
Shorima	5(15)	5(15)	3(6)	5(10)	5(15)	5(10)	5(15)	86	2
Mekelle-1	1(3)	1(3)	3(6)	4(8)	5(15)	5(10)	4(12)	57	20
Mekelle-2	3(9)	3(9)	4(8)	4(8)	5(15)	5(10)	4(12)	71	12
Ga'ambo	4(12)	5(15)	4(8)	4(8)	2(6)	5(10)	5(15)	74	10
Kakaba	2(6)	3(9)	3(6)	5(10)	2(6)	4(8)	5(15)	52	22
Danda'a	4(12)	5(15)	5(10)	5(10)	5(15)	5(10)	5(15)	87	1
Gassay	3(9)	5(15)	5(10)	4(8)	5(15)	4(8)	4(12)	77	7
Alidoro	5(15)	5(15)	5(10)	1(2)	5(15)	1(2)	4(12)	71	12
Digelu	1(3)	4(12)	4(8)	5(10)	5(15)	5(10)	4(12)	70	14
TAY	5(15)	4(12)	5(10)	4(8)	5(15)	5(10)	5(15)	85	3
Sofumar	5(15)	4(12)	4(8)	4(8)	5(15)	4(8)	4(12)	78	5
Mada-Wolabu	5(15)	4(12)	5(10)	4(8)	5(15)	5(10)	5(15)	85	3
Pavon-76	2(6)	2(6)	2(4)	3(6)	5(15)	4(8)	4(12)	57	20
Jefferson	3(9)	1(3)	2(4)	1(2)	4(12)	1(2)	4(12)	44	24
Kingbird	3(9)	3(9)	4(8)	5(10)	4(12)	5(10)	5(15)	73	11

-[Ω]number of participants =22 (male = 16, female = 6). -Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor. Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. -The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

produce to traders and then traders have sold it either to factories or to consumers; farmers could also directly sold to the factories. At locations (Iteya and Bekoji), both female and male traders and consumers were participated in setting criteria for direct and pair wise ranking of varieties. The seed of each variety was packed in transparent polythene bags for grain ranking. The result of direct matrix ranking (Table 9 and Figure 4d) at Iteya (Sero-Anketo) showed that varieties *Bika*, *Hiddasse*, *Mekelle-4*, *Kakaba* and kingbird were ranked first and Meda-welabu ranked sixth for

Table 8. Direct matrix ranking evaluation of bread wheat varieties by group of farmers' (on field) at Sero-Anketo (n=24) [Ω].

Variety \ Relative weight	Ranking of selection criteria for each variety								
	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size	Total score	Rank
	2	3	2	2	3	3	3		
Honqolo	5(10)	5(15)	5(10)	4(8)	5(15)	3(9)	3(9)	76	3
Bika	5(10)	4(12)	2(4)	5(10)	3(9)	5(15)	5(15)	75	6
Mandoyu	5(10)	3(9)	2(4)	4(8)	4(12)	4(12)	4(12)	67	13
Bulluk	4(8)	3(9)	3(6)	3(6)	3(9)	3(9)	4(12)	59	20
Hiddasse	3(6)	5(15)	3(6)	5(10)	3(9)	5(15)	5(15)	76	3
Ogolcho	5(10)	4(12)	5(10)	4(8)	4(12)	4(12)	4(12)	76	3
Hoggana	5(10)	1(3)	4(8)	2(4)	5(15)	2(6)	2(6)	52	22
Hulluka	4(8)	5(15)	3(6)	3(6)	1(3)	3(9)	3(9)	56	21
Mekelle-3	5(10)	5(15)	5(10)	2(4)	4(12)	2(6)	4(12)	69	11
Mekelle-4	5(10)	5(15)	5(10)	5(10)	5(15)	5(15)	5(15)	90	1
Shorima	5(10)	5(15)	4(8)	3(6)	4(12)	4(12)	4(12)	75	6
Mekelle-1	4(8)	5(15)	4(8)	4(8)	4(12)	4(12)	4(12)	75	6
Mekelle-2	4(8)	4(12)	4(8)	4(8)	2(6)	4(12)	3(9)	63	18
Ga'ambo	5(10)	3(9)	3(6)	4(8)	2(6)	4(12)	4(12)	63	18
Kakaba	2(4)	3(9)	3(6)	5(10)	2(6)	5(15)	5(15)	65	14
Danda'a	5(10)	5(15)	5(10)	4(8)	5(15)	3(9)	4(12)	79	2
Gassay	2(4)	3(9)	4(8)	4(8)	4(12)	4(12)	4(12)	65	14
Alidoro	4(8)	1(3)	5(10)	2(4)	4(12)	2(6)	2(6)	49	24
Digelu	1(2)	1(3)	1(2)	3(6)	1(3)	3(9)	3(9)	34	25
TAY	5(10)	5(15)	5(10)	4(8)	2(6)	4(12)	4(12)	73	9
Sofumar	4(8)	2(6)	4(8)	4(8)	4(12)	4(12)	4(12)	66	13
Mada-Wolabu	4(8)	4(12)	4(8)	4(8)	3(9)	4(12)	5(15)	72	10
Pavon-76	4(8)	3(9)	3(6)	4(8)	3(9)	4(12)	4(12)	64	17
Jefferson	2(4)	4(12)	3(6)	2(4)	2(6)	2(6)	4(12)	50	23
Kingbird	4(8)	1(3)	4(8)	5(10)	2(6)	5(15)	5(15)	65	14

- [Ω]number of participants=24 (male = 17, female = 7). -, Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor. Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. -The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

their market value. Seed color, plumpness and large seed were the main criteria for their selection. Varieties *Bika*, *Bulluk*, *Hiddasse*, *Kakaba, Danda'a, Shorima* and Kingbird were selected first at Bekoji (Bekoji-Negesso) (Table 9 and Figure 4d)). The selected varieties had white seed color, plump, uniform sized and large seeded as compared to others and these criteria were expected to have good flour and brea

Table 9. Direct matrix ranking on marketability of bread wheat varieties by traders and consumers, at Bekoji and Iteya, Arsi.

Variety \ Relative weight	Sero=Anketo (n=7)[Ω]				Bekoji-Negesso (n=6)[Ω]			
	Seed color	Plump/uniform size	Seed size	Rank	Seed color	Plump/uniform size	Seed size	Rank
	3	2	3		3	2	3	
Honqolo	4(12)	3(6)	3(9)	18	4(12)	4(8)	3(9)	18
Bika	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Mandoyu	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Bulluk	3(9)	3(6)	4(12)	18	5(15)	5(10)	5(15)	1
Hiddasse	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Ogolcho	4(12)	4(8)	4(12)	7	3(9)	4(8)	4(12)	18
Hoggana	2(6)	2(4)	2(6)	24	1(3)	1(2)	3(9)	25
Hulluka	3(9)	3(6)	3(9)	20	2(6)	2(4)	3(9)	21
Mekelle-3	2(6)	2(4)	4(12)	22	1(3)	2(4)	4(12)	21
Mekelle-4	5(15)	5(10)	5(15)	1	4(12)	4(8)	4(12)	14
Shorima	3(9)	4(8)	4(12)	16	5(15)	5(10)	5(15)	1
Mekelle-1	4(12)	4(8)	4(12)	7	4(12)	5(10)	4(12)	12
Mekelle-2	4(12)	4(8)	3(9)	16	4(12)	5(10)	4(12)	12
Ga'ambo	4(12)	4(8)	4(12)	7	4(12)	5(10)	5(15)	8
Kakaba	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Danda'a	4(12)	3(6)	4(12)	15	5(15)	5(10)	5(15)	1
Gassay	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Alidoro	2(6)	2(4)	2(6)	24	1(3)	1(2)	4(12)	23
Digelu	3(9)	3(6)	3(9)	20	5(15)	5(10)	4(12)	8
TAY	4(12)	4(8)	4(12)	7	4(12)	5(10)	5(15)	8
Sofumar	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Mada-Wolabu	4(12)	4(8)	5(15)	6	4(12)	5(10)	5(15)	8
Pavon-76	4(12)	4(8)	4(12)	7	3(9)	4(8)	4(12)	18
Jefferson	2(6)	2(4)	4(12)	22	1(3)	1(2)	4(12)	23
Kingbird	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1

- [Ω]number of participants = Iteya=7 (2 F & 5 M) and Bekoji=6 (2 F & 5 M). Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor; Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

quality for wheat flour factories and consumers.

Besides these criteria, we had asked some traders about the consumers' needs of wheat grain at grain store (Figure 5). According to traders, consumers preferred to buy wheat grain that comes from mid highland (having comparatively higher temperature than highlands) than highlands (cool) areas. "The reason is the bread made from wheat grain grown at highland areas, having high rainfall and cool temperature; do not absorb much water, the dough and bread could melt (less loaf volume) and the bread dried quickly" said the trader. These may be affected by protein content. The scientific research studied in protein revealed that both quantity and quality of protein affect bread-making property like water absorption, oxidation requirements, loaf volume and crumb characteristics (Finney, 1984). Water absorption in the flour is increased with increasing protein content, resulting large loaf volume and soften bread. It also shows effect on staling rates (bread with higher protein content can be stored longer) (Maliki et al., 1980). Usually, grain protein percent increases when environmental conditions like drought and high temperature hinder grain yield to reach its potential (Fowler, 2003). Both genotype and the environment in which wheat is grown affect grain protein content and composition. Protein percentage in grains grown at the higher temperature is higher than those grown at the lower temperature, and protein content in wheat grain normally decreases with the increase in grain yield (Simmonds 1995).

Bika, *Hiddasse* and *Kakaba* were among the three best varieties preferred based on marketability evaluation by traders and consumers (Table 9). *Hoggana*, *Alidoro*, Jefferson and *Mekelle-03* were selected least at both locations as their seed had red, shriveled, non-uniform or small seeded or their combinations.

Figure 4. Farmers' preference ranking at different growth stages and the seed of varieties. (a) Farmers are trying to select varieties based on their preferences at vegetative stage. (b) Farmers are trying to identify selection criteria and rank their preferences at flowering/dough stage. (c) Similarly, farmers are identifying selection criteria and preference ranking of wheat varieties at physiological maturity. (d) Direct and pairwise ranking of seed of wheat varieties by traders and consumers based on their preference/marketability.

In Pair wise ranking of varieties, *Mekelle-02* and *Kakaba* ranked first and, *Hiddasse* and *Meda-welabu* both ranked third followed by *Ga'mbo* and TAY by traders and consumers around Iteya based on their grain traits (Appendix Tables 4). In contrast, Jefferson, *Alidoro, Mekele-03, Digelu* and *Hulluka* ranked least. Similarly, the traders and consumers at Bekoji identified *Bika*, *Hiddasse* and *Danda'a* as the best and Kingbird, *Shorima* and *Kakaba* ranked fourth to sixth, respectively (Appendix Table 3). Seed color, plumpness, seed size, seed uniformity or their combination were traits used for ranking in both locations. Similarly, Alebachew (2012) indicated that the most important criteria for marketability in bread wheat were grain color, plumpness and seed size. In addition, Belay *et al.* (2006) identified seed color, driven by market forces, is the overriding selection criterion in tef.

Overall ranking of performance, farmers' preferences and marketability of bread wheat varieties

Performance ranking is based on the mean grain yield of the variety obtained from individual location whereas

Figure 5. Researchers asking traders about the consumers' needs of wheat grain at grain store.

preferences and marketability ranks are the average ranks of varieties based on selection criteria using direct matrix and pair wise ranking by farmers and other actors both on field and on seed. The overall ranking, which is used to identify the final best variety/ies for the location, is based on the average rank of performance, preference and marketability (Tables 4, 7, 8 and 9 and Appendix Tables 3 and 4). All ranks were done using "rank and percentile" under "Data analysis" in Excel, to rank each variable/criteria and overall rank in descending order, except disease and insect pest resistance which is in ascending order. Best variety was selected for a location depending on performance, overall rank and disease reaction.

Varieties *Shorima* and *Mekelle-4* were the best at Bekoji-Negesso and Sero-Anketo, respectively, based on farmers' preferences, yield and rust resistance (Table 10). However, *Mekelle-4* was moderately susceptible (20MS) (Appendix Table 5) for both leaf rust (LR) and stem rust (SR) with average coefficient of infection (ACI) of 5.33 for LR and 8.13 for SR (Table 11).

Bika, Shorima, Bulluk and TAY at Bekoji-Negesso and *Mekelle-4, Ogolcho, Bika* and TAY at Sero-Anketo were among the most preferred varieties in which each has better yield and good in both field and marketability preferences ranking. These top preferred varieties at both locations showed resistant type reaction to rusts infection and have been selected for these locations (Tables 10 and 11). The overall ranking for the above selected top varieties showed that the high yielder varieties also top ranked by farmers, traders and/or consumers based on both field and marketability preferences ranking. This also showed the positive input or relationship of farmers' preferences with researchers. However, some high yielding varieties may not preferred by evaluators, e.g. *Hoggena, Hulluka and Mekelle-3* at Bekoji-Negesso and *Danda'a* at Sero-Anketo have relatively high yield but ranked less based on farmers on field and traders and consumers marketability preferences. In other case, *Hiddase* and *Danda'a* at Bekoji-Negesso and *Kakaba* and *Meda-Wolabu* at Sero-Anketo was relatively low yielder but have good overall preference ranking due to their preferred seed for market and consumption (Table 10). This indicated that the field performances and the quality of the grain (in terms of color, plumpness and size) were affected by biotic and abiotic factors like rainfall shortage, diseases and the crop phenological characteristics.

Newly introduced variety to these areas, *Mekelle-4*, and the other variety *Ogolcho* performed better and preferred by evaluators at Sero-Anketo but these varieties were yield and preferred least at Bekoji-Negesso (Table 10). This may be due to specific adaptation of varieties for both yield and seed quality and was also reflected by farmers perspective in which they tend to identify high yielder and quality seed (color and size) for their localities. Zewdie (2004) indicated that development of appropriate crop production technologies require a

Table 10. Mean performance (kg/ha) and farmer overall preference ranking of wheat varieties at two locations.

Variety	Ranks at Bekoji-Negesso					Ranks at Sero-Anketo				
	Perf≈	Preference	Marketability		Overall ranking	Perf≈	Preference	Marketability		Overall ranking
		Direct matrix	Direct matrix	Pair wise			Direct matrix	Direct matrix	Pair wise	
Honqolo	14	14	18	20	17	7	3	18	19	15
Bika	5	9	1	1	2	8	6	1	7	2
Mandoyu	13	17	14	14	15	21	13	7	16	18
Bulluk	1	7	1	7	2	19	20	18	18	21
Hiddasse	19	5	1	1	6	17	3	1	3	4
Ogolcho	24	16	18	14	20	3	3	7	9	2
Hoggana	6	19	25	24	22	25	22	24	25	25
Hulluka	8	25	21	19	21	13	21	20	20	20
Mekelle-3	9	18	21	22	19	12	11	22	22	19
Mekelle-4	25	23	14	12	22	1	1	1	7	1
Shorima	2	2	1	5	1	10	6	16	12	12
Mekelle-1	21	20	12	10	16	9	6	7	9	6
Mekelle-2	10	12	12	9	11	15	18	16	1	16
Ga'ambo	4	10	8	10	7	6	18	7	5	10
Kakaba	12	22	1	6	9	18	14	1	1	7
Danda'a	22	1	1	1	5	2	2	15	16	8
Gassay	15	7	14	14	13	11	14	7	14	14
Alidoro	7	12	23	25	18	22	24	24	23	24
Digelu	20	14	8	14	14	24	25	20	20	23
TAY	3	3	8	7	4	4	9	7	6	5
Sofumar	11	5	14	18	12	23	13	7	13	17
Mada-Wolabu	18	3	8	12	9	16	10	6	3	8
Pavon-76	17	20	18	20	24	5	17	7	14	11
Jefferson	23	24	23	23	25	14	23	22	24	22
Kingbird	16	11	1	4	7	20	14	1	9	12

Perf≈ = performance (yield in kg/ha); Preference = farmer preference on the field.

thorough understanding of site-specific problems. Therefore, location specific varietal adaptation is important since it affects the qualitative and quantitative traits of the varieties and varieties should be grown at climatic conditions that suited their growth for good seed or grain production.

Some varieties have preferred good seed that fetch high price but those that have low yield and low field preference ranking may be due to diseases, e.g. *Kakab* and *Hiddasse.* Nevertheless, others were high yielder but farmers did not preferred their seed color or size since it has low price and less required by consumers. This is due to the fact that seed was either shriveled due to late maturing type or red colored seed e.g. *Hoggana* and *Alidoro* (Tables 9 and 10). Almost all-top ranked high yielder varieties had been selected by farmers' preference ranking, except

Table 11. Average Coefficient Infections (ACI) for the three rusts of bread wheat varieties at Bekoji Negeso and Sero-Anketo.

Variety	Bekoji-Negesso			Sero-Anketo		
	YR	LR	SR	YR	LR	SR
Honqolo	13.3	0	0	0	0.8	0
Bika	8	0	5.3	0	1.33	14.67
Mandoyu	5.67	0	0	0	1.67	4
Bulluk	1	0	0	0	0.8	1.33
Hiddasse	1	0	1.67	0	2.67	33.33
Ogolcho	0.27	0	0	0	0.67	9.87
Hoggana	0	0	0	0	0	0.53
Hulluka	2.67	0	1.67	0	5.33	6.67
Mekelle-3	0.67	0	1.33	0	0	12
Mekelle-4	8	0	0	0	5.33	8.13
Shorima	2.67	0	0	0	0	0.47
Mekelle-1	0	0	0	0	33.33	13.33
Mekelle-2	3	0	0.8	0	8	20.67
Ga'ambo	6.67	0	0	0	1.33	2.13
Kakaba	5.8	0	11.67	0	0	53.33
Danda'a	2.6	0	2.4	0	0	17.47
Gassay	4.13	0	15.33	0	6	36.67
Alidoro	0	0	0	0	1.33	4
Digelu	1.6	1.07	12.33	0	2.67	46.67
TAY	1	0	0	0	12	4
Sofumar	8	0	0	0	0	5.87
Mada-Wolabu	1.6	0	0	0	0	0.8
Pavon-76	1.73	0	0	0	2.93	2.93
Jefferson	0.27	0	0	0	16.67	43.33
Kingbird	0.93	0	0.67	0	2.67	0.67

YR = yellow/stripe rust; LR = leaf rust; SR = Stem rust.

the variety was affected either by moisture stress or by diseases. This is in line with Belay et al*.* (2006) study in which all farmer-selected genotypes gave higher yields in tef.

Disease reaction of tested bread wheat varieties

Pathogenic fungi are by far the most important and yield limiting of the many disease-causing organisms, which attack cereal crops. Of these, the genera *Puccinia* (rusts), *Ustilago* (smuts), *Tilletia* (bunts), *Erysiphe* (powdery mildews), *Septoria, Alternaria, Helminthosporium, Fusarium* and *Pythium* are the most widespread, regularly occurring and potentially dangerous throughout the world. *Puccinia graminis* (causing stem or black rust), *P. recondita* (causing leaf or brown rust), *P. striiformis* (causing yellow or stripe rust) regularly cause serious losses of wheat throughout the world (Stubbs *et al.,* 1986).

Varieties' disease reaction (Table 11) and their coefficients of infection (CI) (Appendix Table 5) were scored and /or calculated. All the tested varieties at Bekoji station showed resistant type of infection for the three rusts (<20 CI). Similarly, at Sero-Anketo, varieties *Kakaba*, Digelu and Jefferson had moderately susceptible to susceptible reaction, whereas *Gassay* and, *Hiddasse* and *Mekelle-02* had moderately susceptible to moderately resistant types of infection for stem rust, respectively. This result was in contrast with the report of EAAPP (2012) and Haile et al. (2013) that found that *Digelu* and *Danda'a* were preferred varieties by farmers in East Hararge, Arsi and Tigray due to higher resistance to yellow rust and stem rust.

Some varieties showed immune (resistant) type of infection in one location and moderately susceptible type in other location as in Jefferson, *Ogolcho* and *Mekelle-04* for stem rust. This may be due to the presence of stem rust race in one location but not in other location. Roelf et al*.* (1992) reported that, inoculum build-up difference or the environment may favor the development of the stem rust and this disparity may be mainly associated with prevailing specific environmental conditions especially rainfall amount and pattern and temperature. Leaf rust at

Bekoji-Negesso and yellow rust at Sero-Anketo were not observed except on *Digelu*. *Digelu* had been resistant and widely grown variety but it became susceptible to rusts. Pathogens distribution may be affected by different factors and varieties may lose their resistance to rusts at any time due to different reasons, genetic or environmental factors, and therefore, frequent survey on rusts and developing resistant varieties has been important to increase resistance varietal diversity for sustainable quantity and quality wheat production.

Conclusions

Farmers adopt varieties if they provide additional benefits to them such as better productivity, yield stability, increased market value, and increased quality. Based on measured traits (grain yield and rusts resistance) and farmers' preference (field performance and market value) ranking: Bika, Bulluk and TAY for Bekoji (Bekoji-Negesso) and Mekelle-4, Ogolcho and TAY for Iteya (Sero-Anketo) are recommended with their full production packages including pesticide usage for moderately susceptible varieties for rusts, as these varieties also had better protein content. For plant breeders, it may be difficult to predict which traits or trait combinations are of prime importance for a particular target group of farmers. Therefore, future breeding program should include the participation of farmers' and their selection preferences early during varietal development, as participatory plant breeding, and adaptation program for cost effective and fast track delivery of new and existed technologies to particular target group of farmers. Development of appropriate crop production technologies requires a thorough understanding of site-specific problems and farmers need. Therefore, participation of farmers in early breeding program could be one of the approaches as to identify the best variety for specific location.

CONFLICT OF INTERESTS

The authors had not declared any conflict of interests.

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ABBREVIATIONS

EAAPP, Eastern African Agricultural Productivity Programme; **EIAR,** Ethiopian Institute of Agricultural Research; **GxE,** genotype by environment; **IRRI,** International Rice Research Institute; **KARC,** Kulumsa Agricultural Research Center; **LSD,** least significant difference.

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APPENDICES

Appendix Table 1. Mean squares from analysis of variance for grain protein content and grain yield of the tested twenty-five bread wheat varieties at Sero-Anketo.and Bekoji-Negesso.

Source of variance	DF	Mean squares			
		Sero-Ankato		Bekoji-Negesso	
		Protein	GYLD	Protein	GYLD
Replications	2	2.15**	82815^{ns}	1.84**	336270**
Blocks within replications (Adj.)	12	0.65**	74753^{ns}	0.51^{ns}	87750^{ns}
Treatments (Unadj.)	24	1.36**	840820**	0.90**	1632418**
Intra block error	36	0.21	73475	0.19	58277
Treatment(Adj.)	24	1.38**	796077.18**	0.92**	1558562.62**

*Significant at 5% probability level; **highly significant at 1% probability level, ^{ns}, non-significant at 5% probability level; GYLD, Grain yield; DF, Degree of freedom; Protien, Grain protein content.

Appendix Table 2. Mean square from combined analysis of variance for grain protein content and grain yield of the tested twenty-five bread wheat varieties at locations.

Source	DF	Mean square	
		Protein	GYLD
Loc	1	284**	110215347**
rep(loc)	2	3.98**	42748.3^{ns}
blk(rep)	12	0.66**	66600.5^{ns}
Treatment	24	1.39**	829634.1**
Loc x treatment	24	0.70**	1529648.6**
Blk x treatmnt(rep)	36	0.24^{ns}	71531.4^{ns}
Error	48	0.24	69141.2

*Significant at 5% probability level; **highly significant at 1% probability level; ns, non- significant at 5% probability level; GYLD, Grain yield; DF, Degree of freedom; Protien, Grain protein content.

Appendix Table 3. Pair wise ranking of 25 bread wheat varieties by traders and consumers at Bekoji-Negesso.

var≈	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	X																								
2	2	X																							
3	3	2	X																						
4	4	2	4	X																					

Appendix Table 3. Contd.

5	5	2	5	5	X																				
6	6	2	3	4	5	X																			
7	1	2	3	4	5	6	X																		
8	1	2	3	4	5	6	8	x																	
9	1	2	3	4	5	6	9	8	X																
10	10	2	10	4	5	6	10	10	10	X															
11	11	2	11	11	5	11	11	11	11	11	X														
12	12	2	12	4	5	12	12	12	12	10	11	X													
13	13	2	13	4	5	13	13	13	13	13	11	13	X												
14	14	2	3	4	5	6	14	14	14	14	11	14	14	X											
15	15	2	15	15	5	15	15	15	15	15	11	15	15	15	X										
16	16	16	16	16	5	16	16	16	16	16	16	16	16	16	16	x									
17	17	2	3	4	5	6	17	17	17	10	11	12	17	14	15	16	x								
18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	x							
19	19	2	19	19	5	19	19	19	19	19	11	12	13	14	15	16	17	19	X						
20	20	2	3	20	5	20	20	20	20	20	11	20	20	20	15	16	20	20	20	X					
21	21	2	21	4	5	6	21	8	4	10	11	12	13	14	15	16	17	21	19	20	X				
22	22	2	22	4	5	22	22	22	22	10	11	12	13	22	15	16	17	22	22	20	22	x			
23	23	2	3	4	5	6	23	8	23	10	11	12	13	14	15	16	17	23	19	20	21	22	x		
24	1	2	3	4	5	6	24	8	9	10	11	12	13	14	15	16	17	24	19	20	21	22	23	x	
25	25	2	25	25	5	25	25	25	25	25	25	25	25	25	16	25	25	25	25	25	25	25	25	25	x
T≈	5	23	11	17	23	11	1	6	3	12	20	13	14	13	19	23	11	0	11	17	7	12	5	2	21
R≈	20	1	14	7	1	14	24	19	22	12	5	10	9	10	6	1	14	25	14	7	18	12	20	23	4

var≈ = varieties; T≈ =Total scores; R≈ = Ranks. The bold numbers represents the 25 bread wheat varieties: 1, *Honkolo*; 2, *Bika*; 3, *Mandoyu*;4, *Bulluk*; 5, *Hiddasse*; 6, *Ogolcho*; 7, *Hoggana*; 8, *Hulluka*; 9, *Mekelle*, 03; 10, *Mekelle*, 4; 11, *Shorima*; 12, *Mekelle-01*; 13, *Mekelle-02*; 14, *Ga'ambo*; 15, *Kakaba*; 16, *Danda'a*; 17, *Gassay*; 18, *Alidoro*; 19, *Digelu*; 20, *TAY*; 21, *Sofumar*; 22, *Medawelabu*; 23, *Pavon*, 76; 24, *Jefferson*; 25, *Kingbird*.

Appendix Table 4. Pair wise ranking of 25 bread wheat varieties by traders and consumers at Sero-Anketo (2015).

var≈	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1	X																								
2	2	X																							
3	3	2	X																						
4	4	2	4	X																					
5	5	5	5	5	X																				
6	6	6	6	6	5	X																			
7	1	2	3	4	5	6	X																		

Appendix Table 4. Contd.

8	1	2	3	4	5	6	8	x																	
9	1	2	3	4	5	6	9	8	x																
10	10	10	10	10	5	6	10	10	10	X															
11	11	2	11	4	5	11	11	11	11	10	X														
12	12	2	12	12	5	12	12	12	12	10	12	X													
13	13	13	13	13	13	13	13	13	13	13	13	13	X												
14	4	2	14	14	5	14	14	14	14	14	14	14	13	X											
15	15	15	15	15	15	15	15	15	15	15	15	15	15	13	x										
16	16	2	16	16	5	6	16	16	16	10	11	12	13	14	15	X									
17	17	2	3	17	5	6	17	17	17	10	11	12	13	14	15	17	X								
18	1	2	3	4	5	6	18	8	9	10	11	12	13	14	15	16	17	x							
19	1	2	3	4	5	6	19	8	19	10	19	12	13	14	15	16	17	19	X						
20	20	20	20	20	5	6	20	20	20	20	20	20	13	14	15	20	20	20	20	x					
21	21	2	3	21	5	6	21	21	21	10	11	12	13	14	15	21	17	21	21	21	X				
22	22	22	22	22	5	22	22	22	22	22	22	22	13	22	22	22	22	22	22	22	22	x			
23	23	2	3	23	5	23	22	23	23	10	11	12	13	23	15	23	17	23	23	20	21	22	x		
24	1	2	3	4	5	6	24	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	x	
25	25	25	25	25	5	25	25	25	25	25	25	12	13	14	15	16	25	25	25	20	21	22	25	25	x
T≈	6	16	10	9	22	15	0	5	3	16	13	15	23	18	23	10	11	2	5	17	12	22	11	1	15
R≈	19	7	16	18	3	9	25	20	22	7	12	9	1	5	1	16	14	23	20	6	13	3	14	24	9

var≈ = varieties; T≈ = Total scores; R≈ = Ranks, The bold numbers represents the 25 bread wheat varieties: 1, *Honkolo*; 2, *Bika*; 3, *Mandoyu*;4, *Bulluk*; 5, *Hiddasse*; 6, *Ogolcho*; 7, *Hoggana*; 8, *Hulluka*; 9, *Mekelle*, 03; 10, *Mekelle*, 4; 11, *Shorima*; 12, *Mekelle-01*; 13, *Mekelle-02*; 14, *Ga'ambo*; 15, *Kakaba*; 16, *Danda'a*; 17, *Gassay*; 18, *Alidoro*; 19, *Digelu*; 20, *TAY*; 21, *Sofumar*; 22, *Medawelabu*; 23, *Pavon*, 76; 24, *Jefferson*; 25, *Kingbird*.

Appendix Table 5. Severity percentages and field responses of the tested bread wheat varieties to the three rusts.

Variety	Severity percentage and response (reaction)					
	Bekoji-Negesso			Sero-Anketo		
	YR	LR	SR	YR	LR	SR
Honqolo	10ms-20ms	0	0	0	0-tms	0
Bika	10ms	0	0-10ms	0	0-5msmr	5msmr-30msmr
Mandoyu	5m-10ms	0	0	0	0-5sms	0-10msmr
Bulluk	0-5m	0	0	0	0-tms	0-5mss
Hiddasse	0-5m	0	0-5s	0	0-10sms	0-60s
Ogolcho	0-tmr	0	0	0	0-5mrms	tms-30mss
Hoggana	0	0	0	0	0	0-tms
Hulluka	5mr-5ms	0	0-5s	0	0-20mss	5msmr-15msmr
Mekelle-3	0-5mr	0	0-5ms	0	0	5msmr-20msmr
Mekelle-4	10m-20m	0	0	0	0-20mss	tr-20msmr
Shorima	0-5ms	0	0	0	0	0-5mrms
Mekelle-1	0	0	0	0	0-50s	10msmr-20sms
Mekelle-2	0-10m	0	0-tms	0	0-30sms	20msmr-30sms
Ga'ambo	10m-10ms	0	0	0	0-5ms	tmr-5mss
Kakaba	tms-15m	0	0-20mss	0	0	40s-70s
Danda'a	tmr-5ms	0	0-5ms	0	0	tms-40s
Gassay	tms-10m	0	10ms-30sms	0	0-10sms	30sms-50s
Alidoro	0	0	0	0	0-tms	0-10msmr
Digelu	0-tms	0-tms	0-30sms	0	0-10sms	40s-50s
TAY	0-5m	0	0	0	0-20sms	0-10msmr
Sofumar	5msmr-10sms	0	0	0	0	tmsmr-20mss
Mada-Wolabu	0-5ms	0	0	0	0	0-tms
Pavon-76	tmr-5mr	0	0	0	0-10ms	tmr-10msmr
Jefferson	0-tmr	0	0	0	0-50s	40s-50s
Kingbird	0-5mr	0	0-ts	0	0-10msmr	0-tmsmr

YR, Yellow/stripe rust; LR, leaf rust; SR, stem rust.