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Performance evaluation of improved bread wheat (*Triticum aestivum* L.) varieties and production technologies in Central High Lands of Ethiopia

Bekele Gemechu[1]*, Amha Besufekad[2] and Abate Mekuriaw[2]

[1]Ethiopian Institute of Agricultural Research. Debrezeit Agricultural research Center, P.O. Box 32, Ethiopia.
[2]College of Development Studies, Addis Ababa University, Ethiopia.

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The aim of this study is to evaluate the performance of five improved varieties of bread wheat and production technologies in Becho District of Oromia, Central Ethiopia. The varieties used were Sanate (T1), Mada-Walabu (T2), Hobora (T3), Hogana (T4), and Hidase as standard check (T5). The experiment was carried out in a Randomized Complete Block Design (RCBD), with six replications using six farmers' fields. Yield and yield related parameters were analyzed using SAS statistical software version 9.0. Economic analysis, preference, gender and nutrition and environmental suitability data were obtained to compare the advantages of treatments/varieties and identify the variety that performs best. All the yields and yield related components were significantly different between the varieties at 5% probability level. Sanate had the highest yield followed by Hobora and Hidase. Sanate variety had a 27% yield advantage over the standard check (Hidase) and 169.6, 143.2 and 156.6% yield advantage over the national, regional and zonal average yield of bread wheat in 2016/2017 Meher season of CSA data. Based on farmers' preference analysis, variety Sanate had the highest acceptability (96%) followed by Hobora (74%) and Hidase (65%), while Hogana variety had the lowest (24%). Economic analysis showed that Sanate variety had the highest net benefit (86,531.65 Birr/ha) followed by Hobora (71,793.96 Birr/ha) and Hidase (69,564.16 Birr/ha). Variety Hogana had the lowest net benefit of about 54,507.63 Birr/ha. Based on the rules of decision making and the integrated scoring on the bread wheat varieties, two of the tested varieties met the requirements for recommendation. Therefore, Sanate and Hobora varieties in addition to Hidase (the control) were recommended for Becho and other areas with similar agro-ecological conditions in the Central Highlands of Ethiopia.

Key words: Becho, economic analysis, environmental suitability, farmers' acceptability, gender aspect, integrated validation, protocol.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important staple food crop in Ethiopia, especially in urban areas. It provides

*Corresponding author. E-mail: oliyad.hn2@gmail.com.

about 15% of the caloric intake for the country with over 90 million population (FAO, 2015a), placing it second after maize and slightly ahead of tef, sorghum, and enset, which contribute 10 to 12% each (Minot et al., 2015). Wheat is also the fourth largest cereal crop produced by about 5 million smallholder farmers, that is, about 35% of all small farmers in the country.

Over the past two decades, both wheat production and consumption have shown increasing trends in Ethiopia. Wheat import has also grown significantly over the past decade. Yet, this substantial increase in domestic production and import has not reversed the increasing trend in wheat product prices, implying an even increased growth in wheat demand. Wheat yield in Ethiopia needs to improve further to level-up with Africa and world average yields, which were 13 and 32% higher than the average wheat yield in Ethiopia, respectively (FAO, 2015a). Beyond the contribution of agro-climatic and political factors to lower yields, technology could play a more dominant role in productivity, enable Ethiopia to enhance its yields and achieve self-sufficiency which in-turn can improve the living standard of its growing population (FAO, 2014).

After South Africa, Ethiopia is the second largest wheat producer in sub-Saharan Africa (FAO 2015b). Wheat is the principal cool-weather grain crop grown in Ethiopia. Besides the use of its grain for food, wheat residue and other by-products are also commonly used to overcome the shortage of livestock feed which is the biggest constraint to the sector in the country. The crop is grown at an altitude ranging from 1500 to 3000 m above sea level (masl), between 6 and 16°N latitude and 35 and 42°E longitude. The most suitable agro-ecological zones, however, are between the 1900 and 2700 masl (Bekele et al., 2000). The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hareghe, Sidamo, Tigray, Northern Gonder and Gojam zones (Bekeke et al., 2000).

Despite their vast number, Ethiopian farmers in general cultivate small plots/acreage. Above half of the smallholders cultivate farms less than a hectare (EEA, 2015). The average farm size has also declined over time. Official statistics, for instance, indicate that over the past five years alone (2009/2010-2013/2014), the proportion of smallholders with farms lower than a hectare has increased by 5.2%, while those who cultivate farmland that vary from 1 and 2 ha and over 2 ha declined by 5.4 and 7.1%, respectively.

Fragmented land holding system added on the low use of agricultural inputs contributed to low productivity in the whole production system. This made Ethiopian farmers to be categorized among the lowest users of fertilizer and improved seeds in sub-Saharan Africa. The other constraint of wheat production in Ethiopia is yellow and stem rust disease which is roughly expected to occur each 7 years. All these wheat production challenges made wheat productivity in Ethiopia lower than other wheat producing countries in the world (Yami et al., 2013).

Out of the total grain crop area, 81.27% (10,219,443.46 ha) was under cereals. Teff, maize, sorghum and wheat took up 24.00% (about 3,017,914.36 ha), 16.98% (about 2,135,571.85 ha), 14.97% (1,881,970.73 ha) and 13.49% (1,696,082.59 ha) of the grain crop area, respectively. As to production, the tables paint similar picture as that of the area. Cereals contributed 87.42% (about 25,3847,23.96 t) of the grain production. Maize, teff, wheat and sorghum are made up 27.02% (7,847,174.66 t), 17.29% (5,020,440.05 t), 15.63% (4,537,852.34 t) and 16.36% (4,752,095.60 t) of the grain production, respectively (CSA, 2017).

Although small-scale farmers dominate wheat production in Ethiopia, there are some large-scale commercial farms that grow wheat. However, large commercial wheat producers account only for 3 to 5% of all wheat cultivated land (Minot et al., 2015). Production of wheat has significantly increased over the past 20 years. It has increased from 890000 metric tons (MT) in the 1991/1992 marketing year to 3.11 million MT in 2009/2010 (Bergh et al., 2012) and to 4.04 million MT in 2014/2015 (Minot et al., 2015).

In the past years, participatory demonstrations and evaluation of integrated improved wheat production technologies were implemented in the area. This innovation created an opportunity for the farmers to efficiently utilize their farmland and increase production and productivity. Especially, the use of improved varieties resistant/tolerant to wheat diseases, along with proper agronomic practices and the use of BBM (Broad Base Maker) to drain excess water from the farm field were practiced, and promising results were obtained.

Even though a lot of work has been done in this regard by different organizations, new varieties of bread wheat with different traits against disease and productivity have been released from different research centers. The objectives of this study were: (1) to assess/evaluate the performance of the newly released bread wheat varieties and production technologies in the farming system and; (2) To generate evidence on the wheat varieties and production technologies.

MATERIALS AND METHODS

Description of the study area

Bacho District is located at mid agro-ecology of South west Shewa Zone of Oromia Regional State at 8°35'0'' N latitude and 38°15' 0'' E longitude; about 80 km South West of Addis Ababa. It has an altitude range of 2,106 to 2,600 masl, with mean annual temperatures ranging from 16 to 25°C. The long term weather information revealed that the area has unimodal rainfall pattern in which the main rainy season is from May to September; its mean annual rainfall is about 1,300 mm per year. The soil of the study area is deep black vertisol, which is moderately fertile and suitable for the production of crops such as tef, wheat, chick pea lentil and other horticultural crops and forages.

Varietal/Treatment selection

The varieties were selected based on their suitability to the area, those newly released and new to the area. The varieties used for the validation activities were identified and obtained from the relevant research system of the country. The varieties were considered as treatments and the experiment was done in randomize complete block design (RCBD), with six replications. Each variety was planted on 10 m × 10 m area on individual farmers' plot and replicated with similar procedure on six farmers' field. The treatments were treated in similar manner to avoid management differences so that the varieties/treatments can express their performance and the difference in varietal performance can easily be exploited.

Site selection and land preparation

Selection of site is important for the successful implementation of activities. Selection of site and land preparation for wheat start immediately after the harvest of the preceding crops when there is residual soil moisture. The residual moisture makes us to get good friable soil structure which is very important for permeability of rain water and good emergence of seed. The preceding crops should not be the same physiologically to minimize the problem of nutrient imbalance and pest build up. Plowing should be done four to five times depending on the type of soil texture. The first plowing helps to decompose any debris in the field. The next rounds of plowing should be carried out when the first rain begins and before it comes to the saturation point. This helps to facilitate the decomposition of crop residues and prevent weed remnants. For the black soils of Becho District, drainage structures should be prepared before sowing using BBM. Sowing was carried out on the drained bed prepared at the beginning of planting when the soil was slightly "Nish". Although all improved technologies that help to improve yield were available, productivity did not improve as expected because the appropriate planting time locally called "Nish" did not coincide. Nish period is a period when the soil is relatively friable and appropriate for cultivation, like row making, using BBM and other practices which are difficult to practice when the soil is too wet. Land preparation was accomplished by using the local "Maresha". This made the soil particles to be fine.

Seed rate and planting methods

Planting was carried out with broadcasting method using BBM due to the heavy vertisol nature of the soil. Vertisol by its nature is a water logged soil, and this makes it difficult to do raw planting on it. A seeding rate of 150 kg/ha, which is common for all wheat varieties in the area, was used.

Fertilizer application

Even though the use of chemical fertilizer varies based on the soil condition and crop varieties, fertilizer application based on area specific recommendation is important. Accordingly, 100 kg/ha of NPS (19% N, 38% P_2O_5, 7% S) and 50 kg/ha of urea at planting stage and 50 kg/ha of urea at tillering stage (35-40 days) after planting were applied.

Data collection and analysis

The validation of the varieties (Sanate, Mada walabu, Hobora, Hogana, and Hidase as a standard check) was conducted on 100 m^2 of land of 6 selected farmers' fields for each variety. Data were collected based on the validation protocol developed by CASCAPE and Wageningen University and Research (de Roo et al., 2017). The validation protocol provides a practical guideline for an integrated validation of best-fit practices with 6 parameters, namely, productivity (agronomic data), profitability (economic data), acceptability (farmers' preference), gender (labor demand), nutrition and environmental sustainability (usage of chemicals). Data were collected in these parameters and the scores of each parameter were integrated to establish standardized scores for each variety; decision was passed based on the integrated score.

Data on yield were analyzed using the ANOVA and mean separation procedures of the SAS statistical software. The remaining data on the other parameters were summarized descriptively using average, sum, percentage, frequency, etc. After separately analyzing the data of each parameter, results of all the protocol components were normalized on a 1-5 scale. Subsequently, three rules were applied to decide the variety to recommend. First, the improved variety should have a higher overall performance than the check or local or conventional variety. Secondly, not more than one parameter should have a value of 1. Thirdly, varieties with a mean value of >4, 3-4, 2-3 and <2 were considered as highly recommended, recommended, acceptable and not acceptable, respectively (de Roo et al., 2017). Furthermore, to summarize and visualize all the data on one panel, a spider graph was employed.

RESULTS AND DISCUSSION

Productivity

All the yields and yield related components were significantly different between the treatments/varieties at 5 % probability level. Sanate (T1) had the highest yield followed by Hobora (T3) and Hidase (T5) (Table 1). There is a significant difference at P<0.001 among the treatments/varieties for grain yield, biomass yield, plant height and maturity date. Sanate had the highest grain yield (7211.8kg/ha) than Hobora (6366.8kg/ha) and Hidase (5667.6kg/ha) while Hogana variety provided the lowest grain yield (4213.8kg/ha). But there is no significant difference among the varieties/treatments for flowering date.

As can be seen in Table 1, the varieties showed significant difference for maturity date. Hidase had the shortest maturity date (101 days) followed by Mada walabu (110 days); Hogana (117 days) had long maturity date. Maturity date is an important trait for farmers of the study area in which they are interested in. Early maturing variety gives chance for mixed cropping (chick pea is planted after wheat harvest with the remaining soil moisture). The result obtained from this study is in line with the study of Bekele et al (2015) in which Hidase variety was preferred by farmers because of its early maturity (in addition to its productivity) and its compatibility with chick pea for mixed cropping (Figure 1).

The grain yield of Sanate variety (T1) has a 27% yield advantage over the standard check (Hidase, T5), and it has a 169.6, 143.2 and 156.6% yield advantage over the national, regional and zonal average yield of bread wheat in 2016/2017 Meher season of CSA data respectively (CSA 2017). As observed from the average yield

Table 1. Mean value of agronomic parameters of bread wheat validation trial

Treatment/Variety	Grain yield (kg/ha)	Biomass yield (kg/ha)	Flowering date	Maturity date	Plant height (m)	Harvest index
1. Sanate	7211.8[a]	36106[a]	69[a]	115[ab]	1.05[a]	0.20[ab]
2. Mada Walabu	4917.2[d]	27297[b]	65[a]	110[b]	0.85[bc]	0.18[bc]
3. Hobora	6366.8[b]	28393[b]	66[a]	113[ab]	0.88[b]	0.22[a]
4. Hogana	4213.8[e]	25141[b]	68[a]	117[a]	0.77[c]	0.16[c]
5. Hidase	5667.6[b]	30237[b]	58[b]	101[c]	0.83[bc]	0.19[bc]
Means	5675.4	29430.85	65	110.96	0.88	0.19
CV%	5.3	9.18	5	3.08	7.75	10.8
LSD	405.08	5236.8	4.4	6.63	0.09	0.02

Figure 1. Field performance of Wheat validation trial at Becho.

obtained from experimental site of all treatments/varieties under evaluation, it is by far greater than the average yield recorded by the CSA 2016/17 for national average (2675 kg/ha), regional average (2975 kg/ha) and zonal average(2811 kg/ha).

Acceptability

Farmers' preference analysis was carried out using CIAT approach (Guerrero et al., 1993). A total of eleven farmers (6 experiment host farmers and 5 neighbor farmers) were asked to list the criteria (traits) that they use to assess the varieties, and the traits listed were checked to see if they were up to their expectation. Accordingly, the farmers identified 5 traits, namely, biomass yield, resistant/tolerant to disease, maturity time, tillering capacity and head size. To detect the relative importance of the traits, a pair-wise ranking was carried out (Table 2). The farmers rated each of the varieties with the developed traits using likert scale (1=Excellent, 2=very good, 3=good 4=poor, 5= very poor) (Table 2).

At the end, acceptability score of each variety was calculated by summing up the scores of all the farmers, and dividing it by the maximum possible score. Then, they were converted to percentage (Table 3).

Based on the acceptability percentage, Sanate was ranked first with acceptability level of 96%, followed by Hobora (74%) and Hidase (65%); but Hogana was ranked last, making it the lowest preferred variety among the farmers with acceptability rating of 24%. In addition to the general scores and ranks given by the farmers, most of the farmers were also interested in some of the varieties with early maturation days. As stated earlier, early maturing variety can provide the chance for mixed cropping (wheat-chick pea). In this regard, Hidase and Mada Walabu could attract the attention of farmers. But, the productivity level of Mada Walabu is low as compared to the other varieties. For instance, it is lesser than Sanate and Hidase by 46.84 % and 15.27 %,

Table 2. Pair wise ranking of set criteria for farmers' preference.

Correlation	Disease resistance (1)	Maturity time (2)	Biomass yield (3)	Tillering (4)	Head size (5)	Number of occurrence	Rank
Disease resistance (1)		1	1	1	1	4	1
Maturity time (2)			2	2	5	2	3
Biomass yield (3)				4	3	1	4
Tillering (4)					5	1	4
Head size (5)						2	2

Table 3. Acceptability score for bread wheat varieties.

S/N	Variety	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	Total	Acceptability (%)	Rank
1	Sanate	23	22	23	22	19	23	23	23	21	23	23	245	96	1
2	M/Walab	13	15	15	17	16	15	15	14	14	13	13	160	62	4
3	Hobora	13	15	15	18	22	15	18	18	19	18	18	189	74	2
4	Hogana	6	5	5	5	5	5	5	5	5	5	5	56	21	5
5	Hidase	16	18	15	14	13	14	14	15	16	16	16	167	65	3

respectively.

Profitability

Profitability analysis is another important element of the integrated validation protocol used to analyze the marginal rates of return to investement among the varities. This analysis is very important to identify the most profitable bread wheat varieties economically from the validated varieties. To estimate this economic effect, CIMMYT (1988) procedure was used. In so doing, the average grain yield of the cultivars was adjusted downwards by 10% in calculating gross field benefits. This was done to compensate for the possible inflated estimation of average grain yield that could arise because of the mode of input application and the small plot effect. The cost of seed is the only input cost that was found to vary across treatments. This implies that the difference in average grain yield and the cost of seed are the only factors that could influence marginal benefit.

The results show that the validated wheat varieties have different results: Sanate had the maximum net benefit (86,531.65 Birr/ha), followed by Hobora (71,793.96 Birr/ha) and Hidase (69,564.16 Birr/ha). Variety Hogana has the least net benefit of about 54,507.63 Birr/ha (Table 4).

Gender and nutrition

In most areas of rural Ethiopia, both male and female members of farm households are involved in various types of farm activities. Newly introduced technologies and practices may require more family labor, particularly women face a heavy work burden, and such burden intensifies when the family does not have the means to hire daily laborers in peak seasons (Assefa et al, 2015; de Roo et al, 2017). In this evaluation of improved wheat varieties, it was observed that the agronomic management practices of both the improved and check varieties of wheat were not different in drawing labor with respect to gender. In such cases, the validation protocol guides used to rate the varieties were the same with the conventional, with a normalization value of 3; thus all the varieties were rated similarly having an integrated score of 3.

In terms of nutrition, all the cultivars are not nutritionally dense, hence a 'No' response was given to all cultivars by following the validation protocol. It is assumed that cereals are not considered as good sources of nutrition compared to pulses (nutritionally cereals are less dense than pulses).

Environmental sustainability

For environmental sustainability, the protocol recommends two variables as proxies: nutrient depletion and pesticide. For this validation activity, no data were collected on nutrient depletion. However, the use of pesticides for the control of broad leaf weeds was the common practice for most farmers due to the difficulty of controlling weed by hand as it needs more labor (majority of the farm households cannot cover with their family labor). Pesticides have acute and chronic toxicity effects on humans; they also harm the environment (pollinators, drinking water, non-target organisms etc). Even though,

Table 4. Profitability analysis for bread wheat varieties.

Inconstant variable	Varieties				
	Sanate	Mada-Walabu	Hobora	Hogana	Hidase
Average grain yield (kg/ha)	7211.8	4917.2	6366.8	4213.8	5667.6
Adjusted grain yield (kg/ha)	6490.62	4425.48	5730.12	3792.42	5100.84
Average straw yield (kg/ha)	28894.2	22374.8	22026.2	20,927.2	24569.4
Adjusted straw yield (kg/ha)	26,004.78	20,137.32	19,823.58	18,834.48	22,112.46
Gross field benefits of grain (Birr/ha)	51,924.96	35,403.84	45,840.96	30,339.36	40,806.72
Gross field benefits of straw (Birr/ha)	36,406.69	28,192.24	27,753.00	26,368.27	30,957.44
Total Gross field benefits (Birr/ha)	88,331.65	63,596.08	73,593.96	56,707.63	71,764.16
Cost of seed (Birr/ha)	1800	1800	1800	2200	2200
Total costs that vary (Birr/ha)	1800	1800	1800	2200	2200
Net benefits (Birr/ha)	86,531.65	61,796.08	71,793.96	54,507.63	69,564.16
Marginal benefit	4,807.32	3433.12	3988.55	2477.62	3162.00

Average yield (kg/ha) = average yield of a given variety over farmers' fields calculated as kg/ha. Adjusted yield (kg/ha) = average yield adjusted downwards by 10% expressed as kg/ha. Gross field benefits (Birr/ha) = Adjusted yield (kg/ha) × field price of the crop (Birr/kg). Cost of seed (Birr/ha) = Cost of seed for a given cultivar calculated as Birr/ha. Total costs that vary (Birr/ha) = sum of associated costs (in this case, it would be similar to the cost of seed). Net benefit (Birr/ha) = Gross field benefits (Birr/ha) - total costs that vary (Birr/ha). Marginal benefit (%)= Net benefit (Birr/ha)/Total costs that vary×100.

Table 5. Integrated scoring of technologies for wheat validation trial

Variable	Sanate	Mada-Walabu	Hobora	Hogana	Hidase
Productivity (tonnes/ha)	5	4	5	4	5
Profitability (Birr/ha)	4	2	3	2	3
Acceptability	5	2	4	2	4
Gender/Labour	3	3	3	3	3
Nutrition (yes or no)	N	N	N	N	N
Pesticide use	1	1	1	1	1
Mean	3.6	2.4	3.2	2.4	3.2

Integrated Pest Management (IPM) approach was used to manage pests, participant farmers in the validation trial used 2-4, D to control broad leaf weeds. This herbicide is grouped under class II of WHO (2010) classification. The protocol rates such graded herbicides to have a score of 1 (lowest value) in the normalization of the integrated scoring. Due to the application of the stated pesticide in all of the varieties, each variety was rated 1. This in fact has affected the sum of the integrated scoring. The rating of environmental sustainability pulled down the scoring of high yielding, highly accepted and more profitable varieties. For instance, the mean score of Sanate (so far the favourite variety) would have been 4.4 out of 5 but was forced to stand at 3.6. This implies the sensitivity of the validation trial to environmental sustainability.

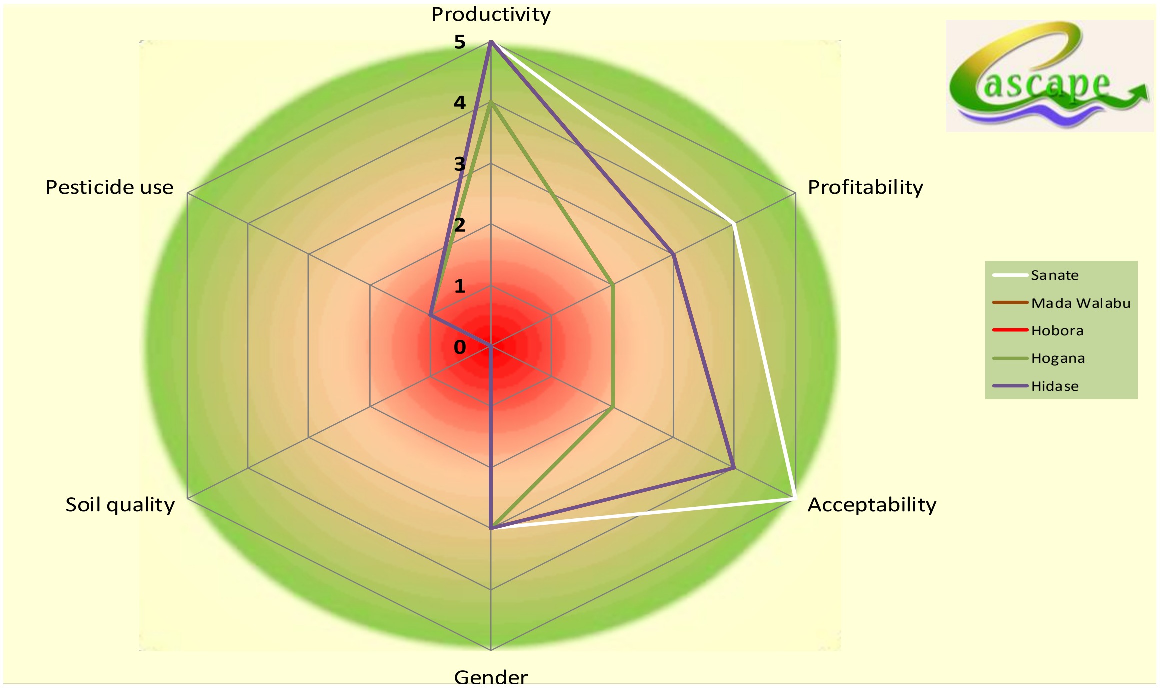
Integration and visualization of results

So far the discussion has been on each of the parameters that constitute the integrated validation protocol of technology validation. However, the final decision as regard which variety should be promoted is done based on the integrated score results. So, it is now necessary to construct a single score by integrating the parameters for each of the varieties. Hence, the results on yield performance, profitability, acceptability, gender, nutrition and pesticide use have been normalized into a 1-5 scale as presented in Table 5.

Based on the rules of decision making and the integrated scoring of improved technologies, two of the improved varieties (other than the check variety) meet the requirements to be recommended. Therefore, we recommend Sanate and Hobora varieties in addition to Hidase for Becho and other areas with similar agro-ecological conditions in the central highlands of Ethiopia (Figure 2).

Conclusion

Over the past two decades, both wheat production and



	Sanate	M/Walabu	Hobora	Hogana	Hidase
Relative area	1.00	0.37	0.73	0.37	0.73

Figure 2. Spider diagram of integrated scoring of wheat production technology validation.

consumption have shown increasing trends in Ethiopia. Wheat import has also grown significantly over the past decade. Yet, this substantial increase in domestic production and import of wheat has not reversed the increasing trend in wheat and wheat product prices, implying an even faster growth of wheat demand. Wheat yield in Ethiopia needs to improve further to level-up with Africa and world average wheat yields, which were 13 and 32% higher than the average wheat yield in Ethiopia, respectively. Beyond agro-climatic and political factors contributing to lower yields, technology could play a more dominant role in productivity, enable Ethiopia to enhance its yields and achieve at least a sufficient yield to feed and change the living standard of its growing population.

According to the set protocol for validation, agronomic data like days to flowering and days to maturity, plant height, disease and pest score, grain yield, and biomass yield were collected from the selected plots. Economic data and farmers' preference, environmental sustainability, nutrition and gender aspect were also part of the collected data and the data were analysed and arranged in integrated validation of technologies so that the best performing technology was identified for further recommendation. Therefore, Sanate and Hobora varieties were recommended for Becho areas and other areas with similar agro-ecological conditions in the central highlands of Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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