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From Validation to Pilot-Testing, and Pre-Extension Demonstration: The Case of Food Barley in the Central Highlands of Ethiopia

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Abstract

Ethiopia is considered as the center of diversity for barley (*Hordeum vulgare* L.), and it is the fifth most important cereal crop in the country. To increase the productivity of the crop, research has been conducted over the past decades by different research institutions, and because of this effort, several varieties have been released. However, barley landraces still represent more than 90% of the cultivated barley diversity in Ethiopia. Barley is a very dependable cereal on the highly degraded mountain slopes of the highlands of central Ethiopia. However, the production system is dominated by age-old landraces. Thus, using the newly developed integrated agricultural technology evaluation protocol and following the innovation pathway, CASCAPE program (Capacity building for scaling up of evidence-based agricultural technologies in Ethiopia) conducted a participatory variety validation, pilot-testing and pre-extension demonstration at Girar Jarso and Tarmaber Woredas of North Shewa, Ethiopia in 2017 and 2018. Data on grain and biomass yield, acceptability, profitability, gender-related labor burden, environmental sustainability, and farmer's feedbacks were collected. For the validation trial, the recorded data on each parameter were normalized on a 1-5 scale and the mean value was computed for each variety. Subsequently, conferring the set-out rules of decision making, HB-1307 with a normalized mean value of 3.8 was selected. HB-1307 has given 3850 kg/ha grain yield, a 30% increase over the landrace. It was also the most preferred variety by farmers (80.83% acceptability score) and with higher profitability compared to the other improved varieties. In 2018, the pilot-testing at Girar Jarso exhibited: 209.76%, 171.78% and 189.3% production benefit than the national, regional and zonal average yield respectively. Likewise, the benefit of HB-1307 on the pre-extension demonstration at Tarmaber was also higher than the local production practice. Following the development pathway and validation protocol of the CASCAPE program, this paper aims to shed light to an effective way of integrating parameters while selecting a crop technology and to the follow-up extension endeavors.

Keywords: Barley; Integrated technology validation; Productivity; Profitability; Acceptability; Gender and nutrition; Environmental sustainability

Introduction

Barley is one of the earliest cultivated crops, with reports indicating that it was domesticated more than 10,000 years ago in the Fertile Crescent of the Near East. It is the most extensively cultivated crop over a wide range of environmental conditions than any other cereal; from 70°N in Norway to 46°S in Chile [1]. Additionally, it can be grown higher on the mountain slopes than the other cereals. With respect to area and production volume, barley is the fourth most important cereal after wheat, rice, and maize in the world; likewise, a chief cereal crop after teff, maize, wheat and sorghum in Ethiopia. In Ethiopia, barley cultivation is reported to be started 5000 years ago. Ethiopia is considered as a center of diversity for barley. The diverse soil and climatic conditions together with the long-term geographic isolation may have likely contributed to the morphological variation between landraces. As a result, the Ethiopian barley germplasm has continuously been an important source of valuable genes in the world [2].

Nowadays, Ethiopian farmers grow barley in various climatic and soil types with an elevation ranging from 1,400 to over 4,000 meters above sea level. Although it grows on wide range altitudes, it performs best at higher elevation areas of the Northern and central regions of the country [3]. Regarding production periods, it can be produced during the main and short rainy seasons as well as under residual moisture. Barley is a staple food for smallholder farmers in every region of the country; in 2015/2016 cropping season alone, it has been produced on 1,141,515.97 hectares of land with a total production of 20,615,83.35 metric tons. In Ethiopia, barley has an immense cultural and nutritional position, it can be used as food, fodder, and beverages in 20 different ways. For instance, it can be used to make bread, porridge, soup, and roasted grain as well as in the preparation of alcoholic and non-alcoholic drinks. Furthermore, its straw can be used as animal feed, thatching roofs, and bedding [4]. Despite its great significance in the farming system of the country, barley production is constrained by many confounding factors. The major production limiting concerns are poor soil fertility, frost, water logging, insect pests (e.g. aphids and barely fly), leaf diseases (e.g., scald, blotch,

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smuts, leaf rust), moisture stress, low-yielding varieties, and inadequate agronomic practices. As a result, assuming the genetic potential of the crop, the national average is relatively lower than the world average. In 2015/2016 cropping season, the national average yield had been 1.96 metric tons per hectare of land [5].

To increase the productivity of the crop, research has been conducted over the last 50 years by different research institutions using exotic and landrace materials and because of this effort, several varieties have been released. However, barley landraces still represent more than 90% of the cultivated barley diversity in Ethiopia [6]. Because barley can withstand extreme marginal conditions of drought, frost and poor soil fertility better than other cereals, it is a very dependable cereal and cultivated on highly degraded mountain slopes of the highlands of Girar Jarso Woreda, North Shewa, Ethiopia. Nonetheless, the barley farming system in the area is highly dependent on the low yielding age-old landraces [7]. Thus, evaluating the performance of the most successful improved varieties in potential food barely production areas and creating demand on the available improved technologies have a principal significance to boost production and improve the livelihood of the highland communities [8]. In view of this, the CASCAPE program (Capacity building for scaling up of evidence-based agricultural technologies in Ethiopia), is mandated on undertaking testing and validation work on the available agricultural technologies in the country. Therefore, considering the suitability of the area and the absence of improved varieties in the locality, an integrated evaluation followed by pilot-testing of the selected cultivar were carried out at Girar Jarso in 2017 and 2018 cropping seasons. Rather than evaluating the different varieties merely on their productivity, an integrated evaluation protocol that involves parameters such as productivity, acceptability, profitability, gender (labor burden on females), nutrition and environmental sustainability in terms of pesticide use was employed.

After validating the improved technology in a small plot experiment, the CASCAPE innovation pathway recommends assessment of the far-reaching scalability of the selected technology into wider recommendation areas. A pilot-testing work often followed the validation activity. Accordingly, in 2018, a pilot-testing work was done at Girar Jarso. Furthermore, to raise awareness and create demand for the validated technology, it is also advisable to do pre-extension demonstration, simultaneously or after the pilot-testing in other intervention Woredas of CASCAPE. Therefore, a demonstration work was carried out at Tarmaber Woreda of the Amhara region in 2018 (Figure 1).

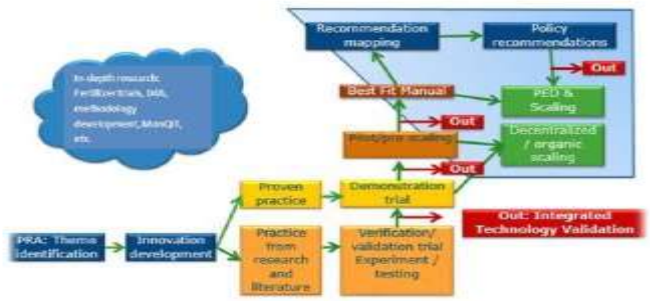

Figure 1: The CASCAPE innovation pathway. Materials and Methods

Study areas

The participatory on-farm evaluation was conducted under the rainfed condition consecutively in 2017 cropping season in the two highland areas-Gino and Elamu Kebeles of Girar Jarso Woreda of North Shewa, Ethiopia. Whereas in the following year, the pilot-testing and pre-extension demonstration were done at Girar Jarso and Tarmaber Woredas respectively. Girar Jarso Woreda is located in Oromia regional state of Ethiopia; it is 112 km in the Northwestern direction from the capital Addis Ababa. The total area of the Woreda is about 42763 hectares. The altitude of the Woreda ranges from 1300 to 3419 meters above sea level. The Woreda lies within thegeographic region between 9035’-10000’N latitude and 38039’-38039’E longitude. The average rainfall amount of the Woreda is about 1200 mm, and maximum and minimum rainfall is about 1115 mm and 651mm, respectively. The temperature of the Woreda ranges from a minimum of 11.5 °C to a maximum of 35 °C. In terms of soil, the cultivated lands are comprised of vertisols, leptosols, luvisols, fluvisols, and cambisols. The dominant soil types in the two testing kebeles were leptosols and luvisols.

Tarmaber is one of the woredas in the Amhara regional state of the country. It is located at the eastern edge of the Ethiopian highlands in the North Shewa Zone, with a geographic coordinate of 9°50'56.6"N and 39°43'56.4"E. The altitude of most of the farming areas in the woreda is within a range of 1500 to 3100 m.a.s.l. The topography is dominated by chains of hills and steep mountains; thereby 15.28% of the woreda is mountainous, 32.78% is flatlands, 6.29% valleys and 45.65% are rugged types. The annual minimum and maximum average temperatures are 15°C and 25°C respectively with a mean monthly precipitation of 1200 mm. Additionally, the coldest and hottest months are November and May respectively.

Site selection, experimental materials and design

In the evaluation phase, a total of six farms (three per kebele) were selected based on accessibility, physical soil parameters and willingness of farm owners to host the trial. Due to the participatory nature of the trial, farmers hosting the trial had been briefed extensively about the trial activities. Three improved food barley varieties. Collected from Holetta and Sinana agricultural centers of Ethiopia, and the widely grown local landrace in the Woreda was part of the trial. Treatments were arranged in a Randomized Complete Block (RCB) design with 6 replications; farmers’ fields as a replication. Each variety was planted on 100 m^2 plot of land with an inter-row spacing of 40 cm and with the seed rate of 110 kg/ha.

Fertilizer at a rate of 100 kg/ha NPSB and 100 kg Urea were applied. Half of Urea was applied at planting and the rest was top-dressed after the first chemical application and hand-weeding. The widely used herbicide-2,4-D (2,4-Dichlorophenoxyacetic acid) was applied to kill off broad-leaved weeds; while the remaining weeds of other types were hand-wed. Following the same agronomic practices as the validation, the pilot-testing HB-1307 was carried out at Girar Jarso on 50 farms of a quarter of a hectare each. The pre-extension demonstration was conducted at Tarmaber on 22 farms of half a hectare each in 2018. On the quarter of a hectare each, HB-1307 with the improved agronomic practice, and the local cultivar with the local management were planted.

Data collection and analysis

For the integrated evaluation of different agricultural technologies and recommending the best performing treatment, CASCAPE has a technology testing and validation protocol. Accordingly, data on productivity, i.e. grain and biomass yield, farmers preference by CIAT, partial budget, gender (gender disaggregated labor contribution), and environmental sustainability (pesticide use) were collected. Data on grain and biomass yield was analyzed using the ANOVA and mean separation procedures of the SAS statistical software system. The remaining data on the other parameters were summarized descriptively using the average, sum, percentage, frequency, etc. procedures of Microsoft Excel 2016. After separately analyzing the data of each parameter, the results of all the protocol components were normalized on a 1-5 scale. Subsequently, to decide on which variety to recommend, three rules had been applied: First, the improved variety should have a higher overall performance than the local/conventional. Secondly, not more than one parameter had a value of 1. Thirdly, varieties that had a mean value of >4, 3-4, 2-3 and <2 was considered as highly recommended, acceptable and not acceptable, respectiv ely. Furthermore, to summarize and visualize all the data on one panel, a spider graph was employed. On the pilot-testing and pre-extension demonstration, data on biomass and grain yield as well as farmers' feedbacks were documented.

Results and Discussion

The variety testing in 2017 is analyzed and discussed consistent with the CASCAPE validation parameters: Productivity, profitability, acceptability, gender, nutrition and environmental sustainability. The results of the pilot-testing and demonstration are described in terms of grain and biomass yield, and farmers' feedbacks.

Productivity

In the 2017 variety testing, both the grain and biomass yield were significantly different between varieties at $P<0.05$. In terms of grain and biomass yield, HB-1307 was the better variety; however, the landrace appeared to be superior to the improved variety Dafo.

The improved variety HB-1307 out-yielded the landrace by about 30 %. The two cultivars Abdene and Dafo are the most recently released varieties, however, the variety that was released in 2006, HB-1307 still gave a higher yield in the trial. This may have been because of specific environmental adaptation or it might as well support on their statement on the recent failure of the national agricultural system to deliver better varieties compared to the performance of the varieties released earlier and the landraces currently found in some barley production areas of the country. The result of our trial is backed in which HB-1307 presented higher yield than the other improved varieties in Dera, South Achefer, Burie and Jabi Tehenan districts of North-Western Ethiopia. Regarding days to maturity, variety Abdene matured 10 and 9 days earlier than the landrace and HB-1307 respectively (Table 1). All along the trial period, no disease or insect pest had been recorded on any of the varieties of the replicate farms.

S. No.	Variety	PH (cm)	DM	BY (kg/ha)	GY (kg/ha)
1	Abdene	114	120.6	17160	3145
2	Dafo	113	125.8	18620	2824
3	HB-1307	113.8	129.2	18880	3850
4	Local	113.2	130.2	18760	2960
	LSD	6.81	5.39	1687.4	76.936
	Sig	NS	**	*	**
	CV	4.354	8.545	6.671	1.747

Abbreviations: Sig: Significant at 1% probability (**) and 5% (*); PH-plant height, DM: Days to 50% maturity, BY: Biomass Yield, GY: Grain Yield, LSD: Least Significant Difference and CV: Coefficient of Variation.

Table 1: Means on grain and biomass yield.

Profitability

To estimate the Marginal Rate of Return (MRR) for each variety, the partial budget analysis method of CIMMYT was followed. To compensate for the possible inflated estimation of average grain and biomass yield, mainly because of the careful application of inputs and the small plot effect, average grain and biomass yield of varieties was adjusted downwards by 10% to calculate the gross field benefits. The cost of seed was the only cost found to be varied across treatments, hence, the difference in average grain and biomass yield and the cost of seed were the only factors that determined the net benefits and the Marginal Rate of Return (MRR). The gross field benefits of two of the improved varieties HB-1307 and Abdene were higher than the local variety. However, the profit of the local variety was higher than the improved varieties. It was because the cost of local seed was lower than the improved seed in the country. The MRR of the local variety, HB-1307, Abdene and Dafo is 2509%, 1847% 1552% and 1497% respectively (Table 2).

	Variety			
Inconstant variables	HB-1307	Abdene	Dafo	Local
Average grain yield (kg/ha)	3850	3145	2824	2960
Adjusted grain yield (kg/ha)	3465	2830.5	2541.6	2664
Average biomass yield (kg/ha)	18880	17160	18620	18760
Adjusted biomass yield (kg/ha)	16992	15444	16758	16884
Gross field benefits (ETB/ha)	36999	31396.5	30360	3131
Cost of seed (ETB/ha)	1900	1900	1900	1200
Total costs that vary (ETB/ha)	1900	1900	1900	1200
Net benefits (ETB/ha)	35099	29496.5	28460	30111
Profitability (MRR %)	1847.32	1552.45	1497.9	2509

Table 2: Profitability analysis for barley varieties.

Acceptability

Farmer's preference analysis is a critical part of any participatory variety selection/adaptation activity. Hence, the preference analysis system of CIAT was applied in the trial. Prior to the actual preference analysis, a group of farmers was given an opportunity to list their parameters of interest while selecting food barley variety phenotypically. Subsequently, spike length, seed size, number of head rows, straw yield, seed yield, and earliness were noted down by farmers. Next to the listing of traits, a cross-wise ranking was carried out and it revealed that seed yield, earliness, and spike length were the three topmost significant traits to farmers (Table 3).

	SL (1)	SZ (2)	NHR (3)	StY (4)	SeY (5)	ER (6)	Frequency	Rank
SL (1)	-	1	1	1	5	6	3	3
SZ (2)	-	-	2	2	5	6	2	4
NHR (3)	-	-	-	3	5	6	1	5
StY (4)	-	-	-	-	5	4	1	6
SeY (5)	-	-	-	-	-	5	5	1
ER (6)	-	-	-	-	-	-	3	2
Abbreviations: HL: Head Length, SZ: Seed Size, NHR: Number of Head Rows, StY: Straw Yield, SeY: Seed yield, ER: Earliness.								

Table 3: Matrix ranking of farmers' selection traits on food barley varieties.

After the pair-wise ranking of selection parameters, each farmer ranked each cultivar against the three highly ranked traits (spike length, earliness, and seed yield). Later, acceptability scores for eachcultivar were calculated by summing up the score of all the farmers, dividing it by the maximum possible score and multiplying it by 100 (Table 4). Hence, HB-1307 and Abdene were the most preferred cultivars by farmers with an acceptability score of 80.83% and 71.25% respectively.

Variety	Farmer													Sum	Acceptability score (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13		
HB-1307	13	13	13	13	#	#	13	15	13	12	13	13	12	194	80.83
Abdene	12	12	11	11	#	#	10	9	12	14	11	11	12	171	71.25
Dafo	7	8	8	8	7	8	9	8	5	7	8	8	7	115	47.92
Local	8	7	8	8	9	7	8	8	10	7	8	8	9	120	50

Table 4: Acceptability score for food barley varieties.

Gender and nutrition

The evaluation protocol by only records the labor contribution of male and female household members to quantify whether the improved technology increases or decreases the labor burden on women. The agronomic management practices of both the improved and local potato varieties were not different. Therefore, 'the same as conventional' normalization value of 3 was used for all varieties (See Annex 1) while integrating evaluation parameters. Regarding nutrition, because the evaluation protocol was indifferent to lab analysis for nutrient composition, it fails to put a distinct line between food barley varieties vis-à-vis their specific nutrient density. But because there always is a clear difference in nutrient content, it can be applied while evaluating the yellow and white fleshed sweet potato varieties in one setting. Therefore, for this specific trial, both the local and improved varieties were considered as not nutritionally dense, hence a 'No' response was given to all varieties.

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Environmental sustainability

For environmental sustainability, the evaluation approach uses two proxies- nutrient depletion and pesticide use. For this validation activity, no data was collected on nutrient depletion, however, 2,4-D herbicide for the control of broad-leafed weeds had been used with the same rate and application method in all treatments of replicate farms. Since the protocol uses the WHO pesticide by hazard classification and 2,4-D is classified as a class II pesticide, a score of 1 was given to all treatments while integrating evaluation parameters for decision making and result presentation.

Integration and visualization of results

Integrated evaluation highly discourages selecting the best performing variety/ies by only taking the result of an individual parameter.

Therefore, integrating parameters and displaying the result into a single presentation panel i.e. spider graph is recommended. Accordingly, the results on productivity, profitability, acceptability, gender, and pesticide use were normalized into a 1-5 scale (Annex 1 for details).

Following the three decision-making rules described earlier, HB-1307 and Abdene fit to have been recommended. Nevertheless, with a mean normalized score of 3.8, HB-1307 was selected as a superior food barley variety for the locality and other areas with similar climatic and social circumstances (Table 5).

Indicator	Abdene	Dafo	HB-1307	Local
Productivity	4	3	5	3
Profitability	5	5	5	5
Acceptability	4	1	5	2
Gender/labour	3	3	3	3
Nutrition (yes or no)	N	N	N	N
Pesticide use	1	1	1	1
Mean (X)	3.4	2.6	3.8	2.8

Table 5: Integrated scoring on food barley varieties.

As part of the protocol, a Macro on excel is created to make a spider graph that can show parameters altogether in one presentation panel. On the graph, if an entry hits 5 on a specific evaluation parameter, for instance, HB-1307 on productivity, it means HB-1307 has given the maximum grain yield set on normalization of results (Annex 1). Because a class II chemical was used to control broad-leaved weeds on all the treatments and replicate farms, the score for all entries on pesticide use was 1, which shows how stringent the protocol is on environmental matters (Figure 2).

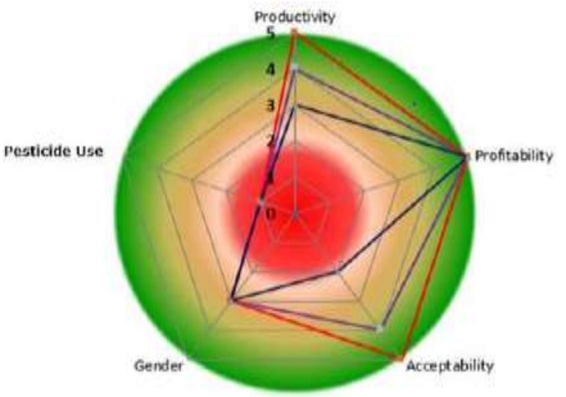

Figure 2: Spider graph showing the relative performance of varieties.

Conclusion

In a country where people struggle for food security, evaluating varieties of staple food crops by integrating all the prevailing economic, social and environmental parameters instead of taking their production alone may seem like a bit of an extravagance. However, the protocol developed by the team of experts from Wageningen University and CASCAPE attempts to assimilate few but important parameters together. For the case of this specific trial, we believe that it serves our purpose profoundly. Nonetheless, there still are gaps, it would become a complete protocol if it adds depth to its gender and nutrition segment and includes other stakeholders in the preference analysis. Moreover, it should also include other attributes of environmental sustainability. In general, by fit in the different parameters, the validation trial managed to recommend a productive, profitable, preferable food barley variety for the highlands of Girar Jarso and other areas with comparable agro-ecological and social settings in the central highlands of Ethiopia. The pilot-testing and pre-extension demonstration are also useful to evaluate the possibility of large-scale promotion, and vital to raise awareness and create demand for the technology.

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