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Integrated evaluation of potato varieties in the highlands of Girar Jarso Woreda, North Shewa, Ethiopia

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In Ethiopia, farmers are cultivating potato under a wide range of environmental conditions. Despite its genetic potential, the productivity of potato is relatively low. Among the long list of production constraints, the absence of high yielding and disease resistant varieties in different corners of the country are the prominent ones. Its suitable edaphic and climatic conditions make the highlands of Girar Jarso Woreda suitable for potato production; however, it is scarce and dominated by local varieties. Hence, by employing its newly developed integrated agricultural technology evaluation protocol, CASCAPE program (Capacity building for scaling up of evidence-based agricultural technologies in Ethiopia) conducted a participatory potato variety evaluation trial at Girar Jarso in 2017 cropping season. Data related to tuber yield, acceptability, profitability, gender-related labor burden and environmental sustainability in terms of pesticide use were collected. Instead of selecting an adaptable variety merely on one parameter, for instance solely by considering yield of the crop, the recorded data on each parameter were normalized in a 1-5 scale and integrated to produce a single value for each variety. Therefore, in relation to the three rules of decision making, a potato variety (Belete) that had an over normalized score of 4.6 with a yield of 47.12 ton/ha, an acceptability score of 97.22 and 960% profitability was selected and recommended for the highlands of Girar Jarso Woreda and other areas with similar agro-ecological and social settings in the central highlands of the country. As a novel system of participatory technology evaluation technique, this paper demonstrates the approach to select and recommend a variety/technology by integrating its production potential, profitability, desirability, gender attributes, and with environmental considerations.

Key words: Potato, Integrated technology validation, productivity, profitability, acceptability, gender and nutrition, environmental sustainability

INTRODUCTION

The cultivated potato (*Solanum tuberosum L.)* originated in the highlands of the Andes in South America and

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belongs to the genus *Solanum* that comprises more than 2000 different species; the widely grown genotypes being tetraploids (2n=4x=48) (Vos, 1999). There is a great deal of genetic variation between varieties of cultivated potato; explaining the specific adaptation of different varieties to specific environments (Hawkes, 1990). In the world, potato currently is the most widely grown food crop following the three prominent cereals: maize, rice and wheat (Vleeshouwers et al., 2011).

In sub-Saharan Africa, potato is the best crop for food and nutrition security where food security is a key priority for the over 200 million people whose number is predicted to double by 2030 (Kyamanywa et al., 2011). Under the increasing pressure on the fixed land, the increasingly degraded environment and uncertainties resulting from climate change, producing crops like potato with high plasticity to environmental regimes and higher yield per unit area is indispensable (Wassu, 2014). Ethiopia has suitable edaphic and climatic conditions to produce high-quality ware and seed potatoes. Potato can be grown in 70% of the 10 million ha arable land of the country (FAO, 2008). Nevertheless, the total area under potato production is estimated to be 296,577 hectares with a total annual production of 3,657,638 metric tons (CSA, 2016). Potato is grown in four major areas in Ethiopia: the central, the Eastern, the Northwestern and the Southern regions. Together, these areas contain approximately 83% of potato growers (CSA, 2016).

In a country where more than 100 million people live, much of the Ethiopian population depend mainly on cereal crops as a food source. Despite their significant contributions towards food security and income generation, the food potential of horticultural crops particularly that of root and tuber crops have not yet been fully exploited and utilized. Among these crops, potato holds a huge but largely ignored promise for improving the livelihoods of hundreds-of-thousands of smallholder farmers in Ethiopia's risk-prone highlands (Gebremedihin, 2013).

Nowadays, potato is regarded as the major food security crop in the world mainly because it can provide a high-volume crop produce with high nutritional products per unit input and with a short crop cycle (mostly within less than four months) (Seifu and Betewulign, 2017). The high potential of potato for improving food security, increasing household income and consequent poverty reduction is a result of the crop's high relative yield and output of carbohydrates, proteins and essential minerals, the increased urban demand for highly valued potato and the decline in average farm size resulting in agricultural intensification for high per-area output (CIP, 1988).

At present, farmers in Ethiopia are cultivating potato under a wide range of weather patterns and less predictable climates; it is planted both in Belg (short rainy season, February to May) and Meher (long rainy season, from June to October) growing seasons (Kolech et al., 2015). Despite the genetic potential of the crop, the productivity of potato in Ethiopia is relatively low, about 9 t/ha (CSA, 2016). The yield of the crop in Ethiopia is three to five times lower than the developed nations (Wiersema and Struik, 1999). Several natural, economic, technical and institutional factors are indicated as the major constraints for potato production in Ethiopia. Frost injury, hail damage, insect pests, diseases, poor production practices and limited access to high-quality seed are the key constraints. Furthermore, lack of high yielding and disease resistant varieties and poor access to the available varieties are the other limiting factors for potato production (Gebremedhin et al., 2008). To deal with some of these production challenges, the Ethiopian agricultural research system released 31 potato varieties (MOA, 2013). All these varieties originated outside Ethiopia, mainly from the international potato center (CIP). Though these varieties are grown in some parts of the country, their adoption by farmers in most potato production areas is low so that only a limited number of them are grown (Gebremedhin, 2013).

Although the edaphic and climatic conditions of the highland areas of Girar Jarso are suitable for potato production, its production is scarce and covered by degenerated local varieties. Because the local varieties, in addition to their being genetically poor yielding, are highly susceptible to late blight, which sometimes leads to 100% yield loss (Bekele and Eshetu, 2008; Endale et al., 2008). Hence, introducing improved varieties to potential potato production areas should be the focus of the Ethiopian agricultural extension system. 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 production requirements for potato at Girar Jarso and the existing room for improving the livelihood of the farming community through evaluation and introduction of improved varieties of potato, an integrated evaluation of the widely acclaimed potato varieties in the central highlands of Ethiopia were conducted at Girar Jarso in 2017. Therefore, the objective of this evaluation study was to identify the best performing potato variety for the locality in an integrated approach. Instead of 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 to select the right variety to the locality and other areas with similar agro-ecological and social settings in the central highlands of the country.

MATERIALS AND METHODS

Study area

A participatory on-farm evaluation trial was conducted under the

Table 1. Means for tuber yield and related data.

Variety	PH (cm)	MY (ton/ha)	unMY (ton/ha)	TY (ton/ha)
Belete	82.4	41.8	5.2	47.1
Jalene	95.2	24.8	3.4	28.2
Gudene	86.8	27.3	3.5	30.9
Local	79.8	24.2	4.2	28.5
LSD	2.9	3.4	1.3	3.9
Sig	**	**	*	**
CV	2.5	8.5	23.6	8.4

PH: Plant height, MY: marketable yield, unMY: unmarketable yield, TY: total yield, LSD: least significant difference, CV: coefficient of variation. Sig: significant at 1% probability (**) and 5% (*).

rainfed condition in 2017 cropping season in the two highland areas: Gino and Elamu Kebeles of Girar Jarso Woreda of North Shewa, Ethiopia. Girar Jarso Woreda is 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 ha. The altitude of the Woreda ranges from 1300 to 3419 m above sea level (m.a.s.l). The Woreda lies within the geographic region between 9035’-10000’N latitude and 38039’-38039’E longitude. The average rainfall amount of the Wored*a* is about 1200 mm, and maximum and minimum rainfall is about 1115 and 651 mm, respectively. The temperature of the Woreda ranges from a minimum of 11.5 to a maximum of 35°C (Woreda BoANR, 2018). In terms of soil, the cultivated lands comprised vertisols, leptosols, luvisols, fluvisols and cambisols. The dominant soil types in the two trial kebeles were leptosols and luvisols (Engidawork, 2015).

Site selection, experimental materials and design

The trial was conducted in two adjacent kebeles. 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. Although there are more than 30 released potato varieties in the country, only three improved varieties (Jalene, Gudene, and Belete), the widely acclaimed varieties in the country were evaluated alongside the local variety. All three of the improved planting materials were obtained at Holetta Agricultural Center of Ethiopia, whereas the local variety was collected from a certified seed tuber producer cooperative at Degem Woreda, adjacent to Girar Jarso Woreda. The randomized complete block (RCB) design with 6 replications, farmers as a replication, were used. Each variety was planted on a 10×5 m plot of land. The intra and inter row spacing was 40 and 75 cm, respectively. According to Abdulwahab and Semagn (2008) recommendation for the soils of the highlands of North Shewa, a fertilizer rate of 110 kg/ha nitrogen and 70.5 kg/ha P_2O_5 were applied (Urea as nitrogen and NPSB as phosphorous source). One-third of the Urea was applied at planting and the rest was top-dressed consecutively on the first and second-hand weeding and earthing-up agronomic management activities.

Data collection and analysis

For cohesively evaluating different agricultural technologies and recommending the best performing treatment, CASCAPE has a technology validation protocol (de Roo et al., 2017). Accordingly, data on productivity, that is, tuber yield (marketable and non-marketable tuber yield), farmers preference by CIAT (Guerrero et al., 1993), partial budget (CIMMYT, 1988), gender (gender disaggregated labor contribution), and environmental sustainability (pesticide use) were collected. Data on tuber 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, results of all the protocol components were normalized on a 1-5 scale (Annex 1). 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, 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 yield and related components were significantly different between the varieties at P<0.05. Regarding total tuber yield (TY), Belete was by far the best yielder followed by Gudene. Attributable to its higher total yield, both marketable and unmarketable tubers were relatively higher than the others (Table 1). To give a general impression on the above ground biomass, plant height was also measured and showed a significant difference between varieties. Except that Gudene performed better than Jalene in the trial, an adaptability study conducted by Misgana et al. (2015) at South Omo zone, Ethiopia, revealed comparable result with the current result. Moreover, a multi-location study by Habtamu et al. (2016) in Eastern Ethiopian highlands exhibited similar results. It might have been because seed tubers of all the three improved varieties were collected from a clean source, the highland nature of trial sites and absence of initial disease inoculum in the area, no leaf or tuber disease were spotted in all improved varieties, however, the local variety exhibited a scab like symptom on its tuber.

Table 2. Profitability analysis for potato varieties.

Inconstant variable	Variety			
	Belete	Jalene	Gudene	Local
Average yield (kg/ha)	47124	28269	30952	28509
Adjusted yield (kg/ha)	42411	25442	27856	25658
Gross field benefits (ETB/ha)	424116	254421	278568	256581
Cost of seed tuber (ETB/ha)	40000	40000	40000	24000
Total costs that vary (ETB/ha)	40000	40000	40000	24000
Net benefits (ETB/ha)	384116	214421	238568	232581
Profitability	960	536	596	969

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 (ETB/ha) = Adjusted yield (kg/ha) × field price of the crop (ETB/kg). Cost of seed (ETB/ha) = Cost of seed for a given variety calculated as $/ha. Total costs that vary (ETB/ha) = sum of associated costs (in this case, it would be like the cost of seed). Net benefit (ETB/ha) = Gross field benefits (ETB/ha) - total costs that vary (ETB/ha). Profitability (%) = Net benefit (ETB/ha)/Total costs that vary×100.

Table 3. Matrix ranking of farmers selection traits for Potato varieties.

Variety	TY	DR	TS	TC	# of occurrence	Rank
TY		DR	TY	TY	2	2
DR			DR	DR	3	1
TS				TS	1	3
TC					0	4

TY: Tuber yield, DR: disease resistance, TS: tuber size, TC: tuber color.

Profitability

To estimate the profitability for each variety, the partial budget analysis method of CIMMYT (1988) was followed. To compensate for the possible inflated estimation of average tuber yield, primarily because of the careful application of inputs and the small plot effect, average tuber yield of varieties was adjusted downwards by 10% to calculate the gross field benefits. The cost of seed tuber was the only cost found to be varied across treatments; hence, the difference in average tuber yield and the cost of seed tuber were the only determinants of the net benefits and profitability. Although the tuber of Belete was much higher than the rest of the varieties, due to the higher price of improved seed tuber as compared to the local, the profitability of the local variety was relatively higher than Belete: 960.29 and 969.09% for Belete and the local variety, respectively (Table 2).

Acceptability

Farmer's preference analysis is a critical part of any participatory variety selection/adaptation activity. Hence, farmers' preference analysis system of CIAT (Guerrero et al., 1993) was used in the trial. Prior to the actual preference analysis, a group of farmers were given a chance to list their parameters of interest while selecting a potato variety phenotypically. Because potato is not cultivated in the area as extensively as the other highland areas in Ethiopia, most farmers struggled to set out the trait of their interest, therefore, they only listed out four traits-tuber yield, disease resistance, tuber size and color. To detect the relative importance of traits, a pair-wise ranking was carried out and it shows that disease resistance followed by tuber yield was the most important traits to farmers (Table 3).

After the matrix ranking of selection parameters, each farmer ranked each variety vis-à-vis the three prominent selection traits (disease resistance, tuber yield, and tuber size). Finally, acceptability score of each variety was calculated by summing up the score of all the farmers, dividing it by the maximum possible score and multiplying it by 100 (Table 4). Consequently, Belete and the local variety were the most and least preferred varieties: 97.22 and 42.22%, respectively.

Gender and nutrition

The evaluation protocol by de Roo et al. (2017) only records the labor contribution of male and female household members to quantify whether the improved technology increases or decreases the labor burden on

Table 4. Acceptability score for Potato varieties.

Variety	Farmer															Sum	Acceptability score (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Belete	12	10	12	12	12	12	12	12	12	12	10	12	12	11	12	175	97.22
Jalene	6	5	6	6	6	6	6	6	6	6	5	6	6	5	21	102	56.67
Gudene	7	11	7	7	7	7	7	7	7	7	11	7	7	8	7	114	63.33
Local	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	76	42.22

An individual farmer has given a score of between 1 and 4: 4 for the first, 3 for the second, 2 for the third and 1 for the fourth favorite with respect to a single selection criterion. Acceptability Score = (sum of the individual farmers' score / the total possible available score) × 100; Total available score=number of farmers × the maximum score a farmer would give to each variety; In this case, 12×15=180.

Table 5. Integrated scoring of Potato varieties.

Indicator	Belete	Jalene	Gudene	Local
Productivity	5	4	5	4
Profitability	5	4	4	5
Acceptability	5	2	4	1
Gender/Labour	3	3	3	3
Nutrition (yes or no)	N	N	N	N
Pesticide use	5	5	5	5
Mean (X)	4.6	3.6	4.2	3.6

women. The agronomic management practices of both the improved and local varieties of potato were not different. Therefore, 'same as conventional' normalization value of 3 was used for all varieties (Annex 1) while integrating evaluation parameters

In terms of nutrition, because the evaluation protocol was indifferent to lab analysis for nutrient composition, it fails to put a distinct line between potato varieties regarding their specific nutrient density. But because there is always 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.

Environmental sustainability

For environmental sustainability, the evaluation protocol uses two proxies: nutrient depletion and pesticide use. For this validation activity, no data was collected on nutrient depletion; however, no pesticide had been applied in any of the replicate farms and treatments. Therefore, a normalization value of 5 was used while integrating evaluation parameters.

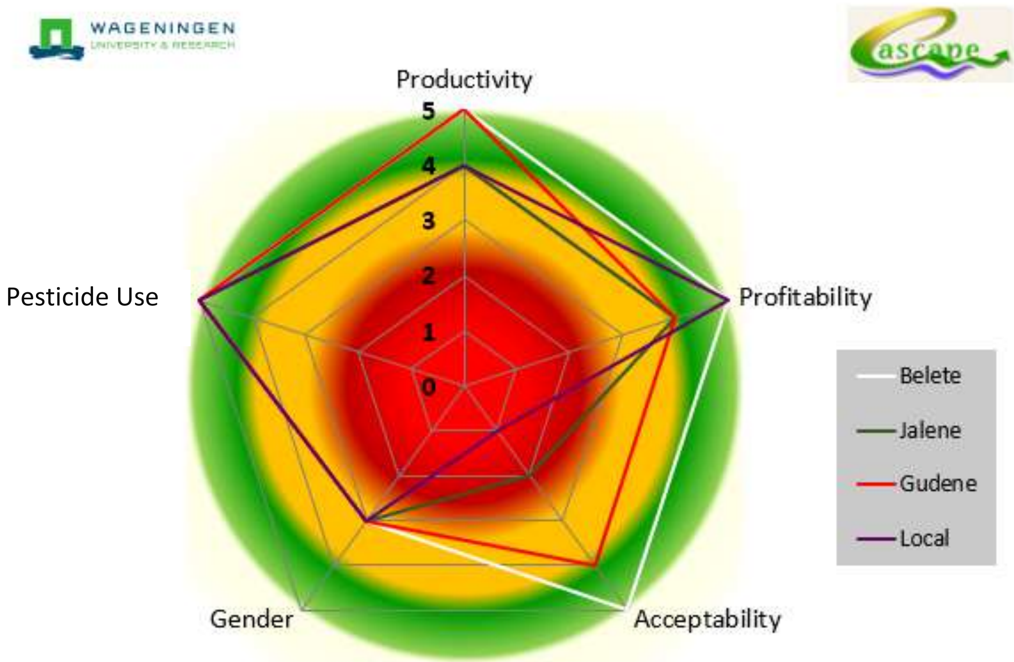
Integration and visualization of results

Integrated evaluation highly discourages selecting the best performing variety/ies by only taking the result of an individual parameter (de Roo et al., 2017). Therefore, integrating parameters and displaying the result into a single presentation panel, that is, spider graph is recommended. Hence, the results on productivity, profitability, acceptability, gender, and pesticide use were normalized into a 1-5 scale (Annex 1 for details). According to the three selection rules, two of the varieties (Belete and Gudene) with a mean normalized score of 4.6 and 4.2, respectively qualified to have been highly recommended. However, the mean value for variety Belete was higher than Gudene, therefore, Belete variety was the first choice followed by Gudene (Table 5).

To display the results of all parameters, a Macro on excel is created to make a spider graph that can show parameters altogether in one presentation panel (Figure 1). On the graph, if an entry hits 5 on a specific evaluation parameter, for instance, Belete and Gudene on productivity, it means the two varieties had given higher than the maximum yield set for normalization (Annex 1). Moreover, the entry that shows the highest relative area on the graph, in this case, Belete variety with a relative area of 1.0 had the better overall performance as compared to the others.

Conclusion

In participatory varietal selection, researchers in Ethiopia often consider the farmers preference aspect in addition to the productivity of the varieties. However, if the yield of



	Belete	Jalene	Gudene	Local
Relative Area	1.00	0.62	0.84	0.60

Figure 1. Spider graph showing the relative performance of varieties; 5 as the highest and 1 as the lowest normalization rank to the displayed parameters on the graph.

the variety (grain, tuber, biomass, etc.) and the farmers preference could not get along, which occasionally do, researchers often reaches into an impasse, hence, sometimes tend to give higher weight to yield than preference. But the evaluation protocol developed by Wageningen University and research center of the Netherlands and CASCAPE works well in the case of the present trial. Nevertheless, there still are gaps, it would become a complete protocol if it adds depth to its gender and nutrition segment and include other stakeholders in the preference analysis. In general, by integrating the different parameters, the trial managed to recommend a productive, profitable, preferable potato variety, Belete to the highlands of Girar Jarso and other areas with comparable agro-ecological and social settings in the central highlands of Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Annex 1. Scoring of parameters to normalize results for visualization of technology validation results (de Roo et al., 2017).

		Yield range					
Score		**1**	**2**	**3**	**4**	**5**	**2014/15 National CSA yield (kg/ha)**
Productivity	Teff	<1300	1300-1700	1701-2100	2101-2500	>2500	1575
	Food barley	<2000	2001-2500	2501-3000	3001-3500	>3500	1965
	Malt barley	<1500	1500-2000	2001-2500	2501-3000	>3000	
	Wheat	<2000	2001-3000	3001-4000	4001-5000	>5000	2543
	Maize	<4000	4001-5000	5001-6000	6001-7000	>7000	3431
	Sorghum	<2000	2001-2500	2501-3000	3001-3500	>3500	2369
	Finger millet	<1701	1701-2200	2201-2700	2701-3200	>3200	2017
	Faba bean	<1800	1801-2300	2301-2800	2801-3300	>3300	1893
	Field pea	<1400	1401-1800	1801-2200	2201-2600	>2600	1485
	Chickpea	<1800	1801-2200	2201-2600	2601-3000	>3000	1913
	Soybean	<1800	1801-2200	2201-2600	2601-3000	>3000	2047
	Haricot bean	<1900	1900-2200	2300-2600	2700-2900	>2900	1600
	Sesame	<600	601-800	801-1000	1001-1200	>1200	687
	Potato	<15000	15001-20000	20001-25000	25001-30000	>30000	13685
	Garlic	<8500	8501-10000	10001-11500	11501-13000	>13000	10098
	Papaya	<17000	17001-19000	19001-21000	21001-23000	>23000	17189
Score		1	2	3	4	5	-
Profitability (MRR%)		100-200	201-400	401-600	501-800	>800	-
Acceptability (6 treatments)		Last rank	5th rank	3rd /4th rank	2nd rank	1st rank	-
(5 treatments)		Last rank	4th rank	3rd rank	2nd rank	1st rank	-
(4 treatments)		Last rank	3rd rank	-	2nd rank	1st rank	-
(3 treatments)		Last rank	-	2nd rank	-	1st rank	-
Gender /labor (% of work done by women)		>20 % increase of labor (time) spent	1-19% increase of labor (time) spent by women	Same as conventional	1-19 % decrease of labor (time) spent by women	>20 % decrease of labor (time) spent	-
Depletion rate N (kg/ha/y)		>80	80-41	40-21	20-10	<10	-
Depletion rate P (kg/ha/y)		>10	8-10	6-8	4-6	<4	-
Depletion rate K (kg/ha/y)		>30	20-30	10-20	5-10	<5	-
Pesticide use		Class II	Class III	Class U or NL	Biological control	No pesticide	-