PARTICIPATORY SELECTION OF POTATO (*Solanum tuberosum* L.) VARIETIES IN THE HIGHLAND AREAS OF GUJI ZONE, SOUTHERN ETHIOPIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author AA designed the study, performed the statistical analysis, wrote the protocol, managed the literature searches, interpretation and wrote the manuscript. Authors ST and BW managed the analyses of the study, planting the trial, data collection of the trial at the field, harvest the trial and data management. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Potato (*Solanum tuberosum* L.) is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where it s grown by farmers and seed producers abundantly. However, in the highland areas of Guji zone an access, well adapted, résistance to late blight and high yielder potato variety is highly limited. Due to this reason, there is an urgent need to develop and replace the previous underproduction varieties that suit for the area. As a result, an experiment was conducted in the highland areas of Guji Zone at Bore on-station and three farmers' fields (Abayi kuture, Raya boda, and Bube korsa) during 2019/20 cropping seasonto select and recommend high yielding, and diseases résistance improved potato varieties through participatory variety selection. Six (6) improved potato varieties (Gudanie, Belete, Jalenie, Dagim, Horro, and Bubu) were used as testing crop. The treatments were arranged in randomized completed block design (RCBD) with three replications for mother trial and farmers were used as replication for baby trials. Both agronomic and farmers data were collected based on the recommended standards. Data collected from mother trail were subjected to analysis of variance where as matrix ranking was used for data collected from baby trials. The analysis of variance indicated that significant differences observed at ($P \leq 0.05$)among the tested Irish potato varieties for day to 50% emergence and flowering, stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed at ($P \geq 0.05$) among the varieties for days to days to 90% maturity, plant height, tuber weight and unmarketable tuber yield. The highest marketable tuber yield was (48.17t/ha) was recorded for Belete followed by Bubu and Gudanie (35.35 and 34.3t/ha) respectively. But, the lowest marketable tuber yield (18.07t/ha) was obtained from improved Dagim variety. In other cases, farmers were allowed to evaluate the varieties using their own criteria. Accordingly, variety Bubu and Gudanie were selected by farmers due to their resistant to disease, stem number, tuber size, tuber color, tuber eye depth, number of tubers and marketability. Therefore, these two improved Irish potato varieties are selected based on agronomic data result and farmers preference and recommended for production to the highland areas of Guji zone.

Keywords: Farmers preference; Irish potato; improved variety; participatory; variety selection.

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1. INTRODUCTION

Potato (*Solanum tuberosum* L.) belonging to the family *Solanaceae*, is an important food and cash crop as an income sources globally [1]. It is an important tuber crop grown widely in humid tropics and used as source of carbohydrates for many people in tropical and sub-tropical areas of the world [2]. Potatoes are among the most widely-grown crop plants in the world, giving good yield under various soil and weather conditions [3]. It is the third most important food security crop in the world after rice and wheat [4].

The potential for high yield, early maturity, and excellent food value give the potato great potential for improving food security, increasing household income, and reducing poverty [5]. Yields are typically three to five times higher in developed nations [6]. Many factors contribute to the low yield, including frost, hail, pests, diseases [7], poor production practices and limited access to high quality seed [8].

So far, different potato varieties have been released and /or registered to satisfy the growing production demands of the farmers in the country. The crop particularly has potential for fertile and waste land where other crops could not survive, to overcome food shortage [9]. In Ethiopia, potato production could fill the gap in food supply during the hunger months of July to August before the grain crops are being harvested.

Therefore, assessment of genotype × environment (including end use) interactions answers the adaptation to the environment and end users because, it is unlikely that one of many potential new cultivars would be best in all environments and for all uses [10]. Although [11] described the biological complexity underlying genotype and environment. The entire variable encountered in producing a crop can be collectively called an environment, while every factor that is a part of the environment, has the potential to cause differential performance that is associated with genotype, genotype to environment interaction in potatoes [12].

The low productivity is attributed due to lack of well adapted varieties which is accepted by the farmers, unavailability and high cost of seed tubers, diseases and insect [13,9,14]. This implies that the country has suitable environmental condition; the average national yield (14.176 tha^{-1}) productivity of potato during 2018/19 season [15] is very low as compared with world average of 17.16 t ha^{-1} [16]. The reason is primarily due to lack of adaptable varieties for marginal ecology and use of low quality seed

tubers for planting [17]. There are also many factors that can contribute directly or indirectly for low yield in Ethiopia, lack of improved technology, low attention to the crop, varieties that were released by different research centers for different agro-ecologies in the country and farmer's potato varieties in the country level is still unidentified.

In the highland areas of Guji zone, the production of potato is low because of lack of stable, well-adapted, high yielding, acceptable and disease resistant cultivars and limited access to the available cultivars. In addition, potato yields varied depending on season, weather conditions, cultivar, and location in the study area. Farmers as well as Seed Producer Cooperative are highly demanding better yielding and late blight resistance varieties to maximize their product, and improve the livelihood of their families. Participatory varietal selection has been proposed as an option to the problem of fitting the crop to a multitude of both target environments and users preferences. In highlands of Guji zone, the varieties that currently under production are not as much as high yielder and resistance to late blight. Therefore, to evaluate different varieties of potato crop with active involvement of farmers' is important to increase the production and productivity of potato in study area. This research was conducted with the following objectives:-

- To evaluate potato varieties with active participation of farmers
- To increase farmers' awareness and their access to improved potato varieties that suit them better than existing ones and,
- To identify and select adaptable, high yielding, and late blight tolerant potato variety (ies) for highland agro-ecologies of Guji zone.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The experiment was conducted at four locations (Bore on-station, and three farmers' fields) during 2019/20 cropping season to select and recommend high yielding and diseases tolerant improved Irish potato varieties through participatory variety selection. Bore Agricultural Research Center site is located at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele*' just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The soil is clay in texture and strongly acidic with pH value of 6.02 [18]. The traditional farming system of the area is

characterized by cultivation of enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system [19].

2.2 Treatments and Experimental Design

About six (6) improved Irish potato varieties (Gudanie, Belete, Jalenie, Dagim, Horro and Bubu) were used as testing crop. The varieties were brought from Holeta, Adet and Bako Agricultural Research Center and Haramaya University. The treatments were arranged in randomized completed block design with three replications for mother trial (Bore on-station) and three farmers' fields were used as replication for baby trials. For this purpose, one farmer field was used as replication for baby trials in which selected farmer's plant materials in one replication and the other host farmers were planted the two non-replicated trials. At both trial sites, the materials were planted on a plot size of, 3 m length and 2.4 m width =7.2 m^2 having 4 rows with 75 and 30 cm between rows and plants. In puts (seeds, fertilizers) and management practices were applied as recommended for Irish potato production. Data were collected in two ways: agronomic data and farmer's data. For agronomic data phenological, Growth, yield and yield components were collected following their own principles. At vegetative and harvest stage of potato the training were arranged.

2.3 Field Management

The experimental field was cultivated by using oxen to fine the soil before planting. Uniform and medium-sized (39-75g) tubers of the test variety with sprout lengths of 1.5 to 2.5 cm [20] was planted on ridges with inter-and intra-row spacing of 75 cm and 30 cm, respectively. The recommend blended NPS and potassium fertilizer rates were applied at planting at the specified rates and placed in banded application methods and urea rates were split applied at planting the rate of (1/4 kg N ha^{-1}) and half (1/2 kg N ha^{-1}) at 15 days after emergence and one forth (1/4 kg Nha^{-1})

at mid-stage (at about and 30days) after emergence respectively. On the other hand, weed control were done timely by hoeing. The first, second and third earthling-up were done 15, 30, and 45 days after planting to prevent exposure of the tubers to direct sunlight, promote tuber bulking and ease of harvesting. Haulms were mowed two weeks before harvesting at physiological maturity for reducing skinning and bruising during harvesting and post-harvest handling.

2.4 Agronomic Data Collection

Agronomic data were collected from a net plot of two rows and selected plants of the plots. Collected agronomic data includes; Days to 50% emergence, Days to 90% maturity, stem number per hill, Plant height (cm), tuber number per hill, Marketable, Unmarketable and Total tuber yield were based on the recommended recording stage and methods.

2.5 Farmers Data Collection

Farmers' evaluation and selection criteria data were collected on plot basis from the three baby trials i.e., farmers were grouped around each host farmer of the trials. Farmer's evaluation criteria were employed viz. resistant to disease, stem number, tuber size, tuber color, tuber number per hill, tuber eye depth, marketability, and high yielder. A rating scale of 1-5 was used for farmer's criteria. Rating of the performance of variety for a given criteria: 5= very good, 4= good, 3= average, 2= poor and 1= very poor.

2.6 Data Analysis

Field data were analyzed by using Genstat 18th edition software for the data following the standard procedures outlined by [22] Comparisons among the treatment means were done using Fisher's protected least significant difference (LSD) test at 5% level of significant. Farmers' data were subjected to analysis using simple ranking method and then ranked in accordance with the given value [23].

Table 1. Description of experimental materials improved potato varieties for highland agro-ecologies of Guji zone

No.	Variety	Breeder	Released year	Recommended altitude (masl)
1.	Gudanie	Holeta research centre	2006	1600-2800
2.	Jalenie	Holeta research centre	2002	1600-2800
3.	Dagim	Adet research centre	2013	1600-2800
4.	Horro	Bako research centre	2015	2000-2800
5.	Belete	Holeta research centre	2009	1600-2800
6.	Bubu	Haramaya University	2011	1700-2000

Source: MoANR [21]

Table 2. Analysis of Variance for different agronomic parameters of different highland areas of potato Varieties from mother trial

Source of variation	Mean square									
	DE (days)	DF(days)	DM (days)	STN (no.)	PH (cm)	TN (no.)	Twt (g)	Myld (tha^{-1})	Umyld (t ha^{-1})	Tyld (t ha^{-1})
Rep(2)	0.39**	2.39**	0.06^{ns}	3.13**	1.24^{ns}	8.17**	30.9^{ns}	28.44**	0.98^{ns}	29.42**
Varieties(5)	27.42**	106.86**	2.09^{ns}	5.58**	17.28^{ns}	15.3**	1372.4^{ns}	275.63**	12.45^{ns}	334.39**
Error(10)	1.06	2.66	2.06	1.16	17.98	3.13	734.8	22.63	5.09	25.19

** = highly significant at $P \leq 0.001$; *= significant at $P \leq 0.05$; ns = not significant at $P \geq 0.05$; a Numbers in parentheses are degrees of freedom associated with the corresponding source of variation; DE: Days to Emergence, DF: Days to Flowering, DM: Days to maturity, SN: Stem Number per hill, PH: plant height, TN: Tuber Number per hill, Tw: Tuber Weight, Myld: Marketable yield, Umyld: Unmarketable Yield, Tyld: Total yield

3. RESULTS AND DISCUSSION

3.1 Mean Square

The analysis of variance (ANOVA) for tuber yield and other agronomic variables of six (6) Irish potato varieties planted at Bore on-station as mother trail. The analysis of variance (ANOVA) indicated presence of significant differences at (P≤0.05 respectively among the evaluated Irish potato varieties for days to 50% emergence and flowering, stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed among the varieties for days to days to 90% maturity, plant height, tuber weight and unmarketable tuber yield (Table 2).

3.2 Phenology and Growth

The mean values for the six (6) varieties are shown (Table 3). The variation with respect to days to emergence and flowering was ranged from 19 to 27 and 58 to 73 days respectively. Based on the study result, the longest days to 50% emergence was revealed by Dagim and Bubu (27 and 26.33 days) followed by Belete (24.33 days) respectively. However, early emergence was recorded for varieties Horro (19 days) followed by Gudanie and Jalenie (22 days). In other cases, variety Horro was early flowering variety (58 days) followed by Belete (64.67 days). Among the tested varieties, Jalenie was late maturing with 107 days followed by Horro, Belete, and Gudanie (106 days) respectively.

The mean values revealed that the highest stem number per hill was recorded by Bubu variety (8.44) followed by variety Belete (6.11) respectively. However, the lowest stem number per hill Jalenie variety (4.44) followed Dagim variety (5.01) respectively. Stem density, which is influenced by genetic makeup, increase tuber yield as stem density increases numbers of tubers, or size of tubers, or both [24]. The longest plant height was exhibited by Horro variety (66.22cm) followed by Belete variety (63.06cm).However, the shortest plant height was recorded by Dagim variety (59.83cm) followed by Gudanie variety (60.06) respectively (Table 3). These differences in plant height among the varieties may be caused by plant genetics and the quality of the plant material [25].

3.3 Yield and Yield Components

Based on agronomic data result indicate that the highest tuber number per hill was recorded from Belete variety (12.33) followed Bubu variety (12.17) where as the lowest tuber number per hill from Dagim variety (6.94) and followed Gudanie variety (7.89) respectively. The highest tuber weight was recorded from Gudanie variety (130.53g) followed Jalenie variety (105.7g) where as the lowest tuber weight from Dagim variety (76.05g) and followed Horro and Bubu varieties (78.96g) respectively. Variation among different varieties in the weight of tubers per plant may be due to the genetics, management practices, the seed quality, or the agro-ecological conditions of the experimental sites [25]. Significant variations were revealed among potato varieties number and weight of tubers per plant [26]. The highest marketable tuber yield were obtained from Belete variety (48.17tha^{-1}) followed by Bubu variety (35.35tha^{-1}) respectively whereas the lowest marketable tuber yield Dagim variety (18.07 tha^{-1}) followed by Horro variety (32.40 tha^{-1}) was recorded respectively. The highest unmarketable tuber yield were obtained from Gudanie variety (9.53tha^{-1}) followed by Jalenie variety (8.61tha^{-1}) respectively whereas the lowest unmarketable tuber yield Dagim variety (4.11tha^{-1}) followed by Horro variety (5.19tha^{-1}) was recorded respectively. In other cases, the highest total tuber yield were obtained from Belete variety (54.67tha^{-1}) followed by Gudanie variety (43.84tha^{-1}) respectively whereas the lowest total tuber yield Dagim variety (22.18tha^{-1}) followed by Horro variety (3.76tha^{-1}) was recorded respectively (Table 4). Thus, the yield differences between these varieties may be related to their genetic makeup in the efficient utilization of inputs like nutrient as reported by [27]. Significant variations were revealed among potato varieties for no marketable and marketable tuber yields [26]. [28] Reported a significant difference in the yields due to genetic makeup of potato varieties.

3.4 Farmer's Variety Selection Criteria's

In variety selection farmers have a broad knowledge based on their environments, crops and cropping systems built up over many years and do experiments by their own and generate innovations, even though they lack control treatment for comparison and statistical tools to test the hypothesis. Based on this concept, farmers were informed to set criteria for selecting best Irish potato variety according to their area before undertaking varietal selection. This was done by making group discussion among the farmers which comprises elders, women and men. After setting the criteria they were informed to prioritize the criteria according to their interest. By doing this, farmers were allowed to select varieties by giving their own value.

Accordingly, resistant to disease, stem number per hill, tuber size, tuber color, tuber number per hill, tuber eye depth, marketability, and high yielder.

Based on set criteria, the evaluated varieties were revealed various values by the evaluators (farmers). With this regard, farmers selected/ranked the varieties Gudanie (1st), Bubu (2nd) and Belete (3rd) were showed better performance resistant to disease, highest stem number per hill, marketable tuber size, attractive tuber color, highest tuber number per hill, low tuber eye depth, good for marketability, and highest yielder. However, farmers ranked least Dagim (6th) and Horro (5th) potato varieties respectively (Table 5). This suggestion is in agreement with that of [29] who report participatory variety selection can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties. This suggestion is consistent also with that of [30] who reported that identification of suitable improved, released cultivars to provide a large 'basket of choices' to farmers. On the other hand, [31] reported that PVS is a more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists.

Hence, Research costs can be reduced and adoption rates increased since farmers participate in variety testing and selection. Moreover, [32] who reported that farmers were actively involved in plant breeding at various levels of the breeding process, the new varieties were successfully adopted. Furthermore, [33] who reported that participatory methods consider the value of farmers" knowledge, their preferences, ability and innovation, and their active exchange of information and technologies as it was demonstrated during farmer field school approach.

Table 3. Mean value of DE, DF, DM, PH and STN of potato PVS from mother trial in highland areas of Guji zone, during 2019/20

Varieties	Phenology and growth variables				
	DE(days)	DF(days)	DM(days)	STN(no.)	PH(cm)
Belete	24.33b	64.67b	106	6.11b	63.06
Gudanie	22c	71.63a	106	6b	60.06
Bubu	26.33a	73a	104.7	8.44a	60.83
Jalenie	22c	73a	107	4.44b	62.17
Horro	19d	58c	106	5.94b	66.22
Dagim	27a	66b	105	5.01b	59.83
Lsd (0.05)	1.87	2.97	2.61	1.96	7.71
Cv%	4.4	2.4	1.4	17.9	6.8
P-Value	0.001	0.001	0.46	0.017	0.49

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability

Table 4. Mean value of TN, TW, Myld, UMyld and Tyld of potato PVS from mother trial in highland areas of Guji zone, during 2019/20

Varieties	Yield and yield components				
	TN(no.)	Twt (g)	Myld (t ha^{-1})	Umyld(t ha^{-1})	Tyld(t ha^{-1})
Belete	12.33a	101.12	48.17a	6.49	54.67a
Gudanie	7.89bc	130.53	34.3b	9.53	43.84b
Bubu	12.17a	78.96	35.35b	7.07	41.76b
Jalenie	8.94abc	105.7	32.52b	8.61	41.13b
Horro	10.78ab	78.96	32.40b	5.19	37.6b
Dagim	6.94c	76.05	18.07c	4.11	22.18c
Lsd (0.05)	3.22	49.31	8.65	4.1	9.13
Cv%	18	28.5	14.2	33	12.5
P-Value	0.016	0.19	0.001	0.12	0.001

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability

Table 5. Farmers' preference scores and ranking for baby trial in highland areas of Guji zone, during 2019/20 cropping season

Varieties	Locations	Farmers selection criteria/traits and ranks									Total	Average	Ranks
		Resistant to disease	Stem Number	Maturity	Number of tubers	Tuber size	Tuber color	Tuber eye depth	Marketability	High yielder			
	Bube korsa	25	20	30	18	49	37	49	42	47			
Gudanie	Raya boda	50	25	32	75	60	57	68	73	65	1188	44	1
	Abayi kuture	26	26	26	60	48	48	36	48	48			
	Bube korsa	32	24	20	18	36	71	59	45	44			
Bubu	Raya boda	22	27	27	52	60	46	15	26	15	928	34.38	2
	Abayi kuture	16	16	16	28	36	60	60	33	24			
	Bube korsa	15	15	15	30	30	37	43	76	61			
Belete	Raya boda	21	22	22	60	75	47	15	52	70	868	32.5	3
	Abayi kuture	26	26	26	12	24	12	12	12	12			
	Bube korsa	22	18	9	37	50	27	30	17	47			
Jalenie	Raya boda	32	20	20	23	45	59	46	27	45	840	31.11	4
	Abayi kuture	24	24	24	24	20	36	30	24	60			
	Bube korsa	4	8	8	57	59	39	34	36	51			
Horro	Raya boda	2	6	4	53	30	57	30	51	30	815	30.19	5
	Abayi kuture	4	6	2	40	60	0	48	60	36			
	Bube korsa	2	3	8	17	16	28	20	15	15			
Dagim	Raya boda	2	6	11	0	0	3	54	0	0	288	10.67	6
	Abayi kuture	4	4	8	12	12	24	24	0	0			

4. CONCLUSION AND RECOMMENDA-TION

In the highland areas of Guji zone an access, well adapted, résistance to late blight and high yielder potato variety is highly limited. In such case, Participatory variety selection is an effective tool in facilitating the adoption, extension and selection of the improved technologies. Furthermore, participatory variety selection is more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists. The farmers are allowed to participate in selecting appropriate technologies by employing their own indigenous knowledge. As the result, the current study was also verified that farmers were able to participate in selecting improved Irish potato varieties through employing their own selection criteria. Improved potato varieties through employing their own selection criteria in order to verified technologies and solve the potato grower problems in short period of time. Therefore, two improved potato varieties i.e. Gudanie and Bubu are selected based on agronomic data results, farmer's preference and recommended for highland areas of Guji zone.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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