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Potato Variety Diversity, Determinants and Implications for Potato Breeding Strategy in Ethiopia

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Abstract Understanding what farmers need in potato varieties and assessing available genetic resources at the farmer and district levels is important for the conservation and improvement of potato in Ethiopia. A survey was conducted in six major potato growing districts representing different agro-ecologies, cropping systems, market outlets, and levels of new variety adoption. Seventy to ninety percent of the farmers surveyed reported growing two or more potato varieties; some farmers reported growing up to five. The greatest diversity at the district level (up to 10 potato varieties) was recorded at Gumer & Geta where there is better access to new varieties while the lowest diversity was reported in districts with low access to new cultivars. The distribution of varieties differed among agro-ecologies as did the traits that farmers were most concerned with, such as drought tolerance, late blight resistance, yield potential, marketability, food value, storage quality, adaptation to low soil fertility, time to maturity and suitability for multiple harvesting. Farmers' decision-making processes and external factors that influence potato variety diversity were also documented. The registration of predominant local varieties and use of these local varieties as a starting point for the development of improved varieties are some of the recommendations for future potato breeding in Ethiopia. Moreover, it is necessary to consider variations in agro-ecologies, cropping systems and market outlets in the process of developing varieties suitable for farmers' and consumers' real needs.

Resumen El entendimiento de lo que los agricultores necesitan en variedades de papa y el análisis de las fuentes genéticas disponibles a nivel del productor y del distrito, es importante para la conservación y el mejoramiento de la papa en Etiopía. Se desarrolló una encuesta en seis distritos importantes en la producción de papa, que representaban diferentes agroecologías, sistemas de cultivo, puntos de venta y los niveles de adopción de nuevas variedades. Del 70 al 90 % de los agricultores encuestados reportaron que sembraban dos o más variedades de papa, algunos hasta cinco. La mayor diversidad a nivel de distrito (hasta 10 variedades) se registró en Gumer y Geta, donde hay un mejor acceso a nuevas variedades, mientras que la más baja diversidad se reportó en distritos con poco acceso a variedades nuevas. La distribución de variedades difirió entre las agroecologias, así como los rasgos que más les importaban a los agricultores, tales como la tolerancia a la sequía, resistencia al tizón tardío, potencial de rendimiento, comercialización, valor alimenticio, calidad en almacenamiento, adaptación a baja fertilidad del suelo, tiempo a la madurez, y adaptabilidad a cosecha múltiple. También se documentaron los procesos en la toma de decisiones de los agricultores y los factores externos que influencian la diversidad de variedades de papa. El registro de las variedades predominantes locales, y el uso de estas variedades locales como un punto de partida para el desarrollo de variedades mejoradas, son algunas de las recomendaciones para el mejoramiento a futuro de la papa en Etiopía. Más aun, es necesario considerar las variaciones en agroecologías, sistemas de cultivo y puntos de venta en el proceso del

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desarrollo de variedades deseables para las necesidades reales de productores y consumidores.

Keywords Genetic diversity · Local varieties · New varieties · Variety traits · Agro-ecology

Introduction

The potato holds great promise for improving the livelihoods of millions of smallholder farmers in the highlands of Ethiopia. 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 (Devauxe et al. 2014). The crop's genotypic variation and relatively short vegetative period allows farmers to find an appropriate season for its cultivation under a wide range of weather patterns and less predictable climates. As a result, the combined area planted to potato in Ethiopia for both Belg (short rainy season - February to May) and Meher (long rainy season - from June to October) growing seasons is about 179, 000 ha (CSA 2014). In spite of its popularity, the productivity of the crop is relatively low, at about 9 t/ha (CSA 2014). Yields are typically three to five times higher in developed nations (Struik and Wiersema 1999). Many factors contribute to the low yield, including drought (Doss et al. 2008; FAO 2010), frost, hail, pests, diseases (Bekele and Eshetu 2008), poor production practices and limited access to high quality seed (Gildemacher et al. 2009; Hirpa et al. 2010).

The Ethiopian potato research system has released 31 new potato varieties to address some of these production problems (MOA 2013). All of these varieties originated outside Ethiopia, mainly from the International Potato Center (CIP). The breeding strategy targets high and stable yield with good level of horizontal resistance (Woldegiorgis 2013). Although these new varieties are grown in some parts of the country (Woldegiorgis et al. 2013), their adoption by farmers in most potato production areas is low (Abebe et al. 2013; Woldegiorgis 2013) so that only a limited number of them are grown (Woldegiorgis 2013). Hence, the majority of smallholder farmers still grow old varieties (Gildemacher et al. 2009; Hirpa et al. 2010).

Maintaining on farm variety diversity is one of the strategies that small farmers adopt to mitigate risks associated with crop production in heterogeneous environments characterized by varying soil quality, temperature, rainfall, topography, etc. (Lando and Mak 1994; Bellon 1996b). Indeed, farmers in different parts of the country grow two or more varieties in the same growing season (Garuma et al. 2013; Tesfaye et al. 2008). According to Bellon (1996b) the choice of small farmers to grow a diverse set of varieties reflects their desire to address concerns including drought, eating quality and storability. Abay et al. (2008) also reported that managing a diverse set of varieties helps farmers to keep their options open and reduce the risk of crop failure. Growing diverse crop varieties is also recognized as an important adaptation strategy for a changing climate (Wolfe 2013).

Ethiopia's tremendous variation in altitude, temperature, rainfall, soil type, and ecological settings gives rise to the need for a wide range of varieties, which are not likely to be provided by existing breeding programs (Cavatassi et al. 2011). Since potato is grown from mid altitudes to very high mountaintops, and from humid to dry areas in the country, improvements in productivity will require varieties to be developed that are collectively adapted to this wide range of environments. Ethiopia is neither the center of origin nor the center of diversity for potato. However, the crop has been cultivated for more than 150 years in the country. Hence, the available set of local varieties has been developed through a constant process of farmer experimentation, evaluation and selection of introduced varieties or clones from outside sources. We will refer to varieties previously selected by farmers as "local varieties"; while varieties developed by the research system over the past 28 years since their first release in 1987 will be referred to as "new varieties". The fate of both local and new varieties is determined by the decisions that farmers make. Jarvis and Hodgkin (1999) noted that decisions made by farmers in the process of planting, managing and harvesting of crops affect crop genetic diversity; these decisions in turn are influenced by a complex set of environmental and socio-economic factors.

Despite the importance and widespread production of potato in the country, few studies have sought to document Ethiopia's potato genetic resources and understand the practices farmers use to manage genetic diversity. A survey conducted by the Holetta Agricultural Research Center documented 29 potato varieties, of unknown origin, that are identified with local names (Tesfaye et al. 2008). However, it was unclear whether any given local name always referred to the same clone, or whether any given clone was always known by the same local name (Woldegiorgis et al. 2008). Two other studies have also cataloged some of the varieties grown in Ethiopia: Yazie et al. (2009) surveyed a potato production system in northwest Ethiopia while Labarta et al. (2012) studied adoption of new potato varieties. Each found that both local and new varieties were being grown.

This paper seeks to further document and understand the reasons why potato varieties are adopted, maintained, or lost at the household level in Ethiopia. Based on interviews and discussions with farmers, we sought to: i) assess the potato variety diversity at the household level, ii) analyze the spatial distribution of these genetic resources at the district level, iii) evaluate the perceived merits of currently available potato genetic resources in order to provide documentation for further breeding and conservation work, iv) document farmers' potato variety selection concerns across agro-ecologies, and v)

understand farmers local seed management practices that contribute to variety diversity.

Materials and Methods

Description of the Study Sites The survey was conducted in the Shashemene, Gumer & Geta, Banja, Laigaint, Yilmana and Quarit districts that collectively represent different agro-ecologies, cropping systems, access to new varieties and market outlets. Descriptions of survey districts and their agro-ecological designations are given in Table 1. Shashemene, located in East Arsi and 250 km from Addis Ababa, is a hub of seed and ware potato markets (Emana and Nigussie 2011). In Shashemene most potatoes are grown for sale as tablestock; in Gumer and Geta most farmers grow potatoes to sell as seed; in the four other districts most potatoes are grown for the family's own consumption, which is typical for most of the country. The Kebeles (lowest administrative units) we surveyed in Shashemene district are all within 10 km of the city of Shashemene. Yilmana, a district 42 km east of Bahir Dar, is a major source of ware potatoes for the city of Bahir Dar. Quarit, a neighboring district of Yilmana, has poor road infrastructure and thus no easy access to new varieties. Laigaint, a district in South Gondar, represents a dry and cool highland with moderate access to new varieties through non-governmental and governmental organizations. Farmers of this district often experience drought and subsequent crop failure. Banja, a district in the Awi Administrative Zone and 100 km from Bahir Dar, represents sub-humid agro-ecology with low access to new varieties. The greatest access to new varieties is represented by the Gumer and Geta districts, both in the Gurage zone. CIP and the Ethiopian Institute of Agricultural Research (EIAR), in close coordination with district agriculture department offices, have been working together to disseminate potato varieties and associated technologies since 2008 (Woldegiorgis et al. 2013). Since Gumer and Geta have similar agro-ecologies and social conditions we treated them as one district. The locations of the study districts are shown in Fig. 1.

Methods of Data Collection This survey was conducted during 2012, except for Gumer and Geta. Gumer & Geta were added in 2014 to incorporate districts that have made intensive efforts to introduce new varieties. The survey design consisted of two stages; in the first stage, districts were selected using farming system data from the Central Statistical Authority

Table 1 Survey area information

Regional state	District	Elevation (meters)	[a]Agro-ecology	[b]Cropping Season	Planting dates	[c]Seed source	Major production constraints
Amhara	Quarit	3050	Moist cool highland	Belmehr	March- April	Belmehr seed	Hail damage, drought
				Mesino	August- Sept	Seed from Sekela area	Drought
				Belg (Irrigation)	January	Belmehr seed	
	Yilmana	2500	Moist mid highland	Belmehr	March- April	Belmehr seed	Bacterial wilt, late blight, drought
				Belg (Irrigation)	January	Belmehr seed	
	Banja	2560	Sub-humid cool highland	Belmehr	March- April	Belmehr & Mesino produce	Hail, bacterial wilt and late blight
				Mesino	September	Belg produce	
				Belg	December	Belmehr produce	Drought
	Laigaint	3120	Sub-moist (dry) cool highland	Belmehr	March- May	Belmehr produce	Drought, hail damage
				Belg (Irrigation)	December	Irrigation produce	
Oromia	Shashemene	1915–2027	Sub-moist mid high land, bimodal rainfall	Meher	July	Belg produce	Drought, bacterial wilt and late blight
				Belg	February–March	Meher produce	
South	Gumer & Geta	2800–2850	Moist cool highlands with bimodal rainfall	Meher	July	Belg produce	Late blight
				Belg	December–January	Meher and Belg seed	Drought some years

[a] Based on MOA (2000) agro-ecology classification system in Ethiopia

[b] Potato can be grown during the primary rainy season (Meher), the small rainy season (Belg), Belmehr season (the cropping season which combines Belg and Meher seasons), the Mesino season (the cropping season for residual potato production immediately following the main rainy season) or at a time of the farmers' choosing when irrigation is available

[c] The seed source for the specific cropping season is the last harvest of the respective cropping season in the same area

Fig. 1 Survey sites across major potato growing districts during 2012 and 2014

The Map Created by: Disaster Prevention and Preparedness Commission (DPPC) Information Centre UN OCHA-Ethiopia

(CSA 2012; 2013) and by consulting researchers at Adet and Hawassa Agricultural Research Centers (ARC) as well as crop extension experts from the Amhara Bureau of Agriculture. Potato-growing districts were selected to represent a diversity of agro-ecologies, varying levels of new variety adoption, and different degrees of access to outside markets. In the second stage, two Kebeles, the smallest administrative unit in Ethiopia (each containing about 500 families) were selected in each district, except in Yilmana and Quarit where one Kebele was selected for each because these districts are neighbors and represent the same moist agro-ecology. Primary data were collected through direct observations of local markets, farmers' potato fields and storage structures, conducting semi-structured interviews with farmers, and discussions with farmer focus groups. Checklists for semi-structured interviews were developed based on the information from direct observations and focus group discussions.

For direct observation of farmers' potato fields, storage structures and markets, a team comprised of plant breeders and a socio-economist, together with agriculture development agents, undertook a transect walk in each of these Kebeles. During each visit, information was gathered on the performance of the potato crop in the field, including disease status, management practices, varieties grown and area allocated for the crop. At least two farmers' storages were also visited per Kebele and data such as the type of storage structure, the varieties stored and seed tuber quality in the storage were collected. The team also visited local potato markets at the district level to collect names of potato varieties, price differences between varieties and source of the produce. Major potato markets in Addis Ababa, Shashemene, Hawassa and Bahir Dar were also surveyed for the same purpose. These major markets were selected because they are potato market hubs in the country (Emana and Nigussie 2011) and some of them (Bahir Dar, Shashemene and Hawassa) are close to the survey sites. From these major cities, at least three main produce stores each from wholesalers and retailers were visited and traders were interviewed about the varieties, price differences and produce sources.

Focus group discussions had at least 10 participants, including development agents and prominent elders of both sexes. The selection of these groups was based on consultation with development agents and local administrators working in each of the Kebeles. Issues such as the cropping seasons and related planting and harvesting dates, and limiting problems for each cropping season, major varieties and their merits, advantages and disadvantages of intercropping, market outlets, and seed sources were addressed in each focus group discussion.

For the semi-structured interviews data collectors, together with development agents, went to randomly selected 'Gots' in each Kebele. Gots are the residential areas within a Kebele; a Got typically contains about five to twenty dwellings. For each Got visited, we interviewed every household where the farmer was home that day, and continued visiting Gots until 20 households had been surveyed per Kebele (in 2012) or 40 households had been surveyed (2014). All of the interviewed farmers had experience with potato production. The larger sample size of the 2014 survey allowed for a more in-depth analysis of the adoption factors for new varieties in Gumer and Geta districts. Information collected included how many varieties are grown per season, whether two crops are grown each year, area allocated and seed sources for each variety, utilization of chemical fertilizers and fungicides, and intercropping and storage practices.

Variety Identity Confirmation To establish whether a variety with a given name grown in one district is similar or different across districts, or within a district, a sample of every variety grown in each district was collected from either markets or farmers' fields, and planted in a screen house at the Adet Agricultural Research Center for genetic fingerprinting. Ten to twenty five tubers were collected from each of the local varieties identified by growers, traders or marketers. Varieties were genotyped with 8303 SNPs, using the potato Illumina Infinium array developed by the SolCAP project (Hirsch et al. 2013). Varieties that shared genotype calls at 99 % or more of the SNP loci were deemed identical.

Statistical Analysis A list of farmers' selection criteria was compiled from answers given by focus group discussion participants when asked about the positive and negative attributes of each variety in each Kebele. Farmers were asked to rank their varieties against each of these selection criteria during our semi-structured interview. To evaluate the relationship of major varieties with farmers' variety selection criteria, Spearman rank correlation was computed at country level based on the procedure outlined by Sokal and Rolf (1981) and performed using JMP software (JMP PRO 10.0.2). The farm area allocated to each variety per interviewed household (in units of "Timad") were summed for each district and converted into percentages. Descriptive statistics and frequencies were also calculated for the proportion of farmers who grow a diverse set of varieties (1–4 varieties), the proportion of farmers involved in different production practices, as well as seed sources and storage types across the districts. Although the data from Gumer & Geta were collected 2 years later than the rest of the locations, we compiled and analyzed the data of all districts together because the multiplication rate of potato is very slow and hence a minimal amount of seed was introduced to Gumer & Geta from outside sources during those two years.

Results

Major Varieties and Their Distribution Across Districts

The major varieties grown in each district are summarized in Table 2. In each district, there are at least three widely grown varieties differing in attributes like time to maturity, cooking and storage qualities, and market value. The highest number of varieties was recorded at Gumer & Geta (ten varieties, five new ones) while the lowest was in Quarit (three varieties, no new variety).

The farmer variety 'Siquare' is widely grown in all four districts of the Amhara region and occupied 24 % of the acreage planted to potato. It was widely grown in Quarit (58 %), Yilmana (39 %), Banja (56 %) and Laigaint (14 %). 'Abalo' is the second most widely grown farmer variety in the cool highlands of the Amhara region (Laigaint, Quarit and Yilamana). 'Samune' is another farmer variety and widely grown in the Banja district of the Amhara region. 'Abateneh' (in Quarit) is grown by some farmers and it is widely adopted in Sekela, a neighboring district outside the survey area.

In Shashemene, 'Agazer' and 'Nech Ababa' are the two dominant local varieties and cover 70 and 23 % of the total sampled potato acreage, respectively. All the farmers in Shashemene reported growing 'Agazer'. It is the leading variety in terms of average area planted per farmer, at 0.43 ha. It has high local market demand and has become the most widely sold variety in national markets, replacing 'Nech Abeba', which is also grown in the same district. Some farmers also grow 'Key Dinch' and 'Jibut'.

In Gumer & Geta, although the new varieties 'Gudene' and 'Jalene' are the most widely grown, some local varieties are still important. A farmer variety that is variously called 'Hosana', 'Holland', and 'Key Dinch' covers about 13 % of the total potato acreage in the districts. Additional local varieties, including 'Ajamazer', 'Nazret', 'Key Tolch', 'Asefu' and 'Askot' are also grown by some farmers in Gumer & Geta.

The distribution and level of production of new varieties differed across study districts (Table 2). New varieties occupy a large share of the total potato acreage in the Gumer & Geta (78 %) and Yilmana (43 %) districts. 'Gudene' and 'Jalene' are widely grown by farmers in Gumer & Geta while 'Sisay' is widely grown in Yilmana. Of the sampled potato farms in Gumer & Geta, 'Gudene' covers about 42 % of the total potato acreage followed by 'Jalene' (32 %) and local varieties (21 %). New varieties had been disseminated to Shasehemene, Laigaint and Baja districts at various times in the past but they had not yet been widely adopted. None of the farmers surveyed in Quarit had ever received seed of any new variety.

Table 2 Predominant potato varieties grown by farmers in different regions of Ethiopia

Common name	Origin	District (percent of total potato acreage planted to varieties)					
		Shasehemene	Quarit	Yilmana	Laigaint	Banja	Gumer & Geta
Agazer	local variety	69.8	–	–	–	–	–
Nech Abeba	"	22.9	–	–	–	–	–
Key Dinch	"	1.8	–	–	–	–	–
Jibut	"	1.9	–	–	–	–	–
Abalo	"	–	40.3	17.2	72.2	–	–
Siquare	"	–	58.3	39.5	14.5	56.1	–
Samune	"	–	–	–	–	41.8	–
Abateneh	"	–	1.4	–	–	–	–
Hosana/Holland	"	–	–	–	–	–	12.6
Ajamazer	"	–	–	–	–	–	3.4
Nazret	"	–	–	–	–	–	2.3
Key Tolch	"	–	–	–	–	–	1.3
Asefu	"	–	–	–	–	–	1.1
Askot	"	–	–	–		–	0.01
Others	"	–	–	–	0.1	0.1	1.4
Local variety Total		**96.4**	**100.0**	**56.7**	**86.8**	**97.8**	**22.2**
Sisay	New variety	–	–	33.7	–	–	–
Jalene	"	2.1	–	–	5.2	–	31.6
Gudene	"	1.5	–	–	1.0	–	41.5
Belete	"	–	–	3.2	7.0	–	4.2
Tolcha	"	–	–	–	–	1.1	–
Gera	"	–	–	6.4	–	–	0.1
Guasa	"	–	–	–	–	1.1	0.4
New variety Total		**3.6**	**–**	**43.3**	**13.2**	**2.2**	**77.8**

(–) denotes "not reported to be present"

Variety Diversity at Farm Level

The number of varieties grown per household in each district is shown in Fig. 2. In all of the districts surveyed, at least 70 % of the farmers grew two or more potato varieties at the same time in the same growing season. The number of varieties grown by each household differed among districts. In districts with better access to new varieties (based on the number of farmers who planted the new varieties), such as Gumer & Geta and Yilmana, 84 and 50 % of the farmers, respectively, grew three or more different varieties for different purposes in the same growing season while at Quarit and Banja, the percentage of farmers who grew three varieties was approximately 10 and 5 %, respectively. About 37 % of the farmers in Gumer & Geta grew four or more varieties while more than 25 % of the farmers in Laigaint, Quarit and Shashemene grew only one variety.

During the group discussions, we asked farmers why they grew multiple varieties at the same time. One answer was that varieties mature at different times, thus planting multiple varieties expanded the time window when they would have food, which is important as there are occasionally regional food shortages. In each of the districts farmers plant early maturing and late maturing varieties, where the late maturing varieties are planted early and the early ones are planted late. A second answer was that they grow different types of varieties for different purposes; some are grown for their own food consumption and others are grown for seed and ware potato markets. 'Abalo' is grown mostly for household consumption at Laigaint and Quarit, while 'Sisay' is mainly grown for distant markets in Yilmana. In Gumer & Geta, 'Gudene' is grown for distant markets and as food in the dry season while 'Hosana' is grown mainly for immediate food consumption after harvest. A third reason was that planting multiple varieties helps to avoid risk in case one variety is destroyed by disease or other natural factors such as drought, hail damage, etc. Some varieties are relatively tolerant to moderate drought (e.g., 'Abalo' and 'Abadamu', the latter a local variety grown by some farmers in cool highlands outside the study Kebeles) while others are resistant to late blight ('Siquare', 'Agazer', 'Sisay' and 'Gudene') and hail damage ('Abateneh', 'Tolcha' and 'Belete').

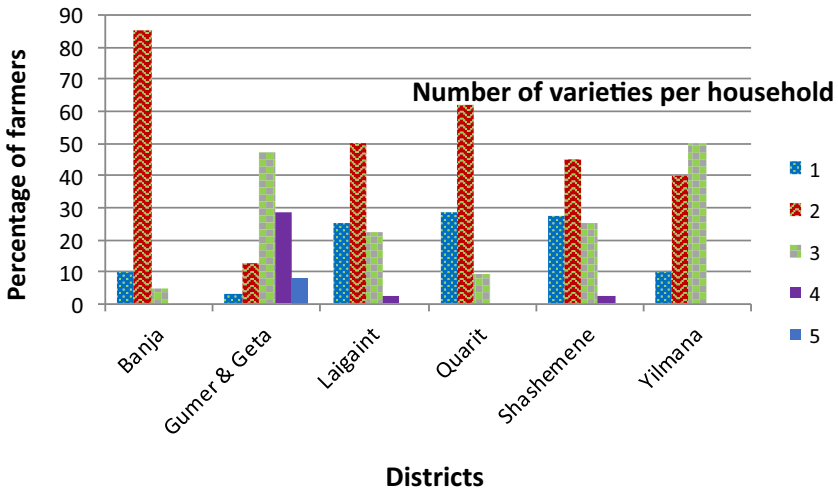

Fig. 2 Number of varieties grown per household in the study districts expressed in percentage of farmers

Farmer Perceptions that Guide Choice of Potato Varieties in Different Agro-Ecologies

Farmers can choose among varieties to help address production challenges (some constraints are summarized in Table 1) and to meet different purposes (Tables 3 and 4). As summarized in Table 3, in each district, farmers have varieties that they can grow for a wide range of purposes. Based on our focus group discussions, high yield, late blight resistance, storability, drought tolerance, suitability for boiling, early maturity and market-desired tuber size are major and common variety selection traits for most of the surveyed districts. Some variety selection traits are district-specific, such as suitability for multiple harvesting (in Laigaint) and adaptation to low soil fertility (mainly in Laigaint, Quarit and Banja districts). Table 4 shows how farmers' perception of each variety relates (Spearman rank correlation) to various traits.

Drought is the major production problem in the Belg season for Shashemene and Gumer & Geta and in the Belmehr season for Amhara region even though the degree of severity is higher in the latter. Farmers learn which clones are tolerant to drought by observing variety performance during drought years. When there is consistent early onset of rainfall (such as

Table 3 Specific characteristics of different potato varieties grown across six districts based on farmers' perception[a]

Traits	Shashemene	Quarit	Yilmana	Laigaint	Banja	Gumer & Geta
Drought tolerance	Agazer	Abalo, Abadamu	–	Abalo,	–	Gudene
Adaptation to low soil fertility	–	Abalo	–	Abalo	Samune	–
Hail damage		Abateneh	–	Belete	Tolcha	–
Late blight resistance	Agazer, Key Dinch, Jibut	Abateneh, Siquare	Siquare, Sisay, Belete	Siquare, Belete	Siquare	Gudene, Belete
High yielding	Agazer, Nech Abeba	Abateneh	Sisay, Belete	Belete	–	Gudene, Belete, Jalene
Storage quality	Agazer	Abalo, Abateneh, Siquare	Abalo, Sisay, Siquare	Abalo, Siquare	Siquare	Gudene
Early maturity	Key Dinch, Agazer	Siquare	Siquare	Siquare	Siquare	Ajamazer, Jalene
Long dormancy	–	Abalo, Siquare	Siquare	Abalo, Siquare	Samune	Gudene, Nazret
Short dormancy	Nech Abeba	–	–	–	–	Hosana
Multiple harvesting	–	–	–	Abalo	–	
Tasty when boiled	Agazer	Abalo	Abalo	Abalo	Samune	Hosanna
Market demand	Agazer, Nech Abeba	Siquare	Sisay, Siquare	Siquare	Samune, Siquare	Gudene
Early planting	–	Abateneh, Abalo	Siquare	Abalo, Siquare	–	
Late planting	–	Siquare	Gera, Belete	Siquare, Belete, Jalene	–	

[a] Compiled from the farmers' rating of different traits, from focus group discussions, and from market and field assessment

Table 4 Spearman rank correlation between predominant varieties grown in different districts of Ethiopia and traits that farmers state are important to them

Variety	Origin	Big tubers	High yield	Early maturity	Taste of boiled potato	Storage quality	LB resistance	Drought tolerance
Abalo	Farmer	−0.097[b]	0.032	−0.347[b]	0.227[b]	0.287[b]	−0.167[b]	0.095[a]
Siquare	“	0.079[a]	0.037	0.149[b]	0.061	0.062	−0.027	−0.110[b]
Agazer	“	0.106[a]	0.162[b]	0.219[b]	0.261[b]	0.182[b]	0.167[b]	0.196[a]
Jibut	“	0.065	0.011	0.017	0.010	0.005	0.014	−0.011
Nech Abeba	“	0.095[a]	0.118[a]	−0.007	0.018	−0.080[a]	0.068	0.012
Key Dinch	“	0.031	−0.024	0.089[a]	0.069	0.069	0.076[a]	0.061
Ajamazer	“	−0.192[b]	−0.153[b]	0.143[b]	−0.113[b]	0.021	−0.008	−0.001
Asefu	“	−0.138[b]	−0.155[b]	−0.047	−0.015	−0.132[b]	−0.133[b]	−0.149[b]
Askot	“	−0.086[a]	−0.066	−0.017	−0.091[a]	−0.057	−0.079[a]	−0.052
Hosana	“	−0.443[b]	−0.437[b]	0.014	0.199[b]	−0.434[b]	−0.311[b]	−0.284[b]
Nazret	“	−0.280[b]	−0.256[b]	−0.173[b]	−0.261[b]	−0.153[b]	−0.215[b]	−0.239[b]
Key Tolch	“	0.074[a]	−0.002	−0.134[b]	−0.157[b]	−0.045	0.004	0.010
Belete	New	0.136[b]	0.164[b]	−0.066	−0.077[a]	−0.029	0.055	0.054
Jalene	“	0.166[b]	0.156[b]	0.249[b]	0.039	−0.269[b]	0.005	−0.077[a]
Gudene	“	0.364[a]	0.273[b]	−0.110[b]	−0.220[b]	0.497[b]	0.451[b]	0.414[b]
Guasa	“	−0.006	0.003	−0.074[a]	−0.082[a]	−0.082[a]	−0.064	−0.070

[a] Significant at 5 % probability level

[b] Significant at 1 % probability level

in Laigaint, Quarit and the cool highlands of Yilmana), late maturing varieties can be grown. These varieties are better than others in tolerating moderate late onset drought. Varieties such as ‘Abalo’, ‘Agazer’ and ‘Gudene’ received a significantly higher ranking in their response to drought. Moreover, based on our focus group discussion, ‘Abadamu’ also has some tolerance to drought. Early maturing varieties such as ‘Agazer’, ‘Siquare’ and ‘Ajamazer’ are able to escape early onset droughts by planting them late in the season during the Belg or Belmehr seasons. Note also that early maturity is an important trait in Shashemene area because it enables the farmers to grow two crops per year.

Variety storability, both in storage structures or in-field, is a very important trait in our survey areas. Long storage varieties are required in districts in the Amhara region and Gumer & Geta, while short storage varieties are needed for the Shashemene area. Interestingly, all of the varieties that ranked highly for drought tolerance also ranked highest in storage quality. Some varieties in the Amhara region such as ‘Siquare’, ‘Abateneh’ and ‘Sisay’ also have a moderate degree of storability both in-field and in storage structures. In contrast, varieties from the south such as ‘Nech Abeba’, ‘Hosana’ and ‘Nazret’ have very short storability both in storage structures and in-field storage.

Resistance to late blight is another important trait that determines the acceptance of a variety. Farmers are forced to plant susceptible varieties in the dry season (Bekele and Eshetu 2008), when rainfall is not dependable. The Spearman rank correlation showed that farmers perceive ‘Gudene’, ‘Agazer’ and ‘Key Dinch’ to have higher late blight resistance (Table 4). ‘Gudene’ and ‘Agazer’ are grown in both the Belg and Meher seasons, because of their better late blight resistance. Based on focus group discussion, the varieties ‘Sisay’, ‘Belete’, ‘Abateneh’, ‘Siquare’, and ‘Jibut’ also appear to have some degree of tolerance to the disease. Most local varieties (e.g., ‘Abalo’, ‘Asefu’, ‘Askot’, ‘Hosana’ and ‘Nazret’) are very susceptible to late blight. Our data further revealed that most of the new varieties and major local varieties in Shashemene (‘Agazer’ and ‘Nech Abeba’) are perceived to have higher yield (Table 4).

Traits demanded by the market are important factors for variety adoption in Shashemene and Yilmana because these districts are hubs for national and regional markets, respectively. ‘Agazer’, ‘Nech Abeba’, ‘Siquare’ and ‘Sisay’ (particularly in Yilmana) produce relatively large tubers and dominate market sales in the country. Resistance to bruising (good for transportation), resistance to tuber disintegration during cooking, and acceptable stew quality for consumers are among the qualities of good marketing varieties mentioned by farmers. Color is a major factor in the Shashemene district but not in districts in the Amhara region. The central market (Addis and neighboring cities) prefers white skin varieties and thus, unsurprisingly, more than 98 % of Shashemene farmland was planted with white skin varieties. Even so, local markets in Shashemene and Hawassa still accept purple skin potatoes (e.g., ‘Local Bule’), although ‘Local Bule’ is mainly grown outside of the Shashemene area. Although ‘Hosana’ (also known as ‘Key Dinch’ or ‘Holland’) is low yielding, has poor

storage quality and is susceptible to late blight and other abiotic and biotic stresses as indicated in Table 3, most farmers in Gumer & Geta want to grow this variety during the Belg season because it has better taste and flavor than the other varieties grown in these districts.

Potatoes in Ethiopia are mainly consumed boiled or in stew. To be accepted, varieties should be suitable for at least one of these purposes. For districts specializing in market production, a variety may be acceptable even if it is not suitable for boiling. 'Sisay' is an example; it cannot be used for boiling (because of a detectable bitter taste), but is acceptable for stew. A good stew potato remains firm, does not disintegrate when boiled, and absorbs fat/oil from the stew. For their own consumption, farmers prefer varieties suitable for both boiling and stew. Based on the rank correlation and focus group discussions, only local varieties, and none of the new varieties, are perceived to have good "taste of boiled potato". Most of the new varieties except 'Jalene' are negatively correlated with "taste of boiled potato". 'Abalo', 'Aagzer' and 'Hosana' have the highest significant correlations to "taste of boiled potato".

Farmers from Laigaint, Quarit and the highlands of Yilmana prefer 'Abalo' for food, drought tolerance, long dormancy, adaptation to low fertility, suitability for long in-field storage, and for multiple harvesting (at least two harvesting dates in the crop growing season) (Table 3). However, due to its susceptibility to late blight (as shown in Table 4), the production of 'Abalo' is limited to cool highlands where late blight pressure is low. Although the production of 'Abalo' is limited to the Belmehr season (a cropping season that starts in the dry season but ends in the main rainy season), it reaches maturity in August (main rainy season). However, in the lower elevation areas, high relative humidity coupled with high temperature creates favorable conditions for late blight infection starting from July. The farmers in the Amhara region prefer 'Siquare' for both market sales and earliness (allowing late planting) and better late blight resistance than 'Abalo'. 'Abateneh' (in Quarit) exhibits high yield, desirable tuber size and shape, and moderate resistance to late blight but is prone to tuber disintegration when cooked.

Farmers in Shashemene prefer 'Agazer' for late blight resistance, high yield, early maturity and good market and food value. They also prefer 'Key Dinch' for early maturity, although because of its colored skin, it has less market value. 'Nech Abeba' is also preferred by many farmers in the district for short storage dormancy (allowing rapid replanting after harvest), high yield, and for its market value due to its attractive white color. However, it is very susceptible to late onset drought during the Belg season and to late blight compared to 'Agazer'.

New varieties are grown by many farmers, especially in Gumer & Geta and Yilmana, for their high yield, late blight resistance (most varieties) and other attributes. In Gumer & Geta, 'Gudene' is preferred for its stress tolerance (drought, heavy rainfall tolerance during main rainy season, late blight resistance), high yield, better storability in-field, better market value due to its firmness during cooking, and its ability to provide consistent food for the family in the dry season. 'Sisay' is widely grown in Yilmana because of its preferred market traits, good late blight resistance, higher yield and good storability.

Potato Production Systems

Cropping seasons and the primary production constraints of the surveyed districts are indicated in Table 1. The majority of the farmers in these districts reported growing potato twice a year, except at Laigaint where 85 % of the farmers grew potato only once per year (Table 5). Farmers in Shashemene have two dependable rainy seasons (Meher and Belg) and all of the farmers in this district reported growing potato twice a year while the farmers in Quarit and Banja reported three cropping seasons that are completely dependent on rainfall. Yilmana and Laigaint districts have two cropping seasons of which one is totally dependent on rainfall; the other is supplemented with irrigation.

Planting dates differed among varieties in Laigaint, Quarit and Yilmana during the Belmehr season. At Laigaint, the 'Abalo' variety is planted from February to April depending on when rain begins while 'Siquare' and new varieties are planted from April to May. Although rainfall in the dry season is erratic and not dependable for potato production in the Amhara region, the farmers plant local varieties 1–3 months ahead of the main rain season anyway. The reason why Amhara farmers do not grow potato in the main rainy season needs investigation and analysis of different issues including biotic and abiotic factors. The farmers in Gumer & Geta plant new varieties during June to July but they do not grow local varieties then because of late blight pressure.

Pest and disease management practices differed among the districts (Table 5). Farmers from Shashemene, Gumer & Geta and Yilmana reported heavy late blight pressure in the main rainy season. However, only farmers from Shashemene (95 %) and Gumer & Geta (88 %) spray fungicide to control the disease. Some farmers (about 25 %) in Yilmana spray Malathion on stored seed potatoes for control of tuber moth, a serious pest in this district.

Intercropping of potato with other crops such as maize, field pea, brassica, linseed and wheat is widely practiced in the districts of the Amhara region while this practice is not common in the Shashemene and Gumer & Geta districts (Table 5). When farmers intend to store potato in the soil for several months, planting a second crop before potatoes have matured gives the relay crop a head start as maturing potatoes offer little competition. The practice also diversifies the crop for risk management.

Table 5 Potato production practices by district, expressed in percentage of respondents

Practice	District					
	Shashemene	Quarit	Yilmana	Laigaint	Banja	Gumer & Geta
Grew two crops a year	100	90	60	15	55	87
Grew new varieties	17.5	0	80	37.5	5	99.4
Apply DAP & Urea	100	100	100	58	0	100
Apply DAP	71.8	68.4	25	0	0	0
Spray fungicide against LB	95	0	0	0	0	88
Spray malathion against PTM	0	0	25	0	0	0
Intercrop potato with other crops	0	81	65	37.5	25	0
Sample size	40	21	20	40	40	160

Most of the farmers in the study districts, except in Laigaint and Banja, apply chemical fertilizer to their potato crop (Table 5). At Laigaint, fertilizer application is a relatively new practice (about 58 % of the farmers applied fertilizer to their potato crop). When growing new varieties Laigaint farmers consider fertilizer application a necessity. At Banja, where the soil is highly acidic, farmers don't use chemical fertilizers at all; instead most of the farmers use compost and animal manure as revealed from focus group discussions. Previously, Yazie et al. (2009) had reported that 82.5 % of the farmers in the Awi zone, which includes the Banja district, apply manure and compost for their potato crop. Most of the farmers in Shashemene (72 %) and Quarit (68 %) and some farmers in Yilmana (25 %) apply only di-ammonium phosphate (DAP); this is not what the Adet and Holetta Agricultural Research Centers recommend, which is application of both di-ammonium phosphate and urea (Desta et al. 2008; Woldegiorgis et al. 2008). This needs further investigation.

Farmers' Potato Storage Practices

Farmers in the surveyed districts employ a variety of storage practices for both seed and ware potato (Table 6). We observed that there is no distinction between seed and ware potato storage practices except for those farmers who have adopted diffused light storage (DLS) for seed tuber storage only. DLS is a system for seed potato storage designed by CIP that helps to delay tuber physiological aging and results in short, strong tuber sprouts (CIP 1985). In this study 48, 5 and 2.5 % of farmers in Gumer & Geta, Yilmana and Laigaint, respectively, utilize DLS to store seed potatoes of new varieties. Our survey also revealed that most of the farmers in the Amhara region and Gumer & Geta employ 'in-field storage' (delayed-harvesting), while no farmer does this in Shashemene. Potatoes are left unharvested for up to 5 months in Quarit, Laigaint, Banja and Gumer & Geta and up to 4 months in Yilmana. After harvest, heaping potatoes in a dark house (either in a bed-like structure or on the floor) is a commonly used storage practice in all of the study districts. Our survey revealed that most farmers in Quarit, Banja, Yilmana and Laigaint practice dark house seed tuber storage, but few farmers in Gumer & Geta and Shashemene do. About 20 % of the farmers in Laigaint use underground pits to store 'Abalo'. In the Shashemene district, about 83 % of the farmers pile potatoes in a fashion that allows ventilation and then cover the pile with crop residue (in a 'ventilated Gotera' structure). Placing seed tubers outdoors but in the shade for two weeks is commonly used to break tuber dormancy for the Meher crop in Shashemene.

Seed Sources and Seed Flow

Sources of seed tubers across the study districts are summarized in Fig. 3. Based on percent farm counts, 90, 88 and 69 % of farmers, respectively, in Gumer & Geta, Banja, and Yilmana save their 'own seed' from the previous crop. Purchasing seed in the market is also common, practiced by 41 and 32 % of the farms surveyed in Quarit and Laigaint (both represent cool highlands), respectively. Seed from local markets is not a good option for the Yilmana, Banja and Shashemene districts because it can be a source of bacterial wilt disease. About 20 % of farms purchase seed from neighbor farmers in Shashemene. In Laigaint about 14 % of farms reported using seed of new varieties that was given as a gift from government and nongovernmental agencies. Seed exchange among growers is common in Yilmana and Quarit, 15 and 6.3 %, respectively, of farms reported this.

Seed produced in one cropping season may or may not be used as seed for other cropping seasons. The last Belmehr seed is used for both Belg and Belmehr potato production throughout the Amhara region but not for Mesino production in Banja because there is not sufficient time to break tuber dormancy. Seed for Mesino production comes from the last seed produced in the Belg season. Harvested seed from the end of

Table 6 Farmers' potato storage practices expressed as percentage of sampled farmers

Storage practices[a]	District					
	Shashemene	Quarit	Yilmana	Laigaint	Banja	Gumer & Geta
In-field storage and then dark-house storage	0	100	95	77.5	100	19.1
Dark-house storage	17.5	0	0	0	0	12.7
In-field storage and then underground pit	0	0	0	20	0	0.6
Heaping in ventilated condition and covering with crop residues (Gotera, etc.)	82.5	0	0	0	0	12.7
In-field storage and DLS (for seed only)	0	0	5	2.5	0	48.4
Sample size	40	21	20	40	40	160

[a] There is no distinction between seed and ware potato storage except that DLS storage is for seed only

the Mesino season is used for Belmehr season production but is not used again for Mesino. (Planting dates and seed sources for these cropping seasons are shown in Table 1). In Gumer & Geta, where new varieties have been adopted, Belg seed is used for the next Meher as well as Belg production seasons. In Shashemene, seed from the Meher crop is used for the next Belg production and vice versa but Meher seed is not used for the next Meher season.

There is also seed flow within and between districts. Exchange of seed tubers is common between seed farmers in high elevation areas and growers in medium or lower elevation areas because farmers realized that seed from the higher elevations provides a healthy crop. Farmers in the Bulchana Kebele of Shashemene are mainly dependent on seed from higher elevation areas. Higher elevation areas are a source of seed of 'Siquare', also known locally as 'Key Dinch', for the lower elevation areas in Laigaint. That is why 'Siquare' has a better price at planting time than 'Abalo' does in the district. The farmers of Quarit district depend on seed from the Sekela area (outside of the survey districts) for Mesino potato production.

Discussion

Variety Diversity at Household Level and Distribution Across Different Agro-Ecologies and Market Access

Our study sought to assess potato variety diversity at both the household and district levels, in part to guide future conservation of current farmer-developed varieties, and in part to guide future breeding efforts. We found that 70–90 % of the farmers in the districts surveyed grow two or more potato varieties at the same time in the same growing season. Some farmers grow up to five varieties, with widely different attributes, at a time. These results are consistent with a prior study by Garuma et al. (2013), who reported that farmers in Gumer & Geta grow more than one variety. Brush et al. (1992) noted that individual households in Peru keep an average of 10 native potato varieties, and some keep up to 35.

Because small potato farmers are faced with many types of production risk, e.g., variation in timing and quantity of rainfall and occurrence of frost, growing more than one variety can reduce the risk of crop failure (Tsehaye et al. 2006; Abay

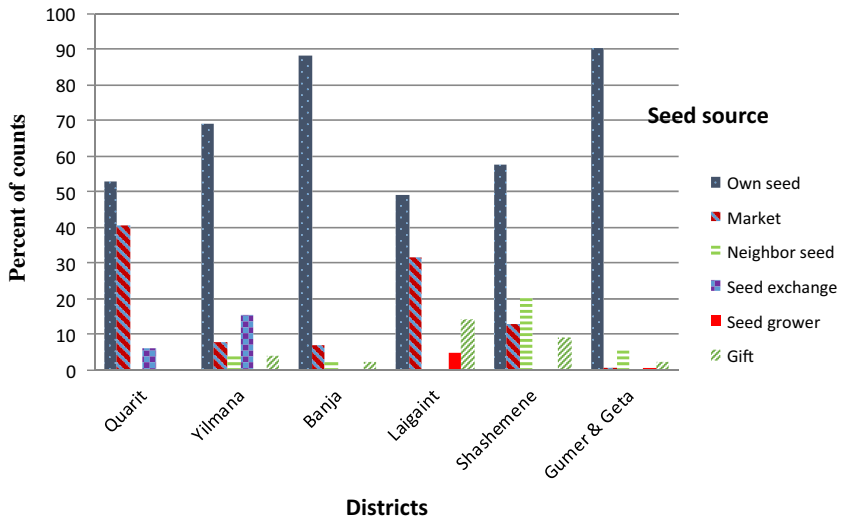

Fig. 3 Potato seed tuber sources in different districts expressed in percent of farm counts

et al. 2008) and allows farming in environments characterized by different soil, temperature and rainfall regimes (Lando and Mak 1994; Bellon 1996b). In addition to risk reduction, we found that Ethiopian potato farmers grow a diverse set of varieties to meet different needs, including food and market value, production timing constraints that can be met by utilizing cultivars that differ in maturity, and varieties that confer resistance or tolerance to biotic and abiotic stresses.

Of the 48 potato varieties recorded in our study, 40 were 'local' varieties and eight were 'new'. Twenty varieties are commonly grown by farmers; the rest are rare. We also found that the distribution of these varieties is influenced by agro-ecology, market access and cropping season. 'Siquare', 'Abalo' and 'Samune' are the major local varieties in the Amhara region which fits well to the Belmehr cropping season but they are not common in Gumer & Geta and Shashemene areas. However, their degree of importance differed between agro-ecologies and market outlets even in the Amhara region. 'Abalo' is predominantly grown in sub-moist (dry) agro-ecology because it is drought tolerant while 'Siquare' is a dominant variety in moist agro-ecology. Yazie et al. (2009) and Labarta et al. (2012) also reported that 'Siquare' and 'Abalo' are the major potato varieties in the Amhara region but neither study mentioned 'Samune', which is mainly grown in sub-humid and acid soil areas in the region. 'Siquare' is also widely grown in other moist and cool Amhara region districts, including Sinan and Bibugn (Yazie et al. 2009) and in some parts of the SNNP and Oromia regions (Labarta et al. 2012). Labarta et al. (2012) estimated that 'Siquare' represented 25.5 and 35 % of national and Amhara region potato production, respectively. Both Yazie et al. (2009) and Labarta et al. (2012) made a distinction between the varieties 'Deme' and 'Ater Abeba', considering them separate varieties. Nonetheless, DNA marker data (unpublished results) have revealed that 'Deme', 'Ater Abeba', 'Key', 'Demas' and 'Siquare' are actually a single variety.

Our survey data further indicates that 'Agazer' and 'Nech Abeba' are the major varieties in Shashemene, which represents a mid-altitude and bimodal rainfall pattern, while the new varieties 'Gudene' and 'Jalene' are widely grown in Gumer & Geta districts followed by the local variety 'Hosana'. Emana and Nigussie (2011) and Abebe et al. (2013) also reported that 'Agazer' and 'Nech Abeba' are widely grown in the Shashemene district.

The influence of market access is another factor that determines which varieties are grown. 'Agazer' and 'Nech Abeba' are the major varieties that fit the requirements of the national markets, as they are suitable for stew, and have desirable skin color and tuber size. 'Sisay' is another variety that is mainly grown for the market. According to Emana and Nigussie (2011) Shashemene is a hub of national food and seed markets. For this reason, varieties widely grown in Shashemene areas are likely to be disseminated throughout the country.

In our study, the aggregate total area covered by new varieties ('Gudene', 'Jalene', 'Sisay', 'Belete', 'Tolcha', 'Gera', 'Guasa') was about 23 % while the area allocated to these varieties at Gumer & Geta and Yilmana was 78 and 43 %, respectively. Labarta et al. (2012) reported a similar value for adoption of new varieties at the national level (28.6 %). The relatively small difference of our study to that of Labarta et al. (2012) is likely due, at least in part, to differences in districts that were surveyed for the two studies.

New varieties are grown mainly in the Meher cropping season because most of them have good resistance to late blight. In Gumer & Geta, new varieties are grown in both the Meher and Belg seasons. However, the majority of farmers in the Amhara region grow potato in the Belmehr (dry) season and plant local varieties, even though rainfall is not dependable for potato production. According to Bekele and Eshetu (2008), severe late blight infection in the Meher season forced farmers to limit their potato production to the dry season. Even if farmers realize significant production challenges and lower yields in the dry season, this crop helps meet the food deficit during the "hungry months" of July and August (Woldegiorgis 2013) when other crops have not yet been harvested. Farmers in Shashemene grow local varieties in both the Belg and Meher seasons since they believe that existing major local varieties have moderate resistance to late blight (Table 3).

Farmers' Choice of Potato Varieties and Selection Concerns

Understanding how Ethiopian farmers decide what varieties to grow is important for guiding future variety development and dissemination efforts. We found considerable variation across the districts; it is obvious that many different varieties will be needed to address the multitude of needs. Late blight resistance, tuber yield and food value were important in all the districts. Drought tolerance, suitability for harvesting more than once in a season, tolerance to poor soil conditions, long dormancy, and market demand (for the Yilmana district) are the concerns in the Amhara region while market demand, early maturity and early dormancy traits are required in Shashemene.

A study by the International Potato Center (CIP 2008) revealed that yield, late blight resistance and early maturity are the attributes most frequently considered by farmers in Kenya and Uganda. In contrast, Abebe et al. (2013) reported these attributes are less important for farmers in Shashemene. This difference might be attributed to the use of different benchmarks. The Abebe et al. (2013) survey included varieties that farmers consider to be resistant to late blight. Similarly, our study showed that a widely grown variety, 'Agazer', has good late blight resistance as indicated in Tables 3 and 4. However, this does not mean that late blight resistance is not a selection

criterion for farmers. Instead, this shows that farmers select their own varieties suitable for their production area and practices. Our study also showed that Shashemene farmers grow early maturing varieties. New varieties such as 'Jalene' and 'Gudene' mature more than 20 days later than the widely grown local variety 'Nech Abeba' and as a result they mature too late to be used for the next season's planting. Thus, even though Shashmene farmers may not have been able to articulate when surveyed by Abebe et al. (2013) that early maturity is important for them, it clearly is.

The reasons for adoption of new varieties such as 'Gudene' and 'Sisay' in Gumer & Geta and Yilmana districts, respectively, may provide two important lessons for future potato breeding in Ethiopia to understand the needs and selection criteria of farmers as well as consumers.

Lesson 1 Farmers will accept a new variety if it meets several important needs, even if it also has some drawbacks. These new varieties are widely grown in these districts because they have several important traits that other new varieties do not. Even though 'Sisay' has bitter taste, it has good market acceptance because it stores well under local storage conditions, has good resistance to late blight and has traits that help it sell in the market (acceptable tuber size, color and shape, resistance to bruising during transportation, firmness during cooking). Similarly, for 'Gudene', although farmers complain that it does not digest easily when eaten during the first three months of storage and doesn't store well in home storage, it is high yielding, late blight resistant, has good storability in-field, good tolerance to tuber spoilage and good tolerance to several stresses.

Lesson 2 It is important to understand the needed characteristics of new varieties during variety development, and to appreciate the value of farmers' participation in the process of variety development. The research system does not currently provide important information on utilization and production characteristics of new varieties, even after release, because varieties are tested only for a few specific traits, primarily yield potential and late blight resistance. Farmers have complained about the suitability for boiling (in case of 'Sisay') and storability for food purposes (in case of 'Gudene'). These two traits are very important to farmers when they consider whether they will adopt a variety or not. Even so, through experience, farmers from both districts identified important traits of these two varieties and so continue to grow them. 'Sisay' was disseminated to Yilmana over 20 years ago. Promotion as well as dissemination of the variety was stopped because the research system realized that it is not suitable for boiling. However, the farmers do not want to lose this variety because they realized that it contains a unique set of traits that make it suitable for regional markets, along with other important traits such as good storability, late blight resistance and higher yield. Similarly, for 'Gudene', the farmers have come to understand that this variety has good storability in the soil and is resistant to tuber spoilage even during the main rainy season. Thus, they developed their own means to use this variety: they leave the potato unharvested and sow barley on it for the whole rainy season. After the barley crop is harvested, they harvest 'Gudene' for food and seed.

New varieties are grown in all the districts studied, with the exception of Quarit, where new varieties have not been introduced. 'Gudene' was disseminated to the Shashemene district but was not well accepted partly due to its longer maturity, which does not fit well with the existing cropping system, and partly because the choice of varieties in this district is not only determined by growers but also by marketers and consumers. Since 'Sisay' is not suitable for boiling, its acceptance in other districts is likely to be low.

Farmers' Decision Making and Variety Diversity

Our study revealed that variety diversity at the household level is influenced by a range of production practices and environmental conditions such as pest and disease management, intercropping, soil fertility management, storage practices, seed sources and seed flows, and planting seasons. In mid altitude moist areas of the Amhara region, varieties with moderate resistance to late blight are common and the farmers in these areas do not grow late blight susceptible varieties such as 'Abalo' even in the Belmehr production season. 'Siquare', 'Abateneh' and several new varieties are alternatives for these areas. Suitability for intercropping is another factor that influences farmer decisions. Farmers in Quarit preferred 'Siquare' over 'Abalo' when they intercrop potato with other crops because of its short stature and early maturity. There are also varietal differences in relation to adaptation to low soil fertility. Chemical fertilizers are difficult to apply when growing potato in the dry season, in such situations farmers prefer 'Abalo' for its performance in soil with low fertility. 'Siquare' and new varieties are mainly grown around homesteads where soil fertility is good.

In our study we observed varietal differences in relation to cropping season and planting time. In the Amhara region, farmers have different varieties suited to late planting (if there is early onset drought) and early planting (if there is enough

moisture during February and March). The farmers in Gumer & Geta plant new varieties ('Gudene' and 'Jalene') in both the Meher and Belg seasons but plant 'Hosana' and other local varieties only during the Belg season because of late blight pressure and heavy rainfall during the Meher season.

Seed sources and seed flows are important factors that influence the selection of varieties grown and help us to understand the diversity present in an area (Bellon 1996a). Our study showed that 'own seed' followed by seed purchased in the local markets are the major seed sources for farmers in all the study districts, consistent with what Gildemacher et al. (2009) and Samberg et al. (2013) have previously reported for Ethiopia. Our study also revealed that market, neighbor purchase and seed gift are important contributors for the adoption of new varieties. For instance, 'Abateneh' was introduced to Quarit from the Sekela area through the seed market system.

Farmers' storage practices (for both food and seed purposes) also influences which varieties are grown. Current local varieties are well suited to available storage practices. However, some farmers in group discussion in the Amhara region complained that new varieties do not fit well with existing storage practices. For example, tubers of 'Guasa' and 'Jalene' rapidly spoil if they remain in the soil while others are liable to damage when stored in a dark house without ventilation. Therefore, when introducing a new variety, either the variety should fit well to existing storage practices or new storage technologies suitable for ware and seed potatoes should be developed and disseminated with the new varieties.

Factors Determining Farmers' Decisions to Accept a Variety

Many authors have identified the strong links between crop diversity and social, economic and cultural factors that together support diversity as a part of a dynamic system (Bellon 1996b). Consistent with this we found that variety diversity at the household level differed among districts due to the difference in agro ecological settings, farming systems, market outlets, extension activities, social aspects and others.

Potato variety adoption is also influenced by market preferences (CIP 2008). Our study found that the requirements of target markets have a significant impact on potato varietal diversity at the household level. Potato skin color is one of the main determining factors for variety preference in Shashemene, a hub of the national potato market. More than 98 % of the farmers in this district grow white skin varieties, because that is what sells in the national market. For farmers who have access to markets, surplus produce can be sold immediately after harvest (as farmers in Shashemene do). For farmers like this, how well the variety performs in storage is not of great concern.

Recommendations

Incorporate Additional Quality and Stress Tolerance Traits During Variety Development

Our study showed that a variety will not necessarily be adopted even if it has high yield and late blight resistance (which have been the major goals of variety development in Ethiopia), as several other factors also contribute to variety adoption. Most of the new varieties that have not been adopted so far either have poor taste after boiling, undesirable stew quality, or poor storability. Several authors have stressed the importance of quality traits - such as storability, taste for both boiling and stew, and market demand for variety adoption (Tripp et al. 1997; Bellon 2002). These traits have largely been overlooked by variety developers in Ethiopia to date. This is not unique to Ethiopia, as Tripp et al. (1997) has observed that many traits are not assessed until the variety has been released even in developing countries. Ideally, variety development should include assessment of all quality traits that are important determinants of variety adoption.

Address the Variation in Agro-Ecology, Cropping Systems and Market Access During Variety Development

Key traits differ among agro-ecologies, cropping systems and market outlets. This needs to be taken into account during variety development. For instance, in Gumer & Geta, late blight resistance and long storage life are the key traits that enable farmers to grow potato in the Meher season and allow year round consumption of potato. Resistance to late blight, suitability for boiling and stew, and long storability are the major drivers for variety adoption in Amhara areas with moist and sub-humid agro-ecologies. In Amhara areas with sub-moist agro-ecology, long storability, drought tolerance and suitability to boiling potato are the major drivers for the adoption of new varieties. Market quality (desirable tuber size, color, shape) are key for variety adoption in the Yilmana district. Market demand, suitability for stew, and early maturity are important traits for adoption of new varieties in the Shashemene area. In contrast to other districts, farmers in Shashemene prefer varieties with short dormancy.

Register the Main Ethiopian Local Varieties, and Prepare an Ethiopian Potato Catalog

The Ethiopian Ministry for Agriculture publishes a variety registration booklet for officially released new varieties on an annual basis. However, since the documentation does not contain detailed descriptions and photographs of these varieties, it is easy for a variety to lose its identity and gain additional names. Preparing an Ethiopian potato catalog that includes the major local varieties will help ensure that everyone

identifies a clone with the same name. This, in turn, will help reduce unnecessary duplication of effort in future research and conservation projects.

Utilize the Available Major Varieties for Future Breeding

Ethiopia has unique and diverse agro-ecologies, different cropping systems and demand for different end uses that justify the need for many types of potato varieties. Selected local and new varieties provide a useful starting point for the development of improved varieties, as they represent the collective, if not technologically sophisticated, efforts of countless farmers to identify clones that meet current needs. Of course a breeding program requires a long-term financial commitment to ensure that adequate human resources, equipment, and facilities can be harnessed for the development of new varieties. It is possible to establish such a program at the national level, where crossing is done at a single location, and subsequent evaluation is conducted in research centers around the nation. The support of the International Potato Center and other institutions would be of tremendous help in establishing an Ethiopian breeding program.

Design Effective Dissemination Approach

New variety adoption in Gumer & Geta provides a good model of a successful dissemination strategy. Here, in addition to providing an adequate supply of clean seed, growers were provided with recommendations for fertilizer, seed storage structures, and support that continued for five years. Strong coordination among developmental partners helped the adoption process.

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