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Novel approaches to promote and diffuse new potato varieties in Kenya

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Abstract

Current efforts for promotion and diffusion of new potato varieties in SSA countries focuses on a combined strategy to develop business-oriented sustainable seed systems including the private sector in producing clean seed stocks and the collaboration of public plant health regulatory institutions. A new private-public partnership model for the establishment of disease free seed production system is currently under development in Kenya with encouraging preliminary results. The model includes the Kenyan Plant Health Inspectorate Service (KEPHIS) to provide the protocols, procedures and health inspection services, private companies for production of large scale potato in-vitro plantlets and minitubers and CIP for strategic support and technical backstopping. Initially two private companies GTIL (Genetics Technologies International Ltd.) and Oserian Flowers specialized in tissue culture technologies on fruit trees, trees were involved in the production of potato in-vitro plants in large scale with high success. Later on, GTIL interested on minituber production, built it's first aeroponics unit together with a traditional system and is successfully producing minitubers. Two CIP derived varieties were used to test variety diffusion through adoption of aeroponics technology for minituber production. In 2009, Kisima farm and the national potato research station at Tigoni also joined GTIL in the production of minitubers via aeroponics technology. All three institutions and the four aeroponic units built are currently well established and under minituber production with a capacity of approximately 390,000 disease-free minitubers per year. This seed will provide clean stocks for the participants to start their seed production on a large scale in the country. The establishment of a sustainable private-based seed production system including pre-basic, basic and certified seed in a commercial scale will provide the tool needed for the more effective introduction and diffusion of new varieties in Kenya.

Keywords: Aeroponics, in-vitro plantlets, minitubers.

Introduction

Diffusion of new varieties requires the availability of clean seed stocks and an efficient sustainable seed system to bulk seed in a short time and make it available to farmers.

CIP's main activities on the diffusion of new varieties in SSA region are carried out together with the country's national potato programs and by using innovative approaches and technologies in line with client needs and local seed regulations. However, sustainable progress is difficult as most potato programs in SSA countries usually operate with insufficient funds and are frequently overburdened with many responsibilities such as production of pre-basic and basic seed and often certified seed; variety releases and diffusion; development of crop and disease management practices, development of post harvest technologies and other related technologies that make them unable to provide efficient services and outputs to meet farmers and consumers demands.

Well established private sector certified seed industries are non-existent in all SSA countries and the lack or insufficient amount of clean basic seed, usually produced by national potato programs and barely covering 1% of the total demand in most countries (Kinyae *et.al.*, 2005), is a major limitation. Most seed production and trade is informal and seed pathways are typically from farmer's saved seed, farmer to farmer and ware market to farmer (Kaguongo *et.al.*, 2007), consequently resulting in poor seed quality with the exception of very few specialized individual or group farmer organizations that manage to acquire limited amounts of basic seed from the national potato programs to propagate one or two additional field generations before is sold to ware producers. In some countries, particularly in Kenya, some seed producers follow government regulated seed certification procedures, but due to the limited number of inspectors and not well-developed and efficient service systems, the majority prefer to produce uncertified seed, but assuring their own seed quality.

The lack of seed or insufficient amount of pre basic and basic seed is a major limitation in establishing a sustainable seed industry in most countries in SSA and because functioning seed systems are the principle vehicle for new variety uptake and diffusion, CIP initiated efforts in Kenya to develop a strategy that involves the private sector in the production of potato in-vitro plantlets and minitubers. The private sector provides additional sources of pre-basic and basic seed which are usually produced by government programs. Private labs with tissue culture facilities, dedicated to the flower industry, trees, fruit tress and industrial crops were targeted for these activities.

The strategy focuses on the following objectives: a) persuading selected private companies to respond to the unfulfilled demand of high quality potato seed in the country by entering the potato seed business, particularly in the production of large scale in-vitro plantlets and minituber production, to complement their own business industry, b) engaging government sponsored plant health inspectorate services (KEPHIS) in the inspection and detection of diseases and pests directly in materials grown in the private sector labs and screen houses and further supervision in later field generations and c) assisting selected private companies in the construction of quarantines screen houses for production of minitubers using both the traditional soil-based system and the new novel system that is nutrient solution-based called "aeroponics"; the latter increases the production of minitubers per plant five fold, replaces the need for substrate sterilization and reduces the final cost of tuber units significantly (Otazu *et.al.*, 2008; Struik and Wiersema, 2009).

Materials and methods

During the first phase, two interested private companies were selected and received technical backstopping for large scale production of in-vitro plantlets; the first, Genetics technologies International Limited (GTIL), a medium size company, located in Nairobi, and specialized in large scale in-vitro production of bananas, trees, fruit trees and herbal plants and the second, Oserian Flower Company, one of the largest companies located in Naivasha, and specialized entirely on export flowers for the European market. GTIL possesses 9 laminar flows, 6 growth chambers and over12 screen houses and Oserian has 30 laminar flows, 10 large growth chambers and numerous screen houses in addition to land. The plant quarantine station (PQS) of KEPHIS, was also included for minituber production of in-vitro plants produced by the two companies using traditional soil-substrate medium.

Advanced late blight resistant breeding materials included two varieties from Ethiopia CIP 384321.9 (Guasa) and CIP 384321.19 (Jalene) and five promising clones from population B3 Cycle 1 (B3C1), CIP 393280.82, CIP 391046.14, CIP 392657.8, CIP 393085.5 and CIP 393371.58; all derived from CIP's advanced late blight resistant breeding program and introduced as in-vitro plants from CIP HQ Lima, Peru.

The methodology in the first phase, involved the introduction of 50 in-vitro plants per clone from CIP Lima, received by PQS and delivered to both companies according to previous agreed protocol by KEPHIS. GTIL received three clones CIP 384321.9 (Guasa), CIP 384321.19 (Jalene) and CIP 393280.82 and Oserian four clones (CIP 391046.14, CIP 392657.8, CIP 393085.5 and CIP 393371.58). Both companies started multiplication of in-vitro plants in their own labs and tissue culture facilities to reach the requested target of 1,200 in-vitro plants per clone and delivered as rooted plantlets.

Sampling of in-vitro plants for virus detection was taken during in-vitro multiplication from both companies and also during the growing period at PQS quarantine screen houses. Water and soil samples were also taken from quarantine screen houses at PQS for bacterial wilt (BW) detection. All disease detection kits were obtained from CIP-Lima.

During the second phase, GTIL and a new interested private farm (Kisima farm) were involved in disease free minituber production while Oserian Flower Company remained on stand by but available for large scale production of in-vitro potato plants. Two commercial varieties derived from CIP, Tigoni and Asante, were used for the production of minitubers as pre-basic seed; and the new "aeroponic" technology (Kim *et.al.*, 1999; Farran and Mingo-Castel, 2006; Otazu *et.al.*, 2008) to produce minitubers was established in quarantines screen houses in both places plus an additional small soil-substrate based screen house at GTIL.

Results and discussion

Involving the private sector in the production of large scale in-vitro plantlets

Several visits to the private companies were carried out during mid 2007 to confirm their infrastructure, adequate tissue culture facilities, technical capacity and to motivate them to enter into the potato seed business sector by getting involved in large scale production of pre-basic seed (in-vitro plants and minitubers), traditionally produced by the research station KARI-Tigoni in limited amounts and unable to meet country's high quality seed demand. Similarly, visits were made to the Kenyan Plant Health Inspectorate Service (KEPHIS), seeking technical supervision and regulatory support to the private sector for their involvement in the potato seed industry including production of pre-basic, basic and certified seed. The KEPHIS approach resulted in an official agreement to support and collaborate with the private industry, the development of procedures and quarantine protocols for introduction of in-vitro plants originated from CIP-Lima and also from PQS, supervision of large scale disease free production of in-vitro plants and minitubers at the private tissue culture facilities and quarantine screen houses. Likewise, agreements with the two selected private companies for the production of large scale in-vitro rooted plantlets, as the first stage to demonstrate their capacity to manage and deliver disease free in-vitro plants from potato, were finalized . Approval for the involvement of private sector in the production of quarantine grown minitubers during a second phase was also reached as well as further field multiplication of basic and certified seed following a three generation seed production strategy ("3G") as a short-time frame work under establishment through a USAID funded CIP project (I. Barker and X. Kaiyun; pers. comm.).

Both private companies GTIL and Oserian delivered 1,200 well developed rooted plantlets per clone in an approximately 2-month period (Tables 1 and 2), although they could have produced larger amounts in the same period or shorter; demonstrating high capacity to produce successfully in-vitro plants from potato at large scale. There is no doubt that these companies after the first experience on producing potato in-vitro plants, could also produce minitubers if adequate quarantine infrastructure was made available; however, their decision to get involved in minituber production as a second stage would depend on the convincing evidence of high quality seed demand in the country, institutional support for building a private seed industry, and need for starter clean seed stocks (pre-basic and basic seed) in larger amounts. Only then, these private companies would show willingness to venture into the production of clean seed stocks and high quality seed, and invest on building the necessary infrastructure (quarantine screen houses). In this regard, CIP together with supporting funds from GTZ and USAID and other stakeholders is committed to provide technical backstopping to these companies, bring novel technologies for minituber production and build the necessary infrastructure on a partly subsidized basis.

Table 1. Production of in-vitro plants by Oserian Flowers and delivery of rooted plantlets

CIP clone Lumber	In Vitro plants from CIP	Plantlets used	Multiplied	Comments	Date	No. of days
393371.58	25 tubes/2 plts each	50	176	1st transfer	25/09/07	
		176	470	2nd transfer	24/10/07	
		470	1,200	3rd transfer	21/11/07	
			1,200	Delivery	10/12/07	75
391046.14	25 tubes/2 plts each	50	194	1st transfer	25/09/07	
		194	590	2nd transfer	24/10/07	
		590	1,200	3rd transfer	21/11/07	
			1,200	Delivery	10/12/07	75
392657.8	25 tubes/2 plts each	50	108	1st transfer	25/09/07	
		108	695	2nd transfer	24/10/07	
		695	1,200	3rd transfer	21/11/07	
			1,200	Delivery	10/12/07	75
393085.5	25 tubes/2 plts each	50	175	1st transfer	25/09/07	
		175	525	2nd transfer	24/10/07	
		525	1,200	3rd transfer	21/11/07	
			1,200	Delivery	10/12/07	75

Table 2. Production of in-vitro plants by GTIL and delivery of rooted plantlets

CIP clone number	In vitro plants from CIP	Plantlets used	Multiplied	Comments	Date	No. of days
384321.19	25 tubes/2 plts each	50	345	1st transfer	9/10/07	
		345	300	2nd transfer	5/11/07	
		300	1,200	3rd transfer	26/11/07	
			1,200	Delivery	10/12/07	61
384321.9	25 tubes/2 plts each	50	375	1st transfer	9/10/07	
		375	300	2nd transfer	5/11/07	
		300	1,200	3rd transfer	26/11/07	
			1,200	Delivery	10/12/07	61
393280.82	25 tubes/2 plts each	50	420	1st transfer	9/10/07	
		420	300	2nd transfer	5/11/07	
		300	1,200	3rd transfer	26/11/07	
			1,200	Delivery	10/12/07	65

Likewise, CIP has initiated studies to diagnose the current situation of the seed industry in the country, quantify the real seed demand and market and propose alternative scenarios for the development of potato seed industry in Kenya with high involvement of the private sector and other relevant stakeholders.

Involving the private sector in the production of in-vitro plantlets and minituber production through conventional soil-substrate based and nutrient-solution based methods

After the successful experience of both companies (GTIL and Oserian) in the production of in-vitro plants, and quarantine minituber production at PQS from in-vitro plants originated in these companies (Table 3), GTIL showed high interest on engaging in the production of minitubers (G1) and two additional field grown generations (G2 and G3) before is sold to seed suppliers and ware producers; whereas, Oserian more cautiously decided to wait for the seed demand study, although expressed immediate interest if market for the miniubers produced are ensured.

Table 3. Minitubers produced at PQS from in-vitro plants delivered by GTIL and Oserian

Clone number	Virus test	BW test	Total tuber weight kg.	Total no. of pots 2 plt/pot	Total no. of tubers (>5 gr)	Total no. of tubers clone	Total no. of tubers	Av. no. tubers/ pot
391046.14	-	-	35.0	497	3,500	1,500	5,000	10
393371.58	-	-	35.4	466	6,500	1,700	8,200	18
393280.82	-	-	18.4	400	2,000	1,350	3,350	8
384321.9	-	-	22.8	550	3,500	1,400	4,900	9
384231.19	-	-	75.2	552	4,120	1,450	5,570	10
Totals	**-**	**-**		**2465**	**19,620**	**7,400**	**27,020**	

* In-vitro clones from 2 clones (1,200 each) were delivered to KARI-Tigoni research station

During mid 2008, GTIL invested on remodeling two screen houses into quarantine environments out of which one is under traditional soil-based substrate and the second to host the nutrient-solution based unit “aeroponics” for disease free minituber production. All activities including remodeling of screen houses, construction of aeroponics units were done under full supervision and technical support from CIP. Two well known local varieties originated from CIP’s germplasm, Tigoni and Asante, currently expanding in main potato areas in the country, were recommended for production of clean seed stocks and further diffusion throughout the country. In late 2008, fifty disease free in-vitro plants per variety, obtained from PQS were delivered to GTIL as starting material for further multiplication. A total of 5,500 in-vitro plants for the two varieties were obtained for transplanting in both screen houses, out of which 3,500 were used in the soil-based substrate SH, hosting 1,620 pots at a rate of two plant per pot and 1,510 in the aeroponic units. Overall minituber production of approximately 90,000 minitubers were expected in early 2009 from both screen houses using conservative estimates of 8 tubers per pot in the traditional system and 50 tubers per plant in the aeroponic system (Otazu *et. al*., 2008; Struik and Wiersema, 1999). However, the overall minitubers production was significantly reduced to a total of 23,229 minitubers as plant growth and survival rate were severely affected by increasing temperatures during the summer season as well as tuberization response (Table 4). Despite the high temperature effects on plant growth and survival, the average rate of minituber production per pot (2 plants) in the traditional system was 14.6 minitubers /pot and 19.2 minitubers per plant in the aeroponics system.

Table 4. Minituber production of cvs. Asante and Tigoni at GTIL (Sept. – Dec. 2008)

Minituber production system	Total SH capacity plants/pots	No. of plants survived	Survival rate (%)	No. of minitubers produced	Ave. no. of tubers/pot/plant
Aeroponics	1,510	512	34	9,850	19.2
(plants)					
Traditional	1,610	916	57	13,379	14.6
(pots)					
TOTAL				**23,229**	

During early 2009, an additional interested private entrepreneur “Kisima farm” was also involved in the production of disease free minitubers via “aeroponics” as starter pre-basic seed (G-1) and intends further field production of basic and certified (G2 and G3). GTIL also constructed a second aeroponic unit with larger capacity (Figures.1 and 2) and CIP built another aeroponic unit at Kari-Tigoni in support to the potato research station. All units were built with technical backstopping from CIP and completed in late April 2009. Planting of in-vitro plants in all aeroponic units were done during the cool season (May – September 2009) and plant growth and development have been established successfully and expected to produce minitubers normally and at full capacity (Table 5). Minitubers produced by the private and public sector as pre-basic seed will be monitored by CIP who will also guide them into the production of additional two field multiplications as basic and certified seed (G2 and G3), before is sold to ware growers and seed suppliers. CIP is committed to provide technical backstopping and monitoring for the successful establishment of these seed systems, particularly in the private sector.

Table 5. Estimated number of minitubers on four aeroponic units and one traditional (May-September, 2009

Institution	SH type	No. Pots/plants	Mtbers/pot/plant	Total no. minitubers
GTIL	Traditional	1,620	8	12,960
	Aeroponics	1,570	50	78,000
	Aeroponics	2,100	50	105,000
Kisima	Aeroponics	1,950	50	97,500
Tigoni	Aeroponics	1,990	50	99,500
	TOTAL			**392,960**

Current CIP efforts to facilitate the establishment of private sector seed systems to improve seed quality and increased capacity to produce larger amounts of seed in Kenya, should result in a more sustainable seed production system, but also contribute to satisfying the currently unmet demand for high quality seed in the country. It will also become a useful and efficient instrument for variety promotion and diffusion of already released varieties, with their associated pro-poor traits, and new ones being introduced through the breeding "pipeline" in the near future.

Figure1. Aeroponic unit at GTIL

Figure 2. Minituber production at GTIL

Involving the private sector seed systems in the promotion and diffusion of new varieties

CIP, with its partners, is facilitating the development of a well established large-scale private sector seed production system, including pre-basic, basic and certified seed and using more efficient and novel rapid multiplication technologies. This enhanced capacity for the production of quality seed will constitute the instrument needed to introduce new varieties and speed up their promotion and diffusion to farmers. By producing large amounts of pre basic, basic and certified seed in a short time framework and making them available to seed suppliers and ware producers, will make variety introduction and diffusion quick and efficient. On the contrary, the lack of seed systems or deficient schemes, as it is at present, makes variety introduction and diffusion lengthy and inefficient, consequently precluding farmers benefiting from additional agronomic and market qualities carried in these new varieties. Additionally, with efficient seed systems, variety replacement and diffusion can be done routinely as needed, responding to farmers and market needs and demands, and also to challenges from increasing environmental and disease constraints.

Complementary to CIP efforts to establish private sector seed systems and diffusion of varieties, CIP is also supporting KARI-Tigoni potato research station to officially release and register new varieties. In this regard a new set of late blight resistant clones with variety potential, high yielding capacity, broad adaptation and high quality for table and processing are currently evaluated in national performance trials (NPT) under KEPHIS supervision for formal variety releases and registration. Newly registered varieties will be the first to be introduced through the newly established seed system for promotion and diffusion, although, varieties Tigoni and Asante have been already used for both establishing the seed system and further diffusion to farmers.

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Seed procurement of native potatoes in the central Andes of Peru: the role of farmer-to-farmer exchange, markets and seed fairs

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Abstract

Procurement behavior of farmers and the role of farmer-to-farmer exchange, regular markets and seed fairs after normal and frost stressed years are compared. A series of surveys were applied in the department of Huancavelica (Peru), both during years with and without seed stress. During normal years seed acquisitions of native cultivars are characterized by transactions involving small quantities, few cultivars, few events of exchange, and seed flows over short distances. Most households exclusively use home produced seed of native cultivars. Uncommon native-floury and bitter cultivars are exchanged infrequently and only few farmers provide them. The capacity of the farmer seed system to annually widely supply and distribute infraspecific diversity is limited. Yet, at the household level, the farmer seed system is efficient at maintaining overall infraspecific diversity. Regular markets have a decentralized capacity to supply and widely distribute seed of selected cultivars. Frequencies of seed exchange at biodiversity seed fairs are low and involve small quantities of a few uncommon cultivars. The resilience of the farmer seed system to cope with severe regional seed stress (scarcity) is insufficient to be able to restore volumes and cultivar portfolios within a short period of time.

Keywords: farmer seed systems, seed stress, potato genetic diversity, Huancavelica.

Introduction

Seed systems are an interrelated combination of components involving diverse actors (farmers and organizations), production systems (planting materials, management options and storage), processes (distribution and access) and institutions (regulatory frameworks and informal rules). Farmer seed systems, also commonly referred to as informal, local or traditional seed systems, are particularly important for smallholder and poor farmers (Louwaars, 2007). In the Andean countries over 95% of the potatoes grown originate from farmer seed systems (Ezeta, 2001). The potato's cultivar diversity is almost exclusively multiplied through seed systems outside the formal regulation (De Haan *et al.*, 2009; De Haan and Thiele, 2004).

Seed procurement may be needed when home saved stocks do not balance a household's demand for seed in term of quantity, quality or cultivar content. The resulting seed flows are spatially determined routes of exchange (acquisition or provision) characterized by distance, volume, cultivar content, mechanism of exchange, source and destination. Seed flows generally cover limited distances (Thiele, 1999), but can cross international frontiers (Velásquez, 2002). Seed exchange can be farmer-to-farmer or arranged through organizations such as regular markets, biodiversity seed fairs, private or governmental agencies. Seed procurement often occurs through social networks which can be based on prestige and recognition, patron-client links or functional reciprocity. (Badstue, 2006; Badstue *et al.*, 2002; Richards, 2007; Tripp, 2001). While monetary exchange always involves sales, non-monetary exchange may include barter (*trueque*), payment in kind (*minka*) or presents (Ferraro, 2004; Mayer, 2002).

Rural markets in the Andes are a key meeting point for farmers where seed, food, animals, tools and other products are exchanged. Such markets have a long history throughout the Andes (Larson *et al.*, 1995); yet, little is known about their role in seed provision. Biodiversity seed fairs, on the other hand, are a relatively recent phenomenon. Since the first biodiversity seed fairs were organized in the late 1980´s the number of fairs organized by municipalities, governmental agencies and NGO´s has increased throughout Peru (Scurrah *et al.*, 1999). Currently, well over fifty biodiversity seed fairs are annually organized throughout the department of

Huancavelica alone. Typically a competition is central in the events as those participants who bring the largest number of cultivars are given a prize. Fairs are supposed to enhance the exchange of native cultivars among participants and visitors (Tapia, 2000; Tapia and Rosas, 1993).

Seed stress (scarcity) can be defined as the lack of sufficient quantities of seed of the desired quality or cultivars. Seed stress can be localized or regional, acute or chronic and caused by biotic or abiotic factors. However, potato seed stress in the Andes is generally localized, acute and caused by extreme weather events such as hail, frost or drought. On rare occasions acute seed stress may be a regional problem. Resilience refers to the seed systems ability to overcome seed stress, ultimately leading to a new equilibrium of desired seed stocks. Potentially, farmer responses to seed stress are diverse. Conventional channels of seed provision may be approached, including other farmers, markets or seed fairs. However, when seed stress is regional and severe, seed system interventions such as donations organized through government or development agencies may become increasingly important.

This article reports the functioning of farmer seed procurement of potatoes in a center of high infraspecific diversity (see: CIP, 2006). It particularly investigates the roles of farmer-to-farmer exchange, markets and seed fairs. Additionally, the study analyzes the impact of climate fluctuations in the form of out-of-season frosts on cultivar loss and seed procurement after seed stress (scarcity).

Materials and methods

A range of semi-structured surveys were applied in different communities within the department of Huancavelica, central Peru.

Survey of household seed exchange

A survey inquiring about 2003 and 2004 seed exchange (acquisition and provision) of native potato cultivars was conducted in 8 communities (n=125 households). Improved cultivars were not included in this particular survey. Each transaction was registered and detailed: cultivar composition, distance, volume, mechanism of exchange, source or destination. The 2002-2003 and 2003-2004 seasons were considered as "normal" production seasons by farmers: no severe regional events caused by drought, hail or frost had affected the potato crop.

Surveys of seed exchange at markets and seed fairs

In 2005, 9 regular markets in the department of Huancavelica were visited and 73 vendors surveyed (n=73). These markets were weekly and daily markets and selected on the basis of their regional recognized role as drivers of agricultural commerce. Individual transactions (n=183) involving seed provision during the 2005 dry season were detailed with vendors specifying cultivars and quantities sold. Additionally, between 2005 and 2006, 10 biodiversity seed fairs were visited and 76 participating farmers surveyed (n=76). The surveys inquired about all cultivar categories (improved, native-floury, native-bitter) and specific seed exchange transactions were detailed.

Survey of seed procurement after a severe frost

On February the 17th 2007 a severe frost affected potato cropping areas in central Peru (Los, 2007). It was an extreme and unusual event and as a consequence acute regional food and seed shortages were imminent. The central government declared Huancavelica, among other departments, an emergency zone. This created a special situation in which regional governmental offices received the mandate and resources to provide seed and food to the affected communities. This shock to the seed system presented itself as a natural experiment to understand resilience. A large survey was conducted at the start of the 2007 - 2008 cropping season to characterize potato seed procurement after the extreme event. The survey involved households (n=280) from 10 communities from central Huancavelica.

Results

Seed exchange during years without seed stress

Of the farmers (n=124) interviewed about seed exchange of native potato cultivars (both native-floury and native-bitter), 41.1 % indicated to exclusively use home-produced seed of native cultivars. The frequencies of partial seed stock renewal vary among farmers: 18.5% of the farmers renew part of their seed stock yearly, 17.7% every two years, 8.9% every three years, and 12.6% every four to six years. Complete renewal of seed stocks is uncommon, even of single cultivars. Households acquiring seed from elsewhere do so to add seed to their home saved stocks.

More households provided (42.4% in 2003, 52.8% in 2004) rather than acquired (21.0% in 2003, 29.6% in 2004) seed of native cultivars during both year of inquiry. The annual number of transactions involving provision was always higher compared to events involving acquisition. Most households acquiring seed did so only once a year (84.9%); only few households were involved in two (13.7%) or three (1.5%) annual transactions to acquire seed. While most households providing seed of native cultivars were only involved in a single annual transaction of provision (59.9%), a comparatively high proportion of households was involved in two (29.6%), three (8.8%) or four (1.8%) transactions. Farmers looked for seed of new (60.3%) or lost (41.1%) native cultivars, rather than for common cultivars already in stock (19.1%) when they acquire seed. Yet, when it came to provision, 67.6% of farmers provided commercial rather than uncommon native cultivars.

Quantities of seed acquired were relatively small with an average of 25.3 and 69.5 kg per household for 2003 and 2004 respectively (table 1). Depending on the community this represents a minimum of 0.8% and a maximum of 7.7% of the annual household need for seed. Between 86.2% (2003) to 96.2% (2004) of the acquisitions of native cultivars involved less than 100 kg. Quantities of seed provided were higher than those acquired, with an average of 372.7 and 489.0 kg per household for 2003 and 2004 respectively. Between 43.2% (2003) and 54.3% (2004) of the seed provisions of native cultivars involved more than 100 kg.

Table 1. Quantities of seed of native potato cultivars acquired and provided by households

Year	Flow	N	Distribution: volume exchanged (%)						Weight (kg)			
			< 5 kg	5-25 kg	25-100 kg	100-500 kg	500-1000 kg	> 1000 kg	Av.	SD (±)	Min	Max
2003	Acquired	27	29.6	37.0	29.6	3.7	-	-	25.3	28.0	0.5	120
	Provided	51	2.0	17.6	37.3	27.5	11.8	3.9	372.7	977.2	3.0	6700
2004	Acquired	36	16.7	41.7	27.8	11.1	2.8	-	69.5	134.9	0.4	600
	Provided	59	1.7	10.2	33.9	39.0	11.9	3.4	489.0	1826.8	2.0	14000

The average number of native cultivars being exchanged by households as seed was relatively low (table 2). In 2003 surveyed households (n=125) acquired and provided a total of 25 and 28 different cultivars while in 2004 households acquired and provided 57 and 34 different cultivars respectively. During both years most cultivars showed low frequencies of exchange and were consequently only acquired or provided by a single household (table 3). These were generally non-commercial native-floury cultivars preferred for home consumption. Without exception those native cultivars with high frequencies of exchange were well-known cosmopolitan cultivars for renewal of commercial seed stocks.

Table 2. Average number of native cultivars exchanged per transaction

Year	Flow	N[1]	Av.	SD (±)	Min.	Max.[2]
2003	Acquired	27	3.7	3.7	1	10
	Provided	53	5.8	3.8	1	10
2004	Acquired	36	3.5	2.5	1	10
	Provided	66	5.4	3.7	1	10

[1] = number of registered transactions; [2] = based on average cultivar content of complete cultivar mixtures (*chaqru*)

Table 3. Total number of native cultivars exchanged by relative frequencies of exchange

Frequency	2003				2004			
	Acquired		Provided		Acquired		Provided	
	No.	%	No.	%	No.	%	No.	%
Low freq. of exchange (1)	17	68.0	12	42.9	39	68.4	17	50.0
Medium freq. of exchange (2-5)	7	28.0	9	32.1	13	22.8	9	26.5
High freq. of exchange (>5)	1	4.0	7	25.0	5	8.8	8	23.5
Total	25	100	28	100	57	100	34	100

Family members and farmers, as well as regular markets and yearly agricultural fairs, were reported to be important sources and destinations for seed exchange of native cultivars during both periods of inquiry (table 4). Farmers did not consider governmental and development organization important sources of seed during these years without regional seed stress. Exchange through sales was the most frequently used mechanism of seed acquisition and provision, followed in importance by presents, barter and payment in kind (fig. 1). Other mechanisms such as loans to and from other farmers or donations from organizations were infrequent. Sales generally involved larger volumes of a limited number of cultivars while presents mostly related to small volumes containing diverse cultivars.

Table 4. Commonly used sources for seed exchange of native potato cultivars (n=72)

	Acquisition (%)	Provision (%)
Family member from the same community	27.8	43.1
Farmers from the same community	18.2	27.8
Farmers from other communities	22.2	26.4
Regular markets / agricultural fairs in other communities	44.4	43.1
Seed company	2.8	-
Others	2.8	1.4

Most of the 2003 (85.7%) and 2004 (74.4%) seed acquisitions originated from within the provincial boundaries of the 7 provinces that constitute the department of Huancavelica. A similar pattern can be observed for seed provision with 84.6% and 88.8% of the 2003 and 2004 transactions ending up within the province where the seed had been produced . On average only 11.8% of the transactions passed provincial limits, yet remained within the department of Huancavelica. Exchanges exceeding departmental boundaries only represented 6.5% of the total number of transactions. On average seed flows covered distances ranging between 15.2 and 49.4 km, depending on the process (acquisition or provision) and year (2003 or 2004). Yet, when looking at frequencies (%), most transactions covered less than 25 km (table 5). Only 5.5% of the total number of seed exchanges covered right-angle distances of more than 100 km.

Table 5: Distances (right-angle) covered by individual seed flows

Year	Process	N	Distribution: distances seed exchange (%)						Distance (km)			
			< 1 km	1-5 km	5-25 km	25-100 km	100-200 km	> 200 km	Av.	SD (±)	Min	Max
2003	Acquired	29	41.4	6.9	34.5	17.2	-	-	15.7	25.7	0.2	98
	Provided	79	26.6	7.6	50.6	11.4	2.5	1.3	18.0	36.4	0.2	258
2004	Acquired	44	29.5	6.8	43.2	4.5	9.1	6.8	49.3	112.5	0.2	528
	Provided	96	29.2	2.1	55.2	11.5	2.1	-	15.2	21.9	0.2	134

The role of regular markets

A range of vendors (n=73) at daily and weekly regular markets were interviewed, including wholesalers (38.4%) and retailers (61.6%). Wholesalers were typically able to provide at least a quarter of a ton of potatoes if demanded while retailers provided relatively small quantities. Overall, 68.8% of vendors were also potato producers. An average of 23.3% of vendors only sold potatoes they themselves produced, while 39.7% only traded potatoes they bought from other farmers and 37.0% provided both self-produced and purchased potatoes. An average of 61.1% of vendors sold potatoes produced in the department Huancavelica. The proportion of produce from Junín was appreciable with an average of 38.9% of vendors providing potatoes originating in this department.

An average of 63.0% of the vendors sold both improved and native cultivars while only 34.2% and 2.7% sold exclusively improved or native cultivars respectively. The total infraspecfic diversity offered at regular markets was relatively low with an average of 4.6 and a maximum of 8.0 cultivars per vendor. The most commonly available cultivars, both in terms of volume and number of vendors offering them, were: *Yungay*, *Canchan*, *Larga*, *Wayru*, *Amarilla Runtus*, *Andina*, *Perricoli*, *Camotillo* and *Peruanita*. An average of 11.1% of the vendors sold complete cultivar mixtures (*chaqru*). Depending on the cultivar, average prices fluctuated between 0.55 and 1.80 Peruvian Soles per kg (0.17 - 0.54 US dollars in the survey year). Few vendors (1.4%) also offered fresh (non-processed) tubers of native-bitter cultivars.

Vendors recalled seed transaction on the basis of demand: transactions based on the client explicitly requesting seed instead of consumption potatoes. Depending on the market, 46.7% to 100% of the vendors sold potato seed in addition to trading consumption potatoes. Averaged over all markets, 63.0 % of the vendors sold seed. The Saturday market in Yauli was the only exception as none of the vendors sold seed. Those vendor who did sell seed during the 2005 dry season, did so providing seed to an average of 8.8 (± 6.4) farmers (min. 1 / max. 25). Most vendors (66.7%) typically provided less than 50 kg of seed per individual transaction while only few vendors provided between 50 to 100 kg (20.0%) and 100 to 500 kg (11.1%). Sales involving more than 500 kg of seed were uncommon (2.2%).

An average of 56.4% of the vendors exclusively sold tubers of consumption potatoes as seed without any kind of selection or formal guarantee. A small number of vendors (15.4%) exclusively offered selected tubers of what is commonly known as "*semilla común*" (common seed: reselected tubers from stocks of consumption potato without any guarantee accrediting quality). Selection of "*semilla común*" is predominantly based on tuber-size and external (visible) seed health. An average of 28.2% of vendors sold both consumption potatoes and selected tubers as seed.

A total of 389 individual seed transactions from 46 vendors to farmers were registered; 183 were detailed by vendors (table 6). The transactions detailed involved more than 27 cultivars (8 improved; 19 native-floury including *chaqru* mixtures) and a total volume of 57,392 kg (36,617 kg improved; 20,775 kg native-floury). These transactions, to be used for the 2005-2006 agricultural season, served a total of 63 farmer communities covering all 7 provinces of the Huancavelica department. Extra-departmental seed flows from regular markets in Huancavelica were limited, representing only 2 out of 63 registered destinations and 4.0% of the total number of transactions.

The details of seed transactions show that native-bitter cultivars were not traded as seed (no transaction were registered). The 8 cultivars offered by most vendors (> 10%) are well-known cosmopolitan improved (4) and native-floury (4) cultivars which are also commonly found in urban markets of Huancayo and Lima. The number of transactions involving seed sales of these cultivars and the quantities sold are considerably higher compared to the other cultivars. Out of the 15 cultivars offered by very few vendors (< 5%), 12 are little-known native-floury cultivars of regional importance. The other 3 are improved cultivars which have gone out of demand as commercial ware potatoes (*Renacimiento*, *Revolución*) or have only been released recently (*Unica*). Only a single transaction was registered for 10 out of the 15 cultivars offered by few vendors. In all cases their traded volume was relatively low compared to cosmopolitan cultivars. The foregoing indicated that only limited infraspecific diversity is being offered at regular markets, with few samples and small quantities of little-known cultivars being traded infrequently by selected vendors. An interesting exception are the complete cultivar mixtures (*chaqru*). *Chaqru* seed was offered by 9.3% of the vendors, involving 10 transactions averaging 128 kg each.

Table 6. Details of individual seed transactions (n=183)

Cultivar	%[1]	Cultivar Category		No. specific transactions registered (n)	Amount Sold (Kg.)			
		IC[2]	NFC[3]		Av.	SD (±)	Min.	Max.
‘Amarillis’	14.0	X		7	371	243	100	700
‘Amarilla Runtus’	7.0		X	12	169	145	50	500
‘Andina’	14.0	X		10	573	1207	80	4000
‘Ajo Suytu’	2.3		X	3	163	118	90	300
‘Camotillo’	18.6		X	6	198	172	40	500
‘Canchan’	58.1	X		26	620	1569	50	8000
‘Casa Blanca’	2.3		X	1	100	-	-	-
Chaqru (*)	9.3		X	10	128	71	30	200
‘Chaulina’	2.3		X	1	50	-	-	-
‘Chunya’	4.7		X	1	24	-	-	-
‘Huanuqueña’	2.3		X	1	50	-	-	-
‘Kuchipa Akan’	2.3		X	1	18	-	-	-
‘Larga’	51.2		X	24	183	200	30	800
‘Perricholi’	7.0	X		4	145	95	50	250
‘Peruanita’	30.2		X	20	324	462	40	2000
‘Puqya’	2.3		X	2	38	3	36	40
‘Renacimiento’	2.3	X		1	40	-	-	-
‘Revolución’	2.3	X		1	200	-	-	-
‘Saco Largo’	2.3		X	1	200	-	-	-
‘Traqin Waqachi’	4.7		X	4	110	60	80	200
‘Tumbay’	2.3		X	2	250	212	100	400
‘Unica’	2.3	X		1	900	-	-	-
‘Villa’	7.0		X	2	95	7	90	100
‘Wayru’	18.6		X	12	299	614	30	2200
‘Wayta Chuko’	2.3		X	1	40	-	-	-
‘Witqis’	2.3		X	2	16	20	2	30
‘Yungay’	62.8	X		27	372	773	12	4000

[1] = percentage of vendors selling the particular cultivar; [2] = improved cultivars; [3] = native floury cultivars; * *Chaqru* = a mix of native-floury cultivars

The role of seed fairs

Every year numerous quite festive biodiversity seed fairs are organized throughout Huancavelica. Of the interviewed farmers who participated in the 10 fairs that this study looked at, 21.9% participated for the first time, while 46.6% had participated for at least four or more years in the same fair. While 28.8% only participated in a single fair a year, many participated in two (32.9%), three (13.7%), four (16.4%) or more (8.2%) annual seed fairs. About three quarters of the farmers (72.6%) knew some of the other participants at the same fair and most of these (69.9%) returned on a yearly basis, suggesting that participants are a select group of farmers who are well-known to each other. This impression is supported by the finding that most farmers (61.6%) considered that only few new participants were observed at the fairs. Farmers knew about the event because they received an invitation (82.2%), heard about it on the radio (31.5%), were notified by other farmers (12.3%) or neighbors (4.1%), or remembered the place and date from previous years (1.4%). Farmer’s personal motivations to participate in fairs were diverse and included: demonstrate their cultivars (45.2%), recognition for the home community (32.9%), win a prize (27.4%), personal recognition (21.9%), comply with invitation (19.2%), obtain new cultivars (15.1%), obtain new knowledge (11.0%), and recognition for the family (6.8%).

Of the farmers interviewed, 68 participated with native potato cultivars only whereas 5 farmers exclusively participated with improved cultivars. Participants typically showed 5 to 10 tubers of each cultivar. Farmers participating with native cultivars (n=68) on average presented 123 cultivars per family collection (n=68). Few farmers presented less than 25 cultivars (4.4%). Other farmers presented 25 to 50 (29.4%), 50 to 100 (26.5%), or 100-200 distinct cultivars (25.0%). A select group of farmers (14.8%) presented family collections consisting of more than 200 cultivars. A total of 86.0% of the respondents indicated that their cultivar variability was a family inheritance while only 14.0% had obtained most cultivars through exchange.

Participant perception indicates that seed exchange at the seed fairs is not common; 60.0% considered that none, 23.3% that few and only 15.7% that some farmers exchange seed at the events. A total of 14.3% of respondents indicated that biodiversity seed fairs could potentially be important events for exchange, but that in practice this does not occur because of competition. An average of 76.6% of respondents considered that farmers participating in the fairs are generally "*celoso*" (jealous) with their seed, meaning that these farmers will not exchange in order to maintain a comparative advantage over other competitors and thereby increase their likelihood to win a prize. When asked about their willingness to exchange seed, 37.7% indicated they would not exchange seed of any cultivar, 23.2% they would be willing to exchange any of their cultivars, and 39.1% they would only exchange well-known cultivars.

An average of 21.1% of participants had acquired seed while 27.8% had provided seed at the 10 fairs where surveys were conducted. Depending on the fair, the percentage of farmers having acquired or provided seed fluctuated between 0 - 66.7% and 0 - 50.0% respectively. Not only do few farmers exchange seed, those who exchange generally do so with few cultivars (av. 5.3, min. 1, max. 10) and small volumes (1 to 5 tubers or 1 to 12 kg per cultivar). Most look for new cultivars at the fairs. An average of 35.6% of participants indicated that the fairs had allowed them to increase cultivar diversity. The most common mechanism of exchange was through sales, followed by barter. A few farmers (4.2%) also mentioned they would try and steal some seeds if they could.

Impact of frost and responses to seed stress

The severe frost that affected the central Peruvian highlands on February the 17th 2007 caused significant crop damage in Huancavelica. In the surveyed communities the frost affected 92.6 to 95.8% of the potato fields. The measured minimum temperature was -4ºC. Fields on flat, non-sloping terrain were particularly hard hit as cold air tends to go downhill and settle where it reaches valley bottoms. Regional levels of yield reduction ranged from a minimum of 70.4% (native-bitter cultivars) to a maximum of 77.2% (mixed stands of native-floury cultivars) showing that general differences between the cultivar categories was minimal.

An average of 75.1% of farmers reported cultivar loss. Loss varied for the different cultivar categories, ranging from 15.4% for native-bitter cultivars to 69.3% for native-floury cultivars, indicating that cultivar loss was proportionally more severe for the diverse cultivar category of native-floury cultivars. On average farmers lost 4.7 cultivars. The average number of cultivars lost was higher for the category of native-floury cultivars (4.3 cultivars lost) compared to improved and native-bitter cultivars (1.3 and 1.2 cultivars lost respectively). Farmers prioritized 5 main reasons for cultivar loss (n=241): cultivars were installed on flat terrain (71.8%), cultivars were susceptible to frost (55.2%), cultivars were already scarce and not abundant in fields (11.2%), cultivars were installed at exceptionally high altitude (10.0%), and the frost was exceptionally severe (6.2%).

An average of 23.3% of farmers lost all potato seed (table 6.14). However, levels of total seed loss differed considerably by community. While a majority of the farmers (69.2%) from the community Pucara lost all their seed none of the farmers from Huachua suffered the same fate. For those farmers who were able to save seed, the volumes stored were low compared to normal years. Overall, farmers only saved about a quarter (25.2%) of the amount of seed they would store during a normal year, evidencing severe seed stress. A total of 97.8% of the farmers also indicated that the frost had affected seed quality: smaller seed size (71.2%), rotting (19.6%), tuber skin damage (11.1%), blackening (5.9%) and higher levels of damage from larvae of Andean weevil (5.5%; *Premnotrypes* spp.) were reported. The later is a consequence of farmers having limited choice and therefore having to include seed with recognized pest damage.

High levels of yield reduction together with cultivar loss explain the need for farmers to acquire seed. A total of 83.2% of the families interviewed for the survey (n=279) had been able to acquire potato seed. An average of 42.5% of combined seed acquisitions for individual households was exclusively coordinated by men, 17.4% exclusively by women and 40.1% by both sexes. Of those farmers having reported cultivar loss 23.6% had not been able to recuperate any of the lost cultivars for the next planting season, 75.3% had recuperated some cultivars, while only 1.1% had been able to acquire all the cultivars they lost.

On average households acquired seed from 2.3 (± 1.3) different sources; some had acquired seed from up to 9 different sources. Table 7 provides an overview of the relative importance of specific mechanisms of seed acquisition in 2007 after the frost: donations, monetary acquisition and non-monetary acquisition. Seed from government donations were the most important source of seed in terms of the number of families having benefited from this mechanism (42.9%), followed in importance by monetary acquisitions from regular markets, monetary acquisitions at agricultural fairs, and non-monetary acquisitions through *minka* (payment in kind). It is interesting to note that each of the ten communities had its own unique portfolio and combinations of mechanisms for seed acquisition. While some mechanism were of no importance in some communities they were relevant in others.

The volume and cultivar content of 574 individual seed acquisitions realized by 253 different households was registered. Table 8 shows summarized information of the quantities of seed acquired per event of exchange. Very few transactions involving native-bitter cultivars were registered, affirming that sources of supply of this cultivar category are scarce. Each seed acquisition involved on average 66 kg. Yet, a high standard deviation indicates that there were considerable differences in the quantities of seed exchanged per transaction. Overall, farmers acquired slightly more seed of native-floury cultivars (279 transactions; av. 81 kg / transaction) as compared to improved cultivars (286 transactions; av. 53 kg / transaction). Differences between communities concerning the average amount of seed acquired per transaction were modest; the community of Sotopampa was the only notable exception.

Most households acquired seed of diverse cultivar categories: improved and native-floury cultivars. The registered acquisition of improved cultivars was limited to 5 cultivars: *Yungay* (58.5%), *Canchan* (27.6%), *Perricholi* (12.2%), *Tomasa* (1.0%) and *Mariva* (0.7%). Farmer acquisition of native-bitter cultivars was rare and only involved 2 cultivars: *Siri* (55.6%) and *Manwa* (44.4%). The acquisition of native-floury seed was characterized by higher levels of diversity with 40 cultivars registered. As expected, common commercial cultivars were most commonly acquired: *Larga* (23.9%), *Wayru* (7.4%), *Peruanita* (7.0%) and *Amarilla Runtus* (6.0%). The acquisition of mixed seed lots (*chaqru*) represented only 7.0% of the total number of individual seed acquisitions of native-floury cultivars. The average total number of cultivars acquired per household was 3.0 (± 2.8;). This means that although most farmers were able to acquire seed, the overall diversity acquired was modest with relatively few farmers having obtained mixed seed lots and the overall acquired diversity consisting of few distinct cultivars. Nevertheless, most farmers (41.7%) did acquire seed of different cultivar categories; improved cultivars predominantly via donations and native-floury cultivars through monetary acquisitions at markets and fairs or through *minka*.

Table 7. Relative importance (*) of different mechanisms of seed acquisition between May - December 2007, right after the season with severe frost

Community	N¹	Donation (%)			Monetary Acquisition (%)					Non-Monetary Acquisition		
		GO	NGO	Family	Regular Markets	Agricultural Fairs	Family	Farmer from the community	Farmer from another community	Loan	Barter	*Minka*: payment in kind
Pucara	26	35.7	-	-	17.9	67.9	-	3.6	3.6	-	-	-
Villa Hermosa	19	68.4	-	10.5	-	78.9	-	-	-	-	-	-
Chuñunapampa	20	60.0	5.0	-	30.0	15.0	5.0	-	-	5.0	-	40.0
Sotopampa	25	96.0	16.0	-	4.0	-	16.0	12.0	4.0	-	8.0	40.0
Ccasapata	24	59.1	4.5	-	40.9	-	18.2	13.6	4.5	-	-	18.2
Santa Rosa	25	-	-	-	4.0	28.0	24.0	4.0	-	-	-	44.0
Ccollpaccasa	25	4.0	4.0	-	40.0	48.0	12.0	12.0	4.0	-	-	8.0
Huachua	22	59.1	4.5	-	40.9	4.5	22.7	4.5	-	-	-	45.5
Chopccapampa	50	12.0	2.0	-	86.0	4.0	6.0	26.0	2.0	-	6.0	-
Limapampa	25	80.0	8.0	-	24.0	32.0	20.0	4.0	8.0	-	-	36.0
Overall	*261*	*42.9*	*4.2*	*0.8*	*34.5*	*25.7*	*11.9*	*10.0*	*2.7*	*0.4*	*1.9*	*20.7*

* = the percentage of households having acquired seed through any of the specific mechanisms; ¹ = No. of households

Table 8. Quantities of seed exchanged per acquisition between May - December 2007, right after the season with severe frost

Community	Potato overall (kg)					Improved cultivars (kg)					Native-floury cultivars (kg)					Native-bitter cultivars (kg)				
	N¹	Av.	SD	Min.	Max.	N¹	Av.	SD	Min.	Max.	N¹	Av.	SD	Min.	Max.	N¹	Av.	SD	Min.	Max.
Pucara	50	52	35	10	155	45	51	35	10	155	5	60	38	25	100	0	-	-	-	-
Villa Hermosa	60	55	31	10	150	43	55	31	10	150	17	55	32	10	100	0	-	-	-	-
Chuñunapampa	38	66	64	2	350	13	64	38	15	150	24	69	76	2	350	1	15	0	15	15
Sotopampa	50	188	686	5	3500	31	49	58	5	285	19	413	1090	5	3500	0	-	-	-	-
Ccasapata	42	49	34	1	150	20	58	32	10	150	21	39	32	1	100	1	100	0	100	100
Santa Rosa	58	46	24	5	150	6	38	18	15	50	51	48	25	10	150	1	10	0	10	10
Ccollpaccasa	76	53	50	5	250	21	45	39	5	150	50	57	56	5	250	5	46	9	30	50
Huachua	63	75	183	3	1000	16	43	35	5	100	47	86	210	3	1000	0	-	-	-	-
Chopccapampa	91	55	47	5	200	61	63	48	5	200	30	40.0	41	5	150	0	-	-	-	-
Limapampa	46	40	35	5	200	30	46	38	10	200	15	31	26	5	100	1	5	0	5	5
Overall	*574*	*66*	*216*	*1*	*3500*	*286*	*53*	*41*	*5*	*285*	*279*	*81*	*307*	*1*	*3500*	*9*	*40*	*29*	*5*	*100*

¹ = Number of individual seed acquisitions

Conclusions

During years without extreme regional events affecting the overall productivity of potato, seed acquisitions of native cultivars are characterized by transactions involving small quantities of seed, few cultivars, few events of exchange, and movements of seed over short distances within communities and provinces. Annual seed acquisitions of native cultivars were practiced by 25% of the households. So, most households exclusively use home produced seed of native cultivars while those acquiring seed do so to partially renew their seed stocks. About half (48%) of the households in the studied communities provide seed and do so more frequently than acquiring seed. Seed provisions also involve larger volumes and distances compared to seed acquisitions. All this suggests that high-altitude and diversity-rich communities are net seed exporters rather than importers of native cultivars during normal years. Seed acquisitions and provisions during normal years typically involve diverse sources including markets, fairs, family and other farmers rather than governmental or non-governmental agencies. Exchange through sales is predominant, but transactions through barter, gifts and payment in kind are also important. It is likely that the socioeconomic conditions of farmers in terms of poverty and availability of cash influence the seed exchange mechanisms they can access.

Even during normal years, uncommon native cultivars are exchanged infrequently and only few farmers provide them. The former contradicts common farmer interest as many look for new or lost cultivars rather than for common cultivars already in stock. It also contradicts the common notion that informal networks of seed exchange are very dynamic. Collectively, communities in Huancavelica maintain at least 500 genetically and morphologically distinct native cultivars (see: CIP, 2006; De Haan, 2009). The maximum total annual regional amount of distinct cultivars being exchanged was 57 (seed acquisition 2004); this translated into 11% of the total cultivar diversity. Most are native-floury rather than native-bitter cultivars. The latter are almost exclusively maintained and reproduced at the household level. Uncommon native-floury cultivars are not actively marketed by farmers who maintain them. However, households wishing to acquire diverse native-floury cultivars have a chance to do so when they know the right specialist channels, such as vendors providing *chaqru* at markets or farmers willing to exchange. The participation of the formal regulated system in seed exchange of native cultivars is minimal. This study shows that the efficiency of the farmer seed system in terms of its capacity to annually widely supply and distribute infraspecific diversity is restricted. However, in the long run, the farmer seed system generally seems efficient at maintaining overall infraspecific diversity at the household level. This is supported by the fact that no evidence of genetic erosion exists and that farmers in Huancavelica still maintain early-generation improved cultivars disseminated in the 1950's.

Regular markets typically provide relatively large volumes of seed of selected improved and native-floury potato cultivars rather than infraspecific diversity. Exchanges of these well-known cultivars are frequent and involve large quantities. Market originating seed flows have a wide outreach, covering all provinces within Huancavelica. Indeed, the strength of regular markets as seed suppliers resides in their decentralized capacity to supply and widely distribute selected cultivars with commercial demand while their weakness resides in the limited infraspecific diversity and quality guarantee they offer. Uncommon cultivars are typically only offered by a few vendors while their transactions are infrequent involving small quantities of seed. Complete native-floury cultivars mixtures (*chaqru*) are offered by a few selected vendors while seed of native-bitter cultivars are generally unavailable. Regular potato markets in the rural areas of central Peru are mostly consumption markets rather than specialized seed markets.

Biodiversity seed fairs are an institutional innovation which potentially changes the way in which transactions occur. The original intention of the fairs was to enhance broad diffusion of native cultivars among farmers. Indeed, contemporary fairs almost exclusively target native-floury and native-bitter cultivars. However, findings of this research suggest that the biodiversity seed fairs are not necessarily doing what they were designed for. Participation at the fairs is often restricted to a select group of recognized farmers. Seed exchange is not an important motive for farmers to participate. Rather, it is prestige, recognition or the possibility of winning a prize which motivates participants. In practice, the frequencies of seed exchange are low. Not only do few farmers exchange seed, those who exchange generally do so with a few uncommon cultivars and small volumes. The number of cultivars and volumes exchanged, though potentially interesting for a collector, are generally not significant for those wishing to acquire seed for planting large areas. The strength of biodiversity seed fairs resides in the impressive amount of native cultivars farmers put on display. Seed fairs are an excellent thermometer to monitor overall genetic diversity. Yet, their weakness resides in selectiveness toward individuals rather than farmers communities and incapacity to create an environment which stimulates seed exchange.

Organizers of fairs could promote wider participation and seed exchange by emphasizing the participation of communities rather than individual farmers, including indicators of seed exchange into the evaluation criteria, and by providing incentives for most participants rather than for the top-three "conservationist" farmers alone.

Inquiry into the dynamic seed system response to seed stress provides diverse lessons. The 2007 February frost severely affected productivity of the potato crop and led to seed stress as a result of the loss of cultivars and acute shortages of planting material. Cultivar loss was predominantly a consequence of severe crop failure rather than farmers not being able to save seed from being consumed. Contrary to normal years, when seed acquisitions from governmental organizations were of little importance for farmers, state-organized donations were regionally the most important source of seed after the frost. Governmental organizations reached numerous communities and households with donations. This in itself does not necessarily imply that the farmer seed system was unable to cope with seed stress. Rather, it reaffirms that external emergency interventions often assume that seed availability is the main problem after a severe shock, discounting the possibility that local channels can supply good quality seed (McGuire, 2007). In practice, regular markets, agricultural fairs, payment in kind (*minka*), acquisitions from family and community members remained important sources of seed. These sources are also commonly used during normal years, but became more important during the period with seed stress. Each community showed a unique portfolio and combination of mechanisms of seed acquisition. Indeed, in all communities a diversity of mechanisms were employed to regain seed. Considering the regional shortage of planting material, the frequency of seed exchanges and sources used suggest impressive resilience of the farmer seed system. The system was, at least partially, able to attend local demands within the first year after the stress and restore part of the cultivar portfolios of individual households.

An average farmer in the studied communities annually dedicates an area of 5,609 m² to potatoes (see chapter 4). This translates into a minimal annual demand of 1,400 kg of seed. In 2007, after the season with severe frost incidence, the average household only saved 25.2% of the potato seed they would normally store. This means a minimum of 350 kg per household and an average household deficit of 1,050 kg. On average households acquired seed from 2.3 different sources, exchanging 66 kg per transaction. The average household thus acquired 152 kg of seed, leaving an overall deficit of 898 kg representing 64% of the total demand. This simple calculation shows that for many households the amount of seed acquired after the frost must have been insufficient to meet the normal demand, even though the real seed deficit may have been less and differences between households exist. This suggests that both the government donations and the regional farmer seed system were both unable to provide sufficient quantities of seed. In addition, government and other organizations donated mostly seed of improved cultivars Information about seed quality and exact origin was not available to farmers. The government's incapability to provide farmers with clear information about the origin of donated seed fomented suspicions from farmers. Resilience of the farmer seed system was incomplete as households were only able to restore part of their original seed stocks, both in terms of volumes and cultivar portfolios. Indeed, several seasons may be needed for households to fully recover their seed stocks. This also means that repeated regional shocks may impede the seed system to fully recover.

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Are viruses important in Native Seed Systems in Huancavelica, Peru?
Viruses and Andean Potato Seed Systems

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Abstract

The Huancavelica region is a hotspot for cultivated potato genetic diversity; De Haan (2009) has recently characterized 3481 accessions belonging to 38 farming families in a cross section of the region, of which 557 were unique cultivars on morphological grounds and 406 unique cultivars based on fingerprints.

To understand how potato varieties are maintained through time and to direct efforts to improve seed, a study in the community of Ccaspata, ranging from 3700 to 4000 m.a.s.l. and part of the larger community of Chopcca, has identified the main viruses harbored in the local varieties and has attempted to quantify their effect on yield. The main findings in this community are that virus free plants are detected in a significant proportion (40%), the main viruses being PVX, PVS, APMV and APLV whereas PVY and PLRV were found in very low frequencies. When varieties rated positive were compared with varieties rated free only virus S showed yield loss. The large quantity of varieties maintained by farmers makes it difficult to differentiate if the varieties are tolerant or if the viruses are "soft" and do not produce severe yield loss. 100% of all plants of some varieties were found to be completely free of all virus such as Puca Huayro (S.Chaucha), while with others, such as Azul Qanchillo, (S. juzepsukii) no plant free of virus was detected.

Introduction

The knowledge that viruses are mainly seed-transmitted and therefore responsible for seed degeneration has influenced how modern Potato seed is produced. The key to this system is that clean plants (virus and pathogen free) are kept in vitro in laboratories and, when needed, are multiplied first in greenhouses to obtain minitubers, which are again multiplied over two more field generations specifically for seed purposes from which certified seed is obtained. It is often argued that low yields obtained by subsistence farmers of native varieties is due to the virus load the seed carries, and much effort is invested in providing small farmers with clean seed, some of which are cleaned up in the laboratories where they are kept and distributed. Highland potato growers are urged to join the modern seed technology system, called "flush out system", where seed always starts in a laboratory and goes through several years from seed to eventually only for eating and thus it never returns as seed. For the first generation greenhouses are established, and there are now several located in high Andean communities. Few native varieties, mainly those linked to a growing market of colored chips, are now available for this kind of seed multiplication scheme. They were given a "special dispensation" by INIA and SENASA (the national research and plant health Institutes) and were entered in the official potato variety registry. The vast majority of native varieties, about 2 to 3 thousand (Tapia 2008), are excluded from the varietal registry a prerequisite for seed certified schemes, however, it is these varieties which sustain the livelihood of highland potato farmers a rough estimate is 160,000. (www.papa Andina)

In the Chopcca community the district of Yauli in Huancavelica Peru, almost all seed planted originates from their own saved seed store, and they differentiate between food and seed only after harvest. A small percentage of their seed is obtained from their neighbors, relatives and local markets. (de Haan 2009) The objective of this study was to identify the health status of their commonly used seed, and to assess the yield differences between virus-free and virus-infected plants in the same varieties. Modern laboratory assays to identify virus make these studies possible. Most yield loss studies have been carried out outside the country and those in Peru only on improved varieties, so there is very little knowledge of the effect of viruses on the yield of native varieties, owing perhaps to the fact that there are numerous varieties being grown, that these are maintained at the family level and mostly grown as mixtures in the same field (De Haan 2009 Jackson1980). These fields with varietal mixtures are called Chaqro. (Chaqro).

Material and methods

Assessment of Virus Infection in Seed in Chopcca: A seed fair was held in Ccasapata in September of 2006, 42 families donated seed for a future "seed bank". Varying numbers of tubers of 82 varieties were planted the following growing season in observation plots in a communal field in Ccasapata at 3, 800 m.a.s.l. When plants emerged 834 leaf samples were collected and ELISA tests (Enzyme-linked immunosorbent Assay) performed for 6 virus (PVY, PVX, APMoV, PVS, APLV, and PLRV) in CIP's virology laboratory.

All varieties were harvested and stored separately according to variety and virus status. Varieties that had enough seed to plant in a replicated trial (minimum of 15 tubers of clean vs. 15 infected) were planted in a balanced designed with three replicates, where each block had two subplots, clean and infected. This trial was planted in Ccasapata in November 2008, this time in a field at 3900 m.a.s.l., and harvested in May 2009. Twelve varieties and four virus status were selected for this trial (Table 1). Leaves of all plants were again sent to CIP's virology laboratory to confirm their status as "clean" or infected in February of 2009.

Table 1. Virus free and infected varieties from Ccasapata grown in trial in the 2008-9 growing season

Treatment Nº	Cultivar	Clean	infected PVX	infected PVS	infected APMoV	infected APMoV + PVS
1	Occe ruiro	15			15	
2a	Ccori marquina	15			15	
2b	Ccori marquina	15		15		
3	Cuchillo Paqui	15			15	
4	Promesa	15			15	
5	Ccollce tupo	15			15	
6	Yuraq tucco **	15				15
7	Llunchuy waqachi	15	15			
8	vaquilla wacran	15	15			
9	Taragallo	15	15			
10	Puqya	15	15			
11	Occe palta	15	15			
12	Yuraq sari- huasahuasina	15		15		

Results and discussion

Virus Infection: Table 2 gives the viruses identified in 834 plants comprising 82 varieties grown in the 2007-8 season from seed donated by 42 families of the Community of Ccasapata

Table 2. Virus identified in 82 Native Varieties from Ccasapata 2008

VIRUS (1)	Nº SAMPLES	%	VIRUS (2)	Nº SAMPLES	%	VIRUS (3)	Nº SAMPLES	%	TOTAL
Virus free	**340**	**40.8**							
PVX	263	31.5	PVX+APLV	25	3.0	PVX+APLV+APMoV	2	0.24	
PVS	52	6.2	PVX+PVS	24	2.88	PVX+PVS+APMoV	2	0.24	
APMoV	46	5.5	PVX+APMoV	20	2.40	PVX+PLRV+APMoV	2	0.24	
APL.	22	2.6	APLV+APMoV	12	1.44	PVX+PLRV+APLV	2	0.24	
PVY	**4**	**0.5**	PVS+APMoV	7	0.84	PVX+PLRV+PVS	1	.12	
PLRV	**2**	**0.2**	PVX+PVY	2	0.24				
			PVX+PLRV	2	0.24				
			PLRV+APMoV	1	0.12				
			PLRV+PVS	1	0.12				
			PVY+APMoV	1	0.12				
			PVS+APLV	**1**	**0.12**				**834**
TOTAL	**729**	**87.41**		**96**	**11.51**		**9**	**1.08**	**100%**

The data on virus infection obtained from leaves collected in the 2007-8 growing season from 82 varieties, originally obtained at the seed fair from 42 families and processed in the CIP laboratories is notable: firstly, no virus was detected in a large number of plants (40%) , secondly, a negligible presence of the two most serious potato viruses, PVY and PLRV, , was identified; and, finally, no virus was detected in six varieties, that is, they seemed to be virus free. (Table Nº3). The most prevalent virus by far was PVX (31%) while PVS and APMoV (Andean potato mottle virus) were similar in prevalence 5.5% and 6.2%, respectively. APMoV is vectored by plant-to-plant contact and the cucumber beetle *Diabrotica* spp. also seems to play an important role (L. Salazar, 1995). Andean Potato latent Virus (APLV) was found only in four plants. Around 100 plants (12%), were infected with two viruses simultaneously, mostly PVX combined with a second virus. Only 9 plants (1%) were infected with three viruses simultaneously. The results in Ccasapata were similar to those published by De Haan (2009) who sampled 22 farms in 8 communities (1317 samples) and found that PVY and PLRV were present in low frequencies. The most prevalent virus was also PVX and APMoV was found in third position similar to ours. He concluded that the most serious virus (averaging 18%) was precisely APMoV. PVS, which is also mechanically transmitted was included in our study (but not in De Haan´s) and was also found to be prevalent.

Table 3. Varieties where no virus infection was detected

Ccoepa Sullun
Cuchipa Acan
Botijuela
Yana Botijuela
Liberteña *
Puca Huayro

* improved variety

Yield Trial: 2008-9

The overall effects on yield, tuber numbers, and tuber size are given in tables 4, 5 and 6

Table 4. Effects of three viruses on yield (g/plant) in 12 cultivars

	Variety	N	Infected Average	Healthy average	Simple effects Pr > F	Virus
1	Occe ruiro	3	1320	880	**	APMoV
3	Cuchillo paqui	3	1027	840		APMoV
4	Promesa	3	1391	851	**	APMoV
5	Ccollce tupo	3	1485	1195		APMoV
6	Yuraq tucco	3	1334	1151		APMoV + PVS
7	Llunchuy waccachi	3	995	665	*	PVX
8	vaquilla wacran	3	1020	702	*	PVX
9	Taragallo	3	865	978		PVX
10	Puqya	3	586	606		PVX
11	Occe palta	3	1200	1082		PVX
12	Yuraq sari- huasahuasina	3	1331	1458		PVS
2a	Ccori marquina	3	1262	951		APMoV
2b	Ccori marquina	3	885	1075		PVS
	Average		1131	956		

Table 5. Effects of viruses on tuber number in 12 cultivars

	Variety	N°	Tuber Number /plant			Virus
			Infected average	Healthy average	Simple effects Pr > F	
1	Occe ruiro	3	55	48		APMoV
3	Cuchillo paqui	3	46	35		APMoV
4	Promesa	3	56	51		APMoV
5	Ccollce tupo	3	42	51		APMoV
6	Yuraq tucco	3	62	76	*	APMoV + PVS
7	Llunchuy waccachi	3	35	28		PVX
8	vaquilla wacran	3	36	26		PVX
9	Taragallo	3	44	50		PVX
10	Puqya	3	25	29		PVX
11	Occe palta	3	47	66	**	PVX
12	Yuraq sari- huasahuasina	3	63	63		PVS
2a	Ccori marquina	3	42	49		APMoV
2b	Ccori marquina	3	35	41		PVS
	Average		45	47		

Table 6. Effects of virus on tuber size in 12 cultivars

Tuber (g)/plant

	Cultivar	N	Infected average	Healthy average	Simple effects Pr > F	Virus
1	Occe ruiro	3	24	19		APMV
3	Cuchillo paqui	3	22	24		APMV
4	Promesa	3	25	16	*	APMV
5	Ccollce tupo	3	35	24	**	APMV
6	Yuraq tucco	3	22	15		APMV + PVS
7	Llunchuy waccachi	3	29	23		PVX
8	vaquilla wacran	3	29	28		PVX
9	Taragallo	3	20	19		PVX
10	Puqya	3	23	21		PVX
11	Occe palta	3	26	16	**	PVX
12	Yuraq sari- huasahuasina	3	21	24		PVS
2a	Ccori marquina	3	30	20	**	APMV
2b	Ccori marquina	3	25	27		PVS
	Average		25	21		

APMoV: All 5 varieties infected with APMoV statistically yielded no different from the "healthy" counterpart, except for Occe Ruiro, and Promesa, both which significantly out-yielded their healthy counterparts (Table 7). ELISA data from previously "healthy" plants of Occe Ruiro in three repetitions and Cuchillo Paqui in two were positive to APMoV. For the analysis, varieties were still classified as "clean" . It was not possible to tell if the titer increased and now became detectable, or if they had become infected after leaf samples were taken in the previous growing season, or they were escapes. The yield increase is mainly given by a remarkable increase in tuber size whereas there is little or no effect on tuber numbers, which are high to begin with in many native varieties.

Table 7. Yield comparison of 5 varieties, which are infected and free of Andean Potato Mop Top Virus, transmitted by *spongospora subeterranea*

Cultivar Name	Yield g/pl				tuber No. /pl			Tuber wt (ave /pl)			
	APMV	Healthy	%		<u>APMoV</u>	Healthy	%	APMoV	Healthy	%	
Cuchillo paqui	1027	840	122		46	35	130	22	24	94	
Occe ruiro	1320	880	150	**	54	48	114	24	19	127	
Yuraq tucco	1334	1151	116		62	76	82	22	15	142	**
Promesa	1391	851	163	**	56	52	109	25	16	153	*
Ccori Marquina	1262	951	163		42	49	85	30	20	153	**
Ccollce tupo	1485	1195	124		42	51	83	35	24	147	
Average	1303	978	140		51	52	100.6	26	20	136	

Potato Virus X: Of five varieties infected and free of PVX, the yield data shows an increase in yield, number of tubers and tuber weight in three of the varieties, namely Llunchuy Waqachi, Vaquilla Wacran and Occe Palta, which also appears to be due to an increase in tuber wt and/or tuber number. The varieties Puqya and Taragallo, commonly found among the households, showed a slight reduction (not significant) in yield and tuber numbers, indicating these varieties to be sensitive to this virus (table 8).

Table 8. Yield comparison of 5 varieties which are infected and free of Potato Virus X

Cultivar Name	Yield g/pl				tuber No. /pl			Tuber wt (ave /pl)			
	PVX	Healthy	%		PVX	Healthy	%	PVX	Healthy	%	
Llunchuy Waccachi	995	665	**150**	*	35	30	86	29	23	122	
Vaquilla Wacran	1020	702	**145**	*	36	27	75	29	28	107	
Taragallo	865	978	**88**		44	50	113	20	19	104	
Puqya	586	601	**97**		25	29	116	23	21	114	
Occe palta	1200	1082	**111**		47	66	**140	26	16	158	**
Average	**933**	**806**	**1182**		**37**	**40**		**25**	**21**	**120.9**	

This surprisingly higher yield response of infected varieties had been noted by Salazar (1995 p183) when he compared native varieties which had been cleaned but which yielded less than the infected original. He suggests that through long co- evolution the viruses gradually become less virulent to the obligate host. Potatoes and viruses may have been co-evolving for more then ten thousand years, which could explain why in the high Andes the prevalent viruses are considered "soft". He also mentions that a cross protection operates on virus infected plants which are less susceptible to late blight (*Phythopthora infestans*). First noted by Munro and Muller in 1951, this was confirmed by others (Fernandez and Thurston 1975, Kalra et al 1989), and could be playing an increasingly important role in the high Andes, as late blight climbs to areas where it was rarely a problem before.

Potato Virus S: Table 9 shows the yield comparison of two varieties infected and free of virus S.

Table 9. varieties which are infected and free of Potato Virus S.

	Yield g/pl		%		tuber No. /pl			Tuber wt (ave /pl)		
	PVS	Healthy			PVS	Hea	%	PVS	Healthy	%
Yuraq sari- Huasahuasina	1330.7	1458.0	**91.3**		63.4	63.4	100.0	20.8	23.5	88.7
Ccori Marquina	884.83	1075.33	**82**		35.12	40.73	86	25.25	26.51	95

The two varieties studied, Yuraq Sari Huasahuasina, and Ccori Marquina infected with potato virus S lost 10 and 20% yield compared to the "clean" variety**.** The community farmers note that Yuraq Sari Huasahusina probably came in from Huasa Huasi where Carlos Ochoa's breeding program was testing advanced clones for releasing improved varieties. The tuber characteristics are those of an improved variety (shallow eyes, smooth oval shape and white skin) but is now part of their varietal portfolio together with Liberteña which also originates from a breeding program, both seem to react in opposite directions, Huasahusina showing sensitivity to virus and Liberteña tolerance or resistance, demonstrating that virus resistance is an important feature to varietal durability.

APMoV+ PVS: Only one cultivar with a double infection entered the trial, Yuraq Tucco and this was PVS and APMV. Here we see a yield increase with the infection and can only infer that APMV maybe also cross protecting the variety, but only further tests would shed light. (Table 10).

Table 10 . Comparison between healthy and Virus S+APMOV. : Yield comparison of 2 varieties which are infected and free of Potato Virus S.

	Yield g/pl		%		tuber No. /pl		%	Tuber wt (ave /pl)			%
	APMV+PVS	Healthy			APMV+PVS	Healthy			APMV+PVS	Healthy	
Yuraq tucco	1334	1151	**116**		62	76	82	*	22	15	143

Final conclusions

Results shown in this study are preliminary but important in that expected yield losses were not realized except for virus S, showing a mutual relationship which evolved over centuries where the virus pathogen may offer some advantages to the host, this however needs to be proven in further studies.

Studies of the interactions between a virus and its host, and how both of these are affected by the environment, are lagging behind in the Andes because of the large number of varieties that are grown, and the secondary worldwide importance of the viruses found. However, the remarkable fact that this seed system has proved to be sustainable over time merits a closer look.

Another important aspect is seed transmission or self infection. A study of differences amongst infected mother plants passing virus infection to their daughter tubers in differing environments was not completed in time to be included in this report, but will shed further light on how native seed systems maintain varieties, as Bertschinger (1992) reported that Yungay, an imorved varietyinfected with Potato virus Y did not transmit this virus to its daughter tubers at high altitudes, whereas they were 97% infected in his lowland site.

Some varieties will probably be shown to be resistant to viruses such as Puca Huayro where all tubers tested in this study were free of virus and as yet unpublished results from a Papa Salud report shows that Puca Huayro is resistant to five viruses:

PVX PVY PVA, PVM and PVS (http://www.neiker.net/neiker/germoplasma/Patata/castellano/Datosdeevaluacion.html.)

Understanding of the scientific and social aspects of current Andean seed systems could help establish better adapted model for improved seed, where Andean farmers play a key role due to the ecological advantages of their communities. This overlooked opportunity, could fail if global climate warming changes the conditions under which potatoes are grown today.

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Current status and opportunities for improving the access to quality potato seed by small farmers in Eastern Africa

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Abstract

The dwindling arable land size in Eastern Africa has compelled farmers to resort to tuber and root crops that produce more food per unit area and time; one such crop is the potato. Experts projected a 250% increase in demand for potatoes in sub-Saharan Africa between 1993 and 2020, with an annual demand growth of 3.1%. About 1.25% of the growth will be realized from increases in area and the rest from improved productivity. The chronic shortage of quality seed potato is an important constraint to increasing productivity and the adoption of new varieties. Quality seed potato covers less than 1% of the seed requirement in eastern Africa, the bulk of which has not been subjected to quality control mechanisms, making seed health a major concern. The most serious threats to seed health are viruses and bacterial wilt, causing degeneration before varieties reach producers. However, the successful promotion of massive production of clean seed from in-vitro plantlets with the involvement of the private sector and community-based organizations will lead to increased seed availability. Producers who are able to invest in clean seed can maintain seed quality for several generations using positive selection and those not able to invest can still benefit from positive selection. Positively selected seed on average resulted in a yield increase of 40% in Ethiopia and 28% in Kenya. The combination of these technological innovations has the potential to improve potato farming systems in the region with a considerable impact on the livelihoods of smallholder producers.

Keywords: seed health, positive selection, small seed plot, stem cutting, aeroponics.

Introduction

Potato is increasingly becoming an important food and cash crop for smallholder farmers in the highlands of Eastern Africa. Experts projected that between 1993 and 2020 the demand for potatoes in sub-Saharan Africa will grow by 250% with an annual growth rate of 3.1% (Scott *et al.*, 2000). They predicted that about 1.25% of the growth will be attributed to increases in area expansion and the rest to growth in productivity. This production growth is driven by a major increase in demand in the ever-growing urbanization and changing consumption patterns of the urban population towards, among others, to processed products, especially chips (Berga et al., 2007) as well as the declining arable land size that has forced the smallholder farmers to resort to crops such as the potato that give high yields per unit time, land area and other resources. The most feasible manner in which the growing demand for potatoes can be satisfied is through increased productivity (Gildermacher *et al.*, 2009a). There are known agronomic technologies that can improve potato productivity, among them quality seed features as a critical component (Beukema and van der Zag, 1990, Endale *et al.*, 2008, Gildemacher *et a*l., 2009a). However, this basic component in modern potato production for developing countries, especially in sub-Saharan Africa, is always in short supply (Wagoire *et al.,* 2005; Endale *et al.*, 2008) and expensive, accounting for 40-50% of potato production costs (Wagoire *et al.*, 2005; Beukema and van der Zag, 1990).

Quality seed potato is the single most important component in improving potato productivity, considering that much of the current growth in potato production in East Africa is attributed to area expansion rather than productivity per unit area (Sikka, *et al.,* 1997, Gebremedhin *et al.*, 2008a, Gildemacher *et a*l., 2009a). Attempts to introduce European seed potato health standards in Kenya in order to maintain high ware potato yields have aggravated seed tuber scarcity because of escalated prices of clean seed as well as the small number of seed growers who can satisfy the strict seed potato inspection and certification standards. In Uganda and Ethiopia, there are no standards for seed potato and other vegetatively propagated crops (Wagoire *et al.,* 2005, Endale *et* *al*., 2008). This has led farmers to continuously use self-supplied seed over generations with inherent seed degeneration because of seed-born diseases such as viruses and bacterial wilt and consequent successive decline in tuber yields (Hakiza *et al*., 2000, Endale *et al*., 2008, Gildermacher *et al*., 2009b). In the absence of seed potato inspection and certification system in Uganda and Ethiopia, seed health is controlled at national research levels up to basic seed production, beyond which an integration of research and farmer seed potato producers associations has evolved into an informal arrangement for seed health control. Both the national potato programs and these informally regulated seed potato producers associations comprise the only credible sources of seed potato; however, the supplied quantities do not meet demand and neither is the health status satisfactory.

In all three countries, attempts have been made to improve supply of seed from both formal and informal sources, but more so in the latter case (Wagoire *et al*., 2005, Endale *et al.,* 2008, Gildermacher *et al*., 2009b). In the formal system, the potato programs in the region have established tissue culture capacity to feed the seed value chain with tissue-culture generated seed tubers, which for a long time have been provided by the International Potato Center (CIP). However, there is no functional seed potato inspection service that checks the action and practices of the national programs in the respective countries. The various research institutes in Uganda, Kenya and Ethiopia have also invested in seed potato storage infrastructure to support increased seed potato production (Wagoire *et al.,* 2005, Endale *et al.,* 2008). However, mini-tuber production using soil substrate does not offer high multiplication rates per transplanted TC plantlet. Consequently, a new production technology, utilizing aeroponics, is being piloted in Ethiopia, Kenya and Uganda to improve seed productivity per plant, space and time.

Considering that not all farmers will access quality seed from formal sources, attempts have been made to improve the quality of on-farm generated seed through use of positive selection and small seed plot technique (Kinyua *et al.,* 2001, Kakuhenzire *et* a*l*., 2005, Gildermacher, *et al*., 2007, Gildermacher, *et al*. 2009c,). This paper analyses some of the attempts in Ethiopia, Kenya and Uganda to avail quality seed potato and reviews endeavors to involve individual farmers, public and private partnerships to invest in quality seed potato production to supply to farmers at affordable prices.

Mini-tuber production through tissue culture

Mini-tuber production is dependent on availability of tissue culture (TC) capacity. Although all three countries now have TC facilities, mini-tuber production is very low (Table 1). Kenya has one of the oldest TC facilities in the region and produces more mini-tubers than the other two countries, but this is still far from sufficient. In Ethiopia, a TC laboratory was commissioned in 2002, but mini-tuber production had not started satisfactorily until the micro-propagation protocols were optimized much later. However, mini-tuber production is still too low to feed the next seed multiplication stages. Similarly, in Uganda potato micro-propagation was started in 2007, but it required skilled personnel and protocol optimization and hence production is in its infancy. Although mini-tuber production has been sub-optimal in three countries, these limited quantities have contributed to sustaining the potato sub-sector, stabilizing the ware potato prices and reducing seed-borne disease. Uganda and Ethiopia heavily depended on stem cuttings as a rapid multiplication technique to produce nuclear seed tuber for the production of pre-basic and basic seed for further multiplication of improved seed.

Table 1. Mini-tuber production in Ethiopia, Kenya and Uganda, 2002-2008

Year	Number of mini-tubers produced		
	Ethiopia	Kenya	Uganda
2004	15,068	74,000	-
2005	10,944	119,000	-
2006	4,707	120,000	-
2007	1,233	130,150	3,463
2008	1,050	145,620	20,031

Source. National Potato Programs of Ethiopia, Kenya and Uganda.

Production of nuclear seed tuber using stem/shoot cuttings

Uganda and Ethiopia, unlike Kenya, were dependant on potato stem cuttings for rapid seed potato multiplication. However, Ethiopia reduced its dependence on stem cuttings when it started producing in-vitro plantlets while Uganda (where the in-vitro technique was adopted only in 2007) has continued depending on stem cutting as a reliable method of rapid multiplication technique (RMT) to produce quality seed. In Uganda stem cutting production has been irregular. Shoot cutting progressively decreased between 2004 and 2006 and then steadily grew to 2004 level by 2008. Corresponding production of nuclear seed tubers from stem cutting transplants showed that the average nuclear seed tuber production for six years was about 7.2 t per annum (Table 2). Productivity was highest when few shoot cuttings were generated in 2006 compared to other years, which may imply that when there were many cuttings handling care was compromised. There is therefore need to balance mass production with management capacity which may impact on productivity and possibly seed quality.

Table 2. Production of nuclear seed using stem cuttings in Uganda, 2004 – 2009

Year	Stem cuttings	Nuclear seed (Kg)	Tuber yield (g) per stem cutting
2004	107,173	10,822	101.0
2005	29,851	5,970	200.0
2006	25,411	5,503	216.6
2007	56,212	7,279	129.5
2008	96,860	8,470	87.4
2009*	61,371	5,143	83.8
Mean	62,813	7,198	136.4

* Data for the first cropping season of 2009. Source: Uganda National Program.

Basic seed potato production

Table 3. Basic seed potato production in Ethiopia, Kenya and Uganda, 2000 – 2008

Year	Basic seed potato production (t)		
	Ethiopia	Kenya	Uganda
2000		37.25	129.2
2001		24.6	78.5
2002		16.2	120.7
2003		8.0	177.9
2004	72.1	21.9	220.9
2005	66.7	35	57.8
2006	64.8	60.9	58.7
2007	90.6	77.5	77.7
2008	78.5	59.15	118.9

Source: Potato programs of the three countries.

Basic seed potato in Ethiopia, Kenya and Uganda is produced by the potato programs of the respective National Agricultural Research Institutes. Ethiopia and Kenya have been producing less than 100 t per year of basic seed since 2000 (Table 3). Even in Uganda, production of basic seed would occasionally fall below 100 t. This production level is very low considering that some of this high quality seed, for example, in Kenya, is used to produce ware potato. In Uganda and Ethiopia, basic seed is distributed through the farmer-based seed system where the recipient farmers multiply it at least once before it is distributed to ware potato growers. This has the following advantages: i) it increases the quality of seed that is available to ware potato farmers with little waste of high quality basic seed, ii) it brings other players into the seed potato production process and reduces public monopoly, iii) it eases the burden on public institutes in seed potato production and distribution, iv) it is a precursor to the private sector-led seed potato production scheme, v) it encourages public private partnership in seed production and vi) it creates new enterprises among farmers that adopt and invest in seed potato production.

Certified seed potato production

It is only Kenya, among the three countries, that has a formal seed potato production and certification scheme. However, the quantity of seed produced is abysmally small compared to the national demand. For example, the certified seed potato production was 8.3 t in 2005, 5.0 t in 2006, 8.8 t in 2007 and 483.3 t in 2008. The large improvement in certified seed potato production in 2008 was a result of intervention by Agricultural Development Cooperation which is a government parastatal that employs an out-growers scheme to produce quality seed potato. The low production of certified seed in Kenya variously blamed on stringent and expensive inspection procedures by the national seed certification service, shortage of suitable clean land and under-investment in the national program. This means that most farmers in Kenya use non-certified seed.

Informal but organized seed potato production system

Informal seed supply, which has been in existence since the beginning of agriculture, is still an important source of seed in developing countries for all crops (Endale *et al.*, 2008). This informal supply system for seed potato has been improved in Uganda and Ethiopia to introduce quality control practices such that ware potato producers get seed of acceptable quality (Tindimubona *et al.*, 2000; Wagoire *et al.*, 2005; Endale *et al.*, 2008). Most of the basic seed produced by the potato program in the two countries is disseminated through the so called informal farmer-based seed system (IFBSS), where it is multiplied at least once before it is sold to other farmers. This is developing into a commercial private sector seed enterprise as opposed to the previous seed potato production and distribution system led by public institutions. However, data from Uganda indicate that production of improved seed by IFBSS is organized through Uganda National Seed Potato Producers Association (UNSPPA) and has been growing since its inception in 1996 (Fig. 1A). Gross revenues of UNSPPA have also been growing (Fig. 1B), generating the crucial income and employment needed at village levels.

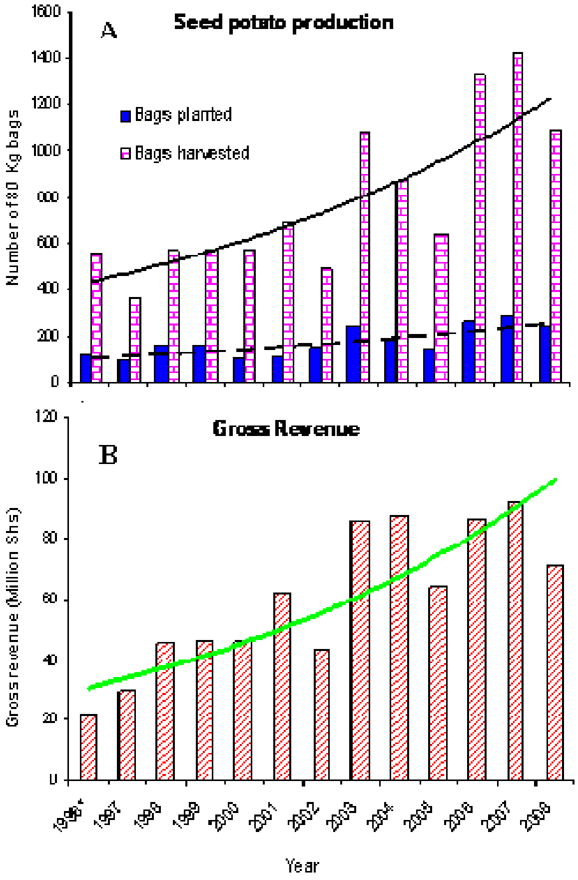

Figure 1. Seed potato production in 80 kg bags (A) and gross revenue (B) of Uganda National Seed Potato Producers' Association, 1996 – 2008

In Ethiopia, seed potato production by IFBSS has been growing since 2004 with a peak in 2008 (Fig. 2). The dramatic growth in seed production from IFBSS in Ethiopia unlike in Uganda is because (1) the farmers there recycle some of the seed and (2) motivated by the high returns of seed production many farmers (about 200 farmers from one district) regard seed production as a business, which has significantly improved their livelihoods (CIP, 2008a). However, it is the case that the health of the seed from IFBSS should now be monitored more appropriately so that seed-borne diseases, especially viruses, are not disseminated.

Farmers engaged in seed growing have also invested in construction of low-cost diffused light stores (DLS) for appropriate seed potato storage. Current DLS numbers run in several hundredss in Ethiopia and Uganda, with

Ethiopia having a higher number. In Kenya, small scale farmers have not generally invested in seed production and DLS, largely because of high seed certification standards. The IFBSS in Uganda and Ethiopia with support from the national programs is developing standards and seed quality control to ensure that the ware potato growers get seed potatoes of acceptable standard.

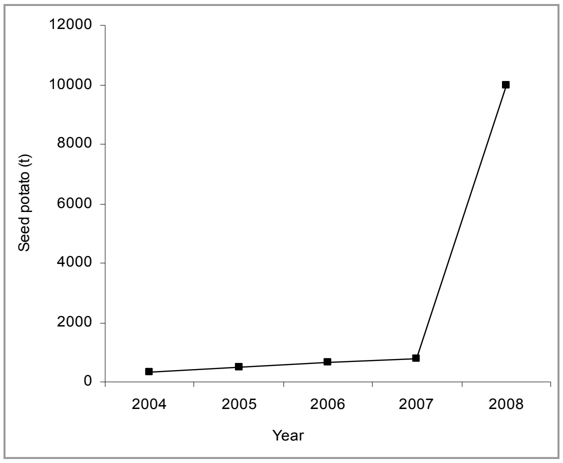

Figure 2. Informal seed potato production in Ethiopia between 2004 and 2008

Innovations for smallholder farmers to access quality seed potato in Kenya and Ethiopia

Smallholder farmers may not be able to access seed from the potato program or organized farmer seed growers in their respective countries. Low-cost technologies such as positive selection have been developed and tested in East Africa to enable smallholder ware and seed farmers to improve self-supplied seed. Table 4 shows that positive selection, where farmers selected the best plants and used tubers harvested from these plants as future planting material, obtained an average yield increase of 28% in first season over several locations in Kenya and 28% of the trained farmers there adopted the technology (Gildemacher, *et al.*, 2009c). In Ethiopia positive selection resulted in a yield advantage of about 40% (Gebremedhin et al., 2008b). Positive selection is a user-friendly technology that can be adopted by many because (a) it is easy to learn, (b) it is not resource intensive and (c) it enables farmers to recycle their seed for more seasons, avoiding high costs of buying improved seed.

Table 4. Advantage of positive seed potato selection among smallholder farmers in Kenya, 2005 and 2006

Farm site	Tuber yield (t/ha)		Yield increase due to positive selection (%)
	Positive selection	Farmer practice	
Dundori	21.4	21.3	0
Elburgon	16.3	8.9	84
Gilgil	19.2	10.1	91
Gitiri	11.1	8.3	35
Heni	20.2	21.0	-4
Kipipiri	11.9	9.0	32
Kirima	8.7	7.6	13
Kuresoi	12.5	11.8	6
Munyaka	16.8	13.6	24
Njoro	11.7	10.4	13
Ol Kalou	4.0	3.9	4
Olenguruone	23.4	22.6	4
Subukia	7.5	4.7	58
Average	**14.2**	**11.8**	**28**

Source: Gildemacher *et al.*, 2009c

Smallholder farmers can also improve farm-saved seed by adopting the small seed plot technique (SSP). This technology was tested and adapted in Kenya (Kinyua *et al.*, 2001) and Uganda with encouraging results. In Uganda analysis of the incidence of latent bacterial wilt infection of seed tubers generated through different seed potato production technologies showed that seed potato from the SSP had the lowest rate of latent BW infection (Table 5). Similar results were obtained from on-farm and on-station experiments in Kenya (Kinyua *et al.*, 2001). The small seed plot technique is probably one of the most pragmatic technologies to produce clean seed, as it is easy to find a small plot free of diseases and manage it well to give a high seed potato yield per unit area.

Table 5. Latent bacterial wilt latent infection of seed tubers from small seed plot and conventionally grown potato in Uganda, 2004

Seed source		Number of samples		Bacterial wilt infection (%)
Small seed plot		28		14.3
Conventional planting		32		31.3
UNSPPA		20		20
Total		80		22.5

Source: Kakuhenzire *et al.*, 2005.

Table 6. Land productivity and bacterial wilt (BW) infection incidence from conventional and small seed plot (SSP) produced seed potato in Kenya

Variety	Production technology	Tubers m^{-2}	BW field incidence (%)	Latent BW infection (%)
Asante	SSP	77.2	1.14	2.1
	Conventional	37.7	1.38	3.7
Kerr's Pink	SSP	125.0	1.22	4.1
	Conventional	46.6	9.14	29.6

Source: Kinyua *et al.*, 2001.

In Kenya, the SSP plot technique yielded higher productivity per unit area and lower incidence of both field and latent BW infection (Table 6). Small scale farmers can produce and maintain high quality seed at the household level. A farmer requires a much smaller area with the small seed plots than the conventional method to produce equal amounts of seed.

Seed potato production using the aeroponics technology

Potato production in greenhouse with potato tissue cultured plantlets in soil or solid media and in hydroponics has been a common feature in most seed programs even in developed countries. Production of seed potato using a soil-less, space-suspended and nutrient mistfed aeroponics technology that proved promising in other countries, is being piloted in Kenya and Uganda. This technology is expected to increase the multiplication rate of potato plantlets from the conventional 10:1 to 50:1 (CIP, 2008b). This technology is hoped to generate ample quantities of mini-tubers in a short time. It is hoped that with large quantities of mini-tubers generated in the aeroponics revolution, new players, especially the private sector and specialized farmer seed growers, will be brought on board to produce basic seed. However, this will require dissemination of new knowledge among pioneer farmers who have been used to large size (35-60 mm diameter) seed tubers. Moreover, special skills will be needed to optimally manage the aeroponics system for maximum mini-tuber production in a sustainable fashion.

Future prospects

The prospects for quality seed production in Eastern Africa look good for several reasons, among which the following merit mentioning: i) governments have recognized potato as one of the potential crops to reduce food insecurity and poverty and hence started developing favorable policies, ii) public and private institutes have started investing more in seed potato production because of increasing demand for quality seed, iii) public private partnerships in seed production are getting stronger, iv) availability of different technologies, including improved varieties and rapid multiplication techniques, v) increased farmer knowledge about potato seed production and management, vi) good networking for intra-regional nuclear seed exchange and vii) strong support from the International Potato Center. The donors equallyhave started supporting clean seed production efforts both at regional and national levels. Currently there are at least three such projects in Ethiopia, Kenya and Uganda that will greatly facilitate access to clean potato seed.

The tissue culture facilities that are now in these countries will provide nuclear seed for further multiplication by other rapid multiplication techniques such as aeroponics that will increase the multiplication rate and reduce seed production costs and the number of seasons for making clean seed available to growers.

Conclusion

Seed potato production in East Africa had been the responsibility of public institutions for a long time and at least until 1996. Seed produced by public agencies has been inadequate, often subsidized and does not satisfy the market demand. Consequently, most potato farmers are forced to use self-supplied seed as planting material that is often of poor quality, resulting in low potato yields. Involvement of farmers in Uganda and Ethiopia following informal farmer based seed systems has slightly improved the supply of quality seed. Development, adaptation and adoption of positive selection and small seed plot techniques have enhanced availability of quality seed potato among smallholder farmers. Further growth and improvement in the seed potato value chain through adaptation and scaling up of novel seed potato production technologies such as aeroponics is vital for breaking the seed bottleneck. Effective private-public partnerships will be necessary to further multiply the produced mini-tubers and distribute quality declared seed in an efficient manner. It is suggested that regular training on seed potato production and management given to all stakeholders and regular seed health monitoring and involvement of public and private sectors in seed production would dramatically improve availability and access of quality seed and hence the potato sub-sector in the region.

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An improved method to produce rooted seedlings from TPS (True Potato Seed) tested in the highlands of Uzbekistan

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Abstract

In Uzbekistan, farmers struggle to obtain high quality seed potatoes at affordable prices. Price of imported seed has in fact risen sharply in recent years obliging farmers to utilize their own saved seed more frequently with declining potato yields due to seed-borne diseases. In an effort to develop research on seed systems, CIP has focused the development of new techniques and practices that should be prerogative of the informal seed system. Different techniques for seed potato production have been tested, including an original variant to produce rooted seedlings from TPS materials under nursery conditions. This technique has the advantage of producing stronger rooted seedlings with substrate intimately attached to the rooting system, thus improving survival rates and reducing considerably transplanting shocks and root damages. Such method of producing rooted seedlings from TPS is extremely simple, cheap, and offers an alternative activity to smallholders who are familiar with vegetable growing and who live in marginal areas. The only obstacle to the adoption of this alternative material may be represented by the duration of the growing cycle of the tested TPS families that would need to be shortened, requiring, therefore, the supply of new TPS materials.

Keywords: potato, seed production, rooted seedlings, growing cycle, day length.

Introduction

Uzbekistan was part of the Former Soviet Union until it became independent in 1991. The country has a total area of 44.8 million hectares with only 4.5 million hectares arable, out of which 4 million are irrigated (FAO-ICARDA, 2006). Potato is traditionally grown from seed tubers, which account for as much as 47% of the total production cost. Seed importation from Holland is the main source of Elite category seed tubers that are locally multiplied for two to three generations by a State company. Potato is mainly produced in the lowlands where about 70% of total production is concentrated, while the rest is cultivated in the highlands and foothills. Potato is cultivated during three growing seasons, which is typical of other countries of the Central Asia and Caucasus region: a double-cropping system in the lowlands, with the first growing season from February-March till May-June, and the second from mid-July till the end of October, while a single-cropping pattern is practiced in the highlands with planting in May and harvest from mid-September till mid-October. Being Uzbekistan situated in the temperate zone of the northern hemisphere, these growing seasons correspond to different photoperiodic regimes, from short to long and viceversa in the double-cropping system of the lowlands and from long to short in the single-cropping system of the highlands. The country does not have an efficient potato seed production system to provide clean seed sold at an affordable price to potato farmers. Further, the cost of seed is high because the cost of transport of Elite seed categories from Europe to destination adds to the production cost and bears on the cost of further seed categories.

True Potato Seed (TPS) was therefore considered as an alternative source of planting material because of its low cost and easy transport. In an effort to assist NARS of Uzbekistan, CIP supplied some TPS families for evaluation of their potential under long day conditions as a means to support local farm-based seed systems. TPS technology is everywhere recognized (Pandey, 2005) as highly cost effective and the most appropriate seed production technique for the resource poor farmers of the less developed countries. Moreover, TPS are a source of healthy planting materials. In fact, except for potato virus T (PVT) and potato spindle tuber viroid (PSTVd) no other major pathogens are transmitted through TPS as they are filtered out as a consequence of sexual propagation (Salazar, 1996). Research was also axed on the evaluation of different planting methods to standardize the technique under local conditions, among them the direct seeding technique and transplanting of rooted seedlings. The latter technique although mostly appreciated by farmers because it would allow the production of commercial-sized tubers already in the first year of production, has been, however, criticized for the fragility of the transplanted seedlings. Upadhya (1999) thought that more research focusing on selecting parents providing hardier seedlings was needed. Since we thought that this character was also depending on the way nurseries are managed and rooted seedlings handled, we tested a simple and low-cost technique to produce strong rooted seedlings able to stand transplanting shocks. As in Uzbekistan the objective is to create a seed system to produce high quality planting materials at affordable prices, this improved technique for the production of strong TPS rooted seedlings has been tested in the highlands of the country during the period May-October, 2006-2007, and compared with the traditional TPS rooted seedling production technique described by several authors (Accatino and Malagamba, 1982; Malagamba, 1988; Singh et al., 1990; Upadhya et al., 1990; Cabello, 1996; Upadhya and Cabello, 2001; Pande, 2005). The objectives researched included: (**i**) the assessment of survival rates of TPS transplanted rooted seedlings issued from two nursery methods described below, and (**ii**) the analysis of yield of TPS rooted seedlings issued from the two methods, once transplanted in the field.

Materials and methods

The experiment was conducted at the experimental site of Pskem, a locality situated about 180 km from Tashkent, close to the Kazakh border, at an altitude of about 1 300 m asl and at 42° N, 70° E . Soil is a typical eroded sierozem with a pH approaching 6.2. Three TPS families were used for the experiment: two hybrid TPS families LT-8 x TS-15 and HPS-I/13, supplied by CIP and CPRI (Central Potato Research Institute), Modipuram, India, respectively, and CH-8, an open pollinated (OP) family supplied by the Research Institute of Vegetables, Melon and Potato, Tashkent. In order to implement such experiment, we set up two nurseries for the production of rooted seedlings to be further transplanted in the open field. They were prepared by digging a trench, 30 cm deep, about 1.2 m wide and 20 m long. Sowing occurred on May 22, 2006, and May 16, 2007, at 0.5 cm depth and different spacing distances. The two nurseries were prepared for the production of rooted seedlings according to two methods: the classic method, called "traditional", with sowing of TPS at 15.0 x 4.0 cm (166 seedlings/m^2), and a second method, herewith called "improved", with a seed density equivalent to 204 seedlings/m^2 (7.0 x 7.0 cm). In both methods, after sowing, each hole was covered with a small amount of well-sifted manure. Immediately after, water was carefully applied with a watering-can by providing a fine mist.

In the so-called "traditional" method, the substrate was composed of well-sifted subsoil and well-decomposed organic manure, thoroughly mixed in a 1:1 proportion. The differences between the two methods were in the seed density (166 vs. 204 seedlings/m^2), the substrate composition and the methodology used, which in the "improved" method ensures operational ease in taking out rooted seedlings from the nursery for further transplant in the field. In fact, in the "improved" method, one layer of perforated transparent polythene sheet was laid down between the substrate composed by well-sifted subsoil and the soil bed, at about 10 cm depth. This was done to ensure water percolation and gaseous exchanges within the substrate and between the substrate and the above soil bed. The soil bed, which was not mixed, consisted of two separated layers of about 5 cm each, with organic manure placed above well-sifted subsoil. A specially-manufactured wooden seed marker was prepared for the occasion. At transplanting time, it was extremely easy to extract with a carpentry slice firm blocks having one rooted seedling each with substrate intimately attached to the rooting system. Other cultural practices comprised thinning, to keep one seedling/hill, spraying against Potato Colorado Beetle (*Leptinotarsa decemlineata*, Say) and watering when needed. About two weeks after emergence, a 0.1% (1 g in 1 liter of water) solution of urea was sprayed every two days until transplanting. Seedlings were ready for transplanting 40 to 42 days after seed sowing, at the 4 to 5 leaf stage.

To compare the efficiency and the feasibility of the two methods above described, an experiment was set up with rooted seedlings of three TPS families (LT-8 x TS-15, HPS-I/13, and CH-8), which were transplanted in the field at the distance of 70 x 15 cm in plots measuring 2.1 x 2.7 m (5.67 m^2), with four rows distant 0.7 m and having 18 transplanted rooted seedlings each, for a total of 72 rooted seedlings/plot. Data, i.e. plant survival rates (%) at 20 days after transplanting, number of tubers, average tuber weight (g) and yield (t/ha), were taken on the two inner rows, and precisely on 14 plants of each row, neglecting the two plants at each extremity so that the yield was measured on the effective area of 1.4 x 2.1 m (2.94 m^2). Each plot was replicated three times, so that there were 18 plots distributed at random. The following fertilizers were applied along the furrows: 26 g ammonium sulfate and 27 g monoammonium phosphate per linear meter, corresponding to 120 N and 176 P_2O_5 per hectare. While monoammonium phosphate was integrally applied prior to transplanting, ammonium sulfate was split in two applications, before first and second hilling-up, that is about thirty and fifty days after transplanting, respectively. At the beginning and until plants were 30-40 cm high, furrow irrigation was provided every 5-6 days, but afterwards it was reduced to an application every 10 days. At about ninety days after transplanting irrigation was stopped and ten days later haulm killing was practiced followed by harvesting about two weeks later. Harvest occurred on October 22 and 14, in 2006 and 2007, respectively, approximately 111 days after transplanting.

The obtained data were statistically processed using MSTAT-C program (1993). The statistical analysis covers the following indicators: mean value (x), and Coefficient of Variation (CV). The experimental design adopted consisted of a 3 (TPS families) x 2 (rooted seedling methods) factorial experiment in a randomized complete block design with three replications for a total of 3 x 2 x 3 = 18 plots. LSD test for the levels of significance of $\alpha=0.01$ and $\alpha=0.05$ was then computed.

Results

(i) Study of survival rates of TPS transplanted rooted seedlings

Statistical analysis of the results indicates that there are significant differences among the two rooted seedling production methods and the interaction production method x TPS family. The "improved" method applied for the production of rooted seedlings gave better results than the "traditional" method in terms of plant survival at 20 days after transplanting, at 1% and 5% level (Table 1). Survival rates of LT-8 x TS-15 rooted seedlings produced according to the "traditional" method were significantly higher than those of CH-8 (86.7 vs. 80.6%). Only in the case of the OP TPS family CH-8, there was a significant interaction TPS family x year.

Table 1. Survival rates (%) of TPS rooted seedlings 20 days after transplanting, adopting two different methods of rooted seedling production in nursery. Pskem, Uzbekistan, 2006-2007. Means of three replications

Method (A)	**TPS family (B)**	**Year (C)**		**Average (AB)**	**Average (A)**
		2006	**2007**		
****Traditional Method (%)**	LT-8 x TS-15	86.9	86.6	86.7**	84.2
	HPS-I/13	84.6	86.3	85.4	
	CH-8	83.4**	77.8	80.6	
	Average (AC)	85.0 ns	83.6		
Improved Method (%)	LT-8 x TS-15	97.2	97.2	97.2**	96.0**
	HPS-I/13	95.0	93.8	94.4**	
	CH-8	97.5*	95.2	96.3**	
	Average (AC)	96.6 ns	95.4		**Average (B)**
TPS family x Year (BC)	LT-8 x TS-15	92.0	91.9		91.9
	HPS-I/13	89.8	90.0		89.9
	CH-8	90.4 *	86.5		88.4
Average year ©		90.7 ns	89.5		**A x B x C** ns

Factor		**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
LSD	**1%**	2.73	3.35	2.73	4.73	3.86	4.73	6.68
	5%	2.01	2.47	2.01	3.48	2.84	3.48	4.91

** = significant at 1% level; * = significant at 5% level; ns = not significant

(ii) Performance of TPS rooted seedlings issued from the two methods once transplanted in the field

Results are shown in Table 2.

Table 2. Field performance of transplanted TPS rooted seedlings, adopting two different methods of rooted seedling production in nursery. Pskem, Uzbekistan, June-October 2006*-2007. Means of three replications

		Yield (t/ha)				No. of tubers				Mean tuber weight (g)			
Method (A)	**TPS family (B)**	**Year ©**		**Mean (AB)**	**Mean (A)**	**Year ©**		**Mean (AB)**	**Mean (A)**	**Year ©**		**Mean (AB)**	**Mean (A)**
		2006	**2007**			**2006**	**2007**			**2006**	**2007**		
Traditional Method (%)	LT-8 x TS-15	20.7	23.1	21.9	19.1	309.3	333.3	321.3**	243.5	23.8	26.7	25.2	25.5
	HPS-I/13	12.1	15.7	13.9		170.0	192.3	181.1		21.3	24.5	22.9	
	CH-8	22.3	20.9	21.6		229.3	227.0	228.1		29.4	27.4	28.4*	
	Mean (AC)	18.4	19.9 ns			236.2	250.9 ns			24.8	26.2 ns		
Improved Method (%)	LT-8 x TS-15	28.3	29.4	28.8**	24.0**	192.3	209.0	200.6	252.6 ns	46.2	41.5	43.8**	30.3**
	HPS-I/13	21.0	22.1	21.6**		243.7	260.3	252.0**		24.9	25.4	25.1	
	CH-8	24.0	19.5	21.7 ns		298.7	312.0	305.3**		24.3	19.6	21.9	
	Mean (AC)	17.2	23.7**	**Mean (B)**		244.9	260.4 ns	**Mean (B)**		31.8 ns	28.8	**Mean (B)**	
TPS family x Year (BC)	LT-8 x TS-15	24.5	26.2		25.3*	250.8	271.1		260.9*	35.0	34.1		34.6**
	HPS-I/13	16.6	18.9		17.7	206.8	226.3		216.6	23.1	24.9		24.0
	CH-8	23.1	20.2		21.6	264.0	269.5		266.7*	26.8	23.5		25.1
Mean year ©		21.4	21.8 ns		**A x B x C**	240.5	255.6 ns		**A x B x C**	28.3 ns	27.5		**A x B x C**

		Yield (t/ha)							No. of tubers							Mean tuber weight (g)						
Factor		**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
LSD	**1%**	3.5	4.2	3.5	6.0	4.9	6.0	8.5	40.3	49.3	40.3	69.8	57.0	69.8	40.3	4.4	5.4	4.4	7.6	6.2	7.6	10.8
	5%	2.6	3.1	2.6	4.4	3.6	4.4	6.2	29.6	36.3	29.6	51.3	41.9	51.3	29.6	3.2	4.0	3.2	5.6	4.6	5.6	7.9

** = significant at 1% level; * = significant at 5% level; ns = not significant

In general, there were no significant differences between the two methods with regard to number of tubers produced by the rooted seedlings. There was on the contrary a highly significant interaction production method x TPS family with regard to tuber number, with LT-8 x TS-15 rooted seedlings produced with the "traditional" method yielding more than those produced with the "improved" method (321.3 vs. 200.6), while the opposite occurred for the other two TPS families.

Yield (t/ha) of rooted seedlings produced with the "improved" method was higher than that of seedlings produced with the "traditional" method (24.0 vs. 19.1 t/ha). Only LT-8 x TS-15 and HPS-I/13 rooted seedlings produced with the "improved" method yielded more than those produced with the "traditional" method. The average weight of tubers issued from rooted seedlings produced with the "improved" method was higher than that of tubers produced with the "traditional" method (30.3 vs. 25.5 g), at 1% level of significance. Tuber weight of LT-8 x TS-15 rooted seedlings produced with the "improved" method was significantly higher than that of seedlings of the same TPS family produced with the "traditional" method (43.8 vs. 25.2 g) and of the other TPS families.

Conclusions and discussion

The technique above described represents an original variant to produce rooted seedlings from TPS materials under nursery conditions. In fact, further to some experiences conducted in Uzbekistan we came to the conclusion that rooted seedlings produced in the traditional way are more prone to losses once transplanted in the field because of transplanting shocks due to two main causes: (i) the rooted seedlings produced traditionally have almost bared roots once they have been transplanted in the open field, thus resulting in weaker and slower plant establishment, and (ii) the traditionally produced rooted seedlings appear particularly weak and more sensitive to intense solar radiation and high temperatures recorded in the highlands of Central Asia during the single-cropping season. The new method explained in the present paper has the advantage of producing stronger seedlings with substrate intimately attached to the rooting system, thus reducing considerably transplanting shocks and root damages, which can open the way to diseases (i.e. *Rhizoctonia solani*), finally ensuring prompt recovery of the rooted seedlings. The so-called "improved" method of producing rooted seedlings from three different TPS families, two hybrids and one Open Pollinated, gave better results in terms of plant survival at 20 days after transplanting. Mean tuber weight and yield of rooted seedlings produced according to the "improved" method were also significantly higher than those of seedlings produced according to the "traditional method". Interaction planting method x TPS family was highly significant for LT-8 x TS-15 in terms of yield and mean tuber weight, while in the case of HPS-I/13 only yield and number of tubers produced were highly significant.

Based on this study, it can be concluded that:

- It is possible to use rooted seedlings produced with the "improved" method, which will ensure better survival after transplanting and better yield although a certain percentage of segregation should be always considered in the progeny;
- The TPS technology herewith described is extremely simple and can be adopted by those smallholders who are familiar with vegetable growing and, especially, by those living in marginal areas. It is probably more labour-consuming, compared with conventional seed potato techniques and the direct TPS seeding technique, but this does not represent an issue in CAC countries because family laborers and unemployed people are numerous in the countryside;
- The major problem to solve, but not the least, refers to the duration of the growing cycle of the tested TPS families: while 120-130 days (Carli and Khalikov, 2006) are necessary for seedling tubers produced according to the direct seeding technique under long day conditions of Central Asia (from sowing till harvesting), about 151 days are needed for rooted seedlings to produce seedling tubers of commercial size (from sowing till harvesting). This could represent a serious obstacle to the diffusion of such alternative planting materials among Uzbek potato growers.

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Diagnostic of seed potato systems in Bolivia, Ecuador and Peru focusing on native varieties

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Abstract

The Papa Andina Initiative of the International Potato Center (CIP) and its partners in Bolivia, Ecuador and Peru promote technological, commercial and institutional innovations along the potato chain to link small-scale farmers to new urban markets taking advantage of potato biodiversity. Markets are responding and demands significant volumes of high quality native varieties. In order to meet this demand, farmers are challenged to improve yield and quality of their crops, but one of the main limiting factors is availability of seed. A diagnostic of potato seed systems in these three countries was carried out in early 2008. Main conclusions were: (i) the availability of most native varieties in the three countries depends on small farmers, who preserve these varieties *in situ*; (ii) in most cases seed of native varieties is produced under *campesino* or mixed systems, mainly for self-consumption and, in a lower degree, for the market; (iii) factors causing seed degeneration and agronomic technologies for seed production are well identified for improved varieties, but almost nothing is known for native varieties; (iv) there are many projects and institutions that are currently helping farmers to produce seed; and (v) sustainability of any seed production system depends on the quality requirements of the market, which becomes the driving force for the development of a quality seed market. Mixed and *campesino* systems were identified as the most promising alternatives for potato seed production with small farmers in the Andes to respond to market demands.

Keywords: Andes, seed production, formal system, informal system.

Introduction

Potato is a staple food in the Andean countries. Hundreds of native varieties are very well appreciated by farmers and their families because of their excellent culinary qualities. These varieties have now better and increased commercial perspectives as big companies, like Frito Lay, have developed new commercial products. In addition, consumption of fresh tubers is increasing. Part of the production is sold in urban markets, and another part is used for self consumption, which make native varieties very important for food security. Unfortunately, small farmers obtain very low yields, partly due to poor seed quality. In order to accomplish new plans to expand markets, it is required to improve the production and quality of seed tubers.

The Papa Andina Initiative of the International Potato Center (CIP) and its partners in Bolivia (PROINPA Foundation, Promoción e Investigación de Productos Andinos), Ecuador (INIAP, Instituto Nacional Autónomo de Investigaciones Agropecuarias) and Peru (INCOPA Project, Innovación y Competitividad de la Papa) implemented this study to diagnose the current situation of the production systems of tuber seeds focusing on native potato varieties of Bolivia, Ecuador and Peru, in order to propose actions for improving these systems, especially for small farmers.

Methodology

Secondary information was collected. Recent information was obtained in early 2008 through direct observations in the field and interviews to farmers and officials of governmental and non-governmental organizations. Interviews were based on visit guidelines and a work plan previously established. The information received was mainly qualitative.

It was difficult to obtain information about volumes of native potatoes for fresh consumption, because official statistics about native potato production are inexistent. However, it was possible to obtain information on the volumes of certified seeds of improved and native varieties produced in Peru and Bolivia, but not in Ecuador. After the field visits and interviews were completed, a workshop was conducted in each country to discuss the situation of the seed potato production. These meetings allowed the experts to discuss the results of this study and also to implement some actions to improve the tuber seed production of native varieties.

Results and discussion

The results of this study are grouped on the following topics: (1) situation of native varieties in each country; (2) formal, informal and mixed seed potato production systems; (3) potential demand and seed needs of native varieties; (4) problems affecting seed quality of native varieties; and (5) seed renewal.

Situation of native varieties in each country. It was established the availability of native varieties in each country.

In Ecuador, there are approximately 400 native varieties grown by indigenous communities (INIAP, 2006), but only 20 of them are present in local markets. Unfortunately, the original collections were lost, but INIAP is collecting again these materials. A publication of INIAP (INIAP-PNRT - Papa, 2005) mentions 17 commercial varieties grown in the central provinces of the country. FONTAGRO (Fondo Regional de Tecnología Agropecuaria) is supporting a project to eliminate pathogens ("clean-up") of several native varieties to multiply them for industrial purposes. FONTAGRO and two CIP projects (Cambio Andino and InnovAndes, Strengthening Capacity for Innovation and Poverty Alleviation in the Andes) are also promoting production and commercialization of native varieties in the central Andes of Ecuador.

In Bolivia, the PROINPA Foundation maintains a gene bank with approximately 1750 accessions. From those, approximately 1050 are multiplied ("refreshed") to produce seed tubers which are also used for commercial purposes. Every year approximately 150 to 200 accessions are cleaned-up. A catalog of potato varieties, mostly natives, was produced in 2002 (Ugarte and Iriarte, 2002). Another catalog of potato and oca varieties of the Candelaria area has been published in 2004, where 32 native varieties are included (Cadima *et al.*, 2004).

Each region in Bolivia has its own native varieties that are utilized mainly for local consumption. In the north of Potosi, 200 native varieties were characterized and four were selected to promote their use. Other five varieties are being used by APROTAC (Asociación de Productores de Tubérculos Andinos de Candelaria), which has successfully consolidated the production and commercialization of seed and fresh tubers for the Cochabamba markets (Oros *et al.*, 2007).

In Peru in the Huánuco department, Mr. Victoriano Fernández (Jr.), a farmer who preserves native varieties in the district of Quishki, indicated that he grows 437 native varieties for tradition and eventual business. He also indicates that there are 14 other farmers who also preserves native varieties, and that each farmers maintains around 200 to 300 varieties. It is also known that CIP has returned 104 virus-free native varieties to the local communities in Chogobamba (3800 masl). In Junín, 15 native potato varieties are being multiplied by the NGO FOVIDA (Fomento de la Vida) and the platform CAPAC (Cadenas Agrícolas Productivas de Calidad), for further process testing by Frito Lay. In addition, INIA (Instituto Nacional de Innovación Agropecuaria) maintain an in-vitro collection of 18 pathogen-free native potato varieties, that was multiplied in Huancayo for the NGO ADERS (Asociación para el Desarrollo Sostenible) to be used for the industry and fresh consumption. In the region of Aymara (Huancavelica) there are several farmers that maintain native potato varieties; each farmer maintains approximately 400 varieties. A FONTAGRO project is supporting the evaluation of the processing aptitude of 12 native varieties for chips and mashed. In Paucarbamba, ADERS is conducting a seed project for multiplying five native varieties for industrial purposes. Farmers involved in this project attend farmer field schools (FFS) to receive training on seed production techniques. Some of these varieties are for fresh consumption in urban markets. It is also important to mention that UNALM (Universidad Nacional Agraria La Molina), CIP and INIA have initiated breeding programs oriented to select improved varieties with colored flesh pigmentation for industrial and fresh consumption purposes.

Finally, CIP maintains under custody the world potato gene bank constituted by samples of the potato germplasm collected in the countries of the Andean Region. This material is available to the scientific community upon request. For example, there are 758 accessions collected in Ecuador, 557 correspond to native varieties and 211 are pathogen-free accessions that could be returned to this country. The three countries are particularly benefited with the presence of CIP, because of the availability of pathogen-free native potato varieties in the germplasm collection and technical assistance. CIP has returned the collected material to farmers and scientists for their use. Tuber seed production can be easily initiated because the materials available are pathogen-free.

Formal, informal and mixed seed potato production systems. The formal and informal seed potato production systems are defined in relation to the improvement, management, replace and distribution of seeds. In the formal system these elements are regulated by the public sector through a seed certification process. In the informal systems (hereafter referred to as *campesino* systems), the above mentioned elements are freely managed by potato farmers, with or without previously established regulations with any participation of a seed certification entity. Mixed systems combine both formal and *campesino* systems (Thiele, 1997).

The use of certified potato seed in Bolivia is relatively low: 3.01 % in 2005 and 2.37 % in 2006. This figure is even lower in Peru; 0.34% in 2005, 0.24% in 2006, and 0.46% in 2007. In Ecuador there is no information about the coverage of certified seed.

In Ecuador, seed certification is done at a low scale and, therefore, the formal system is not fully operative. There is, however, an efficient mixed system (formal/*campesino*) practiced with improved varieties by a farmers' organization (CONPAPA, Consorcio de la Papa).

In Bolivia, the formal system is practiced in five departments and it is implemented by the National Seed Office (ONS), which operates through Regional Seed Offices (ORS). In 2006-07, there were 15 native varieties under certification process (Programa Nacional de Semillas, 2006) distributed in Cochabamba (11 varieties), La Paz (5 varieties), Chuquisaca (2 varieties), Potosí (5 varieties), and Tarija (2 varieties). However, most native varieties are not officially certified and farmers utilize seed produced by *campesino* systems. In 2006, 68 farmers were registered to produce certified potato seeds of native varieties (Programa Nacional de Semillas, 2006). The size of the seed lots in Bolivia is still small.

In Peru, the formal seed certification system was implemented by SENASA (Servicio Nacional de Sanidad Agropecuaria) up to December 2008, and starting on January 2009 by INIA. The seed potato certification system is being implemented in nine regions and in six of them there is certification for native varieties (Ayacucho, Apurímac, Puno, Cusco, Huancavelica and Junín). In these regions, the certified native varieties are: Ccompis, Peruanita, Huayro, Tumbay and Amarilla. In Huancavelica, Cusco, Junín and Apurimac there is an active market of native varieties, but the seed used is non-certified or common seed. Through the InnovAndes project, the NGO FOVIDA and organized farmer communities are supplying Frito Lay with quality potato production of native varieties: Cceccorani, Gaspar, Huayro Macho, Wenccos, Kallhuay and others. Seed of these varieties come from Andahuaylas and have been planted in the communities of Chicche, Pomamanta and Chuquitambo. In Andahuaylas, at least five varieties (Ccompis, Peruanita, Huayro, Tumbay and Amarilla) are certified by INIA. Under the Peruvian seed legislation, the commercial varieties must be registered in the Register of Commercial Varieties in order to produce certified seed. At present, 61 Peruvian native varieties have been already registered.

Potential demand and seed needs of native varieties. In the three countries there is no specific reference on the potential demand of seed of native varieties.

In Bolivia, it was estimated 5000 t of seed tuber is required for the highlands of the country and this amount can be supplied initially with 300 t of basic seed (Programa de Semilla de Papa, 1998). In Ecuador there are no references on any potential demand.

In Peru, it is known that seed producers from Andahuaylas attend seed request based on previous commercial and specific agreements. Recently, the chip industry of flesh colored native varieties would require approximately 500 t of commercial product annually. In order to produce this amount, it would be required the production of 20,000 pre-basic tuberlets produced in beds under rustic screen-house conditions or under green-houses in *aeroponic* facilities (see below). In Peru exists a big number of rustic screen-houses that can be used for the production of high quality pre-basic seed.

Problems affecting seed quality of native varieties. In any of the three countries there are studies indicating the problems that reduce the sanitary quality of the seed tubers of native varieties. It is recognized, however, that certain diseases caused by fungi, bacteria, virus or nematodes, among others, can cause severe losses to the crop and the seed (Rioja and Barea, 2004 y 2006). For seed production purposes, it is essential to initiate the process using pathogen-free materials (Rioja and Barea, 2004 and 2006; Iriarte *et al.* 2001).

In Peru, it is estimated that diseases caused by viruses are an important factor in the degeneration of native varieties (Scheidegger *et al.*, 1995). These authors working with improved and some native varieties estimated on 50% the crop losses in plants with 100% incidence of viruses PLRV (Potato Leafroll Virus) and PVY (Potato Virus Y) transmitted by aphids. The contact viruses PVX (Potato Virus X), PVS (Potato Virus S), APLV (Andean Potato Latent Virus), and APMoV (Andean Potato Mottle Virus) did not affect significantly the yield. Due to the fact that potato producers utilize their own seed, virus incidence increases and consequently degeneration occurs, which makes necessary the periodic renewal with pathogen-free seed.

In the lower parts of Huánuco, Peru, still persist two potentially serious pathological problems that should be taken into consideration if native varieties are multiplied in this zone: PYVV (Potato Yellow Vein Virus) and Bacterial Wilt (*Ralstonia solanacearum).* The latter has not been reported in most seed production areas, but it is necessary to verify constantly the absence of it.

In Ecuador, Fankhauser (2000) demonstrated that the main causes of seed degeneration are not viruses, but soil pathogens and insects, such as *Rhizoctonia solani*, *Streptomyces scabies* and *Premnotrypes vorax*, with incidences from 17 to 78 % and losses from 17 y 30%. Viruses such as PLRV, PVY and PYVV had low incidence (< 3%) affecting individual yield (per plant), but not total yield because of a compensation effect.

Another limiting factor on potato production in the Andean zone, as well as on seed production, is the Potato Cyst Nematode *(*PCN, *Globodera rostochiensis*) (Pacajes *et al*, 2002; Franco *et al.*, 1999). Losses caused by this nematode are very important (Franco *et al.*, 1999), not only for commercial potato productions, but also for seed production. An obvious problem at present is that the rotation periods are too short, which makes almost impossible to multiply seed in areas with PCN incidence.

Seed renewal. For native varieties, seed renewal is done through “refreshing” procedures, i.e., periodic reintroduction of pathogen-free materials every four to five years. In Bolivia, in the Toralapa Experimental Station of PROINPA approximately 2.0 to 2.5 t of certified seeds of native varieties are produced. In addition, a FONTAGRO project is in the process of producing certified seeds of eight native varieties.

In Peru, CIP has repeatedly reintroduced native varieties into communities, since many of them were lost due to social turbulence, natural disasters and abiotic factors. From 1998 to 2006, CIP restored to their original places 3182 samples of 1350 native varieties in 38 communities in 7 departments of Peru (R.Gomez, CIP, personal communication). In Andahuaylas, seed renewal is done by buying certified seed of five commercially produced varieties (Ccompis, Peruanita, Huayro, Tumbay and Amarilla). This is not the case with the rest of native varieties that are produced by individual request. *Campesino* seed is also produced when special projects request seed for specific varieties. This is the case of the production of variety Cceccorani for a project of the NGO FOVIDA in Junín. Seed exchange in local fairs is a common source of seed renewal in Peru and Bolivia.

In Ecuador, seed renewal of native varieties is almost inexistent, as there is no production of certified seed. However, INIAP is cleaning up several native varieties. Exchange in fairs is also low, as most native varieties are not present in markets.

Technical alternatives to produce high quality seeds of native varieties

In order to improve the seed production systems of native varieties in the three countries, it is necessary to take into consideration that most seed comes from *campesino* seed systems. Exceptions are certified seeds produced under the supervision of the ORS in Bolivia and by INIA in Peru. Farmers usually do not practice any type of plant selection (positive or negative) due to the lack of knowledge on limiting factors and also because of cultural beliefs. For example, killing a cultivated plant (i.e., negative selection) is not accepted by many Andean cultures. The following alternatives are proposed to produce high quality seed of native varieties:

Follow a formal system. Under this alternative production is conducted under the regulations of a seed certification scheme based on existing seed laws. It requires a lot of personnel, knowledge and investment from the public sector. Previous experiences in Bolivia, Ecuador and Peru (and in many developing countries) show that this alternative is feasible for large farmers, but not for small farmers. The expected sustainability of these systems is low, since it is necessary a market that demands quality potato production which acts as a driving force to develop demand for certified seed. Low multiplication rates of conventional techniques are not capable of lowering the price of pre-basic mini-tubers to start a seed multiplication program. An innovative technology called *aeroponics* is being tested in Ecuador and Peru for production of pre-basic mini-tubers. Early results suggest that this technology could dramatically reduce the cost of mini-tubers, making more affordable certified seed.

Follow a mixed system. These systems are suitable for small farmers connected to dynamic markets and includes the following components: (i) using seed produced under the formal system (e.g., pre-basic, basic, registered, certified) every certain number of years (usually four or five); (ii) training farmers to re-use the seed that they receive; and (iii) implementing an internal quality control system (e.g., Montesdeoca, 2005). There are good examples of such systems in the three countries, which apply at least one of the components: APROTAC in Bolivia, ADERS in Peru and CONPAPA in Ecuador. The expected sustainability of these systems is medium, as farmers depend on seed from outside every certain number of years.

Follow an informal system. These systems are particularly suitable for small farmers with low connection to markets and living in remote areas with high climatic risk. In this case, farmers are trained to select and manage their own seed to become self sufficient and secure seed supply. The expected sustainability of these systems is high, although the quality of seed stocks can decrease rapidly with poor cultural practices. Examples of these systems are described elsewhere (e.g., de Haan, 1999).

In mixed and *campesino* systems there are at least three points to be considered: (i) in regions with high climatic risk, rustic greenhouses or protected beds (e.g., PROINPA, 1998) could be used to produce small amounts of high quality seed, but the requirements of water, labor and cash could be too high for small farmers; (ii) positive, negative and clonal selection are key elements in both systems and, therefore, training farmers on these simple techniques is crucial; and (iii) small farmers has to be organized in order to implement mixed or *campesino* systems.

Conclusions

The availability of most native varieties in Bolivia, Ecuador and Peru depends on small farmers, who preserve these varieties *in situ*. Small farmers use these varieties mainly for self-consumption, and also to supply the increasing demand of the industry and the fresh market.

Seed of native varieties is mostly produced under *campesino* systems. Although poor cultural practices and free exchange of planting material derived from these systems are some of the main factors for pathogen dissemination, mixed and improved *campesino* systems are the most promising alternatives for potato seed production for small farmers in the Andes to respond to market demands.

A limitation for using formal systems is that native potato varieties need to be registered officially in order to produce certified. This represents an administrative constraint, since bureaucratic paperwork is demanding and time consuming, and it is not clear if this is responsibility of a national or private entity. The work done under the leadership of INCOPA in Peru illustrates how private partners have worked together towards official registration of native varieties.

Seed production techniques and agronomic technologies for seed production have been developed and are well identified for improved potato varieties, but need to be adapted to improve seed production systems for native varieties. New techniques, such as aeroponics, are promising and can have an impact on seed systems. Nevertheless, simpler technologies, such as positive and negative selection, training and technical assistance remain as the key factors to strengthen the existing seed systems to respond quickly to market demands. Similarly, factors causing seed degeneration are well identified for improved varieties, but need to be validated for native varieties.

After the International Year of the Potato, it is evident the increasing demand for native potatoes. As response, an increasing number of NGOs, OGs and projects are helping small farmers to produce seed. It is, therefore, urgent for CIP and its partners to guide these efforts to avoid costly mistakes, such as implementing formal systems, which have proved to be inadequate for small farmers.

Finally, sustainability of any seed production system depends on the quality requirements of the market. A quality demanding potato market (for fresh or processing) will be the driving force for the development of a quality seed market and, therefore, market requirements is a crucial variable when designing and implementing seed systems.

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Effect of partial root-zone drying on the growth of potted potato plants under greenhouse conditions

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Abstract

An indoor experiment was conducted at CIP's headquarters in Lima, Peru, to assess the effect of Partial Root-Zone Drying (PRD) irrigation method on the growth and water consumption of potato (*Solanum tuberosum*) plants. Single plants were grown in pots filled with PRO-MIX, a humic soil substrate with a high water retention capacity. The root zone was bisected by a plastic membrane and the root system was equally divided into two mutually impermeable sections. Alternate irrigation was provided to each root zone section, thus PRD treatment plants were frequently watered but an alternate half of the root zone was also frequently induced to experience water deficits. All plants were irrigated on demand, as defined by daily transpiration determined by the weight of the pots. Treatments contrasted conventional irrigation (non-bisected root zone) at four levels of water supply (reposition of 100%, 60%, 45% and 30% of transpired water) with PRD irrigation at three levels of water supply (60%, 45% and 30% of transpired water). Differential irrigation schedules were initiated 28 days after planting and the experiment lasted 90 days from planting. Results showed that tuber dry matter yield decreased as water supply decreased, regardless of the irrigation system. However, yields at the supply level of 60% of transpired water were higher for PRD compared to conventional irrigation. Total biomass followed the same trends as tuber yields. All restricted water supply showed higher water use efficiency (WUE) than the control, regardless of irrigation method. No differences in WUE between the irrigation methods occurred.

Keywords: Potato, Partial Root-Zone Drying, Irrigation.

Introduction

Potato (*Solanum tuberosum*) is a crop that is very sensitive to water stress, which makes it a water-demanding crop, requiring from 400 to 600 liters of water to produce 1 kilogram of tuber dry matter (Beukema and Van der Zaag, 1979). Under field conditions, the water requirements vary between 350 to 500 mm over the growing season, depending on the growing period, environmental conditions, soil type and cultivar (Sood and Singh, 2003) and the crop can respond with increments of up to 2 t/ha for each 2 cm of water lamina (Harris, 1978). The critical period to water deficit in potato is from tuber initiation to maturity (Salter and Goode, 1967; Jensen *et al.*, 2000 and Egúsquiza, 2000) and even short episodes of water stress during this period can cause significant reductions in yield and quality (Miller and Martin, 1987; Kumar *et al.*, 2003). In many rain fed potato-cropping areas of the world, supplemental irrigation is necessary for successful production. However, in many countries water availability for agriculture is being reduced as a consequence of global climate change, environmental pollution and growing demand for other uses. Therefore, great emphasis is being placed on water management for dry conditions based on plant and crop physiology, with the aim of increasing water use efficiency by major crops, which is highly dependent on well-planned watering with low volume and high frequency (Vayda, 1994; Wright and Stark, 1990). The potato's limited tolerance to drought is due to its comparatively shallow root system (50-60 cm) and stomatal closure (Harris, 1992; Kleinkopf and Westermann, 1981; and Bailey, 2000), which is the first physiological response of plants to water deficit, resulting from the regulation of osmotic pressure in the guard cells, mediated by abscisic acid (ABA) released by roots in drying soil. It is known that when the root system is exposed to dry soil, it responds by sending ABA-mediated chemical signals to the leaves to close stomata and reduce the water loss (Davies and Zhang, 1991). Studies on progressive root drying in potatoes have shown that root-sourced ABA reduces stomatal conductance (Liu *et al.*, 2005). This kind of communication is known as non-hydraulic or chemical signaling, which differs from hydraulic signals, which are based on changes in the xylem sap tension (Stikic *et al.*, 2003). Plants with a good watering regime usually keep turgor and their stomata wide open in response to hydraulic signal through xylem water pressure. When the tips of young roots come into contact with dry soil, the release and high concentration of ABA in the xylem prompts stomatal closure to slow down the fall in plant water potential, reduce water loss and bud growth, and prevent wilting (Zhang *et al.*, 1987; Zhang and Outlaw, 2001; Khalil and Grace, 1993; Jia *et al.*, 1996). However, stomatal closure also reduces leaf extension rates (Haverkort and MacKerron, 2000), CO_2 uptake and photosynthetic activity, increases leaf temperature and photorespiration, and is therefore negative for crop production (Egúsquiza, 2000). Manipulating stomatal opening in potato in order to increase the yield per unit volume of transpired water has been suggested (Harris, 1992) although this increment would also mean a reduction in the yield per unit area. Partial root-zone drying (PRD) is an irrigation method that attempts to manipulate plant response to root drying in order to decrease the agricultural demand for water. PRD is an irrigation technique whereby half of the root zone is irrigated while the other half is allowed to dry out. Water supply is then cyclically reversed allowing the previously well-watered side of the root system to dry down while fully irrigating the previously dried side. When PRD irrigation is applied to a crop, the normal root to shoot signaling system that operates in water-deficient soils is altered, causing the drying half of the root system to release ABA thus reducing stomatal aperture, whereas the fully hydrated roots maintain a favorable water status throughout the aboveground parts of the plant. In other words, PRD uncouples the biochemical signal in response to water stress from the hydraulic signal and physical effects of reduced water availability (Bacon, 2003). PRD is based in the theoretical assumption that this mixed root signals causes a limited closure of stomata to restrict water vapor with a minimum effect on CO_2 uptake and photosynthesis (Jones, 1992). It is expected that contradictory root signals brought about by PRD would cause a slight reduction of the stomatal opening that would decrease the water loss substantially with only a small effect on the photosynthesis rate, provided plant turgor is maintained by the watered fraction of the root system. The expected outcome is reasonably good yields with considerable water savings and higher water use efficiency (WUE), which is of paramount importance in areas where water resources are limiting. PRD also stimulates the growth of secondary roots, which reduces the vulnerability to drought (Zhang and Tardieu, 1996). A root system more widely distributed in the soil volume as a result of the lateral dry-wet cycle can result in an improved uptake of nutrients and water by the root system (Kang *et al.*, 1998). PRD has been successfully used in fruit-producing crops such as tomatoes, grapes, oranges, olive trees, tomato, corn, cotton and others, but no extensive research has been conducted in root and tuber crops, particularly in semi-arid environments where the water resource is scarce. The results in the former crops demonstrated that PRD has no major negative effect on the yield but improves fruit quality with a reduction of more than 50% of the consumption of water (Loveys *et al.*, 2001). However, important issues such as the growth stage at which PRD should be applied to the potato crop to improve WUE without yield reductions remain to be addressed (Liu *et al*, 2006a,b). Interestingly, Xu *et al.*, (1998) stated that ABA stimulates tuber formation in potato whereas Jackson (1999) has suggested that ABA participates in the control of tuber formation although its direct effect is not totally clear yet. The effect of partial root drying in tuber formation has not yet been elucidated.

An indoor experiment was conducted at CIP's headquarters in Lima, Peru, to assess the effect of PRD irrigation method on the growth and water consumption of potato plants. The objective of this study was to test the effects of PRD on WUE and tuber production as compared to full irrigation, and investigate its effect on morphological and physiological characteristics of the potato crop.

Materials and methods

Single plants of the potato variety Unica were grown in pots filled with 1.2 kg of PRO-MIX, a humic soil substrate with a high water retention capacity. The root zone in each of the pots selected for the PRD treatments was bisected by a plastic membrane and the root system was equally divided into two mutually impermeable sections. Each side of the root zone was identified. After emergence the pots were covered with a plastic film all around the plants to prevent evaporation from the soil. Treatments contrasted conventional irrigation (non-bisected root zone) at four levels of water supply (reposition of 100%, 60%, 45% and 30% of transpired water) with PRD irrigation at three levels of water supply (60%, 45% and 30% of transpired water). All plants were irrigated on demand, as defined by daily transpiration determined by the weight of the pots. In the PRD treatments, alternate irrigation was provided to each root zone section, thus PRD treatment plants were frequently watered but an alternate half of the root zone was also frequently induced to experience water deficits. The sequence of alternating watering was determined by the accumulated daily transpiration, being the threshold an accumulated transpiration of 900 g. When this level of accumulated transpiration was reached, watering was switched to the other side of the divided pot. Up to days 27 after planting, all pots were continuously watered to soil capacity. Differential irrigation schedules were initiated 28 days after planting and the experiment lasted 90 days from planting.

Results and discussion

The average total amount of water applied to plants in each treatment is shown in Figure 1. This amount is the sum of the non-differential full watering common to all plants during the first 27 days of the experiment plus the amount of water applied during the experimental phase of differential irrigation from day 28 to the end of the trial. Although plants were irrigated on demand as determined by the rate of daily transpiration, no differences in water consumption between the treatments with similar preset percentages of water reposition relative to daily transpiration were observed. This was due to the fact that rates of transpiration of corresponding normal and PRD treatments with similar preset percentages of water reposition were equivalent, as shown in Figure 2. As a consequence of this lack of effect of irrigation method on daily transpiration and water consumption, total biomass produced under either conventional and PRD irrigation did not show differences at the same level of water restriction, except for the 60% level at which total biomass produced under PRD were higher than the yield under the conventional watering procedure (Figure 3). Overall, total biomass production was a function of water consumption. Figure 3 shows that the control plants produced the higher biomass yield and that significant reductions in total biomass were gradually caused by the reductions in water supply, regardless of the irrigation method.

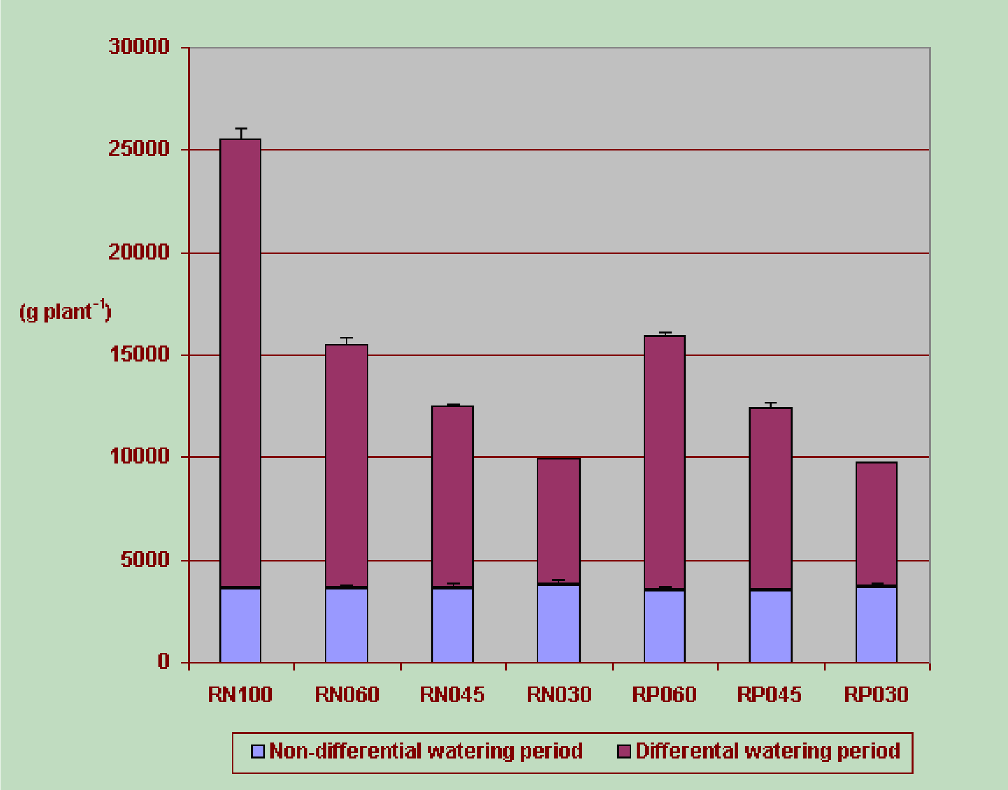

Figure 1. Total applied water

Tuber production followed exactly the same trend described for total biomass, as can be seen in Figure 3. As to harvest index, a significant reduction was observed at the lowest level of water consumption in both the conventional and PRD irrigation methods, as shown in Fig. 4.

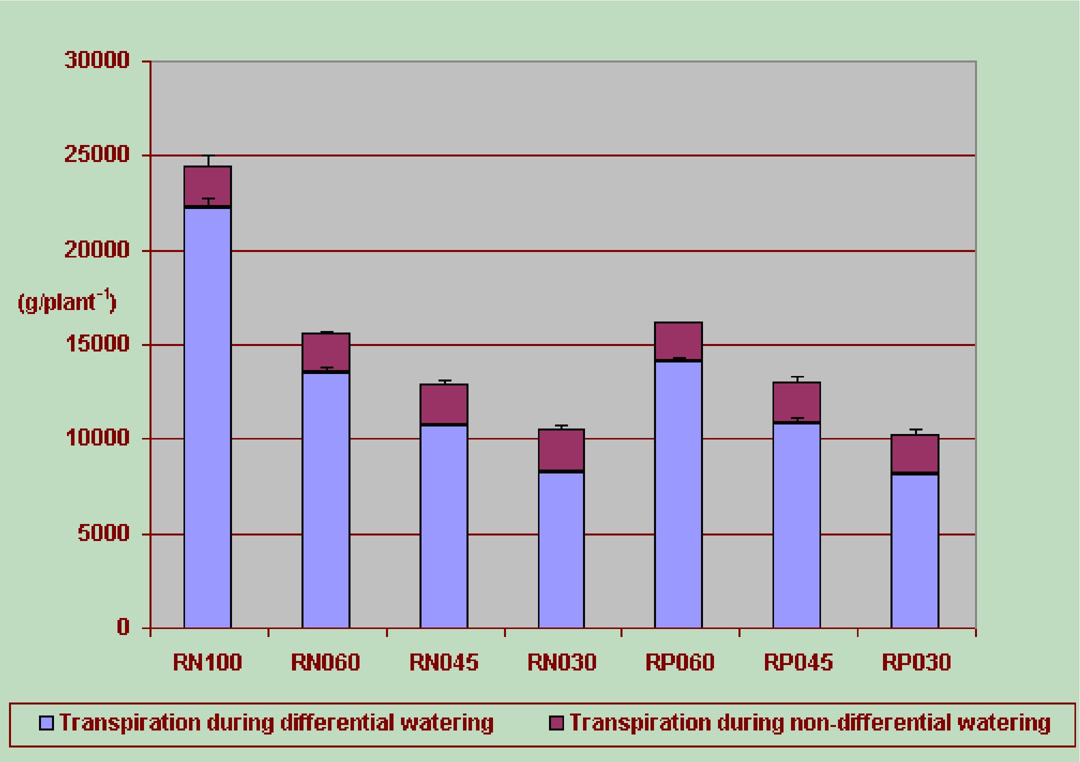

Figure 2. Total Transpiration

As to water transpiration efficiency (WTE), which is the ratio of carbon fixation to water loss (in our case was measured as the ratio of biomass production to water loss), it was calculated for both total transpiration (water transpired during the full growing period, from plant emergence to harvest) and for the period of differential irrigation (from day 27 onwards), as shown in Figure 5. It is not surprising that WTE was significantly higher during the period of differential watering, as that resulted from the shorter period of transpiration included in the analysis. However, it is noteworthy that in all cases water restriction increased WTE compared with the control at both the total growing period and during the period of differential irrigation. Moreover, the level of water restriction, regardless of the irrigation method, positively increased the gap between total WTE and the efficiency during the period of restricted irrigation. Similar results were obtained for water use efficiency, as shown in Figure 6, due to the experimental coupling between water application and transpiration, as the latter defined the demand. It is likely that differential water application based on field capacity rather than transpiration would bring about different results, as it will allow a more clear cycle of watering and drying of the halves of the root zone. It is also likely that the watering determined by daily transpiration has not allowed a long and intense enough partial drying of the root zone, which could explain the absence of differences between the two restricted watering systems applied in this experiment.

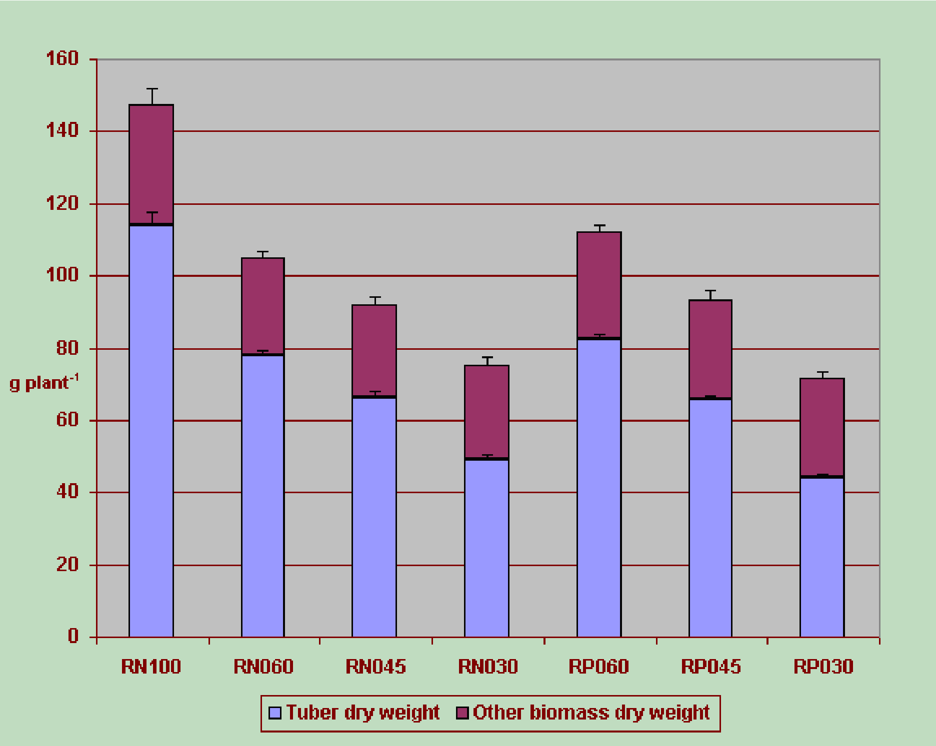

Figure 3. Total Dry Biomass

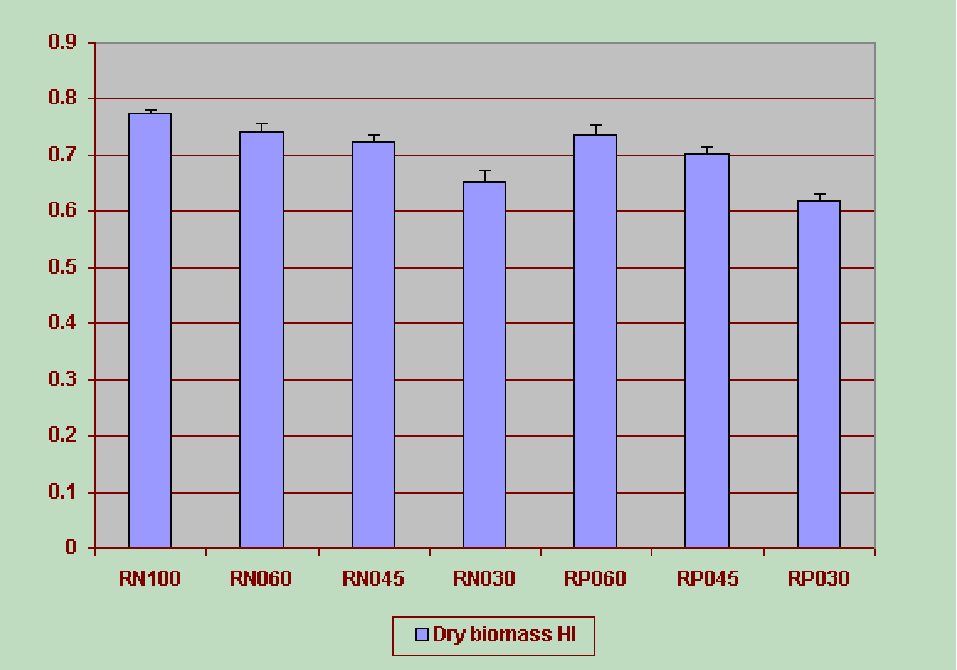

Figure 4. Harvest Index

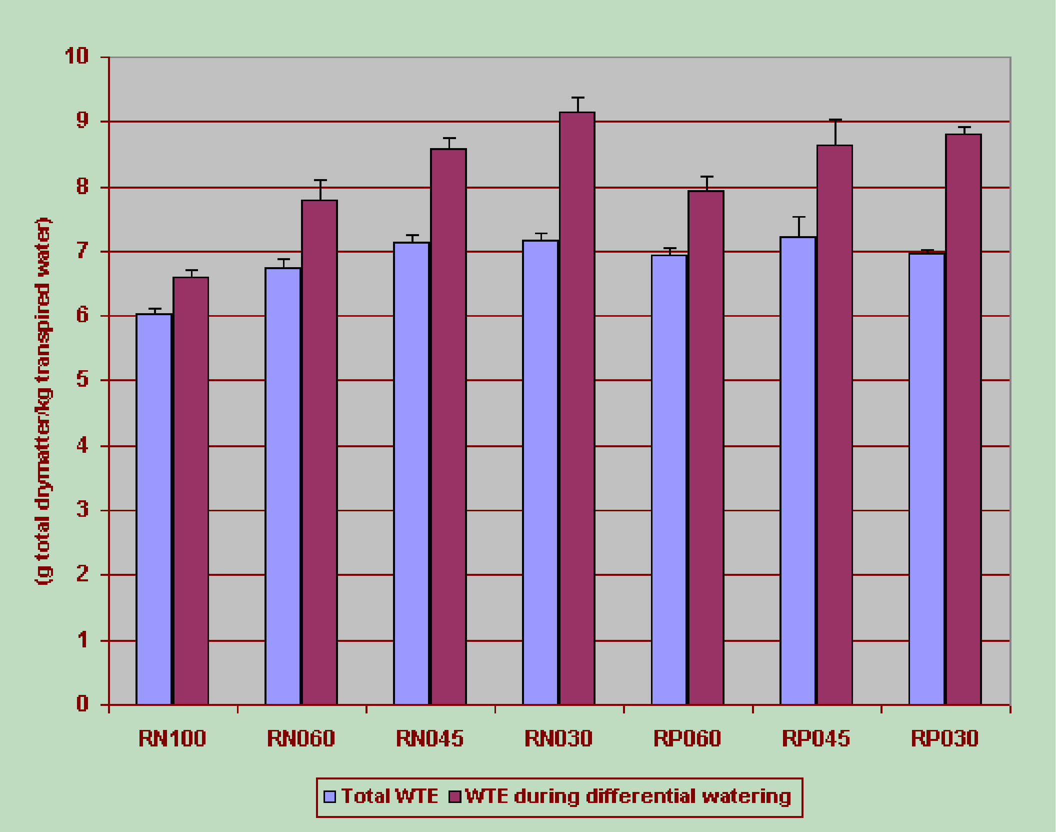

Figure. 5. Water Transpiration Efficiency

Figure 6. Water use efficiency

Conclusions

It was evident that water restriction, regardless of irrigation method, increased both WTE and WUE. However, the trade off between the reduction of both water use and tuber production has to be taken into consideration for practical applications of restricted irrigation. Further work will explore the responses to PRD in the field.

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Improving farmer based seed systems in sub-tropical highlands of Nagaland, India

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Abstract

Inadequate and untimely supply of planting material and high transportation cost limits potato productivity in Nagaland. The improved seed production technologies such as positive and negative seed selection and utilizing TPS derived planting materials were evaluated for maintaining better seed health and to use same seed for greater generations without significant reduction in economic yields. Farmers and extension workers were trained on different seed production techniques. The seed produced by positive selection, multiplied from basic seed supplied in 2007 and produced from conventional system by five farmers each were evaluated at two locations in 2008. The fresh basic seed of Kufri Jytoti was supplied for comparison. At one location, the fresh basic seed gave significantly higher tuber yield (18.9 t/ha) compared to 13.9 t/ha of conventional seed and practices. The second generation basic seed and seed produced by adopting positive selection techniques also gave greater yield than local seed. The suitability of TPS as cheap quality seed source was also studied. In 2006 summer, 600 gram TPS was provided to "Self Help Group" who produced 50 MT quality tuber seed by transplanting in 5ha. In 2007, six individual farmers and a Self Help Group of 10 women farmers produced 20 MT healthy seed tubers. TPS derived seeds yielded 18.6 t/ha compared to 17.4 t/ha of traditional seeds. The Department of Agriculture facilitated the marketing of TPS derived seed tubers. The farmers response was encouraging for both improved clonal seed production technologies and for TPS as supplement planting material.

Keywords: Positive and negative selection technologies, True Potato Seed.

Introduction

Potato is an important food and cash crop for the farmers of Nagaland. The potato yield of Nagaland is just 8.6t/ha compared national yield 18.9t/ha. Inadequate and untimely supply of planting material to farmers and high transportation cost from North India are the main limiting factors for poor productivity. The seed supplied by public sector meets a meager demand. Farmers in this region use highly degenerated seed that reduces productivity. State Department of Agriculture purchases certified and foundation seeds at exorbitant prices from Himachal Pardesh State (North India) to distribute among farmers. Improving farmers own seed system needs to be implemented to increase potato productivity. With the improved seed production technologies such as positive and negative seed selection, farmers could use the same seed for more generations without significant reduction in yields. International Potato Center (CIP-SWCA) and Department of Agriculture Nagaland have jointly assisting farmers to imrove their seed systems. In the year 2007 and 2008, farmers of Khuzama and Kigwema blocks of Kohima district in Nagaland were trained on improved seed selection systems. In addition, the True Potato Seed (TPS) technology was also implemented in Wokha district. TPS technology is found to be an alternate for the existing seed system. The objective of the present work was to enhance income of resource poor farmers of Nagaland by increased potato productivity through quality seed.

Material and methods

Two blocks of Kohima district were selected as models to evaluate and execute the positive and negative seed production techniques. Twenty and ten farmers were selected to evaluate and compare positive and negative seed production techniques respectively with traditional system in 2007. The farmers planted their own seed and adopted local cultural practices. The first visual observation to select healthy looking plants free from diseases mainly viruses were taken after 30 days of planting. The healthy plants selected and pegged were monitored regularly. The pegged plant/plants were rejected if they show any disease symptoms before deahulming. The selected plants were harvested separately. The produce of plants giving greater and uniform tuber number and shape were selected and bulked. The plants not giving satisfactory yields were rejected. The selected tubers of healthy plants were treated with 3% boric acid to check spread of tuber skin borne diseases. The treated tubers were dried and stored for next year planting. To evaluate negative selection technology, the basic seed of variety Kufri Jyoti was supplied to the farmers as starting material for multiplication. The tuber seeds produced in 2007 through positive and negative selection techniques were compared with traditional practices. The data recorded was analyzed statistically for analysis of variance by using RBD (Panse and Sukhatme, 1978).

During 2006, a Self Help Group (SHG) of 28 farmers of Wokha district formed for on farm demonstration trials. Two TPS families 92-PT-27 and HPS-1/13 were used as starters for this experiment. Test location was in Nagaland **at** 1500MSL**.** There was staggered sowing of TPS in nursery beds, A total of 3.0 ha land was transplanted with HPS I/13 and 2.0 ha with 92-PT-27. seedlings were transplaned at 60X30 cm. Seed tubers were harvested and stored in traditional stores. During 2007, a women self help group consisting of 10 farmers and 5 individual farmers were selected for the study. A total area of 2.0 ha was under study. Same methodologies as that of previous year were used carry out the study. .

Results and discussion

In 2007, 14 farmers out of 20, implemented the positive selection properly. The average tuber number and weight/plant in Khuzama and Kigwema of selected plants varied between 7-14 and 260-735 gm, respectively (Table 1). The farmers were able to harvest 4008 tubers from healthy looking plants from their fields for next year multiplication. The farmer looked positive for new technology and showed confidence that they could improve the health standard of their seed which they have using for many generations.

Seeds from 2007 year's positive and negative selection were planted during 2008 to compare their performance with fresh basic seeds and traditional system. The significant higher yields were obtained by improved seed and practices when compared with local seed and practices (Table 2). The highest yield of 18.9 t/ha and 21.6 t/ha were obtained from basic seed in Khuzama and Kigwema, respectively. The planting of healthy seed and practicing improved seed production technologies enhanced the tuber number and weight. The seed plot (improved) technique is recommended to enhnace income of seed potato farmers through increased productivity (Kumar *et. Al.,* 2000). In both the villages, average tuber weight was found to be significantly higher by improved practices than local practices. In Khuzama, the positively selected seed tubers from local seed in 2007 gave significantly higher marketable yield than local seed (mixture) when planted in 2008 (Table 2). Gildemacher *et.al l*(2007) reported that, positive selection a valuable addition to commercial production of seed potatoes.. . In both villages average tuber weight from improved practices were significantly higher than local practices.

The fellow farmers of two villages where positive selection was implemented to improve local seed quality were convinced that they can also improve their own home used seed for enhanced productivity and improved quality through positive selection. 15 new farmers of two villages adopted positive selection at their fields. The observations recorded on the quality seed produced through positive practices are presented in Table-3. The average tuber number and weight/plant in Khuzama and Kigwema of selected plants varied from 7-13 and 315-645 gm, respectively. The farmers harvested 3959 tubers from healthy looking plants which they will use as quality seed for commercial potato production in 2009.

The area covered and tuber yield obtained by afrmers during 2006 from TPS are presented in the Table 4. A total of 52.5 tones of seed potato was produced in 5 ha area with average yield of 10.5 t/ha. It was also observed that, the TPS family 92-PT-27 took longer time for germination. The performance of the 92-PT-27 was a better than HPS 1/13. The tubers produced from 92-PT 27 were oblong and bigger whereas HPS 1/13 are round and small. The survival rate of seedling at the time of transplanting was very high about 85%. Farmers showed much interest towards TPS technology. Self Help Group made a country store of locally available materials to store TPS produce to use as seed in the next season. Due to declaration of year of farmers by Nagaland state, seed tubers of Kufri Jyothi and Kufri Giriraj were supplied to farmers at free of cost. Farmers did not show much interest on

TPS technology during the year 2007. 220 gm TPS (HPS 1/13) from Tripura government were distributed to a self help group and five farmers. 20 tones of seed tubers were produced from 2 ha field by transplanting method. The crop grown with the TPS were found to be more tolerant to blights.

Table 1. Quality seed produced by farmers through positive selection in Nagaland, 2007

Farmers	Number of plants		Tubers number and weight of plants harvested		Average tuber number and weight/plant		Average tuber weight (g)
	Harvested	Selected in starting	Number	Weight (kg)	Number	Weight (g)	
KIGWEMA VILLAGE							
1	60	23	180	9.4	8	408	52
2	55	50	433	27.8	9	556	64
3	110	61	419	28.5	7	468	68
4	55	28	194	8.0	7	285	41
5	60	20	148	7.3	7	363	49
6	100	30	222	18.3	7	610	82
7	55	30	209	8.2	7	274	39
KHUZAMA VILLAGE							
1	75	36	289	16.5	14	555	43
2	79	41	310	20.5	11	735	73
3	60	33	174	13.81	10	570	58
4	60	50	492	29.75	11	680	60
5	70	49	388	22.45	9	535	63
6	38	31	213	8.4	8	260	36
7	80	46	337	18.23	7	498	73

It is clear from the Table 2 that, the average yield obtained from TPS derived planting materials was higher compared to traditional seed tubers. On an average, 18.6 t/ha yield was obtained from TPS derived planting materials compared to 17.4 t/ha yield of traditional seeds. Plants from traditional seed showed leaf curl and chlorosis symptoms.

Table 2. Comparative performance of different seed categories and practices at farm level in Nagaland, 2008

Seed Categories/Practices	Average tuber number/plant	Tuber yield t/ha			Average tuber weight (g)
		Marketable (>.20g)	Non-Marketable (<20g)	Total	
KHUZAMA VILLAGE					
Local seed selected positively/improved practice	5	14.3	2.2	16.5	40
Basic seed second yr./improved practice	7	15.1	1.7	16.9	34
Basic seed first yr./improved practice	8	16.8	2.1	18.9	34
Local seed/local practice	8	11.1	2.8	13.9	21
CD at 5%	1	3.0	0.6	3.0	6

Seed Categories/Practices	Average tuber number/plant	Tuber yield t/ha			Average tuber weight (g)
		Marketable (>.20g)	Non-Marketable (<20g)	Total	
CV%	19	20.0	27.9	15.0	25
KIGWEMA VILLAGE					
Local seed selected positively/improved practice	7	16.1	2.0	18.1	33
Basic seed second yr./improved practice	7	14.5	1.9	16.4	30
Basic seed first yr./improved practice	11	19.4	1.5	21.6	32
Local seed/local practice	9	13.8	2.5	16.8	24
CD at 5%	1	3.0	0.5	NS	NS
CV%	23	18.1	24.4	18.9	22.1

Table 3. Quality seed produced by farmers through positive selection in Nagaland, 2008

Farmers	Number of plants		Total tubers number and weight of plants harvested		Average tuber number and weight/plant		Average tuber weight (g)
	Selected in starting	Harvested	Number	Weight (kg)	Number	Weight (g)	
KIGWEMA VILLAGE							
1	45	29	232	9.0	7	315	47
2	49	38	370	13.5	13	545	44
3	36	26	167	8.5	7	345	50
4	47	32	247	14.5	9	610	72
5	49	28	243	13.0	12	645	52
6	42	34	254	14.0	9	530	62
7	31	22	128	10.0	7	495	73
8	39	32	214	15.5	7	555	80
KHUZAMA VILLAGE							
1	47	45	312	18.5	13	520	41
2	39	36	356	22	12	570	50
3	58	55	324	21	10	480	49
4	48	40	378	23.5	11	600	57
5	42	34	298	16	11	515	46
6	51	42	325	12	8	475	59
7	45	42	325	12	7	405	59

Av. tuber number: average tuber wt are mean of 10 plants

Table4. Potato production using TPS by transplant method

TPS family	Quantity of TPS given (gm)	Area covered (ha)	Total tuber Yield (tons)	Average (t/ha)
HPS I/13	300	3.0	29.5	9.8
92-PT-27	200	2.0	23.0	11.5

Table 5. Yield comparisons between traditional seeds and TPS derived tubers

Farmer	Yield (Kg/plot)		Yield (ton/ha)	
	Tubers from TPS	Traditional seed	Tubers from TPS	Traditional seed
1	22	21	19.80	18.90
2	19	18	17.10	16.20
3	21	19	18.90	17.10
Average	21	19	18.60	17.40

Size of plot: $9m^2$
Number of replications in each farmer's field: 3

Conclusions

During the year 2007, farmers were able to produce nearly 237 kg of healthy potato seeds by positive selection technique. The planting of healthy seed and practicing improved seed production technologies enhanced the tuber number and weight. In 2005-06, 52.5 MT of tubers were produced from direct transplanting of TPS in 5 ha land and were distributed to farmers. During 2006-07, 20 MT of seed tubers were produced from 2 ha field by transplanting method. TPS derived planting materials yielded better than traditional varieties under in same agro-ecology.

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