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

**Berga Lemaga**[1], R. Kakuhenzire[1], P. Gildemacher[2], D. Borus[3], Gebremedhin Woldegiorgis[4], I. Barker[5] J. Low[3], and O. Ortiz[5]

[1]International Potato Center, P.O. Box 22274, Kampala-Uganda; [2]Royal Tropical Institute, PO Box 95001, Amsterdam, The Netherlands, [3]International Potato Center, P.O. Box 25171, Nairobi-Kenya; [4]Ethiopian Institute of agricultural Research, P.O.Box 2993,Addis ababa-Ethiopia [5]International Potato Center, Apartado 1558 , Lima 12, Peru

## 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.

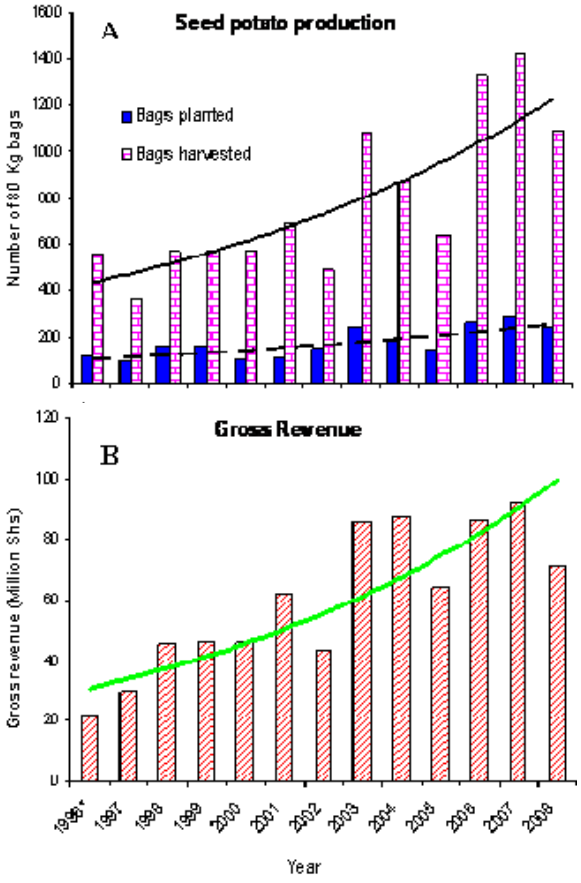


**Figure 1. Seed potato production in 80 kg bags (A) and gross revenue (B) of Uganda National Seed Potato Producers' Association, 1996 – 2008**

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.

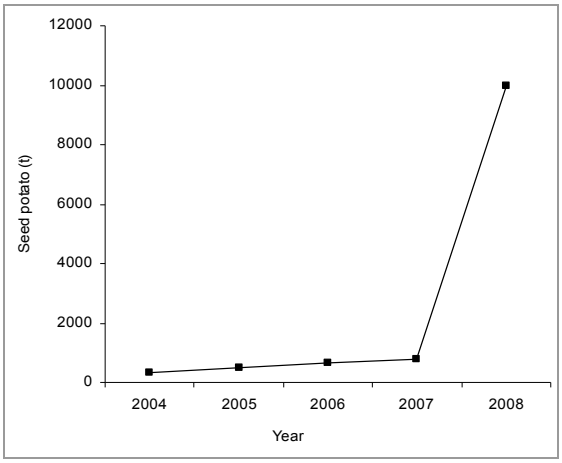


**Figure 2. Informal seed potato production in Ethiopia between 2004 and 2008**

## 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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