Possibilities and Opportunities for Enhancing Availability of High Quality Seed Potato in Ethiopia: Lessons from the Successful 3G Project in Kenya

Ricardo A. Labarta
International Potato Center, Regional Office Sub Saharan Africa (CIP - SSA)
P.O. Box 25171, 00603 Nairobi, Kenya

Introduction

In Ethiopia, potato production could fill the gap in food supply during the "hungry months" of July to August before the grain crops are being harvested. Potato in Ethiopia is currently planted in around 164,146 hectares producing an estimated total tuber yield of 940,087 tons (CSA, 2002). This implies that average yield in the country reaches only 7 t/ha when the potential for small holder is around 25 t/ha. There are many factors that have been identified as the causes for this low yield in Ethiopia and most of the East African countries, but the lack of high quality seed seems to explain most of the differential with the potential yields of the existing potato varieties. Increasing the availability of high quality seed at affordable prices would be a priority in order to significantly increase potato yields in the region.

Following the crisis of world food price in 2008, a group of international and regional agricultural organizations led by the International Potato Center met in Nairobi, Kenya in order to propose immediate actions to respond to the critical situation in East Africa and the lack of enough high quality seed potato. From this meeting an initiative called the 3G revolution emerged and aimed to boost the production of high quality potato seed by involving different stakeholders from both the public and the private sector in Sub-Saharan countries.

This initiative was implemented successfully in Kenya, Uganda, and Rwanda between 2009 and 2011 showing very promising results. In Kenya, the availability of high quality seed increased from an average of 80-200 t/year to a total of 4,000 – 5,000 t /year after 2 years of intervention. More than 20,000 farmers have directly benefited from this experience creating various business opportunities for different potato value chain stakeholders (CIP, 2011). It was shown that large private farmers, medium scale seed multipliers, and small-scale ware producers increased their farm income and improved their food security (Labarta and Mulwa, 2011). Now the challenge is to scale up and out this

experience and to bring this strategy to countries like Ethiopia where the production and consumption of potato continue to grow and where the potential for business opportunities and for generating impacts in poverty alleviation and food security improvement is huge. This paper discusses the opportunities and possibilities to implement the 3G strategy in Ethiopia.

The "3G" strategy and different business opportunities for producing high quality seed potato

The 3G strategy was conceived as an innovative response to the crisis increased on the unavailability of seed potato in East Africa. Encouraging the participation of different stakeholders from both public and private sectors, the 3G strategy aims to drastically lower the cost of production of pre-basic or starter seed and at the same time use extension mechanism to train smallholder potato growers in good on-farm seed management. This is because the strategy involves delivering low cost quality seed to growers in 3 generations of field multiplication, rather than the conventional 5 to 7 generations, the new seed potato strategy is widely known as "**3G**" system. The interventions that the 3G strategy proposes can be summarized as

- Increasing the capacity of National programs to produce and multiply mini-tubers at lower unit cost and reduced number of field generations;
- Encourage the participation of private sector in mini-tuber production and field multiplication;
- Promotion and distribution of clean seed to smallholder private seed multipliers and smallholder growers through voucher schemes, seed fairs and large scale distribution of small quantities of seed in trail packs;
- Promoting the diffusion and adoption of new high yielding and disease resistant varieties;
- Securing farm saved seed supplies at nationally significant scale through positive selection and farmer awareness campaigns; and

Promotion of diffused light stores and awareness rising in the importance of good seed storage.

In the next sub-sections we describe the different business opportunities that are related to the 3G strategy:

Rapid seed multiplication techniques: aeroponics

Technologies and techniques for rapid multiplication of sizeable amounts of quality seed of the best varieties now exist together with expertise. A typical seed potato production system starts with completely virus free plantlets coming from the tissue culture laboratories. These plantlets are planted in an insect -proof screen house to produce clean mini-tubers. Currently the production of mini-tubers plus the first 2-3 multiplication are done by the national public research institutes. The seed potatoes resulting from this are called starter seed potatoes, and are further multiplied by parastatal organizations or commercial seed potato farmers and grower organizations. The production of mini-tubers in soil or compost-based substrate is limited by the natural multiplication rate of the crop that is typically only about 6:1 as well as the increasing cost of energy needed to sterilize large quantities of substrate. Many National programs in Sub-Saharan, also face serious land constraints in providing enough land required to multiply high-grade input seed.

CIP scientists have successfully adapted a previously complex process of producing high quality mini-tubers in a specialized soil-less system known as "aeroponics" to become an affordable and low cost production technique. Experience in South America and in Kenya, Uganda and Rwanda are indicating that multiplication rates of 50:1 can be achieved per season at affordable cost of production. It has also been shown that up to 60,000 mini-tubers cab be produced in a single 15 by 5 m pilot scale screenhouse (compared with some 18 000 mini-tubers in a conventional system), the final amount varying by variety. This innovative system should allow producing mini-tubers at far lower cost, reducing the number of field generations required to multiply seed and thus reduce the impact of serious soil-borne disease constraints such as bacterial wilt.

Specialized high-grade seed producers: G1 and G2 seed production

The 3G strategy participates large-scale and specialized seed producers that would benefit from multiplying high quality mini-tubers (G1) into larger quantities of high quality seed potato (G2 and G3) that could be used to produce commercial ware potatoes or further multiply by other trained farmers for keeping the quality of seed potato and benefit for small-scale farming.

It is expected that mini-tubers harvested from aeroponics and conventional mini-tuber production cycle1, would be stored and multiplied in bacterial wilt free

field for two generations (G1 and G2) (seasons 3 and 4). A balanced mixture of public, parastatal, and private partners that meets the requirements for being a high-grade seed producer (CIP, 2011) could carry out this enterprise. In countries where a certification system is in place, all G2 and G3 field multiplied seed would be certified by appropriate seed regulatory authorities and all fields would be tested pre-planting for freedom of bacterial wilt. Technical assistance for field multiplication of mini-tubers is a key element to guarantee the quality of the seed potato production and the good economic return of the investment in this enterprise.

A network of decentralized seed potato multipliers

The 3G strategy aims potato growers to become aware of available seed multipliers in their locality and catalogues of these seed suppliers will be produced as the scheme enlarges. The encouragement and training of more local specialist seed multipliers is a key component of the strategy. This training is targeted to local seed potato producers with minimum conditions to further multiply 3G or even certified potato seed. The objective would be to generate business opportunities for some local seed producers who would supply high quality seed to the large number of local ware potato producers in the country at large.

The secondary potato seed multipliers would demand high quality seed (G2 or G3) seed from specialized high-grade seed producers and further multiply these seed following good practices and standard for quality seed production. It is expected that these secondary multiplier would be located in different potato producing areas and would lead a decentralized seed potato multiplication next to where the majority of small potato growers are located, generating a business opportunity and increasing high quality seed availability across different potato growing areas.

Farm based seed maintenance: "select the best"

The innovative extension system known as "**Select the Best**" was developed by CIP and national partners in SSA. Through the training, potato producers learn how to maintain the quality of their potato seed for a longer period through positive selection. Furthermore, farmers become aware of the impact of seed potato quality on yield, and the need for regular replenishment of their seed stock with high quality seed from specialized seed growers. The process involves training farmers to recognize healthy plants, which are not showing symptoms of seed borne diseases such as virus and bacterial wilt infection. Healthy plants, representing about 10% of the crop, are marked and later harvested to provide

next years' seed. The intervention is relatively low cost and requires less contact time than a conventional farmers' field school. Essential in the training curriculum is that the farmers plant a demonstration experiment in which they compare the yields through using their existing seed selection method, using positive selection, or buying seed from a specialist. This provides the farmers with options to improve their seed quality. Different evaluations of positive selection have shown a yield gain of over 30% after practicing it a single season (Gildemacher, 2009; Schulte-Geldermann, 2010).

Profitability of quality seed potato enterprises in Kenya

The profitability analysis for all seed enterprises compare production costs with financial benefits derived from each seed production process. The unit of analysis is standardized to screen house production for mini-tubers and to one hectare of land for field seed potato multiplication and for ware potato production. The analysis also contemplates different scenarios that account for the range of input and output prices and the range of rates of multiplication observed during the two years of the implementation of the 3G strategy in Kenya.

Profitability of the mini-tuber production though aeroponics and conventional methods

In Kenya, as in many countries in SSA, mini-tubers are traditionally produced using pots filled with sterilized soil and using one potato plantlet per pot. These are accommodated in standard screenhouses. The 3G strategy introduced the production of mini-tubers using aeroponics (CIP, 2010) in screen houses of 115 square meters with a capacity of using 1,366 plantlets of clean potatoes. In addition, CIP and Kenyan partners tested an alternative improve conventional system that consisted in using the same pot system but using two plantlets per pot and drip irrigation for mini-tuber production. The idea was to produce more mini-tubers in the same sterilized soil. In this section we present the profitability analysis of four alternative systems to produce mini-tubers: (1) the base conventional pot system, (2) the improved pot system, (3) the aeroponics using regular power supply and backup generator, and (4) the aeroponics using a solar power supply with backup generator. All of them produced mini-tubers of the same quality but using different levels of investment, variable cost and showing different multiplication rates of mini-tubers. For the profitability analysis we use the average multiplication rate found for the base conventional pot system (7 mini-tubers per plantlet), for the improved pot system (11 mini-tubers per plantlet) and for both aeroponics systems (26.4 mini-tubers per plantlet). It is

important however to highlight that in some cases and for some potato varieties, the multiplication rate of mini-tubers exceeded the 50 mini-tubers per plantlet.

Table 1 summarizes the profitability analysis of the mini-tuber production under the 4 schemes considered. It presents the level of investment required and assumed to last for 10 seasons (5 years), the variable cost (that includes the cost of plantlets, substrates, nutrients, water, electricity, labor and soil sterilization when needed), the unit cost per mini-tuber, and gross and net benefits of the enterprises along with a benefit/cost ratio. For the benefits and the final ration two alternative scenarios are presented that reflects the current price per mini-tuber (0.31 USD) per mini-tuber) and the expected price (0.25 USD) that is likely to happen when more mini-tuber production would be in place.

The current pot system is financially unsustainable as it is producing negative net benefits and benefit/cost ratios (Table 1). Decreasing the market price of mini-tubers would only worsen the situation. In the public sector that uses commonly this mini-tuber production scheme, the initial investment is not accounted in the production cost and they can barely cover the variable cost that is highly driven by the cost of sterilizing the soil. The improved pot system seems to be a solution in the short term when other systems were not affordable or when trying to take advantage of current infrastructure. Under current conditions, the improved pot system is slightly profitable and reduces the unit cost of mini-tuber from 0.60 USD to 0.24 USD. However, in the end, this system is not attractive as a business; as it would only recover the initial investment and cover, the production cost during 10 seasons. On the other side, the aeroponics systems are showing encouraging financial results. Aeroponics are highly profitable under current conditions and will remain profitable even under reduced market price of the mini-tubers. Also the more efficient production of mini-tubers through aeroponics make the production cost per mini-tuber to be reduced as low as 0.10 USD. With a current price of 0.31 USD and even with an expected lower price of 0.25 USD the production of mini-tubers using aeroponics is very attractive. More stakeholders (from public and private) may have the incentive to enter into the business and increase significantly the production of mini-tubers. With the margins between the production cost and the market price, this enterprise would remain highly profitable.

Table 1: Profitability of mini-tuber production under four different production schemes (Values in USD)

	Base conventional pot	Improved pot system	Normal aeroponics w/backup	Aeroponics w/solar power and backup
Initial investment	31,053	16,970	27,310	32,841
Variable cost (season)	3,146	2,228	1,220	1,315
Discounted total cost	57,288	35,551	37,482	43,809
Unit cost per mini-tuber	0.60	0.24	0.10	0.12
Discounted Gross Benefit (price USD0.31)	24,920	39,160	92,646	92,646
Discounted Gross Benefit (price USD0.25)	19,936	31,828	74,117	74,117
Net benefit (price 0.31)	-32,368	3,609	55,164	48,837
Benefit/cost 1	-0.57	0.10	1.47	1.11
Net Benefit (price 0.25)	-37,352	-3723	36,635	30,308
Benefit cost 2	-0.65	-0.10	0.95	0.69

The initial investment seems to be the most important constraint for entering in to this business; however, the investment required for aeroponics is as high for the traditional pot system. Definitely, the variable cost is much lower in aeroponics due to the more efficient use of resources (like nutrient) and the no need for sterilized soil, which turns out to be a high variable cost (Labarta and Mulwa, 2011). There are difference between aeroponics that would depend on regular power supply and aeroponics that requires a solar power system. Both aeroponics systems would require a backup generator as in SSA, the power supply is not constant and the supply for solar systems are not enough for a 100% operations of the aeroponics unit. However, although an aeroponics using a solar power system is less financial attractive than aeroponics connected to the regular power supply, the first one is highly profitable and can produce a benefit/cost ratio of over 100% for a five years period. In areas where power supply is not present, the production of mini-tubers through aeroponics using solar power is a suitable alternative.

Profitability of the production of high-grade seed potato

Many countries in SSA have trained specialized seed potato producers over the years and also many large farmers specialized in other crops production have the capacity to start the production of high quality seed with the backstopping in the implementation of seed potato technologies. In Kenya, a combination of public organizations and a group of private initiatives have started the process of increasing the process of producing high quality seed potato in large quantities (CIP, 2010).

These specialized seed potato producers use the mini-tubers produced by aeroponics or conventional production to further multiply the seed on potato fields. The main reason for this enterprise is to increase significantly the quantity of high quality seed available, but also to reduce the cost of producing ware potato. If mini-tubers were used directly in ware potato production, it would be required 55,000 mini-tubers per hectare requiring an investment of around 17,000 USD per hectare, which is unaffordable and unprofitable for any potato grower. The specialized seed potato producers constitute the direct demand of the mini-tuber production. For analyzing the profitability of these high-grade seed producers, we consider the production of G2 and G3 seed that in Kenya have received certification by the governmental authorities (CIP, 2011). We start considering all production costs that include the cost of mini-tubers, the land cost, the cost of chemicals used and the labor cost. Finally, the total cost of producing one hectare of seed potato is determined along with the cost of one kg and one bag of 50Kg of high quality seed potato. For the estimation of the benefits, we consider two scenarios. In both scenarios, we use a conservative yield of 15 t/ha in G2 seed production and 25t/ha in G3 seed production, but we differentiate them with the traditional price of certified seed of 27.5 USD/bag of 50Kg and the lowest price that a high-grade multiplier managed to sell the seed (20 USD/bag of 50kg). The summary of the profitability analysis of G2 and G3 seed is summarized in Table 2.

Producing certified seed with just one multiplication (G2) of the mini-tubers is not a profitable enterprise. The cost of mini-tubers accounts almost for 83% of the production cost (USD 14,500) and the cost for producing one bag of 50 kg of high quality seed is around 58 USD while the market price does not exceed 27.5 USD per bag of 50 kg. Once the total cost of G2 is accounted for in the production of G3, the production of certified seed becomes a very profitable enterprise.

As shown in Table 2, producing certified seed by having two field multiplications of mini-tubers (G3) increases considerable the financial benefits of this enterprise. With the current market price (27.5 USD), a high-grade seed multiplier would be making profits of over 100% of their investment in just one season of 4 months. Even in the event of a market price drop (20 USD per 50 kg bag), the production of 3G seed would imply a profitability of 63% of the level of investment. It is important to highlight however, that in Kenya some high-grade seed producer's already selling certified seed at 20 USD per 50kg bag had yields of over 30 t/ha. It implies that keeping a high profitability among high-grade seed producers would guarantee a constant demand for mini-tubers. At the

same time these high-grade seed enterprise would depend on the profitability of large commercial ware producers and of decentralized secondary seed multipliers who would demand the certified seed

Table 2: Profitability of the production of high-grade seed (G2 and G3) in USD

	Production of G2 seed	**Production of G3 seed**
Variable cost (1 ha/season)	17,433	6,127
Unit cost per 50 kg bag	58	12
Gross Benefit (price USD 27.5)	8,250	13,750
Gross Benefit (price USD20)	6,000	10,000
Net benefit (price 27.5)	-9,183	7,623
Benefit/cost 1	-0.53	1.24
Net Benefit (price 20)	-11,433	3,873
Benefit cost 2	-0.66	0.63

Profitability of the production of high quality seed potato among secondary multipliers

The 3G strategy requires a network of secondary seed multipliers to be trained across different potato growing areas as the key link to keep the supply of high quality seed flowing towards the ware potato producers. The target is to have a network of decentralized seed supplier in different potato areas that can produce high quality seed and make it available to hundreds of potato growers that would require them. A key assumption of the 3G strategy is to have a profitable multiplication of quality seed from certified or 3G seed. The aim is for small seed multipliers to produce G4 or G5 that can be used in ware potato production producing high yields among the ware potato producers that invest in this high quality seed. Similar to the profitability of high-grade seed producers, for the secondary seed multipliers this analysis compares the total cost of production for one hectare of land with the total benefits produced in the same unit of land. It also estimates the cost of one bag of 50kg of quality seed potato. The yield information used in the analysis is the average yield of a group of more than 20 secondary seed multipliers in Kenya (14 t/ha for G4 and 13 t/ha for G5) using low inputs. Another important characteristic is that all this seed producers divided the production between seed and ware producers with an average of 50% each. This feature has been incorporated in the analysis that represents the nature of the dual-purpose potato production of these growers. The average market price of G4 and G5 was found to be similar to the G3 seed. Although it is of less quality G4 and G5 are produced locally which avoid the transport cost of bringing G3 seed that could double the market price for this G3 seed. Table 3 summarizes the profitability analysis of G4 and G5 seed potato that were produced by secondary seed multipliers.

Table 3: Profitability of the production of quality seed potato among secondary multipliers

	Production of G4 seed	**Production of G5 seed**
Variable cost (1 ha/season)	1,951	1,648
Unit cost per 50 kg bag	7.3	7.2
Gross Benefit (price USD27.5)	3,137	2,671
Net benefit (price 27.5)	1,186	1,023
Benefit/cost	61%	62%

The level of investment required for G4 and G5 seed potato production is much lower than the investment required for the production of high-grade seed. This characteristic makes this enterprise affordable for a large number of medium scale producers that are located in different potato areas. Both multiplication processes G4 and G5 seed potato are profitable providing a return of 61%-62% of the investment over a four-month period (Table 3). Depending on the location and the proximity to the source of G3 seed production, farmers may decide to combine the production of G3 and G4 seed. It is important to highlight that with the improvement of the seed management these farmers can get yields of around 15 t/ha to 20t/ha which would imply a much profitable enterprise that can attract a larger number of secondary seed multipliers and increase substantially the supply of high quality seed for the ware potato production.

Profitability of ware potato production and the use of positive selected seed

The overall 3G strategy would depend at the end on the profitability of the ware potato production that reflects the demand for table potato and from the potato industry. It can be stated that the higher the demand for potato consumption, the higher the price and the higher the probability of having a profitable enterprise that would require seed potato that offers greater productivity.

For the profitability analysis of the ware potato production, we consider the four options that Kenyan farmers were facing between 2009 and 2011. Most of the farmers were using their own seed to produce ware potatoes, a large number of farmers were using positive selected seed (CIP, 2011) and an increasing number of ware potato producers were using G4 and G5 seed produced by secondary seed multipliers. In general, the two key variables that changes across the four production options is the cost of the seed (increasing from the use of farmer seed towards the use of G4 seed) and the yields of the potato production (also increasing from farmer seed towards the use of G4 seed).

Table 4: Profitability of ware potato production suing different types of seed (values in USD)

	Ware potato using farmer seed	Ware potato with positive selected seed	Ware potato using G5 seed	Ware potato using G4 seed
Variable cost (1 ha)	951	1,072	1,320	1,320
Unit cost per 50 kg bag	4.4	4.4	4.7	4.2
Gross Benefit	1,815	2,088	2,648	2,956
Net benefit (price 27.5)	864	1,016	1,328	1,636
Benefit/cost	0.91	0.95	1.01	1.24

The information coming from a large number of farmers showed that positive selected seed yielded 20% more potatoes, the use of G5 around 40% more potatoes and the use of G4% over 50% of potatoes compared with the base scenario (use of farmer seed). The profitability analysis of ware potato production in Kenya is summarized in Table 4.

In general, the 3G project experience provided evidence that the production of ware potato is a highly profitable enterprise regardless the type of seed used (Table 4). The difference is that the better the quality of the seed used, the higher the profitability that a farmer can achieve and the higher the quantity of food that one hectare of land can produce. The use of higher quality of seed potato would therefore improve farm income and household food security. The analysis from Kenya show that the higher production cost of ware potato using G4 and G5 is largely compensated by the higher profits generated due to much better yields associated with the use of better quality of seed. Potato growers can double the net benefits produced per unit of land and can increase the profitability of this unit of land by almost 35% by using G4 seed instead of farmer seed in the production of ware potato. The high profitability of the ware potato enterprises would guarantee a large demand for high quality seed over the years.

The potential of the 3G strategy in Ethiopia

Ethiopia is a large country with around 165,000 hectares of land under potato cultivation and that has shown an increasing demand for potatoes from urban and rural markets and most recently for processing purposes. However, the yields per unit of land remain very low around 5.7 t/ha (CSA, 2002). The lack of quality seed potato has been also identified as one of the major constraints for not reaching the potential yields of over 20 t/ha. Currently the production of quality seed only reaches 800 t/year out of the 330,000 t that required annually in

Ethiopia. A strategy like the 3G would be suitable for Ethiopia. We discuss here the potential to implement successfully a 3G strategy that could enhance availability of quality seed in Ethiopia. We first start estimating the current demand for high quality seed in Ethiopia that may justify the implementation of 3G strategy and then discuss some ongoing experiences that may facilitate this implementation in Ethiopia.

Existing demand for high quality seed potato in Ethiopia

The estimation of the demand for seed potato starts from the annual requirement of seed needed to plant the total area devoted to potato production. To estimate this annual requirement we used the reported area of the last agricultural census (CSA, 2002). Secondly, it uses the average rate of seed used per ha in Ethiopia reported in two recent large household surveys (Obado, 2010b; 2010c). From the same farm level information, the paper estimated the percentage of farmers that replace their seed stock with off farm sources and the average numbers of seasons that the same seed is used before replacement (among those who replace seed). The next step is to estimate the annual demand for new seed in each country. This represents the total seed potato that is supplied by off-farm sources. We estimated the demand of new seed by multiplying the annual requirement of seed potato by the percentage of farmers that replace seed and by dividing this product by the number of years that takes to replace old seed with new seed (the number of seasons of seed use plus one is divided by two seasons). Although this annual demand of new seed may represent the maximum quantity of seed that can potentially be sourced with high quality seed, a better estimation of the lower bound of the demand for high quality seed is calculated using the average proportion of new seed that used high quality sources (form public sector, research institutes, or trained seed multipliers). This allows us to estimate the minimum quantity of high quality seed that would be expected to be demanded by potato producers in Ethiopia. Table 5 presents the estimation of the demand for high quality seed in Ethiopia.

With existing information and without considering awareness creation for the use of high quality seed performed by projects like CFC and Better potato for better life (CIP, 2011), we can estimate that the demand for high quality seed is at least 9,446 t per year.

Conclusion

The 3G strategy was proposed as a means to overcome the shortage of high quality seed potato in East Africa, aiming to increase significantly potato yields and to contribute to improve smallholder income and food security. The 3G strategy concentrates their efforts in producing large amount of high quality seed potato in 3 generations. It also contemplates parallel investments at the farm level in order to improve farmers' seed management and to generate a sustainable demand for high quality seed.

A critical assumption is that the production and distribution of high quality seed is a profitable demand at all levels of the value chain and that responds to a large demand for seed that allow to increase considerably the potato productivity and respond to the increasing demand for table potato and from the potato processing industry. This paper provides the evidence that all levels of the potato sub-sector have very profitable enterprises and that the production and distribution of high quality seed would be sustainable and supported by business opportunities for different stakeholders.

Ethiopia is a country where potato continues to increase its importance as a cash crop and a key contributor to food security of rural households. Ethiopia has a public sector that has updated its capacity and has some positive experiences from the private sector that makes this country suitable for the implementation of the 3G strategy. The objective would be to produce 10,000 t of high quality seed per year after 5 years of implementation of the 3G strategy expecting to have significant impacts on reducing poverty and improving food security of the rural poor.

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