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Seed Potato Quality Improvement through Positive Selection by Smallholder Farmers in Kenya

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Abstract In Kenya, seed potato quality is often a major yield constraint in potato production as smallholder farmers use farm-saved seed without proper management of seed-borne pests and diseases. Farm-saved seed is therefore often highly degenerated. We carried out on-farm research to assess whether farmer-managed positive seed selection could improve yield. Positive selection gave an average yield increase in farmer-managed trials of 34%, corresponding to a 284-€ increase in profit per hectare at an additional production cost of only 6€/ha. Positive selection can be an important alternative and complementary technology to regular seed replacement, especially in the context of imperfect rural economies characterized by high risks of production and insecure markets. It does not require cash investments and is thus accessible for all potato producers. It can also be applied where access to high-quality seed is not guaranteed. The technology is also suitable for landraces and not recognized cultivars that cannot be multiplied formally. Finally, the technology fits seamlessly within the seed systems of Sub-Saharan Africa, which are dominated by self-supply and neighbour supply of seed potatoes.

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Introduction

Seed Potato Systems in Kenya

Potato (*Solanum tuberosum* L.) is the second most important food crop in Kenya in terms of bulk harvested; it is an important staple and cash crop for smallholder farmers in the Kenyan highlands. Poor seed potato quality is a major yield reducing factor in potato production in Kenya (Gildemacher et al. 2009a, b). In a survey by Fuglie (2007), viruses and bacterial wilt caused by *Ralstonia solanacearum* scored as important priorities for action in the eyes of potato researchers, whereas nematodes scored much lower. Improving seed potato quality is considered a pathway to improve smallholder potato yields and income (Getachew and Mela 2000; Tindimubona et al. 2000; Eshetu et al. 2005; Hirpa et al. 2010).

Seed potato health is a major determinant of the yield potential of a potato crop. Over generations, seed potato quality degenerates as a result of tuber-borne diseases, among which viruses play an important role (Salazar 1996). Turkensteen (1987) identified bacterial wilt, caused by *R. solanacearum* and the viruses PVY and PLRV as seed-borne potato diseases of major importance in Central Africa (Rwanda, Burundi and Eastern DRC), but also mentioned soft rot (*Pectobacterium chrysanthemi*), Fusarium wilt and dry rot (*Fusarium solani*) and Verticilium wilt (*Verticillium albo-atrum*) as being of economic importance. Solomon-Blackburn and Barker (2001) mentioned PVY and PLRV as most important viruses worldwide, and PVX as relatively mild as single infection, but potentially damaging in combination with other viruses.

Degeneration over seed generations is the combined result of increasing percentage of seed tubers infected, increasing number of tubers infected with multiple viruses and an increasing concentration of particles of these viruses in the seed tubers.

The speed with which the yield potential of the seed stock degenerates over generations of re-use as a result of accumulation of viruses depends on a number of factors. Firstly, the disease pressure is related to the abundance of the vector of viruses, most often aphids, and the number of diseased plants present. At high temperatures, viruses reproduce faster within the plants and most virus vectors also have a shorter generation duration and are also more active than at lower temperatures, thus increasing the disease pressure. Secondly, the degeneration depends on the variety grown. Varieties differ in levels of resistance to virus infection and virus particle multiplication within the plant (Salazar 1996). Moreover, some varieties tolerate virus infection better than others, which is reflected in lower yield losses under similar virus incidences.

Yield loss can be avoided through regular replenishment of seed stocks by high-quality seed potatoes multiplied by specialist growers from disease-free starter material. The specialized production skills, distribution system and quality control system required, combined with the low multiplication rate, the bulkiness and the poor shelf life of seed potatoes, all make high-quality seed potatoes expensive. Seed potatoes represent a major component of potato production costs.

In northern countries, where producers have fairly reliable market outlets and relatively predictable yields, the return on investments of high-quality seed potatoes by ware potato producers is positive. In Sub-Saharan Africa, however, yields and profits fluctuate widely as a result of variation in rainfall patterns and unreliable market chains. Investment in planting high-quality seed potatoes is therefore less attractive for Sub-Saharan African farmers. Furthermore, smallholder farmers lack the cash required for investment in high-quality seed potatoes. Rather than relying on specialized seed potato growers, the seed potato systems in Sub-Saharan Africa are dominated by neighbour and self-supply (Crissman et al. 1993; Gildemacher et al. 2009b; Hirpa et al. 2010).

Seed system interventions to improve smallholder potato yields have been initiated in many developing countries. Some interventions introduced and supported formal certified seed potato production schemes with independent quality control like in Kenya (Crissman et al. 1993), Rwanda, Bolivia and Peru, while others focussed on building informal, non-certified, farmer-based seed potato multiplication schemes, like for example in Uganda (Tindimubona et al. 2000). Invariably, interventions were based on a model of specialized seed potato growers as suppliers of high-quality seed potatoes to smallholder ware potato farmers. This could be considered as attempts to transfer successes of specialized seed potato multiplication systems in northern countries, like the Netherlands, UK and Canada (Young 1990), to developing countries. Notwithstanding pilot successes with building such seed potato multiplication systems in developing countries, there is little evidence of cases where building a specialized seed potato system has led to drastic and sustainable improvement of the yields of poor potato producers.

During the temporary successful operation of large-scale seed potato multiplication and distribution in Kenya between 1980 and 1990, this only accounted for about 1% of all seed potatoes planted in the country (Crissman et al. 1993). Excluding the well-established seed potato industry in South Africa, there are currently no examples of Sub-Saharan African countries, with the agro-ecology suitable for seed potato production, that satisfy a substantial proportion of their demand for seed potatoes through formal certified or otherwise quality-controlled seed production. Gildemacher et al. (2009b) calculated that in Kenya, Uganda and Ethiopia, the proportion of seed potatoes originating directly or indirectly from quality-controlled multiplication was less than 3% of the total seed requirement. In spite of the undisputed importance of high-quality seed potatoes as an input for intensive potato production, it is apparently difficult to make commercial high-quality seed potatoes available to the majority of potato producers.

Considering the importance of farm saved seed potatoes in Eastern Africa, Gildemacher et al. (2009b) identified the need to improve seed potato quality management by ware potato producers as a component of improving the overall quality of seed potatoes used. This raised the following question: what technologies can smallholder potato farmers apply to maintain or even improve the quality of their own seed potato stocks?

Positive Seed Potato Selection

Positive selection is an old technology that was used primarily in formal seed potato multiplication to select mother plants from the best plot of potatoes as the starting point of the multiplication system (De Bokx and Van de Want 1987). The best potato plants in a field are marked before crop senescence that obscures disease symptoms. The marked plants serve as mother plants for seed potatoes used for the next season's potato crop. Positive selection has been used in Central Africa as the starting point for a seed multiplication system (Haverkort 1986). Positive selection is now widely regarded as an obsolete technology in formal seed potato production systems. Currently, seed potatoes in formal seed systems are multiplied from tested, disease-free, tissue culture material or from other nuclear stock which has been proven to be disease free. The use of positive selection as an on-farm method to maintain seed potato quality is also mentioned in literature (Struik and Wiersema 1999), but is not commonly used by ware potato producers, nor is its use promoted.

A specific action research programme on positive seed potato selection was implemented by the International Potato Center (CIP) from 2004 till today. The main focus of the programme was the training of ware potato farmers in positive seed potato selection (Gildemacher et al. 2007a). The positive selection initiative integrated research and development objectives into a single effort, aiming at innovation rather than research results alone.

This paper presents the results of farmer-managed trials in which positive selection is compared to common farmer practice. It demonstrates that the technology can provide an additional option for smallholder potato producers to manage the quality of their seed potatoes. The paper goes on to discuss the likely causes of the observed increases in production.

Materials and Methods

The positive selection technology was tested under full farmer control, minimizing the scientist influence on trial execution. It was not the technological soundness of positive selection that had to be proven, but rather the value of the technology in the hands of smallholder potato producers in the Kenyan production system. The technology had been in existence for decades, but was never adopted on a large scale by ware potato growers. Surmising that this could not be the result of the complexity nor the lack of efficiency of the technology, but rather the lack of effective training and promotion, a great deal of attention was put on the development of a training methodology that could potentially be scaled out to a national level.

Training Methodology

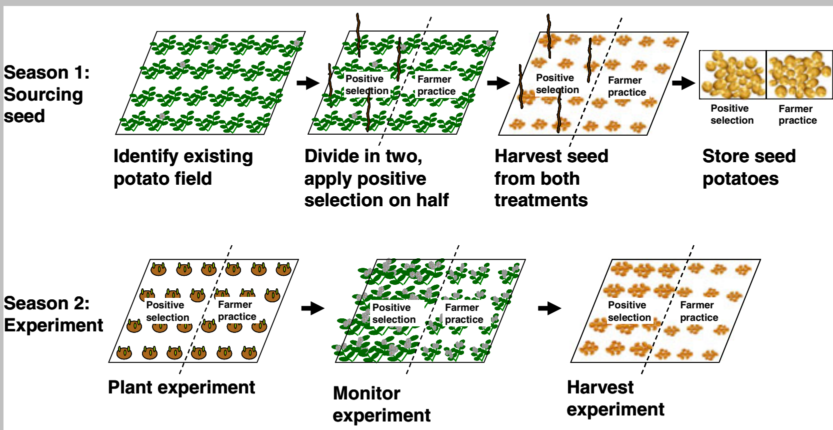
A training approach for farmer groups, resembling farmer field schools (FFSs), was used for the training in positive selection, with some deliberate differences. The positive selection training was less intensive than usual in FFSs to minimize the required facilitator and farmer time. The meetings of the farmer groups were more facilitator-led than usual in FFSs and the agenda was fixed by the programme. Rather than trying to cover a diversity of potato issues, a specific choice was made on seed potato quality management and seed-borne diseases. The training of the facilitators was limited to 2 days, with further support and interaction on-the-job. The total number of meetings of the farmer group was nine times over a period of roughly 10 months. The demonstration experiment comparing farmer practice with positive selection formed the centre of the farmer group training.

It was attempted to meet both the scientist and the farmer need for experimentation simultaneously. The setup of the trials was such that it resembled most the manner in which a farmer would experiment without involvement of scientists (Bentley 1994). Positive selection was tested against the current farmer practice (see Box 1). Replications were over farmer groups rather than within farmer groups.

Box 1 Setup of the farmer-managed positive selection experiments

POSITIVE SELECTION TRIAL SET-UP

1. Let the group of farmers select an average potato field.
2. Divide it into two and let farmers peg healthy looking plants just before flowering in half of the field; reconfirm the health status of pegged plants two weeks later.
3. Harvest seed potatoes after judging the tubers of each pegged plant in the positive selection plot; select seed from the farmer practice plot using common farmer practice.
4. Store seed potatoes from both sources under the same conditions.
5. Plant an equal number of the positive selection and farmer selection seeds in adjacent plots, perpendicular to the slope.
6. Monitor the experiment; let the group of farmers practice positive selection once more.
7. Harvest separately the two plots, record total weight and evaluate.



Seed potatoes were obtained by the farmer group from an existing potato field of at least 1,000 m^2, planted with a popular variety, and considered to be representative of their potato fields. The field was divided into two equal portions. One half was designated to source seed potatoes using positive selection, the other half using farmer common practice. For positive selection, the farmers pegged the best-looking plants as they were taught, just before flowering, roughly 10 weeks after planting. Two weeks later, the farmers inspected the field and removed pegs from plants with newly developed disease symptoms. Pegged plants were harvested individually and plants with few, small or misshaped tubers were rejected. Tubers of 25–90 mm from the remaining pegged plants were collected as seed potatoes for the positive selection treatment of the demonstration trial. Seed potatoes for the farmer practice treatment were selected from the bulk of potatoes harvested from the other half of the field, according to common farmer practice. Seeds from both sources were stored next to each other using the common farmer practice.

For the experiment, a field supplied by the farmer group was divided into two, perpendicular to the slope. One half was planted with seed tubers obtained through positive selection, the other with farmer practice-derived seed tubers. Planting, fertilizer application, disease control, hilling and weeding were all done by the farmer groups using their common practice.

Data Collection and Analysis

Eight weeks after planting, a random sample of minimum 400 plants was inspected for visual virus and bacterial wilt symptoms. The number of plants showing symptoms as well as the total number of plants was recorded. At harvest, the total number of plants in both plots was counted, and both plots were harvested. Marketable yield of the plots was recorded as all tubers above 25 mm.

Here, data are presented from two separate seasons of farmer experimentation, the short rainy season of September 2005–February 2006 and the long rainy season of April–August 2010.

In 2005–2006, yield data could be collected from 13 farmer groups and 12 trials yielded useful disease data. Reasons for rejecting trials were several, including incorrect data collection by the teams of farmers and extension staff, harvest of the trial by thieves, destruction of the field by porcupines, a differential treatment during the growing season or separate seed storage of one of the two treatments and complete crop failure as a result of drought.

For 2010, yield data was available from 72 trials, but only in a selection also disease data were collected. A first selection of trials for data analysis was made by taking those trials having both yield and disease data. Furthermore, trials that did not yield more than 3 t ha^{-1} for the farmer selection treatment were omitted from the analysis of yield differences. Trials from Eldoret East were omitted from the analysis of disease data because of irregularities in field data collection.

Paired sample *t* tests were conducted to evaluate the effect of positive selection compared to farmer selection on yield as well as farmer-scored visual bacterial wilt and virus incidence.

Results

Experimental Results

In 2005–2006, the positive selection plots gave an average yield of 14.2 t ha^{-1} which was significantly higher than the 11.8 t ha^{-1} for the farmer seed selection plots. The average yield increase of positive selection over farmer selection was 28% (Table 1).

Table 1 Yield of positive seed selection plots and farmer selection plots in farmer-managed trials in Nyandarua and Nakuru districts, Kenya, October 2005 to February 2006

Farmer group	Yield (t ha^{-1})		Yield increase due to positive selection (%)
	Positive selection	Farmer selection	
Dundori	21.4	21.3	0
Elburgon	16.3	8.9	84
Gilgil (Eburru)	19.2	10.1	91
Gitiri (North Kinangop)	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 (Bahati)	16.8	13.6	24
Njoro	11.7	10.4	13
Ol Kalou 2	4.0	3.9	4
Olenguruone	23.4	22.6	4
Subukia (Mbogoini)	7.5	4.7	58
Average	14.2	11.8	28
t value		3.02	
Degrees of freedom		12	
P		0.005	

In 2010, the positive selection lots gave on average 13.1 t ha^{-1}, compared to 8.6 t ha^{-1} for the farmer seed selection, a yield increase of 53% (Table 2).

Figure 1 shows that the effect of positive selection was apparent notwithstanding the yield of the farmer selection treatment. The average yield increase for the 25% lowest yielding trials was 2.7 t ha^{-1}, which is a 55% increase. The average yield increase for the 25% highest yields was 5.1 t ha^{-1}, which represents a 29% yield increase.

Tables 3 and 4 show that the visible virus incidence, as scored by the farmers in the demonstration trials, was significantly reduced as a result of positive selection from 9% to 5% in 2005–2006 and from 18.8% to 7.1% in 2010.

Also, bacterial wilt incidence was significantly lower in the positive selection plots than in the farmer selection plots (Tables 3 and 4). In those trials in 2005–2006 where bacterial wilt was observed, the positive selection plots had an average incidence of 1.3% compared with 3.5% in the farmer selection plots. In 2010, positive selection reduced bacterial wilt infection from an average of 7.6% to 2.6%.

Economic Analysis

Table 5 shows that the average yield increase obtained in the trials was 3.5 t ha^{-1}. This yield increase gave an increase in the gross benefit per hectare of 290€. The required investment in additional labour was estimated at four man days per hectare,

Table 2 Yield of positive seed selection plots and farmer selection plots in farmer-managed trials in Eldoret East, Kiambu East, Mt. Elgon and Transmara districts, Kenya, May 2010 to September 2010

Farmer group	Yield (t ha^{-1})		Yield increase due to positive selection (%)
	Positive selection	Farmer selection	
Eldoret East 1	8.0	4.8	67
Eldoret East 2	7.5	6.0	25
Eldoret East 3	8.7	6.0	44
Eldoret East 4	8.0	6.7	20
Eldoret East 5	13.0	7.9	65
Kiambu East 1	12.8	5.0	156
Kiambu East 2	6.0	5.0	20
Kiambu East 3	8.8	6.8	29
Kiambu East 4	11.2	7.2	56
Kiambu East 5	8.0	7.2	11
Kiambu East 6	12.6	8.0	58
Kiambu East 7	15.0	8.0	88
Kiambu East 8	11.0	9.2	20
Kiambu East 9	13.2	9.2	43
Kiambu East 10	18.2	11.8	54
Kiambu East 11	20.0	17.6	14
Mt Elgon	6.5	4.0	63
Transmara 1	23.6	15.6	51
Transmara 2	37.3	16.9	121
Average	13.1	8.6	53
t value		4.33	
Degrees of freedom		18	
P		<0.001	

Fig. 1 Absolute and relative average yield increase as a result of positive selection compared to farmer selection for the demonstration trials of 2005–2006 (*n*=13) and 2010 (*n*=19) combined, per quartile of farmer selection yield level

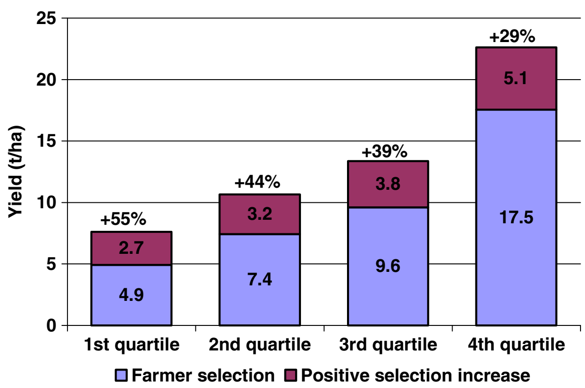


Table 3 Farmer-scored virus and bacterial wilt infection rates of positive seed selection plots and farmer seed selection plots in farmer-managed trials in Nyandarua and Nakuru districts, Kenya, October 2005 to February 2006

Farmer group	Farmer virus incidence scores (%)		Incidence of wilted plants (%)	
	Positive selection	Farmer selection	Positive selection	Farmer selection
Elburgon	5.4	9.1	0.3	6.3
Gilgil	4.7	7.9	0.0	0.3
Kirima	4.6	8.8	0.0	0.0
Kuresoi	3.6	6.8	8.2	16.9
Molo	4.3	11.1	1.2	4.1
Gitiri	5.4	9.8	0.0	0.0
Njoro	5.1	14.9	0.8	1.1
Ol Kalou 2	5.0	9.1	0.0	0.0
Olenguruone	2.0	3.6	0.1	1.1
Pagma Naivasha	8.1	8.8	0.0	0.0
Rurii Ol Kalou	7.3	9.7	0.4	2.5
Shamba Ndogo	5.0	9.0	0.4	0.0
Average[a]	5.0	9.0	1.3	3.5
t value		5.87		2.32
Degrees of freedom		11		7
P		<0.001		0.027

[a] Average incidence and *t* value of bacterial wilt infection calculated as a function of those fields that did have a detected infection

costing 6€. Adopting the technology would result in an estimated marginal net benefit of 284€/h at a moderate farm gate price level of 900 Ksh/110 kg bag of potatoes. The return on labour, provided the smallholder farmer would invest his or her own time in positive selection, is 70.9€/day of labour, roughly 46 times the cost of labour.

Discussion

Positive selection showed to be a valuable technology for smallholder producers. Potato yields in the demonstration trials under full farmer management were significantly increased as a result of the use of positive seed potato selection by producers. Based on the results from the two seasons of demonstration trials presented here, a yield increase under Kenyan conditions between 28% (2005–2006) and 54% (2010) can be expected.

These yield increases have been obtained over a wide variety of circumstances, such as different varieties and locations. As such, the technology has proven to be robust and effective notwithstanding the variation in circumstances. The technology substantially increased yields in situations where the farmer selection yielded very poorly, but also there where yields were already well above the Kenyan average of

Table 4 Farmer-scored virus and bacterial wilt infection rates of positive seed selection plots and farmer seed selection plots in Kiambu East, Mt. Elgon and Transmara districts, Kenya, May 2010 to September 2010

Farmer group	Farmer virus incidence scores (%)		Incidence of wilted plants (%)	
	Positive selection	Farmer selection	Positive selection	Farmer selection
Kiambu East 1			0	2
Kiambu East 2			1	2
Kiambu East 3			0	1
Kiambu East 4			0	3
Kiambu East 5			2	2
Kiambu East 6			0	2
Kiambu East 7			0	1
Kiambu East 8			0	1
Kiambu East 9			0	3
Kiambu East 10			0	1
Kiambu East 11			0	2
Mt Elgon 1	2	9	5	18
Mt Elgon 2	3	8	7	11
Mt Elgon 3	6	11	8	19
Mt Elgon 4	6	16	7	22
Mt Elgon 5	7	26	6	21
Mt Elgon 6	27	34	14	23
Transmara 1	3	21	0	8
Transmara 2	3	25	0	2
Average[a]	7.1	18.8	2.6	7.6
t value		4.79		4.15
Degrees of freedom		7		18
P		0.001		0.0003

[a] Average incidence and *t* value of virus infection calculated as a function of those fields with observations. Fields without figures represent trials in which no virus incidence levels were scored

about 9 t ha^{-1}. In addition, the yield increase was obtained through farmer management, under circumstances very much representative of Kenyan smallholder potato farming.

Most importantly, this yield increase could be obtained without any additional cash investment, which is of essential importance for cash-poor smallholder farmers. The additional labour required for cutting pegs, pegging the healthy plants and harvesting the pegged plants one by one yields an estimated return of 70.9€ per man-day, which is 46 times the estimated cost of casual labour in the Kenyan countryside.

From a scientific point of view, the question remains why positive selection has worked. Considering the data collected by the farmers themselves with respect to virus and bacterial wilt incidences, positive selection can reduce both significantly. A

Table 5 Marginal net benefit of the adoption of positive selection based on the average yields obtained in 2005–2006 and 2010

	Positive selection	Farmer practice
Price per kilo (€)[a,b]	0.08	0.08
Productivity (t/ha)[c]	13.7	10.2
Gross benefit (€/ha)	1,142	853
Additional labour cost (€/ha)[d]	6	–
Marginal net benefit (€/ha)	284	–
Return on labour (€/day)	70.9	

[a] Estimated minimum farm gate price (900 Ksh/110 kg bag)

[b] 1€=97.79 Ksh at www.oanda.com, 01/09/2010

[c] Average over the 2005–2006 and the 2010 season trial data

[d] Casual labour estimated at 150 Ksh/day

substantial reduction in virus and bacterial wilt infection could well be a contributing factor to the yield increases observed. The reduction of seed-borne pathogens other than virus and bacterial wilt disease may have contributed to the yield difference observed between positive selection and farmer practice. Turkensteen (1987) identified *Erwinia* spp. bacteria (nowadays called *Pectobacterium* spp.) and *Fusarium* spp. fungi as 'important' seed-borne pathogens in Central Africa.

Virus incidence levels were scored by producers, after a very basic explanation of virus symptoms by an extension worker. The observed virus infection levels by the farmers could well be much lower than the real infection levels. Visual virus infection detection is not all that easy for experts, let alone for potato farmers who have been briefly trained in the field. Measurements of virus incidences are scarce, but in a quick survey of seed potatoes sold in rural markets in Kenya, an average incidence of 71%, 75%, 57% and 41% for PLRV, PVY, PVX and PVA, respectively, was recorded (Gildemacher et al. 2007b). This is substantially higher than the incidence scores by the producers presented in this paper.

During the training of farmers, it quickly became apparent that the identification of diseased plants requires thorough understanding and experience, which is not easy to obtain in a few group trainings. Fortunately, positive selection is based on the identification of the most healthy plants or 'select the best' (Gildemacher et al. 2007a). Selecting the best-looking plants in a potato field is far easier than identifying accurately each and every diseased plant.

Another possible contributing factor to the increase in yield through the positive selection treatment may be related to an unintentional shift in seed tuber size. As only a selection of plants gets pegged by the producers, they are under pressure to accept both smaller as well as larger tubers as seed potatoes than they are normally inclined to plant. Average seed tuber weight was not recorded specifically in the farmer run trials. The facilitators instructed producers to not go for tubers smaller than 25 mm, which is smaller than the average tuber size planted in Kenya, and not beyond 90 mm, which is larger than the average tuber size. In the farmer-managed plots, producers were selecting according to common farmer practice, which is to select 'egg sized' tubers from the bulk of potatoes harvested. It cannot be ruled out that part of the yield effect is caused by an unintentional shift in tuber size, and not by reducing seed-borne diseases alone.

The increases in yields are the result of a single season of positive selection, by farmers with no prior experience in practicing this technology. It may be expected that yield differences could increase if further positive selection was practiced consistently over several seed generations. A first indication of a potential of add-on effects over seasons is that positive selection assured a 55% average yield increase for the 25% lowest-yielding trials, but still a 29% increase for the 25% highest-yielding plots.

There is a large variation in the yield increase obtained through the technology. This can partly be attributed to differences in effectiveness of training of the farmer groups which may have different causes, ranging from the motivation and capacity of the facilitator of the public extension staff assisting the group, to the motivation and cohesiveness of the farmer groups involved. Other causes for variation may include the different disease incidence and varieties grown in the fields where the seed potato was sourced for the experiment.

The farmer-managed trials with positive selection convincingly show that the technology can substantially increase smallholder potato productivity. This, however, does not automatically mean that it is the best possible solution for potato farmers. The regular replacement of a farmers' seed stock with high-quality seed potatoes from a more formal seed multiplication system may well be more economic. A number of demonstration trials in which an additional plot was planted with certified seed (data not presented) indicate that this can outyield positive selection under most circumstances. For farmers who can afford the risk of investing in certified seed potatoes because they have yield security, the required cash and a fairly sure market, buying high-quality seed regularly is probably more economic than practicing positive selection. This does assume that these farmers have access to these certified seeds of the right variety at the right time.

Considering the simplicity of positive selection and the apparent good fit within the prevailing informal seed potato system of Kenya, one has to question why potato farmers have not been practicing this technology all along. A number of reasons can be identified. An important first reason is the limited understanding of seed degeneration and the role of potato viruses in this among farmers and extension staff alike. The training on positive selection and viruses was an eye-opener that made farmers and extension staff aware of the poor health status of the average Kenyan potato field. The knowledge tests implemented before the training of both trainers and farmers in 2005–2006 confirmed this limited understanding (data not shown). Secondly, the potato crop dies off before harvest and its product is found below ground. In maize production, positive selection of the best cobs for next season's planting is well-known and widely practiced for open pollinated varieties. For potato, this is more complicated, as plants need to be pegged before senescence sets in, and ideally before the crop closes and starts flowering. Finally, positive selection was not seen as a technology suitable for large-scale seed potato multiplication, with good reason. For a specialized seed multiplier, positive selection can only be of assistance in selecting mother plants in the first generations. In later generations, the removal of sick plants from a largely healthy field (negative selection) is the only possible way to bulk-up seed of high quality for commercialization.

Seed potato quality management has invariably been addressed through specialized seed multipliers. This has provided an excellent solution to seed potato degeneration in Northern countries. In less perfectly functioning rural economies of developing countries with higher production risks and market insecurities, specialized multiplication systems have been much less successful. Decision makers in seed potato programmes and projects have been focussing fully on seed *multiplication*, and not paid enough attention to the potential of seed potato quality *maintenance by non-specialized ware potato farmers.*

A number of research questions with regard to the mechanisms behind the success of the positive selection technology remain. In addition, it would be of interest to consistently continue positive selection over a number of seasons in the same potato plant population to assess the potential of the technology to further increase the yield over several generations. To study the technology in further detail, more thorough replicated trials under controlled conditions, quantifying the virus load in the plant population would be recommended. Furthermore, it would be advisable to control more rigidly the stability of seed tuber size in these replicated trials.

Nevertheless, the results of the farmer-managed trials demonstrate that positive selection is an important alternative and complementary technology to regular seed replacement. In the first place, it does not require cash investments and is thus accessible for all potato producers. Secondly, it can be applied where access to high-quality seed is not guaranteed. Thirdly, the technology is also suitable for landraces and cultivars that are not officially recognized and can thus not be multiplied formally. Fourthly, the technology fits seamlessly within the currently most important seed system of sub-Saharan Africa, which is dominated by self-supply and neighbour supply of seed potatoes.

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