

Effect of Field Multiplication Generation on Seed Potato Quality in Kenya

Schulte-Geldermann, E., Wachira, G., Ochieng, B. and Barker, I.

International Potato Center, Regional Office Sub Saharan Africa (CIP-SSA), P. O. Box 25171, 00603 Nairobi, Kenya; Email: e.schulte-geldermann@cgiar.org

Introduction

The current average potato yields in Eastern Africa has been reported to be about 8 t*ha⁻¹ (Obado *et al.*, 2010; FAO, 2010), which is well below the yields of 25 t*ha⁻¹ attained by some progressive smallholder farmers, harvesting in the same soils and under the same rain fed conditions in these countries.

The adoption of clean seed and new varieties can significantly help to close this “yield gap” and boost on-farm productivity. This yield gap can be attributed to the use of low quality seed potatoes (Kinyua *et al.*, 2001), low yielding varieties, poor disease management (Olanya *et al.*, 2001), and inadequate soil fertility management (Berga *et al.*, 2001). However, potato seed quality is an important determinant of the final yield and quality (Struik and Wiersema, 1999). Low quality seed is believed to be one of the major yield reducing factors in potato production in Sub Sahara Africa (Fuglie, 2007). The accumulation of seed borne diseases in farm saved seed potatoes used for several cropping cycles causing severe degeneration (Gildemacher *et al.*, 2007). Turkensteen (1987) identified bacterial wilt, caused by *Ralstonia solanacearum* Smith and virus diseases caused by *Potato virus Y* (PVY, family Potyviridae, genus Potyvirus) and *Potato leaf roll virus* (PLRV, family Luteoviridae, genus Polerovirus) as the most important seed borne potato diseases in Africa.

Despite several efforts to enhance seed potato multiplication systems in potato sub-Sahara Africa (Monares, 1987; Potts and Nikura, 1987; Crissman *et al.*, 1993), potato farmers in Kenya still identified quality of seed potato as their major concern within potato production system and it was prioritized as an important technical intervention to improve smallholder potato profitability (Gildemacher *et al.*, 2006).

Most potato growers in Kenya have two choices when faced with the decision of where to get their seed. They can use seed from their own harvest with higher disease levels each season, purchase seed from a neighbour, the local market, or from a specialist clean seed multiplier. The clean seed multipliers in turn get their

input seed traditionally from National programs who supply what is known as basic or certified seed. Basic and certified seed may have been inspected by a mandated government agency depending on National seed regulations. National programs produce basic seed by multiplying disease free “minitubers” in isolated fields, and are traditionally grown in pots in insect proof screenhouses. This whole cycle typically takes 5-7 seasons and the potato seed stocks inevitably accumulate seed borne diseases such as viruses or bacterial wilt through each cycle.

However, the choice to use high-grade seed is strongly limited by its availability. In Kenya the amount of quality, regulated (certified) seed has been less than 1% of the estimated demand of 48,000 tons per year. Another 2% of seed is produced by informal seed multipliers using basic seed (3rdFG) multiplying this for 1-3 seasons before selling it to ware potato producers (Obado *et al.*, 2010). Additionally, about 2% of potato farmers practice “Positive Selection” method to improve their seed quality. The innovative extension intervention system known as “Select the Best” was developed by CIP and KARI and ran from 2004 up to 2007. Through the training potato producers learn how to maintain the quality of their potato seed for a longer period through positive selection. The process involves training farmers to recognize healthy plants, which are not showing symptoms of seed borne diseases such as virus and bacterial wilt. Healthy plants, representing about 10% of the crop, are marked and later harvested to provide next year’s seed. The intervention is relatively low cost and requires less contact time than a conventional farmer’s 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. However, 95% of potato farmers use seed of minor quality. Besides low availability of high-grade seed, Obado *et al.* (2010) evaluated more than 1200 potato farmers in a countrywide baseline survey and reported that the awareness of the benefits of high-grade seed was very poor and many considered the investment in high-grade seed as too high.

To increase the availability of high-grade potato seed, CIP together with its national partners, have tested and developed the components of an innovative seed strategy, which both dramatically lowers the cost of production of pre-basic or “starter” seed coupled with extension-based interventions to train smallholders in the better on-farm management of their own seed. Engagement with the private sector as a means to widen the supply base and satisfy demand for clean seed is also a key component of the strategy. Because the strategy involves the delivery of low cost quality seed to growers in 3 generations of field multiplication, rather

than the conventional 5 to 7 generations, this new strategy has been named as “3G” system. CIP believes that wide-scale adoption of these technologies, as well as capacity building in conventional technology (field management and storage), would be an appropriate response to current concerns over rising food prices and to secure seed supplies for the next few seasons and to put the whole seed supply chain onto a more sustainable path for the future. The introduction of new technologies, lowering seed production costs, improving farmer knowledge, widening, and strengthening the seed supply base (including private sector suppliers) may also put the whole seed production chain onto a more sustainable basis for the future.

The purpose of this study is to determine the yield gap caused by degeneration of various seed qualities compared with Farmers saved seed (hereafter called Farmers practice). The seed qualities used were from the 2nd field generations (2ndFG) of a private seed multiplier. Basic seed from the National program (3rdFG), certified seed from a public seed multiplier (6thFG), informal seed which is seed obtained from credible farmers but which had been produced without the normal certified seed production regulations (FG 4-6) and “Positively selected seed .The yield gap caused by seed quality was determined by carrying out multi-location On-Farm trials with three main varieties over two seasons in potato growing regions of the country. Besides the evaluation of the yield gap caused by the seed quality, these trials were acting as demonstrations for farmers to create awareness of the importance in using high-grade seed. At each side field days were held were farmers, extension officers and other stakeholders were invited.

Materials and Methods

At 16 locations in the main potato growing areas of Kenya On-Farm trials with different seed qualities were set up in the “Short Rains”, SR (mid October 2009 - mid January 2010)and “Long Rains”, LR (mid April 2010 – early August 2010) seasons, respectively. Plots compromised 40 plants with 3 replications in a randomized complete block design (RCBD) layout at each site. In the LR an additional on station trial with 4 replications was conducted at the field research station of the University of Nairobi, Lower Kabete, Nairobi. Fertilization was based on 90 kg N supplied by a 10 N, 26 P, 10 K fertiliser applied at planting.. Late blight was controlled according to the respective disease pressure with the alternating sprays of Ridomil and Mancozeb. Following seed qualities of the varieties Asante (released in 1998 - CIP 381381.20), Dutch Robyjn and Tigoni (released in 1998 - CIP 381381.13):1-CF and 2-CF private: Project seed (USAID funded –“3G” project) multiplied by Kisima Farm, Timau, Mt. Kenya region: seed

from the first and second field multiplications, respectively. Tested and certified by the national certification body (Dutch Robyjn not available). 3-Basic: supplied by the National Potato Program of the Kenyan Agricultural Research Institute: Three field multiplications. Tested and certified by the national certification body. 6-CF: Certified Seed Agricultural Development Cooperation (ADC): Six field multiplications (Asante not included in On-Station trial) 4 inf., 5 inf., 6 inf. = obtained from credible farmers but which had been informally produced seed without the normal certified seed production regulations – four, five and six field multiplications at the same farms, respectively. PS: Positive selected seed (PS) from farmer groups involved in the project training modules. (Asante not available in SR). FP: Seed quality farmers use to plant - obtained from the same field where farmers practiced positive selection, but from a different section where PS was not practiced. The On-Station trial included PS and FP from 4 Farmer Groups of Asante and Tigoni varieties, respectively.

Assessments

Seed lots forming the different categories were tested for incidence of Potato virus Y (PVY), Potato leaf roll virus (PLRV) and Potato virus X (PVX) using enzyme-linked immunosorbent assay (DAS-ELISA:CIP, Lima, Peru) with leaf sap obtained from eyes cut after harvest and grown in aphid free greenhouse chambers for 4-6 weeks (Casper and Meyer, 1981; Torrance, 1992). At the point of testing, seed quality 6-CF was not available and thus not tested. Yield determination was made by weighing on per plot basis and transferred into $t \cdot \text{ha}^{-1}$. Tuber number was counted for the On-Station trial and converted into tubers per m^2 .

Statistical analysis

Statistical analysis was based on the SPSS GLM procedure (Version 19). Fixed effect models were analyzed per seed quality. Random effects were for the On-Station trial the replication and for On-Farm trials the interaction between replication and site. The Bonferroni-Holm Test was conducted to separate means with a confidence level of 95%. Relative values have been arcsine transformed before analyzing.

Results and Discussion

Seed quality is closely related to degeneration due to viral infections, especially PLRV and PVY which contribute to severe yield losses. The potato seed qualities tested in this study show a clear increasing virus infection level with increasing number of field generations (FG) with all three varieties (Table 1).

The results reveal that certified seed from field generation 1 and 2 (private multiplier) was free from both viruses. Considerable PVY infections could be observed in certified seed from field generation 3 (National program) with varieties Dutch Robyjn (15%) and Asante (7.5%) and lesser with Tigoni. Seed obtained from informal non-certified shown increased virus levels with both PLRV and PVY on all varieties. However, the results reveal that the variety Dutch Robyjn has the highest PVY infection resulting in a level of 40% already after 5 FG. This is mainly due to the already high PVY level from the seed from the National program, which the informal seed multipliers are using for further seed bulking. Farmers practicing the PS technology were able to half the infection levels for both viruses and varieties (Table 1).

Table 1: PLRV and PVY infections of different seed qualities available in Kenya differing in number of field multiplication generations (1-6) from certified (CF) or informal production systems as well as Positively Selected and Farmers Practice seed of varieties Asante, Dutch Robyjn and Tigoni in 2010. Variety

	Virus (%)	No. of field generation and seed source							PS	FP
		1-CF	2-CF	3- CF	4-inf.	5-inf.	6-inf.			
Asante	PLRV	0.0	0.0	0.0	0.0	17.6	13.8	11.3	27.5	
	PVY	0.0	0.0	7.5	10.0	20.6	23.8	18.8	41.3	
Dutch Robyjn	PLRV	-	-	0.0	5.0	10.0	12.5	20.0	38.1	
	PVY	-	-	15.0	18.8	40.0	45.0	25.0	52.4	
Tigoni	PLRV	0.0	0.0	0.0	10.0	17.5	-	15.0	22.5	
	PVY	0.0	0.0	2.5	2.5	15.0	-	15.0	27.5	

In general, the results obtained in this study indicated that these viruses can be a limiting factor to potato (ware and seed) production in Kenya and informal seed multipliers poorly practice the importance of vector control and the practice of negative selection. Moreover, considering that all seed sources were obtained from altitudes above 2200 masl the steady increase of virus levels with number of FG's indicate that virus transmitting aphid populations may have moved towards higher altitudes most likely due to increasing temperatures and possibly caused by effects of climate change. Hence, field multiplication generations have to be reduced to maintain high yield potential, which is the rationale behind the 3G project with the main effort in reducing the number of FGs from 5-7 to 2-3 seasons. Having in

mind that knowledge of insecticide applications is poor among farmers and that application of those harmful for human health should be minimized, the introduction of virus resistant varieties seems to be the most promising future option to reduce seed degeneration caused by viruses. Promising CIP germplasm with combination of late blight and virus resistance is available for variety deployment in tropical highland regions. A screening of 292 clones from B1C5 (fifth cycle of recombination of the pure native Andigena group B1) showed extreme resistance to both viruses, resulted in a high percent of clones showing resistances to PVY (70%) and PVX (73%). Likewise, 59% of clones showed resistance to PLRV (Landeo, 2003).

The yield determination undermines clearly the importance of seed quality and the prominent effect of seed borne diseases in particular bacterial wilt caused by *Ralstonia solanacearum* (Smith) and virus. However, poor seed quality also carries important seed borne diseases e.g. soft rot (caused by *Erwinia chrysanthemi*), Fusarium wilt and dry rot (caused by *Fusarium solani*) and Verticilium wilt (caused by *Verticilium albo-atrum*) and limited to two regions (Meru and Taita Hills) also *Rhizoctonia solani* (Kuehn).

The average yield of farmer's seed in the On-Farm evaluations was 11.1 t*ha⁻¹ and 9.3t*ha⁻¹ in the SR and in the LR seasons, respectively, which were very low, although grown with relatively high fertiliser and strict late blight control. The low yields with farmer's seed clearly show the yield gap produced by the quality of seed. With all varieties additional FG's led to considerable yield losses (Table 2). FG 2–CF out-yielded all other seed qualities significantly with yields in-between 243 and 352% of the yield obtained with FP seed (Table 2), followed by FG-3-CF with significantly higher yields than in the plots planted with seed of lower quality. However, yield increase of FG-3-CF was lowest with variety Dutch Robyjn, which can be linked to the already high PVY infection level of this seed quality (Table 1 and 2). Yields were comparable to better when seed potatoes obtained from informal seed multipliers after one informal multiplication (4 FG) were planted than the certified seed that was 6 FG old. A second informal multiplication (FG 5 inf.) although caused further significant yield losses. However, yield increases compared to farmers seed still range been between 56 and 90%. The Positive selection method also increased the yield considerably compared with FP, but the effect differed between varieties. Whereas, high yield increases of 55% and 29% and 44% (SR and LR) could be obtained with Dutch Robyjn and Asante, respectively, lower yield increases of 18 and 23 % were realized with Tigoni. The main reason might be that symptoms of viral infections are more distinct with varieties Dutch Robyjn and Asante than with Tigoni, which made the selection

process more difficult and less effective with this variety. However, this cannot be confirmed by this study as the varieties were grown with different farmer groups and difference in knowledge and accuracy of selection were not determined.

Table 2: Average relative yield of different seed qualities available in Kenya differing in number of field multiplication generations (1-6) from certified (CF) or informal production systems as well as Positively Selected compared with Farmers Practice seed (=1) of varieties Asante, Dutch Robyjn and Tigoni. Data obtained from 6 On Farm sites in Short rain season 09/10 and 6 different sites in the Long rain season '10 in Kenyan potato growing woredas, respectively

Variety	Season	No. of field generation and seed source					
		2-CF private	3-CF public	6-CF public	4-inf.	5-inf.	PS
Asante	LR 2010	2.67a	2.25b	1.97c	2.18bc	1.89d	1.44e
Tigoni	LR 2010	2.80a	2.44b	1.98c	2.04c	1.90d	1.18e
Asante	SR 2009/10	2.43a	2.10b	1.92c	-	1.61d	1.29e
Dutch Robyjn	SR 2009/10	-	1.88a	1.73b	-	1.56c	1.55c
Tigoni	SR 2009/10	3.52a	2.77b	2.58c	-	1.85d	1.23e

The additional On-Station trial indicates the same effects on yield as obtained with On-Farm trials. However, the inclusion of more FG's from different seed qualities allows a better insight. The overall yield potential was limited by low precipitation and thus water deficiency at mid –end of flowering. Nevertheless, the differences in tuber number and yields are enormous between seed qualities. Whereas, no significant differences between the FG 1-CF and FG 2-CF could be observed both had significantly higher tuber numbers and yields than all other seed qualities tested. Compared to FP seed the number of tubers was doubled and the tripled with FG 1-CF and FG 2-CF (Table 3).

Table 3: Tuber number m^{-2} and yield in $\text{t}\cdot\text{ha}^{-1}$ of different seed qualities available in Kenya differing in number of field multiplication generations (1-6) from certified (CF) or informal production systems as well as Positively Selected (PS) and Farmers Practice seed (FP) of varieties Asante and Tigoni in the Long rain season '10 at the University of Nairobi

Variety		No. of field generation and seed source							
		1-CF	2-CF	3-CF	4-inf.	5-inf.	6-inf.	PS	FP
Asante	Tubers $\cdot\text{m}^{-2}$	30.9a	31.5a	25.1b	22.4c	23.1bc	18.9d	16.8d	14.5e
	$\text{t}\cdot\text{ha}^{-1}$	28.6a	28.8a	22.7b	21.6b	19.8c	16.8d	11.4e	8.7f
Tigoni	Tubers $\cdot\text{m}^{-2}$	38.5a	36.7a	29.5b	30.4b	24.5c	26.1c	21.8d	18.9e
	$\text{t}\cdot\text{ha}^{-1}$	34.6a	32.1a	26.3b	25.9b	23.3c	20.7d	13.0e	11.0f

In general, yields and tuber number were reduced more or less gradually by seed age for both varieties (Table 3). However, biggest differences in yield and tuber number were determined between FG1+ FG2 from the private multiplier to FG3 from the national program (6 $\text{t}\cdot\text{ha}^{-1}$ and 5-7 tubers $\cdot\text{m}^{-2}$) (Table 3), which clearly can be attributed to the virus –free status of FG1+ FG2 and the PVY infection levels in FG 3 (Table 1). Differences of PS(31 and 18% yield increase with Asante and Tigoni, respectively) FP are also according to the results of the ON-Farm trials.

Conclusions

For SSA, Scott *et al.* (2000) projected a 250% increase in demand for potato between 1993 and 2020, with an annual growth in demand of 3.1%. The growth in area under production is estimated at 1.25% a year, the rest of the increase being achieved through predicted growth in productivity. For both increased productivity and area under production, a timely availability of good quality seed of improved potatoes varieties will be vital. As this study clearly reveals the number of field multiplication generations of seed potato and a good quality control system affect the productivity to a substantial magnitude. However, pressure of virus transmitting aphids is high enough in reducing the number of seed FG possible to produce high quality seed compared to European conditions and pointing out the need for varieties combining i.e. virus and late blight resistance. Other seed borne diseases could also be reduced significantly by the use of high-grade seed. In Kenya, the spread of bacterial wilt with infected seed as the predominant source of inoculum is of major concern.

The “3G” approach for making available seed to farmers in three generations instead of the usual seven or more generations provides one of the best

opportunities to exploit the contribution of the potato to improve livelihoods. Objectives in this projects is the use rapid minituber multiplication technologies such as aeroponics and reducing the number of field generations and thus less land will be used per seed production unit. The overall objective is to increase the availability of high-grade seed in Kenya from 1% to 10% within the next two years. Additionally the training in the “Select the Best” method will enable farmers to keep the quality of their seed for a longer time through positive selection and suitable storage. There is a great potential to boost potato productivity and total production, especially if these are coupled with best cultural practices.

References

- Casper R, Meyer S. 1981. Die Anwendung des ELISA Verfahrens zum Nachweis pflanzenpathogener Viren. *Nachrichtenblatt des Deutschen Pflanzenschutzbundes* 33:49-54.
- Crissman, C.C., L.M. Crissman, and C. Carli. 1993. Seed potato systems in Kenya: a case study. Lima: CIP.
- FAO. 2010. <http://faostat.fao.org/site/567/default.aspx>, August 2010. Rome: FAO.
- Fuglie, K.O. 2007. Priorities for potato research in developing countries: results of a survey. *American Journal of Potato Research* 84(5): 353–365.
- Gildemacher, P.R., P. Maina, M. Nyongesa, P. Kinyae, W. Gebremedhin, Y. Lema, B. Damene, T. Shiferaw, R. Kakuhenzire, I. Kashaija, C. Musoke, J. Mudiope, I. Kahiu, and O. Ortiz. 2006. Participatory analysis of the potato knowledge and information system in Ethiopia, Kenya and Uganda. In *Innovation Africa: enriching farmers’ livelihoods*, ed. P.C. Sanginga, A.W. Bayer, S. Kaaria, J. Njuki, and C. Wettasinha, 203–219. London: Earthscan.
- Gildemacher, P., P. Demo, P. Kinyae, M. Nyongesa, and P. Mundia. 2007. Selecting the best plants to improve seed potato. *LEISA Magazine* 23(2): 10–11.
- Kinyua, Z.M., J.J. Smith, C. Lung’aho, M. Olanya, and S. Priou. 2001. On-farm successes and challenges of producing bacterial wilt-free tubers in seed plots in Kenya. *African Crop Science Journal* 9(1): 279–285.
- Landeo, J.A. 2003. Integrated management of late blight -breeding for improved late blight resistance. International Potato Center-Subproject Annual Progress Report .Reporting period: January 1, 2003- December 31, 2003
- Lemaga, B., R. Kanzikwera, R. Kakuhenzire, J. J. Hakiza and G. Maniz. 2001: The Effect of crop rotation on bacterial wilt incidence and potato tuber yield. *African Crop Science Journal*, Vol. 9: 257-266
- Monares, A. 1987. Analytical framework for design and assessment of potato seed programs in developing countries. The social sciences at CIP Report of the third social science planning conference, held at CIP, Lima, Peru, September 7-10, 1987.
- Obado, J. 2010. 3G Baseline Report, Kenya in the USAID funded project: Tackling the food price crisis in Eastern and Central Africa with the humble potato: enhanced productivity and uptake through the “3G” revolution. March 2010, unpublished.

- Potts, M.J. and Nikura, S. 1987. Seed potato farm developed in Burundi encourages new ideas and techniques. *Agriculture International* 39(9–10): 266–270.
- Scott, G.J., Rosegrant, M.W., and Ringler, C. 2000: Global projections for root and tuber crops to the year 2020. *Food Policy*, 25 (5): 561-597.
- Struik, P.C. and Wiersema, S.G. 1999. Seed potato technology. Wageningen University Press.
- Torrance, L. 1992. Developments in methodology of plant virus detection. *Netherlands Journal of Plant Pathology* 98 Suppl.2:21-28.
- Turkensteen, L.J. 1987. Survey of diseases and pests in Africa: fungal and bacterial diseases. *Acta Horticulturae* Vol. 213: 151–159.