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Improving potato tuber yields using genotypes with multiple virus resistance in Kenya

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ABSTRACT

Potato (*Solanumtuberosum L.)* viruses play a major role in lowering yields and quality of ware and seed tubers in Kenya. This experiment was conducted to determine potential of potato clones with multiple virus resistance in minimizing virus related crop losses. The trials were conducted in two sites for four successive seasons of re-using seed tubers. The genotypes were exposed to natural sources of virus infection without spraying insecticides to control (aphids) virus vectors. Genotypes with multiple virus resistance experienced significant ($P \leq 0.05$) lower rate of yield loss (21.2 %) compared to the major local varieties (68.4 %). There was successful identification of a higher yielding virus resistant clone (CIP396286.7) with significant ($P \leq 0.05$) higher mean yield (30.3 T/ha) compared to the highest yielding local variety (24.3 T/ha), Tigoni. The number of tubers per plant was significantly ($P \leq 0.05$) higher (12.1) in the virus resistant clones than in the local varieties (7.3). Reduced rate of yield loss, higher yield performance and higher number of tubers per plant in the tested clones was attributed to genetic contribution of multiple virus resistance. Virus related crop losses currently experienced by local farmers can be minimized with use of such virus resistant genotypes.

KEY WORDS: Potato, yield, virus resistance, Kenya

INTRODUCTION

The potato (*Solanum tuberosum L.*) crop makes a significant contribution to food security in Kenya as the second most widely grown food crop after maize. Major constraints of potato production include high incidence of pests and diseases and lack of sufficient quantity of certified seed tubers (Schulte-Geldermann *et al.,* 2012). Among the important diseases of potato in the country, viruses have been a major concern because of the role they play reducing seed tuber quality and the associated crop losses (Muthomi *et al.,* 2009). In many cases, viral infection in potato crop results in poor yields and vegetative growth accompanied by symptoms such as leaf rolling, leaf curling, leaf mosaic, inter-veinal banding, leaf drop, plant stunting and production of small or undersized tubers (Jayashige*et al*., 1989; Beukema and van der Zaag 1990). Diseases severity increases over the seasons once the crop is infected leading to successive yield and crop quality losses (Hide and Lapwood, 1992; Omer and El-Hassan, 1992; Rahman *et al.,* 2010).

High rate of transmission of these viruses have been attributed to abundance and high rate reproduction of aphid vectors in the potato growing areas (Nderitu and Mueke, 1986; Muthomi *et al.,* 2009; Olubayo *et al.,* 2010). Virus indexing experiments have reported high prevalence of potato viruses in the major potato growing areas (Machangi *et al.,* 2004; Olubayo *et al.,* 2010; Gildemacher, 2012). The potato viruses responsible for major yield reductions are the potato virus Y (PVY), potato leaf roll virus (PLRV) and potato virus X (PVX), which occurs in combination with mild viruses such as potato virus A (PVA), potato virus M (PVM) and potato virus S (PVS) to cause more severe yield losses (Kabira *et al.,* 2006; Schulte-Geldermann *et al.,* 2012). The highest yielding major varieties have been reported to experience yield losses due to these viruses (Lung'aho *et al.,* 2007). Development and utilization of higher yielding and disease tolerant varieties have

been viewed as a sustainable way of managing crop losses associated with such virus infections (MoA, 2005; MoA/GTZ-PSDA, 2009). Potato genotypes with multiple virus resistance are available at the International Potato Centre (CIP) germplasm collection (CIP, 2006) but little is known regarding resistance of these clones under the Kenyan potato growing conditions. This study was therefore conducted to determine the role of such virus resistant clones in reducing virus related crop losses.

MATERIALS AND METHODS

Genotypes, seasons and sites: Disease free *in-vitro* plantlets obtained from CIP Lima, Peru were multiplied in tissue culture and planted in the greenhouses to produce disease free minitubers which were planted for one season in the field to produce seed for the first season trial. Prior to the first season trial, enzyme linked immune-sorbent assay (ELISA) test was conducted on tuber samples to ascertain that the tubers planted in the first season were free of six of the most important potato viruses namely: PVY, PVX, PLRV, PVS,PVM and PVA. The genotypes and their parentage were as follows: 394903.3 = (720118.1 x BWH87.183), 395196.4 = ([C83.621 x KATAHDIN] x BULK 1-RKN), 395438.1= (BWH87.344R x TXY.11), 396286.6 = (TXY.3 x 1-1039), 396286.7 = (TXY.3 x 1-1039), 394905.8 = (CRUZA -148 x C90.205) and 394904.17 = (720118.1 x (C90.205)17). These genotypes were selected based on their levels of resistance to different viruses (*Table 1*) in addition to other locally important diseases like late blight (*Phytopthora infestans* Mont. de Barry) and bacterial wilt (*Ralstonia solanacearum*) (CIP, 2006). Three popular Kenyan varieties Asante, Tigoni and Kenya Sifa and two Ugandan varieties Nakpot 1 and Nakpot 4 were used as virus susceptible checks. Virus infected variety Tigoni (denoted Tigoni*) which had been subjected to natural virus pressure for 3 seasons in the seed field at KARI Tigoni was included as a virus infected control. The experiments were conducted at the Kenya Agricultural Research Institute (KARI)-Tigoni and at KARI–Molo (Marindas) for four seasons long rains (LR) season of 2007, short rains (SR) of 2007, LR of 2008 and during SR 2008. The seed tubers for planting each second were sourced from the harvest of previous season of each of the sites respectively.

Table 1: Resistance of the potato clones to (PLRV, PVY and PVX) according to CIP standard trials in Lima Peru

CIP No	PLRV Resistance	PVY Resistance	PVX Resistance	Late blight resistance	Bacterial wilt resistance	Tuber skin colour
395196.4	S	ER	ER	MR	S	Cream
396286.6	S	ER	ER	R	S	Purple
396286.7	MR	ER	ER	R	S	Red
394905.8	S	ER	ER	MR	MR	Cream
395438.1	MR	ER	ER	MR	MR	Red
394904.17	MR	S	ER	MR	MR	Cream
394903.3	MR	ER	S	MR	MR	Cream

ER *Extreme resistance*
S *Susceptible*
MR *Moderately resistant*
MR *Moderately resistant*

Experimental design and crop management: The trials were planted in randomized complete block design (RCBD) with four replications. Each plot measured 3 m X 3 m (9 m^2) with four ridges per plot spaced at 0.75 m apart and were planted with 40 tubers with a spacing of 0.3 m between the 10 consecutive tubers within a row. All crop husbandry activities followed previously described recommendations (Lung'aho *et al.,* 2007). The crop was not sprayed with the insecticides to encourage infestation of the crop with the virus vectors (aphids) and subsequent natural virus transmission during the cropping period. The crop was harvested at full physiological maturity.

Data collection and analysis: Data were collected on number of tubers per plant and the marketable tuber weight at harvest of every season. Tuber yields (T/Ha) per season were used to calculate percentage yield reduction between seasons. All the data

collected were subjected to analysis of variance (ANOVA) using General statistics (GENSTAT) software (Lawes, 1995). The differences between the means were compared using least significant difference at LSD 0.05 (Steel and Torrie, 1980).

RESULTS

Yield reduction over seasons: All the seven CIP sourced genotypes with multiple virus resistance experienced significant (P≤ 0.05) lower yield losses over the four cropping seasons compared to the local Kenyan and Ugandan varieties (*Table 2*). Percentage yield reduction ranged from 58.1 % to 58.5 % among the susceptible Ugandan varieties and 55.6% to 56.5 % in Kenyan varieties while the CIP sourced virus resistant clones ranged between 4.6 % to 32.8 %. The CIP clones were found with only 21.2 % yield reduction compared to 68.4 % in local varieties (Kenyan and Ugandan) which was a 43.6 % difference in the overall mean percentage yield reduction. The lowest percentages of yield reduction were found in CIP 396286.6, CIP 396286.7 CIP 394905.8 and CIP 395438.1 with 4.6%, 6.9%, 7.3% and 11.5% respectively. Percentage yield reduction in the four clones were significantly (P≤ 0.05) lower than those of the rest of the other CIP clones, CIP 395196.4, CIP 394904.17 and CIP 394903.3 which had 24.5 %, 29.4% and 32.8 % respectively. The most virus resistant local variety (Tigoni with 55.6 %) had significantly (P≤ 0.05) higher percentage of yield reduction than the most susceptible (394903.3 with 32.8 %) CIP clones evaluated.

Table 2: Mean percentage yield reduction during the 2007 and 2008 cropping seasons in the trial conducted at Tigoni and at Molo

Variety/clones	Tigoni				Molo				OMR
	R1	R2	R3	OR	R1	R2	R3	OR	
396286.6	0.3	1.4	1.4	3.1	4.2	0.5	2.1	6.1	4.6
396286.7	4.9	1.7	2.9	9.3	2.2	0.7	1.6	4.4	6.9
394905.8	0.0	5.3	3.1	8.2	0.1	5.9	0.5	6.5	7.3
395438.1	0.0	2.9	0.0	2.9	13.4	7.7	0.0	20.0	11.5
395196.4	24.1	2.2	8.3	32.0	3.3	10.1	4.4	16.9	24.5
394904.17	26.8	14.5	4.1	40.0	7.5	3.2	9.4	18.8	29.4
394903.3	28.7	10.2	11.3	43.2	16.1	3.7	4.0	22.5	32.8
Tigoni	31.9	14.6	25.6	56.7	13.3	23.7	31.4	54.6	55.6
Asante	33.6	16.4	17.3	54.1	34.1	25.9	12.4	57.2	55.7
Kenya Sifa	37.6	22.3	20.7	61.5	14.2	23.3	26.2	51.4	56.5
Nakpot 1	48.4	6.3	21.9	62.2	25.2	15.5	27.3	54.0	58.1
Nakpot 4	28.9	18.8	22.7	55.4	16.5	47.2	13.0	61.7	58.5
Tigoni *	20.9	37.8	28.0	64.6	20.3	40.4	27.8	65.7	65.1
Grand mean	22.0	11.9	12.9	37.9	33.4	38.2	43.1	48.0	43.0
Mean of local varieties	33.5	19.4	22.7	59.1	53.7	61.7	69.7	77.7	68.4
Mean of CIP clones	12.1	5.5	4.4	19.8	16.0	18.2	20.4	22.6	21.2
LSD (5%level)	8.1	7.5	6.6	8.4	6.1	6.7	7.9	8.8	8.6

R1: Percentage yield reduction between the first and the second season (LR 2007 /SR2007).
R2: Percentage yield reduction between the second and the third season (SR2007/LR 2008).
R3: Percentage yield reduction between the first and the second season (LR 2008 /SR2008).
OR: Percentage yield reduction between the first and the last season (LR 2007 /SR2008).
*OMR: Overall mean percentage yield reduction between the first and the last season in the two sites.Tigoni * Infected variety Tigoni which had been exposed to virus pressure for 3 seasons at KARI- Tigoni before the beginning of the first season trail of LR 2007.*

The overall percentage in yield reduction over the four cropping seasons was highest in variety Tigoni* (65.1 %) which had been exposed to virus infection prior to the start of the first season. The high initial virus incidence (at the beginning of the first season) in the seed of variety Tigoni* contributed to significantly (P ≤ 0.05) higher percentage yield loss compared to that of variety Tigoni.

Tuber yield (T/ha): A higher yielding virus resistant clone was identified during the exposure to natural virus pressure over the four cropping seasons in the two sites (*Table 3*). This clone, CIP 396286.7 which produced an average of (30.3 T/ha) was found with significant (P ≤ 0.05) higher yield than the highest yielding local variety, Tigoni which produced 24.3 T/ha.

Table 3: Tuber yield (T/ha) during the cropping seasons of 2007-2008 in the trial conducted at Tigoni and Molo

Variety/ clone	Tigoni					Molo					
	S^1	S^2	S^3	S^4	M^1	S^1	S^2	S^3	S^4	M^2	M^{12}
396286.7	36.4	34.6	34.0	33.0	34.5	26.2	25.6	25.4	25.0	25.5	30.3
396286.6	29.4	29.3	28.9	28.5	29.0	24.5	23.5	23.0	23.0	23.5	26.5
395196.4	29.4	22.3	21.8	20.0	23.4	33.8	32.7	29.4	28.1	31.0	25.4
Tigoni	38.3	26.1	22.3	16.6	25.8	39.9	34.6	26.4	18.1	29.7	24.3
Asante	45.8	30.4	25.4	21.0	30.7	39.7	26.2	19.4	17.0	25.6	24.3
394903.3	34.5	24.6	22.1	19.6	25.2	31.0	26.0	25.0	24.0	26.5	23.8
394904.17	31.0	22.7	19.4	18.6	22.9	26.1	24.2	23.4	21.2	23.7	21.8
Nakpot 1	39.7	20.5	19.2	15.0	23.6	34.8	26.0	22.0	16.0	24.7	20.3
Nakpot 4	33.6	23.9	19.4	15.0	23.0	35.0	29.2	15.4	13.4	23.2	19.9
394905.8	20.7	20.7	19.6	19.0	20.0	20.4	20.4	19.2	19.1	19.8	19.7
Kenya Sifa	33.8	21.1	16.4	13.0	21.1	24.9	21.4	16.4	12.1	18.7	17.4
395438.1	20.6	20.6	20.0	20.0	20.3	12.5	10.8	10.0	10.0	10.8	16.0
Tigoni *	25.4	20.1	12.5	9.0	16.8	30.3	24.2	14.4	10.4	19.8	15.3
Grand mean	32.2	24.4	21.6	19.1	24.3	29.2	25.0	20.7	18.3	23.3	21.9
Mean of local varieties	29.6	22.6	20.4	18.0	22.6	27.1	24.3	21.1	18.6	22.8	21.1
Mean of CIP clones	34.5	25.9	22.7	20.0	25.8	30.9	25.5	20.4	18.0	23.7	22.6
LSD (5%level)	6.2	4.1	5.5	5.8	4.9	6.4	7.7	7.0	5.4	5.5	5.9

S^1The mean tuber yield in the first season trial.
S^2 The mean tuber yield in the second season trial.
S^3 The mean tuber yield in the third season trial.
S^4 The mean tuber yield in the fourth season trial.
M^1 Mean tuber yield of the trial conducted at Tigoni.
M^2 Mean tuber yield of the trial conducted at Molo.
M^{12} Overall mean of both sites (Tigoni and Molo).

All the CIP sourced virus resistant clones used in this study except 394903.3 and 394904.17, did not experience any significant (P ≤ 0.05) yield loss over the four cropping seasons. The local Kenyan and Ugandan varieties yielded significantly (P ≤ 0.05) higher than the CIP sourced virus resistant clones during the first season (LR 2007) but after severe exposure to virus infection by the end of the fourth season (LR 2008), the local varieties yielded less than the CIP clones. During the second (SR 2007) and the third (LR 2008) seasons, there was no significant (P ≤ 0.05) difference in mean yield between the CIP and the local varieties. There was more rapid decline in yield in the local Kenyan and

Ugandan varieties than in the CIP sourced virus resistant clones over the four cropping seasons.

Seed source with higher virus incidence experienced lower yields that those which were less infected at the beginning of the trial. Virus infected variety Tigoni (denoted Tigoni *) which had been exposed to virus pressure for 3 seasons at the beginning of the first season experienced significantly lower yield (P ≤ 0.05) compared to similar variety Tigoni which had not been exposed. There was no signifiant (P ≤ 0.05) difference in mean yield of the two sites.

Number of tubers per plant: Over the four cropping seasons, the CIP sourced virus resistant clones produced higher number of tubers per plant than the local cultivars (*Table 4*). Mean number of tubers per plant in the CIP clones was 12.1 and was significantly (P ≤ 0.05) higher than that of the cultivars which was7.3. The tuber numbers per plant in the CIP clones ranged from 8.8 to 17.8 while that of the cultivars was from 4.0 to 8.2. The highest number of tubers was found in CIP 394903.3 which produced significant (P≤ 0.05) higher number of tubers than the rest of the genotypes evaluated. Four CIP clones, (CIP 394903.3, CIP 394905.8, CIP 395196.4 and CIP 396286.7) produced significant (P≤ 0.05) higher number of tubers per plant (17.8, 13.0, 12.0 and 11.8 respectively) than variety Tigoni, the local variety with the highest number of tubers.

Table 4: Number of tubers per plant during the cropping seasons of 2007-2008 in the trial conducted at Tigoni and Molo

Variety/ clone	Tigoni					Molo					
	S^1	S^2	S^3	S^4	M^1	S^1	S^2	S^3	S^4	M^2	M^{12}
394903.3	19.1	17.3	17	16.6	17.5	18.6	18.4	17.8	17.5	18.1	17.8
394905.8	14.1	13.8	13.1	12.8	13.5	13.4	12.8	12	12	12.6	13.0
395196.4	12.2	12	11.5	11.2	11.7	12.8	12.4	12.1	12	12.3	12.0
396286.7	12.8	12.5	12.4	12.2	12.5	11.5	11.3	10.9	10.6	11.1	11.8
396286.6	11.1	11	10.9	10.6	10.9	12.2	11.8	11.5	11.5	11.8	11.3
395438.1	9.6	9.4	9.3	9.1	9.4	10.5	10.2	10.1	9.5	10.1	9.7
394904.17	9.1	9.1	8.9	8.7	9.0	9.7	8.6	8.4	8.2	8.7	8.8
Tigoni	12.2	8.5	5.5	4.2	7.6	13.4	9.4	6.5	5.6	8.7	8.2
Asante	11.7	8.4	6.4	3.2	7.4	13.4	9.5	7.4	4.5	8.7	8.1
Nakpot 4	12.6	7.7	6.5	4.9	7.9	11.2	7.2	6.1	5	7.4	7.7
Kenya Sifa	12.6	9.6	5.4	4.8	8.1	10.4	7.8	5.5	3	6.7	7.4
Nakpot 1	8.7	6.2	4.1	2.5	5.4	7.6	5.9	4.8	3.2	5.4	5.4
Tigoni *	7.6	4.8	3.4	2.1	4.5	5.9	4.2	2.5	1.7	3.6	4.0
Grand mean	11.8	10.0	8.8	7.9	9.6	11.6	10.0	8.9	8.0	9.6	9.6
Mean of local varieties	11.6	8.1	5.6	3.9	7.3	11.2	8.0	6.1	4.3	7.4	7.3
Mean of CIP clones	12.6	12.2	11.9	11.6	12.1	12.7	12.2	11.8	11.6	12.1	12.1
LSD (5%level)	2.1	3.4	2.6	3.2	3.3	3.4	2.8	3.1	1.7	2.9	3.1

S^1The mean number of tubers per plant in first season trial
S^2 The mean number of tubers per plant in second season trial
S^3 The mean number of tubers per plant in third season trial
S^4 The mean number of tubers per plant in fourth season trial
M^1 Mean number of tubers per plant of the trial conducted at Tigoni
M^2 Mean number of tubers per plant of the trial conducted at Molo
M^{12} Overall mean of both sites (Tigoni and Molo)

DISCUSSION AND CONCLUSION

Yield reduction over seasons: The minimized rate of yield loss among the CIP sourced clones used in this study was attributed gene action of multiple resistances in the genotypes. Like in this study, degeneration of potato yield over generations of using the same seed stock depends mainly on variety grown among other factors (Rahman *et al.,* 2010). This is due to difference in mechanisms favouring virus particle multiplication within the plant (Salazar, 1996). More accelerated yield losses occur when there is multiple infection of the crop by different viruses which increases severity of the diseases (Beukema and van der Zaag, 1990; Hide and Lapwood, 1992). Multiple virus infection is common in Kenya where most important viruses include PLRV, PVY and PVX usually occur in combination with other mild viruses such as PVA, PVM and PVS to cause even more severe crop losses (Kabira *et al.,* 2006; Schulte-Geldermann *et al.*, 2012). Varieties such as Asante, Tigoni and Kenya Sifa used in this study have been reported to experience significant yield losses when exposed to viruses in the field (Lung'aho *et al.,* 2005; Muthomi *et al.,* 2009). Frequent insecticide sprays to control aphids (virus vectors) are also known to raise environmental concerns (Salazar, 1996). In Kenya, smallholder farmers can not afford the pesticides and certified seed tubers are the majority (Kanguongo *et al.,* 2008; Muthoni and Nyamongo, 2009).To grow virus susceptible local varieties, farmers are usually advised to replace their seed with a certified seed more frequently (Muthoni and Nyamongo, 2009; Rahman *et al.,* 2010). With the use of genotypes with multiple resistances to viruses, such farmers would be able to grow their crop over more seasons with less rapid yield reduction while maintaining better seed quality.

Tuber yield (T/ha): Genotypes with multiple virus resistance exhibited higher yield potential when exposed to natural sources of virus infection in the field than the popularly cultivated local varieties. Higher yielding CIP 396286.7 identified in this study would automatically pass the standard yield requirement for release recommendation at national performance trials (NPT) normally conducted by the Kenya Plant Health Inspectorate Service (KEPHIS) due to it's higher yields compared to that of highest yielding local variety, Tigoni (Lung'aho *et al.,* 2006). Such higher yielding varieties with additional desirable agronomic and market demanded attributes fit for the whole potato value chain are highly demanded by local farmers and consumers (Kaguongo e*t al.,* 2008; Ooko and Kabira, 2011). Natural exposure to virus infection in this study simulated real cropping situation (Davies *et al*. 1975) common among many small holder farmers in Kenya, many of whom do not know how to manage seed borne viruses (Gildermacher *et al.,* 2011). Field exposure has been used in the past to determine to determine level of virus resistance under natural conditions and to be sure that the results obtained are relevant to the real crop situation (Davies *et al*., 1975; Solomon and Barker, 2001). Number of seasons of exposure to natural virus infection in the field are important in determining virus incidence and the potential yield loss (Gildermacher *et al.,* 2011). Selection for higher yields, multiple virus resistance in addition to other traits such as resistance to late blight (*Phytophthora infestans*), good storability, early maturity, good storability and good cooking and processing qualities will increase acceptability of new varieties across the whole Kenyan potato value chain (Kaguongo e*t al.,* 2008; Ooko and Kabira, 2011). From this experiment, it was evident that, such genotypes can be succesfully introduced and utilized under the Kenyan potato growing conditions. More virus resistant clones should be evaluated and released to increase availability of virus resistant varieties suiting diverse consumer niches while improving crop yields and seed tuber quality.

Number of tubers per plant: Multiple virus resistance in CIP sourced clones lowered the rate of reduction of number of tubers over seasons. Reduction in number of tubers in virus as observed in susceptible local varieties in this study corresponded to reduced in yield and tuber quality. This has been also been reported by other authors in experiments where potato crop was subjected to natural virus pressure and there by reducing the crop yields (Hide and Lapwood, 1992; Omer and El-Hassan, 1992; Rahman *et al.,* 2010). Tuber sizes and quality can determine marketability of tubers for consumption and for processing (Ooko and Kabira, 2011). With virus resistant potato varieties, local farmers will grow their crop more profitably with reduced virus related crop losses.

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