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Incidence of Aphid-Transmitted Viruses in Farmer-Based Seed Potato Production in Kenya

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Abstract: Field studies were carried out in farmer-based seed potato production to determine the incidence of potato aphids and potato aphid-transmitted viruses in two potato-producing areas of Kenya. Parameters determined included aphid population, virus disease incidence and tuber yield. Aphid population was monitored on leaves and in water-pan traps. Virus infection was determined based on symptoms and the viruses were identified in tubers sprouts by DAS-ELISA. Tuber yield was determined for plants showing virus symptoms and healthy-looking plants. Five aphid species were identified, with the most abundant being *M. euphorbiae* and *A. gossypii* on leaves and *M. persicae* and *A. gossypii* in water traps. The average aphid population was between 1.4 and 4.2 aphids per three leaves and 4.68 and 9.64 aphids per water pan trap. Farms with higher population of *M. persicae* had higher virus disease incidence. The most prevalent viruses were PVS, PLRV and PVM. Healthy looking plants had a latent infection rate 57.2% compared to 76.6% for symptomatic plants. Virus infection reduced the number and weight of tubers by 74 and 62.7%, respectively. However, virus infection increased the number and weight of the chats grade. The results indicated that aphid infestation and virus disease incidence were higher than the recommended for seed potato production. Therefore, there is need to create awareness among the farmers on aphid and virus symptom recognition and use of clean certified seed potato.

Key words: Aphids, seed potato, tuber yield, viruses

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the second most important food crop after maize in Kenya (Ministry of Agriculture, 2006). The national average yield is about 9.1 t ha^{-1} compared to 40 t ha^{-1} under research conditions (Ministry of Agriculture, 2007a; Kabira *et al*., 2006). The low productivity has been attributed to low quality seeds and diseases, especially bacterial wilt and viruses in smallholder farms. The informal sub sector contributes 99% of the seed potato in Kenya. This sector involves seed potato production without going through the certification processes and it includes unregistered growers and suppliers of seed mainly in their immediate localities (Kenya Agricultural Research Institute, 2006). It encompasses seed potato production with involvement of Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs), seed private growers and individual farmers through seed plot technologies and positive selection. However, the seed potato production rules require that the proportion of plants infected with virus, bacterial wilt and nematodes should not exceed 10, 3 and 3%, respectively (Ministry of Agriculture, 2006).

The low potato productivity is partially attributed to high losses due to pests and diseases, lack of adequate quantities of healthy planting materials and inadequate use of farm inputs (Ministry of Agriculture, 2006). Seed potato of most popular potato varieties has degenerated and need to be cleaned, multiplied and distributed to the industry. Due to lack of adequate and affordable certified seed potato, farmers generally recycle seed from previous harvests. This leads to further spread of tuber borne viruses and other diseases. About 40 viruses have been reported to affect potato (Bostan *et al*., 2006). Most of these viruses, such as potato leaf roll virus, potato virus X and potato virus Yare spread by aphids and tubers. The potato spindle tuber viroid is transmitted by aphids only together with potato leafroll virus. The green peach aphid (*Myzus persicae*) is the most efficient vector in transmission of virus diseases and is known to transmit over 100 viruses in different plants (Braendle, 2006; Ming *et al*., 2007; Raman, 1985). However, the capacity of

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farmers to recognize and manage aphids and potato virus diseases is very low (International Potato Centre, 2006; Kabira *et al*., 2006; Kibaru, 2003; Machangi, 2003). This lack of awareness about the damage caused by aphids and aphid-transmitted virus diseases in the informal seed potato production system contributes to seed degeneration and low yields.

The study was carried out to determine the levels of aphids and viruses in farmer-based seed potato production system and the associated yield losses.

MATERIALS AND METHODS

Experimental site and design: The study was carried out on smallholder farmers' fields in Njabini, Nyadarua south and Limuru, Kiambu west districts of Kenya over two seasons between November 2006 and February 2008. It targeted individual farmers or farmer groups involved in seed potato production. Four seed-potato producing farms were selected in each district. The experimental design was randomized complete block design. In each farm, 0.25 ha potato plot was selected and divided into four equal portions, which acted as replicates while the farm acted as a block.

Assessment of aphid population: Aphid population was monitored on leaves and by use of yellow water pan traps. Leaves were used to monitor wingless (apteral) aphids while the yellow water pan traps were used to monitor winged (alate) aphids. Sampling of leaves was done weekly from second week after emergence to maturity. Ten potato plants were randomly selected from each plot and three leaves were picked from top, middle and bottom of each plant. The leaves from each plant were put in separate labelled paper bags and kept in cool box until aphids were counted and identified. The yellow water pan traps consisted of yellow basins 3/4 filled with water and a few drops of liquid detergent added to break surface tension to make the trapped insects sink to the bottom. Five water pan traps were placed in each 0.25 ha plot. The traps were replaced weekly and aphid counts taken. The aphids were counted and identified to species level under a stereo telescopic dissecting microscope (x40 magnification). Aphid identification was based on aphids colour in life, lateral abdominal spiracles, antennal tubercles, shape of siphunculi and dorsal abdominal pigmentation.

Assessment of virus disease and effect on tuber yield: In each 0.25 ha portion of the farm, 100 plants were selected at random and observed for virus symptoms. Incidence of virus infection was determined as the proportion of plants showing leaf roll and mosaic symptoms. Virus incidence was determined weekly from the second week after emergence to crop maturity. At harvest, the tubers were tested for presence of potato leaf roll virus (PLRV), potato virus X (PVX), potato virus S (PVS), potato virus M (PVM), potato virus Y (PVY) and potato virus A (PVA) by double antibody sandwich-enzyme linked immunosorbent assay (DAS-ELISA) method as described by International Potato Centre (2007) and Clark and Adams (1977).

At flowering 10 healthy-looking and 10 symptomatic plants were tagged in each 1/4 portion of the 0.25 ha potato plot such that a total of 40 healthy-looking and 40 symptomatic plants were tagged. At maturity, tubers from each plant were harvested separately and graded into ware (>55 mm), seed (55-25 mm) and chats (<25 mm). The number and weight of tubers in each grade were determined and percentage yield reduction calculated as the percentage difference between the number or weight of tubers from the healthy-looking and the symptomatic plants.

Data analysis: All data were subjected to analysis of variance (ANOVA) using Genstat software and differences among the treatment means compared using Fisher's Protected LSD test at 5% probability level.

RESULTS

Aphid species identified were *Macrosiphum euphorbiae*, *Aphis gossypii*, *Aphis fabae*, *Myzus persicae* and *Rhopalosiphum maidis*. The most abundant species on leaves were *A. gossypii* and *M. euphorbiae* while the least abundant was *R. maidis* (Table 1). The most abundant species in water pan traps were *M. euphorbiae* and *M. persicae* in Njabini but higher populations of *A. gossypii* and *R. maydis* were caught in Limuru during both growing seasons. However, high levels of *A. fabae* were trapped in water pan traps in Limuru only during the short rain season. The farms differed in population and

Table 1: Mean population of different aphid species per 3 leaves and per water pan trap during short and long rain seasons in two potato-producing areas of Kenya

Treatments	Me	Ag	Af	Mp	Rm	Total
Njabini						
Leaves short rains	3.3	1.0	0.6	0.3	0.0	5.2
Leaves long rains	2.4	6.5	0.7	1.3	0.5	11.4
Water pan short rains	9.3	0.4	0.5	14.9	0.7	25.8
Water pan long rains	7.0	3.5	0.3	14.0	4.6	29.5
Limuru						
Leaves short rains	4.1	10.8	8.4	5.1	0.1	28.5
Leaves long rains	10.1	18.3	4.3	4.1	1.4	38.1
Water pan short rains	7.9	48.0	22.6	10.7	33.2	122.4
Water pan long rains	12.4	26.9	5.4	9.2	25.1	78.9

Me = *M. euphorbiae*, Ag = *A. gossypii*, Af = *A. fabae*, Mp = *M. persicae*, Rm = *R. maidis*

Table 2: Mean aphid population trend per 3 leaves and per water pan trap during short and long rain seasons in two potato-producing areas of Kenya

	Weeks after emergence									
Treatment	3	4	5	6	7	8	9	10	Mean	LSD
Njabini										
Leaves short rains	0.6	0.5	0.6	0.7	1.3	1.5	-	-	0.9	1.9
Leaves long rains	1.4	0.8	1.7	0.8	3.6	3.2	-	-	1.9	2.0
Water pan short rains	6.4	5.7	6.7	2.0	1.6	3.5	-	-	4.3	5.7
Water pan long rains	6.0	5.3	2.8	1.9	4.4	6.0	-	-	4.4	ns
Limuru										
Leaves short rains	5.7	1.8	5.9	4.7	2.1	1.7	4.2	2.4	3.6	0.7
Leaves long rains	6.2	7.3	3.5	9.1	3.2	3.1	2.8	3.1	4.8	1.7
Water pan short rains	15.7	18.4	14.4	25.7	19.9	18.1	7.0	3.3	15.3	2.8
Water pan long rains	9.2	10.3	9.4	7.6	9.1	12.0	11.7	9.7	9.9	2.2

ns: Non significant

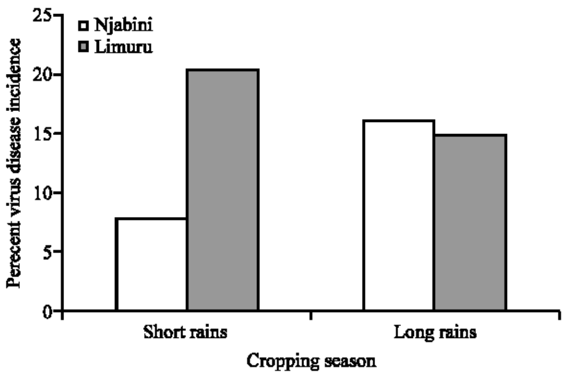

Fig. 1: Mean percent virus disease incidence on potato plants in Njabini and Limuru, Kenya, during the short and long rain seasons

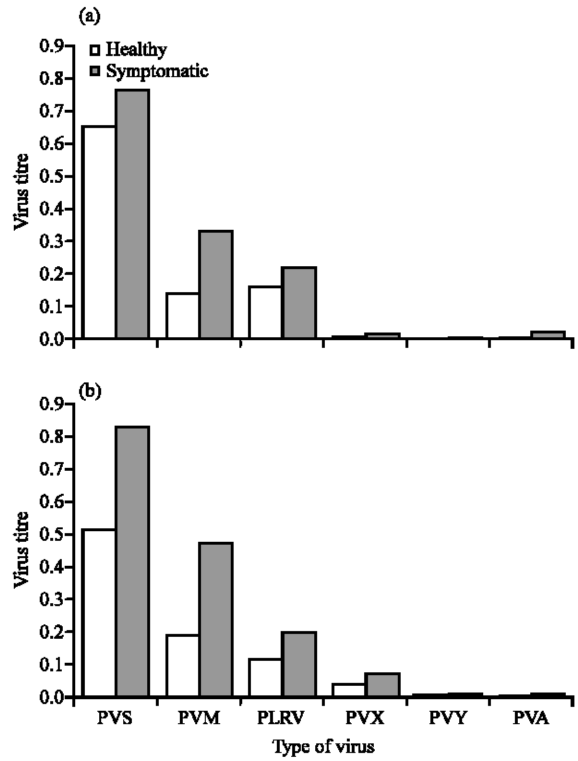

Fig. 2: Types and amounts of viruses infecting healthy looking and symptomatic potato plants in farmer-based seed potato production units in (a) Limuru and (b) Njabini, Kenya in the 2007 season

distribution of different aphid species. Aphid population was higher and more widely distributed in Limuru than in Njabini. However, higher numbers of *Myzus persicae* were caught in water traps in Njabini than in Limuru. But more of this species was found on potato leaves in Limuru than in Njabini. The aphid population on leaves generally increased with growth of the crop, then decreased towards maturity, with peak population being between 6th to 8th weeks after crop emergence (Table 2). There was a higher total aphid population during the short rain season compared to the long rain season.

Potato virus incidence was found at higher levels (2-30%) in Njabini than in Limuru (10-21%) (Fig. 1). Farms with higher population of *M. persicae* had higher virus disease incidences. Potato viruses detected in tubers were potato leaf roll virus (PLRV), potato virus M (PVM), potato virus X (PVX), potato virus Y (PVY), potato virus S (PVS) and potato virus A (PVA). The most prevalent virus was PVS (100%) followed by PLRV (92.5%) and PVM (90.3%) while the least prevalent was PVY (16.9%) (Fig. 2a, b). Healthy-looking plants had a lower incidence of latent infection of 57.2% compared to 76.6% for plants showing virus symptoms. A higher virus load was detected in tubers during the short rains and tubers from Njabini had higher virus titre in tubers from both the healthy-looking and symptomatic compared to Limuru (Fig. 2).

The viruses detected in highest amounts were PVS, PVM and PLRV over the two seasons. Virus infection reduced the number of tubers by between 9.6 and 35.5%. The number of tubers from healthy-looking plants was significantly ($p \leq 0.05$) higher than from symptomatic plants during the two seasons (Table 3). In Njabini, the reduction in number of potato tubers was by 9.6 and 29.7% during the short and long rains, respectively, while

Table 3: Mean number of tubers per 10 plants for different grades harvested from healthy-looking and symptomatic potato plants during short and long rain seasons in two potato-producing areas of Kenya

	Short rains				Long rains			
Treatments	Ware	Seed	Chats	Total	Ware	Seed	Chats	Total
Healthy-looking, Njabini	23.8	62.1	8.4	94.2	25.1	100.2	33.9	159.2
Symptomatic, Njabini	9.0	51.1	22.6	82.7	13.8	69.4	29.3	112.5
LSD ($p \leq 0.05$)	3.1	ns	4.6	ns	11.1	9.3	ns	15.8
CV (%)	8.5	11.0	13.2	8.1	25.3	4.8	8.1	5.2
Healthy-looking, Limuru	25.0	68.8	10.0	103.7	36.6	95.6	9.8	141.9
Symptomatic, Limuru	6.9	36.2	15.2	58.4	18.8	79.5	18.2	116.5
LSD ($p \leq 0.05$)	4.4	8.5	4.8	11.8	6.5	8.4	ns	9.2
CV (%)	12.2	7.2	17.1	6.4	10.5	4.3	30.4	3.2

Ware >55 mm, Seed 25-55 mm, Chats <25 mm, H: Healthy, S: Symptomatic, ns: Not significant

Table 4: Mean weight of tubers per 10 plants in kg for different potato grades harvested from healthy-looking and symptomatic plants during short and long rain seasons in two potato-producing areas of Kenya

	Short rains				Long rains			
Treatments	Ware	Seed	Chats	Total	Ware	Seed	Chats	Total
Healthy-looking plants Njabini	3.82	3.50	0.08	7.40	3.91	5.36	0.42	9.69
symptomatic plants Njabini	1.37	2.36	0.19	3.94	2.11	3.20	0.27	5.57
LSD ($p \leq 0.05$)	0.58	0.44	0.04	0.74	1.70	0.41	ns	2.01
CV (%)	10.00	6.70	12.10	5.80	25.10	4.30	21.10	11.70
Healthy-looking plants Limuru	3.84	3.82	0.11	7.77	5.89	4.91	0.10	10.90
Symptomatic plants Limuru	1.04	1.74	0.16	2.93	2.80	3.94	0.16	6.90
LSD ($p \leq 0.05$)	0.70	0.68	ns	1.34	1.41	0.42	ns	1.64
CV (%)	12.80	10.90	17.70	11.10	14.50	4.20	25.50	8.20

Ware > 55 mm; Seed 25-55 mm; Chats < 25 mm; H: Healthy; S: Symptomatic, ns: Not significant

in Limuru, reduction was by 17.7 and 35.5% during the long and short rains, respectively (Table 3). The reduction in the number of tubers was also significant ($p \leq 0.05$) among the potato grades during the two seasons. The reduction in number of tubers was greatest (46-74%) for the ware grade but the symptomatic plants produced higher number of chats compared to the healthy-looking plants. Tuber weight was significantly ($p \leq 0.05$) reduced by between 36.4 and 62.7% (Table 4). The highest weight reduction was in the ware grade at 65 and 47% in Njabini and 62.7 and 36.8% in Limuru during the short and long rains, respectively. However, symptomatic plants had higher weight of chats grade during the two seasons.

DISCUSSION

Potato aphids were prevalent in small-scale potato farms, with an average of 1.4 and 4.2 aphids per three leaves in Njabini and Limuru, respectively. This translates to 46.6 and 140 aphids per 100 leaves, respectively, which is higher than the threshold of between 3 and 10 aphids per 100 leaves recommended for seed potato production (Capinera, 2001; Thomas, 2002). Among the five species identified, *M. persicae* is the most efficient vector of potato viruses (Bostan *et al*., 2006; Bunt, 2001; Braedle, 2006; Ming *et al*., 2007). The population of this species was higher during the short rains than during the long rains. This can be explained by the warm conditions that favour aphids during the short rain season (De Temmerman *et al*., 2002). Factors that affect aphid population include weather conditions, nutrition and presence of predators (Handizi and Legorburu, 2002). Temperatures of less than 17.8°C greatly restrict the number of *M. persicae* (Radcliffe, 1982) while vegetation around potato plots play a critical role in aphid population dynamics (Handizi and Legorburu, 2002). Therefore, the differences in population of the different aphid species in the two potato-growing regions could be due to variation in types of other crops grown and the type of vegetation in the vicinity of potato fields.

The results indicate that aphid control measures, such as chemical spray and rouging of infected plants, are required to reduce virus spread in the seed potato (Struik and Wiersema, 1999; Thomas, 2002; Walingo *et al*., 2004). Peak aphid infestation was observed at the seventh and eighth week after crop emergence, which agrees with an earlier study by KARI (Kabira *et al*., 2006). Therefore, the control measures should start early in the season, preferably immediately after crop emergence by rouging infected plants. Chemical control is applied when aphid population reaches economic threshold of between three to ten aphids per 100 leaves irrespective of the stage of growth (Capinera, 2001; Thomas, 2002). Apterae aphids have been found to transmit more viruses into a potato plant than alate aphids (Yvon *et al*., 2000) and there is a positive correlation between aphid population and viral load in tubers suggesting that aphids are directly responsible for the virus contamination of the tubers (De Temmerman *et al*., 2002; Powell *et al*., 2006; Verheggen *et al*., 2007). Therefore, reducing aphid population would have a direct effect of reducing infection and increase potato yields (Walingo *et al*., 2004; Paola *et al*., 2005).

The study showed that the average virus disease incidence was between 12.4 and 17.7%, which is higher than the maximum threshold of 10% recommended in seed potato production (Machangi *et al*., 2004; Ministry of Agriculture, 2006; Nderitu and Mueke, 1986). Disease incidence is a measure of seed purity and is used in seed potato certification under the formal seed potato production system (Ministry of Agriculture, 2007b). The high incidence can be attributed to lack of aphid control measures by the farmers who have no capacity to recognize aphids and they are not aware of the dangers posed by aphids in seed potato production (Kabira *et al*., 2006). Recycling of seed due to unavailability of clean, certified seed is also common. Infected seed potato tubers transmit viruses to the germinating plants and therefore the virus load continues to increase in successive seasons until the yield is diminished (Ming *et al*., 2007; Paola *et al*., 2005; Syller, 2001). Healthy-looking potato plants were latently infected with viruses but the virus load was lower than for symptomatic plants. This is consistent with other studies done elsewhere (Birch *et al*., 1999; De Temmerman *et al*., 2002; Jonathan and Alison, 2008; Bostan *et al*., 2006). Therefore, farmers could be advised to rogue symptomatic plants early after crop emergence to leave healthier plants and thereby increase production (Kabira *et al*., 2006). Visual disease incidence was correlated to viral load of PVY and PLRV suggesting that cumulative vector intensity and disease incidence could be used to predict virus threat to seed potato (Basky, 2002).

Reduction in the number of tubers in symptomatic plants ranged between 9.6 and 35.5% while the reduction in tuber weight was between 36.8 and 62.7%. The results indicate that virus infection has a direct effect on potato yield and therefore the income the farmer would get from the crop (Khurana, 2000; Saucke and Doring, 2004). Virus infection reduced the number and weight of ware and seed grades but increased the yield of the chats grade. The chat grade has no economic benefit to the farmer both in terms of food or seed. This indicates that even with good agronomic practices, the farmers would not attain desired yields unless virus diseases management is incorporated in the production system (Robert and Bourdin, 2000; Hoffmann *et al*., 2001; De Temmerman *et al*., 2002; Kabira *et al*., 2006; Kenya Agricultural Research Institute, 2007; Yvon *et al*., 2000). Therefore, there is need to create awareness on importance of aphid management and use of certified seed in farmer-based seed potato production systems in Kenya.

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