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ORIGINAL PAPERS

Comparative assessment of pest management practices in potato production at Farmer Field Schools

Modesto Olanya · Rebecca Nelson · Johnson Hakiza · Peter Ewell · Ramzy El-Bedewy · Rogers Kakuhenzire · Samuel Namanda · Imelda Kasheija · Williams Wagoire · Brima Ngombe · Charles Musoke

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Abstract Farmer field schools (FFS) and other participatory approaches are useful methods for rapid delivery of agricultural technologies, knowledge, and information in resource-constrained agro-ecosystems. Cultivar selection, weekly fungicide applications and integrated disease management (IDM) based on a disease monitoring strategy were evaluated at FFS for late blight control. Farmers' knowledge and perceptions of pest management and agronomic practices were also assessed for both FFS participants and non-participants from 1999–2002. Late blight development and tuber yield varied among field schools, but cultivars had significant effects on late blight severity and yield over a range of disease management options relative to the untreated check. FFS participants and non-participants used diverse sources of pest management information, but differed significantly ($P<0.05$) in their use of management methods and practices. Cultivar resistance and fungicides were ranked as major components of pest control by 18%–85% and 7%–30% of FFS participants and non-participants, respectively. Differences in knowledge of cropping practices and pest biology, causal agents, disease symptoms, factors favoring disease development and cultural management of insects and storage pests were recorded. Participatory field experiments, access to resistant cultivars, disease management and use of various agronomic practices learnt at FFS can greatly improve pest control and potato production.

Keywords Farmers · Late blight · Bacterial wilt · IPM · Uganda · *Solanum tuberosum* · Food security

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M. Olanya (✉)
USDA-ARS, New England Plant, Soil and Water Laboratory,
Orono, ME 04469, USA
e-mail: modesto.olanya@ars.usda.gov

R. Nelson
Cornell University,
Plant Sciences Building,
Ithaca, NY 14853, USA

J. Hakiza
Kawanda Agricultural Research Institute,
P.O. Box 7065, Kampala, Uganda

P. Ewell
USAID-REDSO,
P.O. Box 30261, Nairobi, Kenya

R. El-Bedewy
Agriculture Research Center,
Giza, Egypt

R. Kakuhenzire · S. Namanda
International Potato Centre, SSA,
Liasion Office,
P. O. Box 22274 Kampala, Uganda

I. Kasheija · W. Wagoire
Kachwekano Zonal Agricultural Research
and Development Institute,
P.O. Box 421, Kabale, Uganda

B. Ngombe · C. Musoke
Africare/Kabale,
P.O. Box 403, Kabale, Uganda

Introduction

Potato (*Solanum tuberosum* L.) is an important food and cash crop in both developing and developed countries (Scott et al. 2000; FAO-CIP 1995). Potato production is estimated at about 100 million tons per year in the developing countries (Scott et al. 2000). Production and consumption of potato has increased in recent years due to changes in food systems, market demand and population increase as well as the availability and dissemination of well-adapted potato cultivars (Scott et al. 2000; Low 1997; Akimanzi 1992). Increase in potato production in the next decade is expected to surpass that of some other major food crops grown in various parts of the world, and potato is expected to be among the top five crops in terms of total global production (Scott et al. 2000).

In the tropical highlands of southwestern Uganda, potato is produced by smallholder farmers with less than a half hectare per farm. These farms are characterized by limited use of quality seed, depleted soil nutrients, multiple potato cropping cycles per year, increased pesticide use, poor cultural and agronomic practices as well as rudimentary storage and post-harvest management techniques (Akimanzi 1992; Sengooba and Hakiza 1999). Most of the potato produced by these farmers is sold in the local markets for consumption (table stock or ware). A small proportion is retained for use as seed in subsequent plantings or in some cases used for chip processing in local cottage industries.

Although there is a trend toward increasing consumption, the production of potato in the highland tropics of East Africa is seriously affected by abiotic and biotic constraints (Olanya et al. 2004). Diseases and insect pests have the greatest potential for yield reduction. The most commonly reported diseases are late blight (caused by *Phytophthora infestans*), bacterial wilt (caused by *Ralstonia solanacearum*) and viruses (Kinyua et al. 2005; Olanya et al. 2001; Tussime et al. 1996). The most commonly reported insect pests are cutworms (*Agrotis* spp.) and potato tuber moth (*Phthorimae operculella*) (El-Bedewy et al. 2001). Losses in potato production attributed to these diseases and pests are variable and are influenced to a large extent by cultivar susceptibility, environmental factors and management practices (Olanya et al. 2001).

Previous research and extension efforts to address potato production constraints and optimize yield in this region have often achieved minimal results. This is partly due to limited access to new technologies by farmers and poor linkages between agricultural research and extension (Bentley and Thiele 1999; Van de Fliert et al. 2003; Zelazny et al. 1985). In order to enhance farmers' access to information, knowledge and technology with the aim of increasing potato productivity in south-western Uganda, the farmer field school (FFS) methodology was adapted for management of major potato production constraints (Nelson 1997; Olanya et al. 2000).

The FFS approach relies on learning by doing: farmers engage in field-based learning sessions through a complete crop cycle (Gallagher 1993). We modified the FFS curriculum for integrated pest management (IPM) of potato based on the FFS Field Guide for late blight, previously used in South America (Nelson 1997; Nelson et al. 2001), and adapted it for production constraints of potato in Uganda, identified in base-line studies (Sengooba and Hakiza et al. 1999; Olanya et al. 2000). Learning sessions were designed with emphasis on the participation of farmers in field activities relevant to potato growth and development. Experimental activities were aimed at engaging farmers in the research process as well as at knowledge exchanges among farmers, researchers and FFS facilitators.

The curriculum was designed with the aim of empowering farmers' decision-making in the management of potato pests, diseases and other production constraints. Therefore, one of the objectives of this research was to evaluate pest management practices associated with potato cultivation and production at FFS and between FFS participants and non-participants. This would reveal the effectiveness of FFS methodology in contributing to farmers' information, knowledge and practices in potato production. Some of the outcomes of the FFS project on potato integrated pest management (IPM) funded by the International Fund for Agricultural Development (IFAD) and implemented by the International Potato Center (CIP), National Agricultural Research Organization (NARO), Uganda and Africare, an American non-governmental organization (NGO) operating in Uganda are reported in this paper. Results dealing with preliminary implementation of FFS have been previously published (Olanya et al. 2000).

Research design and methods

Study site

The study was conducted in Kabale district in the highlands of southwestern Uganda where the conditions for potato production are favorable. Elevation of the region ranges between 1,750 and 2,800 m above sea level. Monthly temperatures range from 12 to 26°C and the total annual rainfall ranges from 900 to 1,500 mm. The district, besides having ideal conditions for potato production, also had collaborating partners such as Africare, a seed potato producers association (UNSSPA), African Highlands Initiative (AHI) and the potato research station of the National Agricultural Research Organization (NARO). Sites for the study were chosen on the basis of previous assessments of the intensity of potato cultivation in the district and production constraints (Low 1997).

Formation of Farmer Field Schools (FFS)

In a previous study, FFS were conducted at Nyamiyaga, Nyabyumba, Kirerea, Mwirangizo, Kabira and Kayore. This paper reports on FFS which were implemented principally at Kirerea, Mabungo, Kagyera and Kayoyero with some data from other FFS. Each field session addressed concepts or constraints to potato production or pest management at specific stages of potato growth or crop health. Establishment of FFS was facilitated by the presence of community-based farmer groups in various villages in the Kabale district of Uganda, previously organized by Africare for various self-help projects. Farmer groups were selected based on their interest in potato cultivation, common goals in overcoming major potato production constraints and interest in poverty eradication. Geographical proximity of farmer groups was also considered. Eight FFS were formed during the 1999 cropping cycle, another eight in 2000 and by 2002, the total had reached 23.

Implementation of Farmer Field Schools

Each FFS consisted of 25–35 individuals who were voluntarily enrolled and whose gender and age were recorded. A full cycle of the FFS curriculum ran over two field seasons, each equivalent to a potato cropping season of approximately 4 months and consisted of 15 one-day weekly sessions. Each session was conducted at a FFS field site where the potato crop was grown for participatory experimentation.

The field sessions had various topics such as: 1) introduction and knowledge, 2) attitude and practices in pest and potato management, 3) potato seed quality and selection, 4) basic concepts in experimentation, 5) potato crop management, 6) symptoms and diagnosis of late blight and other potato diseases, 7) bacterial wilt disease and its causes, 8) integrated management of bacterial wilt, 9) insect pest management in potato, 10) late blight development and cultivar reaction to disease in the presence of fungicides, 11) fungicide application for late blight control, 12) small-holder potato production technology, 13) yield assessment and profit analysis, 14) post harvest considerations for potato, 15) evaluation of FFS approach. Experimental learning in the FFS was moderated by a facilitator. In each group, assistant facilitators were selected among group members to lead sub-groups in a FFS. Each FFS also had a management committee which consisted of a chairman, secretary, treasurer, committee members and a time keeper.

Participatory cultivar × fungicide experiments

Five potato cultivars with different levels of late blight resistance were each treated in three ways. One treatment was a control with no fungicide. The second treatment was a weekly application of the contact fungicide, mancozeb. The third treatment was an integrated disease management (IDM) programme in which fungicide applications were based on field monitoring, scouting and environmental conditions favorable for blight development. Plots were 12.5×4.5 m with three replications and arranged in a randomized block design. Buffer zones of 2.5 m were established between plots.

Assessment of pest management practices and potato production constraints

Farmers' knowledge and practices before and after participation in FFS were assessed using participatory appraisal techniques. A control group of farmers who did not participate in FFS but resided in the same locality as FFS participants was also subjected to the same assessment.

Evaluation of late blight severity and tuber yield

Late blight development was evaluated by assessing cultivars for disease severity at weekly intervals as percent leaf area affected on a scale of 0% to 100%, where 0 represented no disease and 100% referred to potato foliage completely destroyed by late blight. Disease assessment was initiated at 4 weeks after planting, or as soon as late blight symptoms were observed. At harvest, potato tubers from each plot were counted and weighed in order to determine yield.

Statistical analysis

Data on farmers' knowledge of disease and insect pest symptoms and signs, causal agents, disease development, disease and insect pest management and post-harvest practices in potato production were analyzed based on the responses from both FFS participants and non-participants. Averages and standard errors of the means across all field schools were computed by Proc Means (SAS Institute, Inc. Cary, NC). The relative ranking of responses between FFS participants and non-participants were computed. A Z-statistic test was used to compare the means and test for significance of responses of participants and non-participants to pertinent questions. Late blight severity ratings were used to compute areas under disease progress curves for comparison of cultivars within a FFS. Mean aggregate disease among cultivars and disease management options were compared with standard errors and Fisher's Protected least significant difference (Fisher's LSD). Total tuber yield was computed for each cultivar per plot and expressed on a per hectare basis (tons/ha).

Results

Composition of FFS

The number of participants in each FFS ranged between 20 and 42 with an average of 26 (Table 1). The average age of participants ranged from 30 to 45 years across the schools with a mean of 35 years and there were more females (42%–1100%) than males (0%–58%). Two FFS were composed solely of females (Table 1).

Seed sources and agronomic practices used in potato production

The participants and non-participants of farmer field schools obtained seed potato for planting from various sources. Retention of potatoes from their own fields (previous harvest) was the most popular source and there was no significant difference in the proportion of farmers who obtained seed potato from this source between FFS participants or non-participants, 42.8% and 38.2%, respectively (Table 2). A significantly ($P<0.05$) higher proportion of non-participants than participants of FFS obtained potato seed from neighbors or local markets. Participants were also significantly ($P<0.05$) more likely to acquire seed potato from NARO, organized seed producers, Africare, and FFS (Table 2). Various agronomic practices were used in potato production by the two groups. These were volunteer removal, weeding, hilling, row planting, chemical spraying, residue destruction, dehaulming and uses of organic manure and fertilizer. Apart from weeding and hilling, significantly higher proportions of farmers who had participated in FFS adopted these practices (Fig. 1).

Planting practices and potato hilling

The rationale for planting potato in rows include control of soil erosion, ease of weeding, better land use and higher yield (Fig. 2a). However, 40% of non-participants did not plant potatoes in rows and had no justification for not adopting this practice (Fig. 2a). Very small percentages of farmers from both groups were aware that hilling of potato could contribute to pest management such as prevention of tuber infestation, control of late blight or control of potato pests (Fig. 2b). The implications of potato hilling as a crop management technique varied between participants and non-participants of field schools (Table 3). No significant differences were recorded between participants and non-participants with regard to their perceptions of potato hilling except for regulating vegetative growth and reducing soil erosion (Table 3).

Table 1 Location, numbers, gender and age composition of participants of Farmer Field Schools (FFS) for potato late blight in S.W. Uganda during 1999 to 2002

Field Schools location[a]	Altitude (m)	Geographical coordinates	Number of participants	Age	Gender composition (%)	
					Female	Male
Ikumba	2009	1°07′S29°54′E	29	37	59	41
Kabira	2218	1°17′S 29°55′E	23	45	55	45
Kagyera	2327	1°24′S29°56′E	21	36.4	43	57
Kamusiza			17	34.7	42	58
Karubanda	1956	1°12′S29°56′E	30	31.6	90	10
Kayorero	2107	1°12′S29°52E	42	33	69	31
Kirerea	1939	1°07′S30°03′E	24	36.3	50	50
Mabungo			27	37.2	70	30
Mwirangizo			24	31	96	4
Nyabyumba	2320	1°21′S 29°59′E	30	32	57	43
Nyakasharara			25	36	100	0
Nyamiyaga	2141	1°12′S 29°57′E	26	39.1	100	0
Rukaranga	1726	1°12′S29°42′E	27	36	92.6	7
Rushongati	2260	1°21′S29°59′E	20	30	80	20
Mean		–	26	35	72	28

[a] Locations of some farmer field schools where field sessions were conducted

Table 2 Sources of seed potato among potato farmers participating in or not participating in farmer field schools in Kabale district during 1999 to 2001

Variables	FFS Participants[a]		Non participants[b]		*Z*-Values	*P*-Values[d]
Seed sources	Percent[c]	Rank	Percent[c]	Rank		
Own field	42. 8±5.7	1	38.2±6.6	2	1.107	ns
Neighbours	18.3±5.5	3	28.1±6.5	3	2.681	0.05*
Market	25.0±7.0	2	44.0±6.3	1	4.596	0.01**
NARO (Res. Stn)	8.3±2.8	7	1.7±1.5	5	3.327	0.05*
Seed Producers	9.6±4.8	5	2.1±1.1	4	3.575	0.05*
Africare (NGO)	9.2±4.7	6	0.9±0.2	7	4.18	0.05*
Field Schools	17.3±5.7	4	1.0±0.4	6	6.378	0.05*

[a] Farmer field school participants were evaluated in comparison to non-participants in a semi-structured survey conducted after two cycles of training activity. The sample size was about 25 participants per farmer field school from 11 FFS (n=275 for all field schools)

[b] Non-participants of farmer field schools (n=275) were drawn from the same locality as the participants of the FFS surveyed

[c] Values are the mean percentage of respondents. The ± sign refers to standard errors of the mean

[d] Significant differences between means are denoted by * and ** at the 5% and 1% level, respectively:.ns=non significant

Weed management and use of fallow in potato production

Weed management in potato production was practiced more assiduously by FFS participants than non-participants but the rationale for weed management was very similar between the two groups, the most important being perceived as reduction of competition with the crop (Fig. 3a). Other factors such as prevention of disease spread, increase in yield and avoidance of unfavorable microclimate were considered by only a small minority of farmers. While both participants and non-participants of field schools recognized that land fallowing was an important component of crop management, over 35% of participants and non-participants did not practice this technique (Fig. 3b). The use of fallow as a rotation practice varied from one potato production cycle (4 months) to more than 1 year (Fig. 3b).

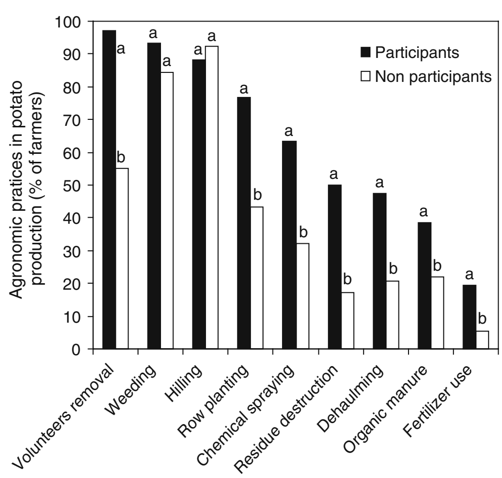

Fig. 1 Cropping practices commonly used in potato production by farmers at field schools in south western Uganda between 1999 and 2001

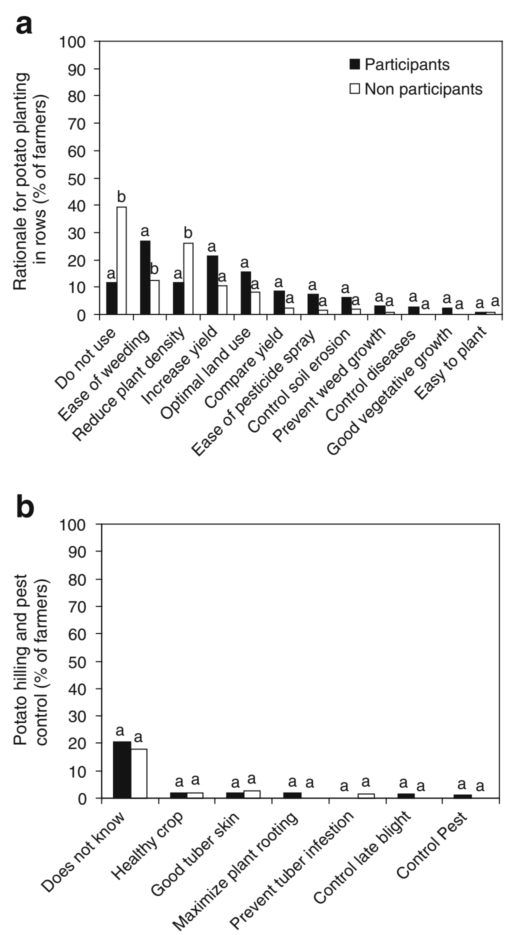

Fig. 2 Comparative assessment of implications and rationale of planting potato in rows (**a**), and hilling (**b**) in relation to pest management as perceived by farmers at field schools

Table 3 Implications of potato hilling as an improved crop management practice among farmers in south western Uganda between 1999 and 2001

Variables	FFS Participants[a]		Non participants[b]		*Z*-Values	*P*-Values[d]
Implications of hilling	Percent[c]	Rank	Percent[c]	Rank		
Reduce tuber exposure	11.6±3.2	3	11.2±4.1	3	0.234	ns
Increase tuber bulking	33.0±8.1	1	32.1±6.9	1	0.159	ns
Vegetative growth	7.1±3.0	4	3.4±1.9	4	1.855	0.05*
Reduce tuber infection	2.8±1.1	6	2.6±1.9	5	−0.118	ns
Reduce soil erosion	4.4±2.0	5	0.6±0.5	6	2.258	0.05*
Do not know	17.1±4.0	2	19.4±5.9	2	0.499	ns

[a] Farmer field school participants were evaluated in comparison to non-participants in a semi-structured survey conducted after two cycles of training activity. The sample size was about 25 participants per farmer field school from 11 FFS (n=275 for all field schools)

[b] Non-participants of farmer field schools (n=275) were drawn from the same locality as the participants from same locality of the FFS surveyed

[c] Values are the mean percentage of respondents. The±sign refers to standard errors of the mean

[d] Significant differences between means are denoted by * at the 5% level: ns=non significant

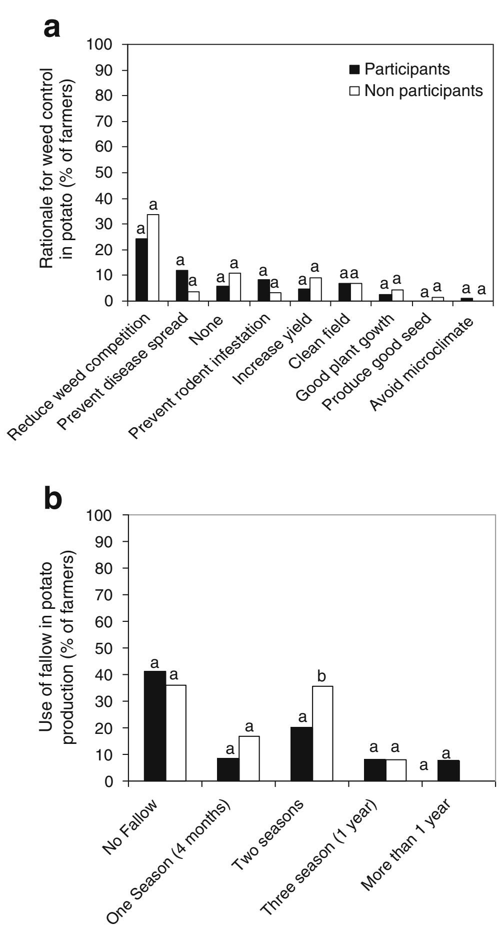

Fig. 3 Farmer's perception of weed management practices and the use of land fallow as a rotation practice in potato production. Participating farmers at field school and non-participants were surveyed

Sources of information for pest and disease management in potato

Both FFS participants and non-participants obtained information on pest control options from a variety of sources such as agricultural officers, neighbors, non-governmental organizations, FFS and seed potato producers, although more than 40% of non-participants did not receive information from any source (Table 4). Among the FFS participants, most respondents obtained information on pest and disease management from the FFS itself (75.9%), from Africare (28.1%) and from agricultural extension officers (11.5%). Not surprisingly, participants were more likely (P<0.001) to obtain their information from FFS, but participants were also more likely (P<0.05) to obtain their information from agricultural officers, neighbors and Africare (Table 4). Non-participants generally obtained information from neighbors (Table 4).

Late blight severity and tuber yield (cultivar × fungicide experiments)

The cultivar by fungicide experiments enabled FFS participants to evaluate the resistance of potato cultivars in combination with late blight management options. The cultivars Rutuku, 575409 and 382171.4 had low Area Under Disease Progress Curve (AUDPC) values based on weekly spray schedules at various FFS sites compared to Kabale and Victoria (Table 5). Cultivars Rutuku, and 575409 were the most resistant with AUDPC values averaged across sites measured as percent-days, of <400 without treatment (Table 5). Cultivars Victoria and Kabale were the most susceptible to late blight at all four sites and when averaged across sites (Table 5, Fig. 4). Late blight severity was significantly reduced by both fungicide

Table 4 Sources of information for pest and disease management of potato at Field Schools (1999–2000 and 2000–2001).

Variables	FFS Participants[a]		Non participants[a]		*Z*-Values	*P*-Values[c]
Sources of information	Percent[b]	Rank	Percent[b]	Rank		
Agriculture Officers/NARO	11.5±4.5	3	2.5±1.32	7	3.809	0.05*
Neighbours	4.1±1.5	4	19.0±4.2	2	5.352	0.05*
Researchers	0.8±0.5	7	1.6±1.1	9	0.247	ns
Africare (NGO)	28.1±8.7	2	14.5±6.6	3	3.610	0.05*
Farmer Field Schools	75.9±7.6	1	5.8±2.4	5	16.397	0.001**
Seed producers	0.7±0.4	9	2.8±1.8	6	0.752	ns
Extension	3.6±2.6	5	2.0±1.2	8	0.863	ns
Other groups	1.8±1.3	6	14.5±1.1	4	5.437	0.05*
None	0.7±0.7	8	41.3±13.5	1	11.393	0.001**

[a] FFS participants (n=275) and non-participants from the same localites (n=275) were surveyed

[b] Values are the mean percentage of respondents. The ± sign refers to standard errors of the mean

[c] Significant differences between means are denoted by * and *** at the 5%, and 1% levels, respectively: ns=non significant

applications on a 7-day schedule and application of an integrated disease management (IDM) regimen for most cultivars-sites. Neither treatment differed significantly from each other except for cvs. Victoria and Kabale (Fig. 4).

The total tuber yield was significantly ($P<0.05$) higher in plots that had the 7-day and IDM treatments than the untreated control, except for cv. Kabale across all sites. Tuber yields of all five cultivars were low and varied among field sites, ranging from 16 M tons/ha to 38 M tons/ha when averaged across sites (Table 5 and Fig. 4). Total tuber yield was in the range of 13.9 to 45.8 tons/ha (Table 5). Similar trends in disease resistance of potato cultivars were observed as the cultivars 575049 and Rutuku had consistently lower AUDPC values, reflective of their high resistance, than Kabale, Victoria or 382171.4 and similarly higher tuber yield.

Sources of late blight and bacterial wilt infections

Both FFS participants and non-participants readily recognized the foliar symptoms of late blight although divergence in the description of symptoms occurred (Table 6). A significantly ($P<0.05$) higher percentage of FFS participants than non-participants correctly indicated that dark-brown lesions on leaves, whitish growth on lower leaves and brown spots on potato stems were due to late blight infection (Table 6). FFS participants also knew the sources of inoculum such as volunteer potato plants, discarded potato, diseased plants from nearby fields, and infected seed and linked development of the disease to predisposing factors such as rainy, foggy and humid days.

In response to a questionnaire, both participants and non-participants attributed the cause of potato bacterial wilt to infected or rotted tubers as well as rain and there were no significant differences between the two groups (Table 7). A significantly greater proportion of non-participants than participants thought that insects were a source of the disease but the reverse was true for diseased plants as a source of infection. Not surprisingly, participants were far more likely to attribute the cause of disease to bacteria than non-participants while more non-participants did not know the cause (Table 7).

Management of late blight and bacterial wilt

Fungicide application (85%) and volunteer plant removal (29%) were the most common management practices for late blight control among participants of FFS (Fig. 5a). Considerably fewer FFS non-participants used these techniques—fungicides (30%) and volunteer removal (4%). Fewer than 20% of both participants and non-participants used host resistance for late blight management and the difference between them was not significant (Fig. 5a). Of the non participants, 43% did nothing to control late blight and none practiced residue destruction (Fig. 5a). Few farmers of either group utilized crop rotation, proper weeding or early planting

In the case of bacterial wilt, significantly ($P<0.05$) higher proportions of FFS participants than non-participants destroyed volunteer potato plants, used disease-free seed tubers and rogued diseased plants (Fig. 5b). In contrast, significantly fewer FFS participants than non-participants did nothing to manage bacterial wilt and none used chemical sprays (Fig. 5b). There were no significant differences between the proportions of those participants and non-participants who used seed sorting, crop rotation, two-year fallow, controlled soil erosion or practiced good seed storage (Fig. 5b).

Few FFS participants left rotten potato tubers exposed in the field, whereas nearly 60% of non-participants did so. In contrast, over 40% of participants buried rotten tubers in the soil whereas few non-participants did so. Equal proportions of participants and non-participants removed and destroyed rotten tubers but these were fewer than 20%. Some members of both groups fed the rotten potatoes to livestock and others burnt them but few adopted these procedures and there was no significant difference in the proportions between the groups (Fig. 6a)

Table 5 Effect of pest management strategies (fungicide treatments) and potato genotypes on late blight and potato tuber yield at various Farmer Field Schools during the 2001 and 2002 cropping seasons at Kabale district.

Pest Mgt[a].	Cultivars[b]	AUDPC (percent days)				Tuber yield (t/ha)			
		Ikumba[c]	Nyakasharara[c]	Nyakibande[c]	Nyakatudunda[c]	Ikumba	Nyakasharara	Nyakibande	Nyakatudunda
Weekly sprays	Rutuku	112.0	70.0	53.4	93.6	45.4	18.6	28.5	36.0
	575049	43.8	43.8	52.5	61.3	42.2	14.0	35.8	22.0
	Kabale	498.8	738.5	208.3	565.3	59.1	23.9	37.7	38.2
	382171.4	308.0	163.6	182.9	510.1	35.1	16.8	41.2	42.3
	Victoria	365.8	165.4	167.1	102.4	45.3	19.7	45.8	31.6
IDM application	Rutuku	424.4	75.0	73.6	46.4	42.9	25.2	26.4	28.6
	575049	106.8	61.3	71.5	24.5	35.7	15.1	29.3	21.4
	Kabale	945.0	949.4	525.0	542.5	67.3	22.1	32.2	35.1
	382171.4	586.3	392.9	218.8	427.9	25.6	21.0	42.3	42.3
	Victoria	1076.3	748.1	311.5	192.5	39.4	24.5	31.4	43.0
Control	Rutuku	688.6	292.3	508.4	151.4	31.6	21.1	23.3	33.4
	575049	446.1	122.5	185.5	104.1	28.0	17.4	30.4	17.4
	Kabale	2197.1	1723.8	1806.9	1907.5	9.8	16.2	20.5	19.8
	382171.4	1785.0	1120.0	1453.4	1277.5	10.9	15.0	20.9	25.0
	Victoria	1443.8	1080.6	1094.6	1155.0	15.0	13.9	18.0	29.4
	LSD (0.05)	286.9	351.8	174.9	356.5	15.9	9.4	12.7	10.8
	CV (%)	17.9	31.3	17.4	34.3	26.3	23.6	29.6	27.5

[a] Refers to different pest management used at Farmer Field Schools. Weekly = application of protectant fungicide (mancozeb) for late blight control once a week, IDM strategy = fungicide application (2.5 g/litre) for blight control based on monitoring of rainfall and temperature and humidity conditions, and Control = check treatment in which no fungicides were applied to field plots

[b] Cultivars used in FFS plots

[c] Refers to representative field schools from which late blight and yield data were quantified

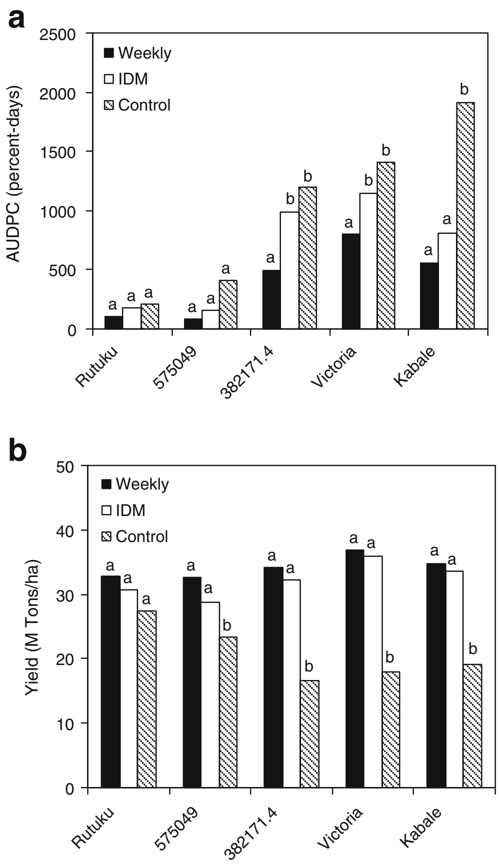

Fig. 4 Effect of pest management and potato cultivars on late blight (**a**) and tuber yield (**b**) at Farmer Field Schools during 2000 to 2001 years. Pest management treatments were: 7-day fungicide application, IDM = fungicides application based on disease monitoring and environmental conditions, and control = no fungicides. Late blight and yield data were averaged across four field schools

All participants and nearly all non-participants uprooted plants that had wilted owing to infection by *Ralstonia solanacearum*, but the methods of disposal differed between the two groups, reflecting the curriculum of the FFS. A significantly higher proportion of non-participants than participants left the uprooted plants where they were, whereas over 40% of the participants buried them in the soil compared with 5% of non-participants. More than 20% of non-participants left wilted plants in piles in the field whereas only 5% of participants did so. No non-participants burnt uprooted plants but about 20% of participants did so (Fig. 6b).

Seed storage options and post-harvest management of potato diseases

Low-input techniques such as storage in rooms with diffused light and raised shelves were used in attempts to control post-harvest problems (Fig. 7). However, the only technique for which there were differences between participants and non-participants of FFS was the storage on dry grass containing marigold plants, which have insecticidal properties (Fig. 7).

FFS participants and non-participants generally referred to post-harvest or storage diseases as tuber rots but a very low percentage of either group attributed these to bacterial wilt or late blight. Although tuber rots could be incited by causal agents of these diseases as well as others such as *Fusarium* spp., *Helminthosporium solani*, or *Rhizoctonia solani*, the distinctions among these was not readily understood by farmers (Fig. 8a). More than 60% of farmers who attended FFS made an attempt to control post-harvest diseases but the number of non-participants who attempted control was closer to 20%. Nearly 40% of participants of FFS used an insecticidal spray to control potato tuber moth, while only <5% of non-participants did so. For other techniques such as sorting rotten and healthy tubers, curing tubers and including marigold plants or ash in the storage space, there was little uptake and no significant differences in the proportion who adopted the techniques between the two groups (Fig. 8b).

Table 6 Farmers' perception of symptoms associated with late blight (*Phytophthora infestans*) development on potato at Field Schools (FFS) between 1999 and 2001 in Kabale, Uganda

Symptoms associated with late blight	FFS Participants (n=275)		Non participants (n=275)		Z-Values	P-Values[b]
Perception of symptoms	Percent[a]	Rank	Percent[a]	Rank		
Whitish growth on lower leaves	40.4±7.1	3	11.2±4.0	3	7.709	0.001**
Brown lesions on stems	53.4±6.8	2	23.7±4.4	2	6.899	0.05*
Brown color on tubers	7.7±2.3	4	6.5±3.1	5	0.336	ns
Yellowish foliar lesions	7.8±6.0	5	9.2±7.3	4	0.481	ns
Dark-brown lesions on leaves	65.9±7.9	1	74.5±9.28	1	1.957	0.05*
Do not know	2.3±1.4	6	3.7±1.4	6	0.723	ns

[a] Farmer field school participants were evaluated in comparison to non-participants. Values are the mean percentage of respondents for each question. The±refers to standard errors of the mean

[b] Significant differences between means are denoted by * and ** at the 5% and 1% level, respectively: ns=non significant

Table 7 Farmer's perception of sources of bacterial wilt (*Ralstonia solanacearum*) on potato. A semi-structured questionnaire was administered to farmers after the completion of two cycles of field school sessions (1999–2000 and 2000–2001)

Variables	FFS Participants (n=275)		Non participants (n=275)		*Z*-Values	*P*-Values[b]
Sources	Percent[a]	Rank	Percent[a]	Rank		
Infected tubers	36.0±6.1	1	30.2±5.2	1	1.405	ns
Insects	9.7±3.1	7	18.6±5.1	3	2.988	0.05*
Tuber rots	11.5±3.9	6	13.6±4.2	6	0.569	ns
Infested soil	30.6±8.6	3	14.5±4.4	5	4.668	0.05*
Bacteria	32.8±6.4	2	7.7±2.7	7	7.261	0.001**
Diseased plant	17.7±2.7	4	4.1±2.0	8	5.092	0.05*
Rain	12.4±2.6	5	14.9±4.1	4	0.906	ns
Do not know	6.9±1.3	8	23.9±17.5	2	5.148	0.05*

[a] Values are the mean percentage of respondents for each question. The± refers to standard errors of the mean

[b] Significant differences between means are denoted by * and ** at the 5% and 1% level, respectively: ns=non significant

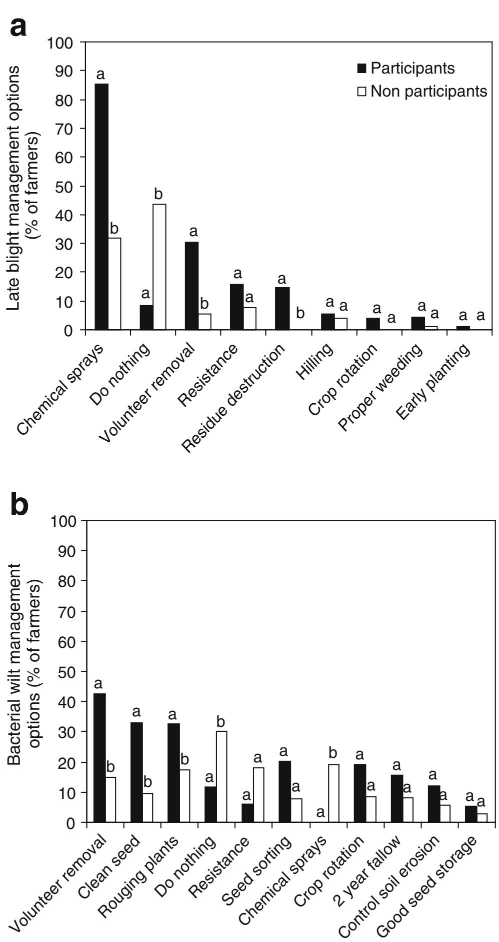

Fig. 5 Management options for late blight, caused by *Phytophthora infestans* (**a**) and bacterial wilt caused by *Ralstonia solanacearum* (**b**) identified by participants of field schools and non-participants, based on a semi-structured survey from 1999 to 2002

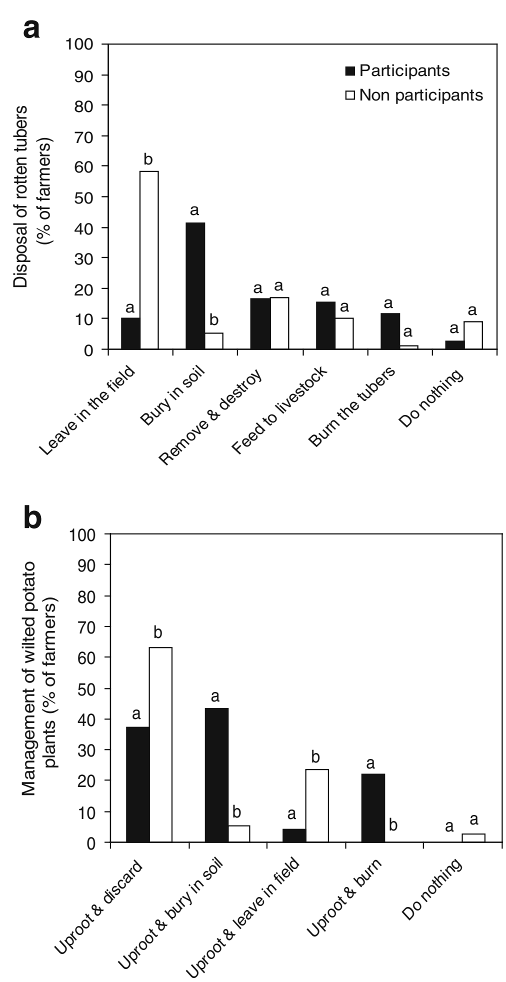

Fig. 6 Cultural options used by farmers in disposal of rotten potato tubers and wilted plants during the cropping season (**a**) and management of bacterial wilt infections on potato (**b**)

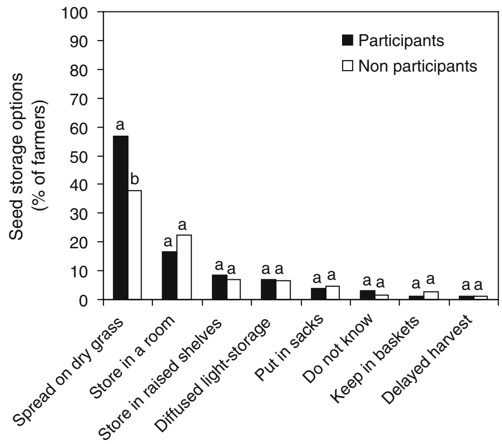

Fig. 7 Methods used for the storage of seed and ware potato at field schools in S.W. Uganda. A sample size of 275 participants from farmer field schools and corresponding non-participants (275) were used in the analysis

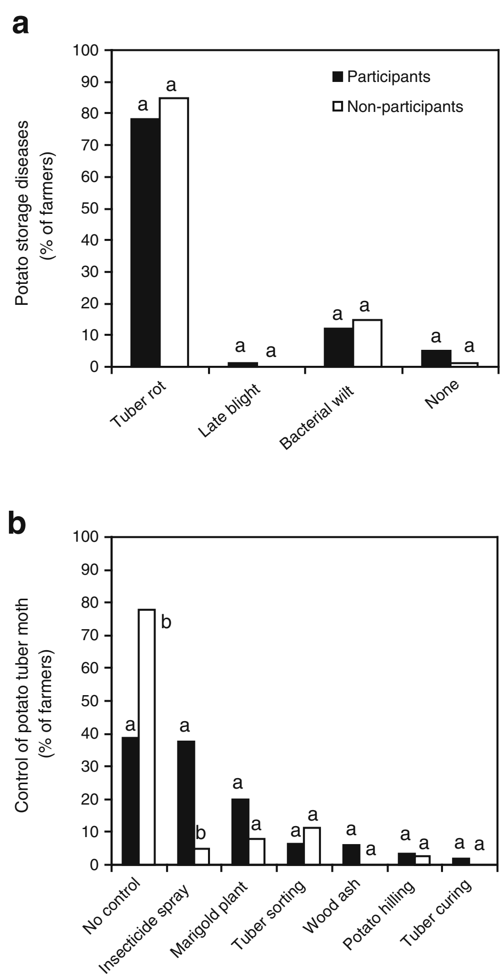

Fig. 8 Potato storage diseases and methods used by farmers to control post-harvest pest such as potato tuber moth. The participants (275 members) and non-participants (275 respondents) of field schools were assessed

Discussion

Approaches employing FFS experimental learning were effective in technology development and dissemination of improved agronomic practices for pest management of potato and sweetpotato (Nelson et al. 2001; Olanya et al. 2000; Van de Fliert et al. 2003) and have been practiced previously on the African continent (Ladela 2001). The weekly FFS sessions on IPM of potato in this study implemented according to a set curriculum and based on crop phenology provided ample opportunities for problem-solving and farmer-facilitator interactive learning with great potential for increased potato production.

There were similarities in the sources of seed potato tubers between FFS participants and non-participants, but FFS participants were more inclined to obtain seed potatoes from reputable sources than non-participants. This suggests that FFS participants had greater awareness of the use and implications of quality seed in potato production. The acquisition of seed potato from unregulated market localities or neighbors irrespective of their health status by some participants and non-participants suggests that during planting time, seed potato availability takes precedence over quality. The challenges and successes of potato production based on timely availability of potato seed and other agronomic inputs have been previously documented in this region (Tindemubona et al. 2000). Similarly, the production drawbacks associated with low quality seed attributed to biotic constraints have also been demonstrated (Kinyua et al. 2005).

Agronomic or cropping practices in potato production were diverse. Row planting, weeding, potato hilling, manure use and residue destruction, dehaulming or vine removal and potato storage strategies were among the practices used. Both farmers who had participated in FFS and non-participants used similar practices, but differed in their timing or rates of application. FFS participants had greater knowledge of various potato production techniques and some of this information may have diffused to non-participants through their proximity to participants or possibly previous exposure to training by government extension systems or NGO interventions. Knowledge of the rationale for the use of certain practices such as row planting or hilling differed between participants and non-participants, implying that FFS could have contributed to knowledge empowerment and through this the potential for increasing potato production, availability and accessibility.

Previous studies have shown that farmers used diverse sources of information for pest management and other crop production activities (Nathaniels et al. 2003). This was also true for pest management and potato production practices used by FFS participants and non-participants in the present study. However, here a paucity of knowledge of the biology of important potato pests, pest management techniques and potato production practices were recorded among farmers in FFS. Therefore, implementation of the techniques taught at FFS, are likely to be important mechanisms by which potato production could be considerably increased.

Farmer participatory experiments demonstrated that cultivars differed significantly in their reaction to blight. The cultivars Rutuku and 575049, for example, were highly resistant compared to Victoria and Kabale. Similarly, FFS participants were able to observe how two different disease management options affected disease development and final severity compared to the non-fungicide control (untreated check). Significant increases in yield were recorded for most cultivars at field schools in response to the two disease management options. Where increases in yield were not recorded as a result of treatment, the cause was probably confounding of the results by bacterial wilt infection, resulting in lower yields than expected.

Although both FFS participants and non-participants were aware of specific disease agents such as late blight or bacterial wilt or plant parts affected by the pathogens, non-participants were less well informed and were not able to associate disease symptoms with causal agents. Most FFS participants correctly linked late blight to high humidity, rainfall and low temperature. Similarly, the occurrence of bacterial wilt was correctly linked to infested soil, seed, or infected potato plants. The linkage of disease to weather or soil conditions by farmers has been previously documented in other pathosystems (Trutmann et al. 1996). Understanding of pathogen or pest biology and its interaction with the environment are important for effective disease or pest management. FFS participants had better understanding of the ecology of late blight and bacterial wilt than non-participants and this could be attributed to the knowledge they acquired during learning sessions.

Before attendance at FFS, most participants as well as non-participants preferred fungicide control as an option for late blight control, while cultural measures were used for bacterial wilt management. This may be attributed to farmers' desire for total control of disease. Absolute disease control may not be necessary when resistant cultivars are used as few lesions on potato foliage would not drastically affect tuber yield. On-farm surveys and experiments on fungicide use in combination with resistant cultivars indicated that most graduates of FFS used resistant cultivars in combination with fungicides for late blight control (Namanda et al. 2004). Many of the farmers who did not participate in FFS indicated that they did nothing to control or manage late blight and bacterial wilt. This may be due to inadequate understanding of available options and mechanisms for pest management.

Storage of seed and ware potato is still rudimentary in the study area. Few farmers from either group kept their seed potato in diffused light or on shelves. This suggests that financial constraints are the reason rather than lack of knowledge. Attempts should be made to improve storage of seed and ware tubers as a component of improved seed potato production and supply as this would have a tremendous positive impact on the food security of the community.

Conclusion

The potato FFS implemented in southwestern Uganda have shown the potential for increasing knowledge about agronomic and disease control practices which, if widely adopted, would make a substantial impact on food security in the area. Generally, participants at FFS were more adept at employing these techniques but they were also practiced to a more limited extent by non-participants, possibly as a result of the diffusion of knowledge from participants by word of mouth. Graduates of FFS had a better perception and appreciation of improved agronomic practices and pest management than non-participants and were therefore more liable to put them into practice. However, restricted financial resources were a limiting factor, the lack of construction of diffuse light storage facilities being a case in point. The extent to which knowledge intensive approaches such as FFS enhance the adoption of improved agricultural technologies and overall food security needs to be quantified over time. This should be done in terms of yield, food availability and access to food and also in social and economic terms in order to assess the long-term impact.

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Modesto Olanya is a Research Plant Pathologist with the US Department of Agriculture—Agricultural Research Service (USDA-ARS) at the New England Plant, Soil and Water Laboratory, Orono, Maine. His laboratory is conducting basic and applied research on the biology, ecology, epidemiology and management of *Phytophthora infestans*, the causal agent of potato late blight. Before joining USDA-ARS, he was a Regional Pathologist at the International Potato Center (CIP), Regional Office for Sub-Saharan Africa in Nairobi, Kenya (1999–2002), and Assistant Research Professor (1997–1999) at the University of Maine. He also worked as a Post-doctoral Associate (Plant Pathologist) at Iowa State University and a Post-doctoral Fellow (Maize Pathologist) at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Modesto holds a Ph.D. degree in Plant Pathology from North Carolina State University, USA.

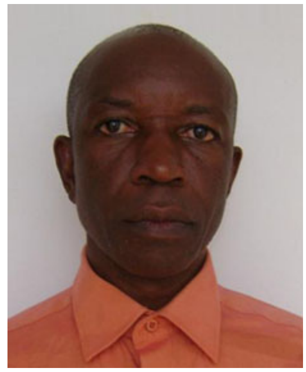
Rebecca Nelson is an Associate Professor in Plant Pathology and Plant-Microbe-Biology, Plant Breeding and Genetics and International Agriculture and Rural Development at Cornell University. She serves as Scientific Director for The McKnight Foundation's Collaborative Crop Research Program. Her laboratory works on the genetic dissection of quantitative disease resistance in maize, in collaboration with maize geneticists and breeders at Cornell, in Kenya and elsewhere. Prior to moving to Cornell in 2001, she worked at the International Potato Center in Lima, Peru (1996–2001), and at the International Rice Research Institute in the Philippines (1988–1996). Rebecca holds a B.A. degree from Swarthmore College and a Ph.D. from the University of Washington, USA. A MacArthur Fellow from 1998 through 2003, she has served on the editorial boards of Theoretical and Applied Genetics, Phytopathology and the International Journal of Agricultural Sustainability.

Johnson Hakiza is a Senior Research scientist (retired), Plant Breeder, and former Program Leader for Horticultural Crops (2002 to 2008) at Kawanda Agricultural Research Institute (KARI), in Kampala Uganda. He previously served as Potato Program Leader at Kalengyere Research Station (1996–2001) in S.W. Uganda, where he worked on development of potato cultivars for resistance to late blight and yield stability. From 1988–1995, he worked as a Research Officer at Namulonge Research Station as a senior maize breeder. Dr. Hakiza holds a B.Sc. (Agriculture) from Makerere University, Kampala, Uganda; M.Sc. from Makerere University and Ph.D. from the Ohio State University, USA.

Peter Ewell is Senior Regional Advisor with the United States Agency for International Development (USAID) in Nairobi, Kenya. His current responsibilities are in sustainable development and implementation of agricultural development projects in East and Central Africa on regional USAID-funded projects. From 1988-2002, he was the Regional Representative of the International Potato Center (CIP), Regional Office for Sub-Saharan Africa, Nairobi, Kenya, where he directed and administered agricultural collaborative research and training projects in East, Central and Southern Africa. Peter holds a Ph.D. from Cornell University, USA in Agricultural Economics.

Ramzy El-Bedewy is a Senior Advisor on Potato and Sweet Potato with the Ministry of Agriculture and Agricultural Research Center in Egypt. He is currently serving on the Executive Committee of the African Potato Association. From 1998 to 2002, he was the Regional Potato Breeder at the International Potato Center (CIP), Regional Office for Sub-Saharan Africa at Nairobi, Kenya, where he worked on variety development and resistance to many diseases, advanced clonal selections and propagation of potato and sweet potato. Prior to joining CIP in Nairobi, Ramzy worked on various collaborative research activities on true potato seed (TPS), management of potato tuber moth and other production constrains on potato in Egypt. Ramzy holds a Ph.D. degree from the University of Gottingen in Germany.

Rogers Kakuhenzire is a Scientist with the International Potato Center (CIP) Liaison Office in Kampala, Uganda. He was previously a Research officer and Plant Pathologist (2002–2008) at Kachwekano Zonal Agricultural Research and Development Center, Kabale, Uganda, where his research was focused on integrated disease management, potato variety development for highland tropics and long term late blight development behavior. From 1994–2001, he worked as a Research Officer at Kalengyere Research Station, where he specialized on seed potato system development and integrated disease management, development of cultivars with high stability resistance to late blight and yield. Rogers holds a Ph.D. in Plant Pathology from Makerere University, Uganda.



Samuel Namanda is a Scientist with the International Potato Center (CIP) Liaison Office in Kampala, Uganda. From 2003–2007, he was coordinator of sweet potato FFS at Soroti, Uganda and worked on the project funded by FAO-CIP. He previously was an Assistant Scientist with the International Potato Center (CIP) from 1999–2002. From 1996–1999, he served as graduate research assistant at the Department of Crop Science, Makerere University. Samuel holds an M.S. degree in Crop Science from Makerere University, Uganda.

Imelda N. Kasheija is a Director of Research with the National Agricultural Research Organization (NARO), based at Kachwekano Zonal Agricultural Research and Development Institute, where she has been working since 2001. She was previously a Scientific Officer (1985), and a Research Officer who planned and executed research projects on plant parasitic nematodes and banana weevil, under the National Banana Research Programme. In 2001, she was a Senior Research Officer and Center Manager of Kachwekano Agricultural Research and Development Centre. Since 2007, she has worked as a Principal Research Officer and Director of Research in which she oversees systems levels research, administers and coordinates research on potato, fruits, wheat, and other highland-based cropping systems as well as dissemination and technology up-take. Imelda is leading and participating in Integrated Agricultural Research for Development (IAR4D) in Uganda and other countries in Africa. Imelda N. Kasheija holds a Ph.D. degree in Agriculture from the University of Reading, United Kingdom.

Williams Wagoire is the Acting Director of Research and Plant Breeder at Buginyanya Zonal Agricultural Research and Development Institute, Sironko, Uganda. He has previously served as Senior Research Officer and Leader of the National Potato Program at Kachwekano Zonal Agricultural Research and Development Institute, Kabale, Uganda (1998–2008) and Leader of the Uganda National Wheat Program

(1980–1998). His major focus was on development of potato cultivars for resistance to late blight, optimization of seed potato production techniques, farming systems research and research management as well as working on wheat and barley development projects. William holds a Ph.D. degree in Plant Breeding from the Royal Veterinary and Agricultural University in Denmark.

Brima Ngombe is a Program Manager for Food Security and Livelihoods for Save the Children / USA based in Leogane, Haiti. In this capacity, he heads and manages multi-sector projects including education, protection, health & nutrition, water & sanitation as well as Food Security & Livelihoods. For over 15 years, he has been working in the implementation of International Development Programs in the Central African Republic (Africare), Uganda (Africare and Save the Children/USA), Sudan and Sierra Leone as well as in Central Asia (Tajikistan) and Asia (Afghanistan). Brima holds a Ph.D. in Agricultural & Extension Education from Michigan State University with emphasis on Program Development, Implementation, Monitoring and Evaluation.

Charles Musoke is a Scientist with the International Food Policy Research institute (IFPRI) Liaison Office in Kampala, Uganda. Since 2007 he has headed the seed systems component of the reaching end users project jointly implemented by IFPRI HarvestPlus and CIP. He previously worked with the Danish Development Agency (DANIDA) supported project as manager of district agricultural information and technology development centers in Uganda between 2004 and 2007. He was manager, agricultural production, Africare, Uganda from 2001–2004. From 1997–2000, he served as graduate researcher at the Department of Crop Science, Makerere University. Charles holds an M.S. degree in Crop Science from Makerere University, Uganda.