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Farmers' knowledge and perceptions of potato pests and their management in Uganda

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Abstract

As we initiate entomological research on potato (*Solanum tuberosum* L.) in Uganda, there is need to understand farmers' knowledge of existing insect pest problems and their management practices. Such information is important for designing a suitable intervention and successful integrated pest management (IPM) strategy. A farm household survey using a structured questionnaire was conducted among 204 potato farmers in six districts of Uganda (i.e., Kabale, Kisoro, Mbale, Kapchorwa, Mubende, and Kyegegwa) during August and September 2013. Diseases, insect pests, price fluctuations, and low market prices were the four highest ranked constraints in potato production, in order of decreasing importance. Cutworms (*Agrotis* spp.), aphids (*Myzus persicae* (Sulzer)), and potato tuber moth (*Phthorimaea operculella* (Zeller)) were the three most severe insect pests. Ants (*Dorylis orantalis* Westwood), whiteflies (*Bemisia tabaci* (Gennadius)), and leafminer flies (*Liriomyza huidobrensis* (Blanchard)) were pests of moderate importance. Major yield losses are predominantly due to late blight (*Phytophthora infestans* (Mont.) de Bary) and reached 100 % without chemical control in the districts of Kabale, Kisoro, Mbale, and Kapchorwa. On average, farmers had little to moderate knowledge about pest characteristics. The predominant control methods were use of fungicides (72 % of respondents) and insecticides (62 % of respondents). On average, only 5 % of the 204 farmers knew about insect pests and their natural enemies. This lack of knowledge calls for training of both farmers and extension workers in insect pest identification, their biology, and control. Empowering farmers with knowledge about insect pests is essential for the reduction of pesticide misuse and uptake of more environmentally friendly approaches like IPM. Field surveys would need follow-up in order to assess the actual field infestation rates and intensities of each insect pest and compare the results with the responses received from farmers.

Keywords: *Solanum tuberosum*, ethnoentomology, integrated pest management, participatory technology development, local knowledge

1 Introduction

Potato (*Solanum tuberosum* L.) is the world's most important tuber crop (FAO, 2012), and is an important staple crop and a source of cash income in the densely populated East African highlands. It is estimated that 82 %, 71 %, and 61 % of potato grown in Kenya, Uganda, and Ethiopia, respectively, are for sale and the farming systems are quite intensive and diversified (Gildemacher, 2012). In Uganda, losses caused by diseases such as late blight (*Phytophthora infestans* (Mont.) de Bary) are high, ranging from 40 % to 60 % of the total production and can reach 100 % if infection occurs early in the season when climatic conditions are favourable for disease development (Olanya *et al.*,

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2002). Yield losses due to other diseases such as bacterial wilt (*Ralstonia solanacearum* Smith) and insect pests such as the potato tuber moth (*Phthorimaea operculella* Zeller) or the leafminer fly (*Liriomyza huidobrensis* (Blanchard)) are, however, barely documented in scientific literature. Further, climate change has been reported to further accelerate pest infestations of the potato tuber moth in Africa (Kroschel *et al.*, 2013). In order to overcome biotic production constraints, farmers routinely apply pesticides to control fungal diseases and insect pests (Namanda *et al.*, 2001; Okonya & Kroschel, 2015). In potato, good efforts to apply integrated pest management (IPM) have been made in South America (Bolivia, Peru); South Asia (India); North Africa (Tunisia, Egypt) and southern Africa (South Africa, Zimbabwe); Australia; and other regions (Kroschel, 1995; Lagnaoui & El-Bedewy, 1997; Palacios & Cisneros, 1997; Horne & Page, 2008; Kroschel & Lacey, 2008; Ortiz *et al.*, 2009; Kroschel *et al.*, 2012). The development and introduction of the IPM concept for potato production systems in Uganda is a new initiative. Having adequate information about farmers' knowledge, perceptions, and practices in pest management is key for the development and adoption of a successful IPM program (Heong *et al.*, 2002; Parsa *et al.*, 2014). Moreover, after the introduction of an IPM program, the present study could be used for ex-post evaluations of IPM adoption, providing information which is often rarely available. On the basis of the pest management issues raised by farmers, an IPM approach for Uganda is discussed that could effectively support a reduction in current pesticide use. Such a reduction could help to protect the environment, increase crop productivity, promote natural enemy population build-up, and reduce the development of pesticide resistance and human health-related risks.

1.1 *The problem*

Very little research has been devoted to potato pest management in Uganda. For instance, insect species – pests and natural enemies – associated with potato in Uganda are barely documented in scientific literature. Similarly, little is known about farmers' perception and knowledge about insect pests and their management practices. The study reported here aimed to fill that knowledge gap for setting up research agendas to develop and design appropriate pest management strategies that could facilitate technology uptake and developing messages for communication and training (Fujisaka, 1994; Escalada & Heong, 2007).

1.2 *Objectives*

In this paper, we report results of a cross-sectional survey conducted in six major potato-producing districts of Uganda. The survey sought to (i) identify and rank potato production constraints based on farmers' perception of their importance in Uganda, (ii) identify the pest problems that farmers perceive as most important, (iii) describe local names of potato insect pests, and (iv) document farmers' knowledge about insect pests, their damage, and management practices.

2 Materials and methods

2.1 *Study sites*

The study was conducted in six districts (Kabale, Kisoro, Mbale, Kapchorwa, Mubende, and Kyegegwa) in Uganda (Fig. 1). The sub-county which grows the most potato per district was then selected for this survey. These were Muko sub-county in Kabale district (1947–2457 m asl), Nyarusiza sub-county in Kisoro district (1969–2298 m asl), Wanale sub-county in Mbale district (1876–2032 m asl), Kapchesombe sub-county in Kapchorwa district (2047–2544 m asl), Kibalinga in Mubende district (1279–1345 m asl), and Kakabara sub-county in Kyegegwa district (1206–1414 m asl).

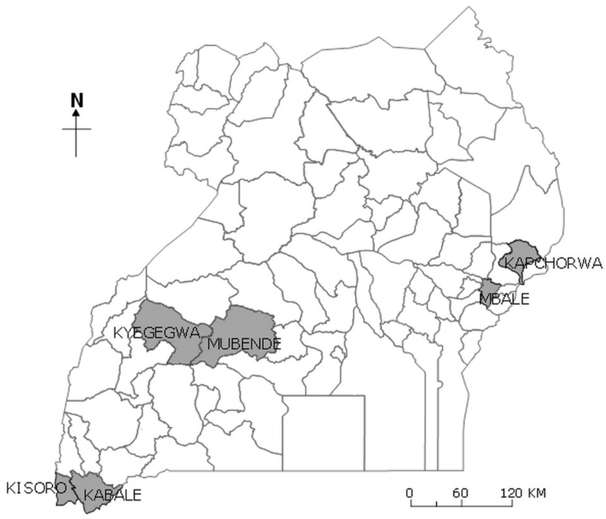

Fig. 1: *Map of Uganda showing the geographical position of the surveyed districts.*

2.2 *Farm interviews*

Individual interviews using a questionnaire were conducted between August and September 2013. In each sub-county, local agricultural extension workers and community-based facilitators were involved in the study to facilitate data collection. Within a sub-county, 34 households spaced 1–5 km apart were randomly selected for individual interviews. The household heads were the targeted respondents, although any adult in the household who was familiar with potato production was interviewed if the head of the household was absent. Because the study focused on insect pests, farmers' perception and understanding of potato diseases and other production constraints were not analysed in more detail. The following data were collected:

(i) To assess farmers' knowledge of insect pests, farmers were asked to mention the pest features they knew. This was then rated based on a four-point scale (Table 1).

(ii) Farmers were asked to state the main constraints in potato production or marketing. After all constraints had been recorded, farmers were asked to rate the importance of each constraint mentioned based on a six-point scale, whereby 5 = most important, 4 = important, 3 = moderately important, 2 = little importance, 1 = very little importance, and 0 = not a problem (Table 2a).

(iii) To assess farmers' perception of the severity of insect pest damage, colour pictures of all possible potato insect pests were shown to farmers, who were then asked to score for the level of damage caused by each pest identified. A five-point scale (5 = very severe damage, 4 = severe damage, 3 = moderate damage, 2 = little damage, and 1 = very little damage) was used for rating the damage level perceived to be caused by each insect.

2.3 Data analysis

Data were analysed through descriptive statistics (frequencies, percentages, and means) to generate summaries and tables at district level using SAS software V.9.2 for Windows (SAS Institute Inc., 2008). Chi-square and one-way analysis of variance (ANOVA) were conducted to assess any differences between districts. Significance level was set at $P \leq 0.05$ and means separated by LSD test.

3 Results and discussion

3.1 Constraints of potato production and marketing from the farmers' perspectives

Among the constraints to potato production and marketing, farmers ranked diseases as the most important, with an overall score of 4.0±0.09 by 96 % of respondents, followed by insect pests (scores of 3.0±0.11 by 85 % respondents) (Table 2a). The importance of constraints varied across districts. Price fluctuation for ware potato was ranked third most important constraint (scores of 2.6±0.12 by 75 % of respondents), whereas low market prices for ware potato came fourth (scores of 2.6±0.23 by 72 % of respondents). Seven constraints that were ranked as having very little importance (score ≤1.0) included the following: damage by wild animals, late maturity and short dormancy of some potato varieties, tuber damage by rodents and tuber damage by millipedes. Of the 14 constraints to potato production and marketing ranked in Table 2a, 11 were mentioned by >50 % of the farmers (Table 2b).

Table 1: *Criteria followed for scoring farmers' knowledge of insect pests*

Score	*Knowledge level*	*Criteria*
0	No	farmer could not mention a potato pest by a name, its description, or the type of damage
1	Low	farmer named one pest, one feature, and one type of damage caused by the pest
2	Medium	farmer named two pests, and described at least one feature of each pest and at least one type of damage caused by each of the two pests
3	High	farmer named three or more pests, described one or more features of each, and described at least one type of damage caused by each of the three pests

Adapted after Midega *et al.* (2012).

Table 2a: *Mean scores of constraints reported by potato farmers in six districts of Uganda (2013 survey; n=204)*

No.	*Constraints*	*Kabale*	*Kisoro*	*Mbale*	*Kapchorwa*	*Mubende*	*Kyegegwa*	*Overall*
1	Diseases	4.4±0.13 *a*	3.8 ±0.26 *b*	4.7± 0.11 *a*	4.7±0.10 *a*	3.3±0.28 *b*	3.4±0.22 *b*	4.0±0.09
2	Insect pests	3.8±0.19 *a*	3.6±0.25 *ab*	2.7±0.27 *c*	3.0±0.24 *bc*	1.9±0.31 *d*	3.0±0.24 *bc*	3.0±0.11
3	Drought (unpredictable rainfall)	3.4±0.30 *a*	3.0±0.31 *a*	2.1±0.23 *b*	1.0±0.21 *c*	3.1±0.32 *a*	2.8±0.30 *ab*	2.6±0.13
4	High cost of fungicides	3.6±0.25 *ab*	3.1±0.27 *b*	4.1±0.18 *a*	2.0± 0.31 *c*	1.1±0.29 *d*	0.4±0.14 *e*	2.4±0.14
5	Seed (poor quality & high cost)	2.5± 0.27 *bc*	3.0 ±0.23 *b*	4.0±0.27 *a*	2.0±0.28 *cd*	1.5±0.30 *de*	1.0±0.24 *e*	2.3±0.13
6	Low market prices	2.0±0.29 *b*	2.4±0.31 *b*	3.5±0.27 *a*	3.4± 0.25 *a*	1.8±0.33 *b*	2.4±0.32 *b*	2.6±0.13
7	Price fluctuations	2.9±0.30 *ab*	3.3±0.23 *a*	3.4±0.23 *a*	1.9± 0.26 *c*	2.1±0.32 *c*	2.2±0.35 *bc*	2.6±0.12
8	Low soil fertility	2.2 ±0.31 *b*	2.6±0.32 *b*	3.9±0.17 *a*	3.5±0.18 *a*	0.9±0.23 *c*	0.7±0.18 *c*	2.3±0.13
9	High cost of insecticides	3.3±0.28 *ab*	2.8±0.28 *b*	3.6±0.25 *a*	1.4± 0.24 *c*	0.7±0.22 *cd*	0.3±0.10 *d*	2.0±0.13
10	Poor roads	1.3±0.25 *bc*	1.9±0.32 *ab*	2.7±0.32 *a*	2.6± 0.25 *a*	0.9±0.27 *c*	1.7±0.33 *bc*	1.9±0.13
11	High cost of transport	1.6±0.28 *b*	1.8 ±0.28 *b*	3.5 ±0.33 *a*	1.6± 0.28 *b*	0.7±0.24 *c*	1.4±0.31 *bc*	1.8±0.13
12	Exploitation by brokers	1.2±0.33 *b*	1.4±0.34 *b*	2.7± 0.33 *a*	1.7± 0.31 *b*	1.1±0.28 *b*	1.5±0.35 *b*	1.6±0.14
13	Long distance to market	1.2±0.27 *bc*	1.4 ±0.27 *b*	2.8± 0.29 *a*	1.2±0.25 *bc*	0.7±0.21 *c*	0.8±0.25 *bc*	1.4±0.12
14	Floods	2.4±0.36 *a*	1.8±0.26 *ab*	1.2± 0.24 *bc*	1.2±0.31 *bc*	0.7±0.20 *cd*	0.4±0.15 *d*	1.3±0.12
15	Others (millipedes, high perishability, late maturity and vermin)	1.5 ± 0.22 *b*	1.9± 0.23 *b*	2.5± 0.21 *a*	1.6± 0.20 *b*	1.6±0.25 *b*	1.8±0.22 *b*	1.8±0.09

Scores: 5 = most important, 4 = important, 3 = moderately important, 2 = little importance, 1 = very little importance, 0 = not a problem. Mean values with the same letter in the same row are not significantly different at P<0.05.

Table 2b: *Percentage of potato farmers reporting each constraint in six districts of Uganda (2013 survey; n=204)*

No.	*Constraints*	*Kabale*	*Kisoro*	*Mbale*	*Kapchorwa*	*Mubende*	*Kyegegwa*	*Overall*	χ^2
1	Diseases	100	91	100	100	88	97	96	11.97*
2	Insect pests	97	91	85	88	59	91	85	24.86*
3	Drought (unpredictable rainfall)	82	79	77	50	82	82	75	14.84*
4	Price fluctuations	82	91	91	68	59	56	75	22.51*
5	Low market prices	65	71	85	91	53	68	72	16.58*
6	Seed (poor quality & high cost)	79	91	88	74	53	41	71	33.03*
7	Low soil fertility	68	71	100	100	38	41	70	64.34*
8	High cost of fungicides	91	82	97	59	44	26	67	60.53*
9	High cost of insecticides	85	82	91	56	35	26	63	55.53*
10	Poor roads	56	65	71	85	35	53	61	20.65*
11	High cost of transport	56	65	79	62	29	44	56	20.76*
12	Others (Long distance to market, Exploitation by broker, Floods, Millipedes, high perishability, Rodents, Late maturity, Vermin)	91	97	100	88	76	85	90	13.22

* Values are statistically different at P≤0.05.

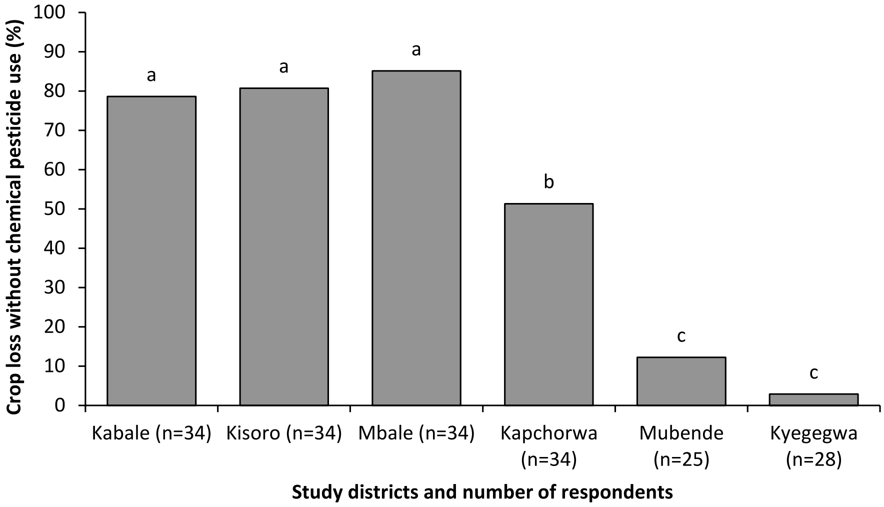

Fig. 2: *Perceived mean potato yield loss due to pests and diseases reported by farmers in six potato-growing districts if pesticides are not applied (2013 survey). Mean values with the same letter are not statistically different at P≤0.05.*

Insect pests (potato tuber moth, aphids, and leafminer flies) and diseases (viral, bacterial wilt, and late blight) are some of the most important constraints to potato production in Uganda, Kenya, and Ethiopia (Sileshi & Teriesa, 2001; Gildemacher, 2012; Were, 2012; Were *et al.*, 2013). Likewise, insect pests of other tropical crops are ranked among the top biotic constraints to production of sweetpotato (*Ipomoea batatas* L. Lam), cotton (*Gossypium hirsutum* L.), yam (*Dioscorea* spp.), tomato (*Solanum lycopersicum* L.), cabbages (*Brassica* spp.), and coffee (*Coffea* spp.) (Sinzogan *et al.*, 2004; Nyirenda *et al.*, 2011; Midega *et al.*, 2012; Loko *et al.*, 2013; Okonya *et al.*, 2014).

3.2 *Impact of pests and diseases on potato (economic loss estimates)*

In cases where farmers did not apply any chemical pesticides, economic losses from pests and diseases were reported to range 20–100 % in Kabale, 30–100 % in Kisoro and Mbale, 10–100 % in Kapchorwa, 1–50 % in Mubende, and 1–30 % in Kyegegwa districts (Fig. 2). Losses, however, depend on the amount and distribution of rainfall for late blight, which can cause up to 100 % during a rainy season; in the case of insect pests, losses depend on the length of the dry season (Kroschel & Koch, 1994; Olanya *et al.*, 2002). Losses in Mubende and Kyegegwa are lower than we would expect at low elevations (1200–1400 m asl) and a warm climate (average annual temperatures 22.9°C). This may be because potato has recently been introduced into these two districts by farmers from the Kabale and Kisoro districts who have migrated and settled here. Production is still very limited, and the areas' long dry season without the host plant has likely not allowed the pest population to increase.

3.3 *Farmers' knowledge of insect pests of potato and associated natural enemies*

Overall, 14 insect pests known to attack potato were mentioned by farmers. These include:

(i) Potato tuber moth, *P. operculella*: Larvae were known as *Kayari*, *Eshokondwa*, or *Enjogori* in Kabale district, *Nyirakadoli* or *Eshoko* in Kosoro district, and *Kamasa* in Mbale district. *P. operculella* was only reported as a pest when seed potato tuber was stored.

(ii) Leafminer fly, *L. huidobrensis*: Larvae were known as *Toduura* in Kisoro district.

(iii) Green peach aphids: *Myzus persicae* are known as *Obukoko bwe mondi* in Kabale, *Obusimba* or *Enungwe* in Kisoro, *Bufuhu* in Mbale, *Ataawa* in Kapchorwa, and *Obusisimuzi* in Mubende.

(iv) Cutworms, *Agrotis* spp.: Local names exist in all the six districts surveyed: *Eshinya* in Kabale, *Enandi* or *Eshinyi* in Kisoro, *Ingutsukira* in Mbale, *Toltoliet* or *Cheptutuliedet* in Kapchorwa, *Kisukundu* in Mubende, and *Esokolwa* or *Ekinyogoru* or *Oramba* in Kyegegwa.

(v) A reddish brown ant, *Dorylis orantalis*, feeds on the stem and young shoots of the potato plant.

It is known as *Tsimonye* in Mbale, *Malalik* in Kapchwora, *Emunyi* or *Ebinyomo* or *Ebinyumu* in Mubende, and *Ekinyumu* or *Ebisamunyu* in Kyegegwa.

(vi) The remaining four insect pests had a local name in only one district. These are the white fly (*Bemisia tabaci*) known as *Kapata* in Kapchwora; leafhopper (*Empoasca* spp.) known as *Ekiharara* in Kisoro; white grub (Coleoptera: Scarabaeidae) known as *Ekishorobwa* in Kabale; and termite (Macrotermitinae) known as *Enkuyege* in Mubende.

No local name was mentioned for the flower thrip, *Ceratothripoides brunneus* Bagnall (Thysanoptera: Thripidae), and mealybug (Hemiptera: Pseudococcidae) in all the six districts. Farmers described a pest mostly by its features, a particular symptom, or by the plant part under attack (e.g., aphids in Kabale are known as *Obukoko bwe mondi*, literally "insect pests of potato"). The association of insect pest names by farmers with the crop or the damage caused has been reported elsewhere for insect pests of (i) yam and cotton in Benin (Sinzogan *et al.*, 2004; Loko *et al.*, 2013); (ii) sweetpotato, maize (*Zea mays* L.), tomato, banana (*Musa* spp.), cassava (*Manihot esculenta* Crantz), and bean (*Phaseolus vulgaris* L.) in Uganda (Kabeere, 2006); (iii) potatoes, barley (*Hordeum vulgare* L.), beans and apples (*Malus domestica* Borkh.) in Bolivia (Bentley & Herbas, 2006); and (iv) various crops in Bangladesh (Harun-Ar-Rashid *et al.*, 2006). The description of local names of insect pests is expected to help entomologists, extension workers, and others who work with rural communities to better understand pest occurrence and appreciate local knowledge (Bentley *et al.*, 2009).

On average, farmers had little to moderate knowledge of insect pests (score, 1.1–2.4). That is, farmers named one or two insect pests, and described at least one feature of each pest and at least one type of damage caused on potato by each of the two insect pests (Fig. 3). Farmers in Kisoro had the best knowledge of insect pests of potato; those in Kapchorwa knew the least. This could be because potato has been grown longer in Kisoro than in Kapchorwa. Various authors working in Kenya, Benin, and Zambia have found a significant positive relationship between farmers' knowledge of insect pests and socioeconomic factors such as household size, gender, farming experience, and education (Sinzogan *et al.*, 2004; Nyirenda *et al.*, 2011; Midega *et al.*, 2012).

Aphids were the most widely occurring insect pests in the six districts and were reported by 68 % of respondents, followed by cutworms (*Agrotis* spp.) (62 % of respondents) and potato tuber moth third (47 % respondents). It is important to note that the potato tuber moth was only reported as a pest during seed potato tuber storage, whereas aphids and cutworms were field pests (Table 3a). The cutworm was reported to be the most severe insect pest, followed by aphids, the reddish brown ant, and the potato tuber moth, in order of decreasing severity scores of 3.4±0.11, 3.3±0.12, 3.0±0.18, and 3.0±0.12 (Table 3b).

Overall, the cutworm was ranked as most important insect pest, probably because it comes early in the season (1–4 weeks after sprouting) and cuts down the tender plants. Four aphid species (*Macrosiphum euphorbiae* Thomas, *Aphis gossypii* Glover, *M. persicae*, and *Aphis fabae* Scopoli) have been reported to be vectors of potato viruses - especially potato virus Y (PVY), potato leafroll virus (PLRV), potato virus X (PVX), and potato virus A (PVA) - all of which occur in Uganda and Kenya (Gildemacher, 2012). Seed-borne diseases and viruses specifically are widespread in Uganda due to use of farm-saved seed-tubers instead of clean, certified seed-tubers. Aphids are not only more abundant under warm conditions, but are also found on plant shoots and so are more visible to the farmer. This could explain why aphids (vectors of viruses) were ranked as the second most important insect pests. Farmers' lack of knowledge on how to identify leaf damage by the leafminer fly and potato tuber moth in the field may be another reason why these two pests were ranked fourth and fifth most important, although the damage they cause could be higher. *P. operculella* was reported to be a problem during storage of seed potato especially in Kabale and Kisoro; hence farmers in the two districts apply malathion dust during storage to reduce seed potato tuber damage by *P. operculella*.

Only 26 % (9 farmers) and 6 % (2 farmers) of the farmers in Kapchorwa and Mbale districts knew about one natural enemy, the predatory army ant (*Dorylus* spp.). The difference between districts was significant (χ^2=37.15, df=5, P<0.0001). Knowledge about natural enemies, unless learned from extension courses, is usually low among farmers, as was observed also in Benin (Sinzogan *et al.*, 2004; Loko *et al.*, 2013).

3.4 Farmers' pest management practices

Most of the farmers mentioned insecticides and fungicides as the most effective methods of managing insect pests and diseases. All farmers in Kabale and Kisoro districts used insecticides and fungicides (Table 4); however, farmers in Kyegegwa district rarely used pesticides. It was common for farmers to apply insecticide

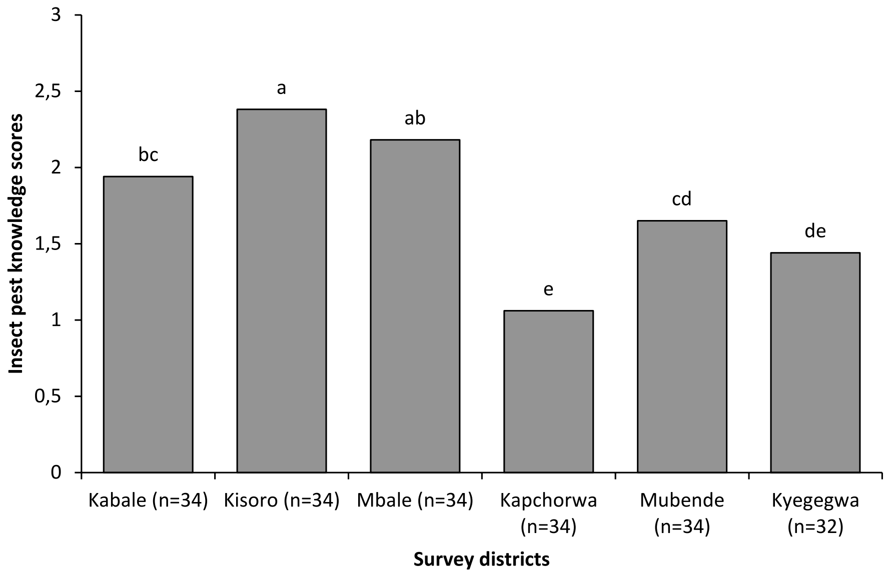

Fig. 3: *Farmers' knowledge about insect pests of potato in six districts of Uganda (2013 survey). Scores: 0 = no knowledge, 1 = low knowledge, 2 = medium knowledge, 3 = high knowledge. Bars with the same letter are not statistically different at P≤0.05.*

Table 3a: *Perceived incidence of potato insect pests in six districts of Uganda (2013 survey; percent respondents; n=204)*

Insect pest	*Kabale*	*Kisoro*	*Mbale*	*Kapchorwa*	*Mubende*	*Kyegegwa*	*Overall*	χ^2
Aphid (*Myzus persicae*)	88	85	85	45	53	50	68	32.05*
Cutworm (*Agrotis* spp.)	53	74	76	88	29	50	62	33.38*
Potato tuber moth (*Phthorimaea operculella*)	91	74	15	55	26	24	47	64.45*
Leafminer fly (*Liriomyza huidobrensis*)	18	69	19	37	18	6	28	43.11*
Reddish brown ant (*Dorylis orantalis*)	6	3	18	62	18	65	28	63.79*
Whitefly (*Bemisia tabaci*)	26	38	24	33	6	9	23	16.32*

* Means statistically different at P≤0.05.

Table 3b: *Perceived mean severity scores for the six major insect pests of potato in six districts of Uganda (2013 survey)*

Constraints	*Kabale*	*Kisoro*	*Mbale*	*Kapchorwa*	*Mubende*	*Kyegegwa*	*Overall*
Cutworm (*Agrotis* spp.)	3.9±0.17 *a*	3.9±0.18 *a*	3.5±0.13 *a*	3.8±0.19 *a*	2.0±0.39 *b*	1.9±0.28 *b*	3.4±0.11
Aphid (*Myzus persicae*)	4.2±0.12 *a*	4.0±0.15 *a*	4.2±0.14 *a*	2.3±0.37 *b*	2.0±0.21 *b*	1.7±0.24 *b*	3.3±0.12
Reddish brown ant (*Dorylis orantalis*)	1.5±0.5 *b*	5.0±0 *a*	2.0±0.26 *b*	3.4±0.28 *ab*	2.8±0.48 *b*	3.1±0.31 *ab*	3.0±0.18
Potato tuber moth (*Phthorimaea operculella*)	3.6±0.14 *a*	3.6±0.18 *a*	2.6±0.68 *b*	1.8±0.2 *c*	2.4±0.24 *bc*	1.8±0.16 *c*	3.0±0.12
Leafminer fly (*Liriomyza huidobrensis*)	3.1±0.63 *ab*	3.5±0.28 *a*	2.3±0.52 *abc*	1.7±0.35 *bc*	1.3±0.21 *c*	1.0±0 *c*	2.6±0.20
Whitefly (*Bemisia tabaci*)	2.2±0.32 *ab*	2.5±0.31 *a*	2.5±0.38 *a*	1.8±0.38 *ab*	1.0±0 *b*	2.0±0.58 *ab*	2.2±0.16

Scores: 5 = very severe damage, 4 = severe damage, 3 = moderate damage, 2 = little damage, and 1 = very little damage. Mean values with the same letter in the same row are not statistically different at P≤0.05.

Table 4: *Insect pests and disease control methods (% responses; n=204)*

Control method	*Kabale*	*Kisoro*	*Mbale*	*Kapchorwa*	*Mubende*	*Kyegegwa*	*Overall mean*	χ^2
Fungicides	100	100	100	97	26	6	72	161.29^*
Insecticides	100	100	94	56	18	6	62	134.77^*
Botanicals, wood ash and others	12	3	15	9	0	29	11	18.41^*
Mechanical control (hand picking)	3	0	0	6	0	0	1	7.12^{ns}
Cultural control								
(i) uprooting infected plants,	48	74	79	50	44	50	57	15.42^*
(ii) clean seed,	58	53	79	44	15	9	42	49.99^*
(iii) intercropping,	45	85	18	6	76	76	51	76.90^*
(iv) early planting,	36	24	74	44	32	32	41	21.77^*
None	0	0	0	0	9	12	3	14.84^*

* means statistically different at P = 0.01. ^{ns} = not significant at P<0.05.

and fungicide mixtures (Okonya & Kroschel, 2015). Farmers also used wood ash and home-made botanicals such as extracts of ripe chilies (*Capsicum* spp.) or fruits of a wild herb locally known as *Nyabebe* in Rukiga, in combination with laundry detergents (Omo or Surf) or human and cow urine. Handpicking, for cutworm management only, was practiced by very few farmers in Kabale (3 %) and Kapchorwa (6 %). Early planting and intercropping were practiced by 41 % and 51 % of the farmers in this study, respectively. Although such cultural practices can reduce pest and disease damage (Abate *et al.*, 2000), their use in the current study were not primarily for this purpose. Early planting was used to capture high market prices for ware potato at the start of the cropping season. Uprooting of infected plants was mainly used to manage bacterial wilt. Very few farmers (9 % and 12 % in Mubende and Kyegegwa districts, respectively) used no control measures. Physical traps, resistant varieties, or IPM strategies were not mentioned as ways to manage potato insect pests and diseases. The concept of IPM was understood by very few farmers: 9 % in Kabale and Mbale, 15 % in Kisoro and Kapchorwa, and 0 % in Mubende and Kyegegwa districts. The majority of the farmers in this study used pesticides. Similar findings have been reported among cotton farmers in Kenya (Midega *et al.*, 2012) and tomato and cabbage farmers in Zambia (Nyirenda *et al.*, 2011).

3.5 Potato IPM in Uganda

That farmers frequently use insecticides is a good indication that insect pests are causing economic damage in potato, to justify their use of pesticides. Whether this is the definitive reason would need further research to confirm how pesticides are being used, as discussed above. It may be as farmers know so little about pests that they perceive the occurrence of any pest as being damaging. Aphids, for instance, are hardly known to cause direct damage to potato yet are mentioned by farmers as a main target of pesticide applications. Some control measures currently being used by farmers present an opportunity to develop an organised, sustainable, and environmentally friendly IPM package. This should include the use and better promotion of best cultural practices to reduce pest infestation (e.g., crop rotation, intercropping, early planting, hand picking) or the use of botanicals as already practiced by some farmers. Additional control methods of potentially vital importance for IPM approaches in Uganda would include the use of classical biological control for the potato tuber moth and the leafminer fly. Both pests are invasive, having been introduced unintentionally from South America. Several parasitoids have been successfully released in several countries or identified to be used in a classical control approach that could reduce pest abundance and related yield losses in Uganda (Mujica & Kroschel, 2011; Kroschel & Schaub, 2012). Other approaches to be promoted are the use of habitat management to augment natural control, use of biopesticides and biorationals, especially for storage management (Kroschel *et al.*, 2012; Kroschel & Zegarra, 2013), and the use of only moderately to slightly hazardous pesticides when pest incidence has reached the point of causing economic damage.

4 Conclusions and recommendations

Farmers consider insect pests to be the second most important constraint to efficient production of potato in Uganda, with cutworms, aphids, and the potato tuber moth being seen as the most important. Knowledge of local names can improve research scientists and extension workers' understanding of a particular insect pest. This study revealed that farmers have little to moderate knowledge of insect pests, and so underscores the need to train farmers and extension workers in insect pest identification, biology, and control. A more environmentally friendly strategy such as IPM needs to be implemented in Uganda, both to reduce reliance on chemical pesticides as the primary method of pest management and to adapt to increasing pest constraints under a changing climate. The proper use and adoption of an IPM package will require practical training of farmers.

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