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Source: International Journal of Insect Science, 5(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/IJIS.S13456

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International Journal of Insect Science

Pest Status of *Acraea acerata* Hew. and *Cylas* spp. in Sweetpotato (*Ipomoea batatas* (L.) Lam.) and Incidence of Natural Enemies in the Lake Albert Crescent Agro-ecological Zone of Uganda

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ABSTRACT: The present study presents the results of farmers' field surveys of the sweetpotato butterfly, *Acraea acerata* Hew., and the two African sweetpotato weevils, *Cylas puncticollis* Boheman and *C. brunneus* F. infestation and damage. The objectives of this study were to determine (i) occurrence and distribution of *A. acerata* and *Cylas* spp. as well as infestation and losses in sweetpotato (*Ipomoea batatas* (L.) Lam.), and (ii) the occurrence and abundance of parasitoids of *A. acerata* in the Lake Albert Crescent (LAC) agro-ecological zone of Uganda. Field surveys were conducted in 240 sweetpotato fields in eight subcounties in Masindi and Buliisa districts at the end of each of the two cropping seasons of 2012 (March to May and September to November). *A. acerata* and *Cylas* spp. occurred in 17% and 90% of the fields, respectively. *A. acerata* did not occur in two subcounties of Buliisa district. *A. acerata* infestation was low, with up to two and four larvae per plant in the first and second cropping season, respectively, causing minor defoliation of up to 4.1% of the sweetpotato plant. Larvae of *Cylas* spp. caused root yield losses of up to 56.5% and 47.5% in the first and second cropping seasons, respectively. Parasitism rates of *A. acerata* larvae ranged from 0.0% to 15.1% in season 1 and 0.0% to 6.3% in season 2. Out of a total of 1020 larvae collected, 8.43% were found to be parasitized. Parasitoids occurred in 56% of fields infested by its host. *Charops* spp. was the main parasitoid. It was evident that *Cylas* spp. were more prevalent than *A. acerata* in the LAC agro-ecological zone of Uganda. Conservation of *A. acerata* natural enemies may contribute to better management of this pest. Urgent attention for management of *Cylas* spp. is required.

KEYWORDS: Farmers' field infestation, insect pest severity, sweetpotato butterfly, sweetpotato weevil, parasitoids

CITATION: Okonya and Kroschel. Pest Status of *Acraea acerata* Hew. and *Cylas* spp. in Sweetpotato (*Ipomoea batatas* (L.) Lam.) and Incidence of Natural Enemies in the Lake Albert Crescent Agro-ecological Zone of Uganda. *International Journal of Insect Science* 2013:5 41–46 doi:10.4137/IJIS.S13456.

RECEIVED: October 21, 2013. **RESUBMITTED:** November 12, 2013. **ACCEPTED FOR PUBLICATION:** November 18, 2013.

ACADEMIC EDITOR: Helen Hull-Sanders, Editor in Chief

TYPE: Original Research

FUNDING: The German Federal Ministry for Economic Cooperation and Development (BMZ) provided funding under the project *"Predicting climate change induced vulnerability of African agricultural systems to major insect pests through advanced insect phenology modeling, and decision aid development for adaptation planning"*.

COMPETING INTERESTS: Authors disclose no potential conflicts of interest.

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Introduction

Sweetpotato, *Ipomoea batatas* (L.) Lam., is a vitamin A rich staple food crop contributing to household income, food, and nutritional security in Africa.[1] Sweetpotato production, however, continues to be threatened by a complex of biotic constraints, including insect pests, that have led to a decline in crop quality and yields in Africa. The most significant insect pests are the sweetpotato butterfly, *Acraea acerata* Hew., the two African sweetpotato weevils, *Cylas brunneus* F. and *C. puncticollis* Boheman, and the clearwing moth *Synanthedon* species.[2–7]

A. acerata and *Cylas* spp. have been reported in all sweetpotato growing countries in Africa.[5,8,9] *A. acerata* larvae are voracious herbivores, defoliating plants by up to 100%; during outbreaks plants can fail to establish due to severe leaf and vine damage. Additionally, feeding by larvae of *Cylas* spp. on the sweetpotato roots and stems can result into 100% root yield loss, especially during long dry seasons.[2,4,10–13]

Despite the serious threat to sweetpotato production by *A. acerata* and *Cylas* spp., detailed information on their seasonal abundance and distribution in Uganda is limited except for the *A. acerata* parasitoids abundance surveys conducted between 1994 and 1995 by Lugojja.[14] *Charops* sp. was the most abundant of the three parasitoid species (*Meteorus* sp. and *Caricelia normula* Wyatt) collected in Central Uganda. The current study was therefore conducted to determine (i) occurrence and distribution of *A. acerata* and *Cylas* spp. and their damage to sweetpotato and (ii) parasitization of *A. acerata* larvae in the Lake Albert Crescent (LAC) Agro-ecological zone of Uganda. This region was selected for study as it is one of the leading sweetpotato production zones in Uganda, producing over 100,000 tons per year. In addition, the sweetpotato butterfly and the sweetpotato weevils are ranked first and second most important sweetpotato pests, respectively.[7,15]

Information gained in this study can help to understand pest ecology and help to design suitable management options based on pest distribution and severity. It will also guide development of a biocontrol strategy for *A. acerata*. This baseline survey will fill data gaps on pest severity and efficacy of natural enemies in sweetpotato.

Materials and Methods

Survey sites. Masindi and Buliisa districts in the LAC Agro-ecological zone of Uganda were surveyed. The survey area was sub-divided into four sites for sampling. Sampling involved stopping at regular predetermined distances of approximately 1 to 5 km between farmers' fields along major motorable roads traversing each sampling site. Masindi district is located in the mid-west part of Uganda (01°41'N, 31°44'E). The district is generally a plateau land with an altitude range of 1,100 m to 1,510 m above sea level. The district receives an average of 1,360 mm bimodal rainfall annually which allows for two cropping seasons, the first being from March to May and the second from September to November. Seventy three percent of the population in the district is engaged in smallholder agricultural activities. Major crops grown include sweetpotato (*I. batatas*), maize (*Zea mays* ssp. *mays* L.), cassava (*Manihot esculenta* Crantz), sugarcane (*Saccharum officinalis*. L.), and tobacco (*Nicotiana tabacum* L.). Soils are mainly sandy loams. Long-term min and max temperature for the period 1982 to 2011 are 17 to 31°C for Masindi, but are unknown for Buliisa district due to absence of a meteorological station. Buliisa is a district in northwestern Uganda (02°11'N, 31°24'E) and lies on the floor of the Western Rift Valley at an elevation of 600 to 1,030 m above sea level. The district receives low rainfall (<800 mm) and is primarily rural with most people being pastoralists, fishers, or subsistence farmers of mainly cassava, sweetpotato, and cotton (*Gossypium hirsutum* L.). Soils are mainly sandy.

Sampling of *A. acerata* and *Cylas* spp. infestation on sweetpotato. One to two month old sweetpotato fields were surveyed for populations of *A. acerata* while older fields ready for root harvesting (≥3 months after planting) were surveyed for *Cylas* spp. infestations. A total number of 120 fields were surveyed in the two seasons for each pest, each measuring approximately 0.03 to 0.07 ha in February and September 2012. The survey included 99 fields from four subcounties (Miirya, Pakanyi, Nyangahya, and Bwijanga) in Masindi and 141 fields from four subcounties (Biiso, Kihungya, Buliisa and Ngwedo) in Buliisa. A total of 10 plant stands or hills with at least three vines per hill were assessed along two diagonals in each field.

***A. acerata* and *Cylas* spp. infestation.** Sweetpotato field infestation rates by *A. acerata* and *Cylas* spp., densities of and vine defoliation rates by *A. acerata* larvae, vine damage, and root yield loss by *Cylas* spp. were assessed based on the methodology recently reported in Okonya & Kroschel.[16] Destructive sampling was used in the assessment of vine and root damage by *Cylas* spp. The infestation rate of these pests was recorded as the proportion (expressed as a percentage) of farmer fields in which the pests occurred. Since the two African *Cylas* spp. occur together in the field and cause similar damage, this study did not differentiate between the damage caused by *C. puncticollis* and *C. brunneus*.

***A. acerata* larval parasitization.** A total of 1,020 *A. acerata* larvae were collected from the 21 fields infested by the pest (larvae were randomly searched for in the field if none were found on the 10 sample plants) during the survey. *A. acerata* larvae were placed in 15 cm diameter transparent plastic containers with fresh sweetpotato vines as diet and labeled appropriately according to location of origin and date of collection. These larvae were reared on sweetpotato vines in a screen house at the National Crop Resources Research Institute (NaCRRI), Namulonge, Uganda (0°32'N, 32°35'E; altitude 1150 m above sea level), until emergence of larval parasitoids. *A. acerata* larval parasitization by *Charops* sp. or other larval parasitoids was determined by examining the parasitoid cocoons and any emerged adults. Percent larval parasitization of *A. acerata* was determined for each field.

Data analysis. Ranked data were square root transformed, percentage data were arcsine transformed while number counts were log (x + 1) transformed.[17] Differences in vine damage severity due to *Cylas* spp., defoliation due to *A. acerata*, root yield loss due to *Cylas* spp., and *A. acerata* parasitization were analyzed by analysis of variance (ANOVA), using the general linear model (PROC GLM). Mean values were separated using the least significant difference (LSD) test at a significance level of $P < 0.05$. All data were analyzed using the SAS® program (release 9.2 for Windows).[18]

Results and Discussion

***A. acerata* and *Cylas* spp. infestation.** Both *A. acerata* and *Cylas* spp. occurred in the two districts and in both seasons (Table 1). Of the 240 fields sampled (120 for *A. acerata* and 120 *Cylas* spp.), 16.5% were infested with *A. acerata* while

Table 1. Infestation rates of *Acraea acerata* and *Cylas* spp. in sweetpotato crop during 2012.

SURVEY SITE (SUBCOUNTIES)	INFESTATION RATE (%)			
	A. ACERATA		*CYLAS* SPP.	
	SEASON 1: MAR–MAY	SEASON 2: SEP–NOV	SEASON 1: MAR–MAY	SEASON 2: SEP–NOV
Masindi North (Pakanyi + Miirya)	50.00 (8)*	18.75 (16)	100.00 (8)*	92.86 (14)
Masindi South (Bwijanga + Nyangahya)	25.00 (16)	8.33 (12)	87.50 (16)	88.89 (9)
Buliisa upper (Biiso + Kihungya)	41.18 (17)	7.14 (14)	100.00 (17)	94.12 (17)
Buliisa lower (Buliisa + Ngwedo)	0.00 (19)	0.00 (18)	100.00 (19)	65.00 (20)

*Number of fields surveyed.

90% were infested with *Cylas* spp. (Fig. 1). Field infestation was higher in the first cropping season (25% for *A. acerata* and 97% for *Cylas* spp.) than the second cropping season (8% for *A. acerata* and 83% for *Cylas* spp.). This is the first report on farmers' sweetpotato field infestation and yield loss by *A. acerata* and *Cylas* spp. in Masindi and Buliisa districts. Field infestation rates by *A. acerata* recorded in this study compare well to those of 18% reported in Kabale district, although they are relatively low.[16] *A. acerata* does not always occur in sweetpotato fields all year round, or every year, and outbreaks occur once in a while during a prolonged dry season.[8] The percentages of sweetpotato fields infested with *Cylas* spp. in this study were significantly higher than those observed for Kabale district (50%). This could be due to higher temperatures (17 to 31°C) in the LAC Agro-ecological zone as compared to those in the southwestern highlands (11 to 25°C).

Infestation intensity. The average level of *A. acerata* infestation intensity was slightly higher in season 2 (1.16 *A. acerata* larvae per plant) than in season 1 (0.90 *A. acerata* larvae per plant) (Table 2). Although the highest numbers of *A. acerata* larvae per plant (2.03 larvae) occurred in sweetpotato fields of Masindi South during the first cropping season, this was not the case during the second cropping season as the highest *A. acerata* larvae density (4.11 larvae per plant) occurred in sweetpotato fields in Buliisa upper. In both cropping seasons of 2012, no *A. acerata* larvae occurred in the surveyed fields in Buliisa lower. Sweetpotato fields surveyed during the first cropping season experienced higher defoliation rates by *A. acerata* larvae (2.17%) than those surveyed during the second cropping season (0.04%). Masindi North had the highest sweetpotato plant defoliation by *A. acerata* larvae during both the first and the second cropping seasons at 4.06% and 0.16%, respectively. Defoliation levels of this magnitude do not significantly reduce root yield, unlike during outbreaks when plant defoliation levels of over 50% occur. However, quantitative studies on the effect of *A. acerata* defoliation on root yield are lacking. *A. acerata* larvae in Masindi South and Buliisa upper caused no defoliation during the second cropping season as *A. acerata* larvae were too young and still clustered (1st instar) and had barely started to feed. Voracious feeding by *A. acerata* larvae has been observed to start in the solitary 4th instar larvae.[19] The relatively low *A. acerata* densities and very low defoliation rates detected in this study are probably due to the fact that this survey was conducted when there was neither an outbreak of *A. acerata* in Masindi nor Buliisa district. Secondly, there was also no distinct or prolonged dry season, to

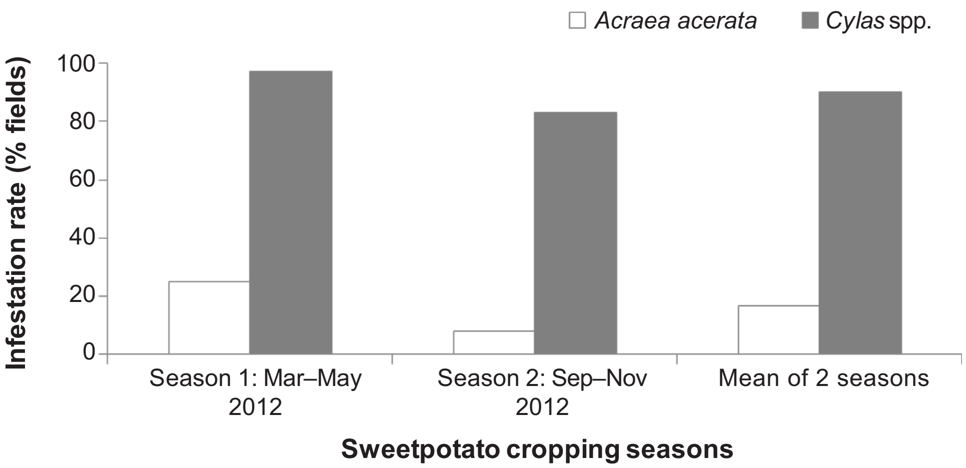

Figure 1. Infestation rate by *Acraea acerata* and *Cylas* spp. in sweetpotato crop in 2012.

Table 2. Infestation intensity and defoliation of *Acraea acerata* in sweetpotato crop in 2012.

SITE (SUBCOUNTIES)	SEASON 1		SEASON 2	
	INFESTATION INTENSITY (LARVAE/PLANT)	DEFOLIATION (%)	INFESTATION INTENSITY (LARVAE/PLANT)	DEFOLIATION (%)
Masindi North (Pakanyi + Miirya), n = 24	0.64 ± 0.30a	4.06 ± 1.56a	0.53 ± 0.51a	0.16 ± 0.16a
Masindi South (Bwijanga + Nyangahya), n = 28	2.03 ± 1.53a	2.50 ± 1.27ab	0.30 ± 0.30a	0.00a
Buliisa upper (Biiso + Kihungya), n = 36	0.98 ± 0.56a	3.38 ± 1.23a	4.11 ± 4.11a	0.00a
Buliisa lower (Buliisa + Ngwedo), n = 31	0.00a	0.00b	0.00a	0.00a
Total mean	0.90 ± 0.44A	2.17 ± 0.55A	1.16 ± 0.97A	0.04 ± 0.04B

Means followed by the same letter within a column (small letter) and within the last row (capital letter) are not significantly different according to the LSD-test at $P < 0.05$.

allow high pest populations to build up in Masindi and Buliisa districts during both cropping seasons of 2012.

***Cylas* spp. infestation intensity.** External vine damage scores by *Cylas* spp. ranged from 1.47 to 1.74 in season 1 and 1.18 to 1.89 in season 2 (Table 3). Similarly, internal vine damage scores by *Cylas* spp. ranged from 1.50 to 1.89 in season 1 and 1.12 to 2.11 in season 2. However, external and internal vine damage scores by *Cylas* spp. did not significantly differ between seasons and were relatively low. Although different sweetpotato varieties were assessed for vine damage in this study, Muyinza et al[12] reported comparable vine damage scores of between 0.9 and 3.3. Root yield loss was higher in the first cropping season (42.80%) than in the second cropping season (26.64%). Buliisa upper had the highest root yield loss during both the first and second cropping seasons at 56.53% and 47.54%, respectively. Root yield losses due to *Cylas* spp. damage reported in this study are lower than those observed in the drought-prone Soroti district (98.0%) but equal to the highest damage levels (55.6%) reported in Serere district.[4,12] Damage by *Cylas* spp. has been shown to increase with reduced rainfall amounts, less number of rainy days, and shorter below ground root storage time.[2] Since early harvesting is the main cultural method used by farmers to avoid *Cylas* spp. root damage in most regions of Uganda (Okonya & Kroschel, unpublished), farmers in Masindi district did not leave sweetpotato in the fields for more than six months after planting, making it impossible to register root infestation levels of near 100% during this survey.

Though not targeted in this study, relatively high infestation rates by the clearwing moth (*Synanthedon* spp.; Lepidoptera: Sesiidae) which occupies the same ecological niche (basal vines) as *Cylas* spp. were observed to occur in approximately 75% of fields in lower Buliisa, causing over 75% of basal stem damage. Therefore, studies on how *Cylas* spp. interact with *Synanthedon* spp. in the field might be of interest. Nderitu et al[6] indicated that *Synanthedon* spp. was an important insect

Table 3. Vine damage and root yield loss by *Cylas* spp. in sweetpotato crop in 2012.

SITE (SUBCOUNTIES)	MEAN ± SE					
	SEASON 1			SEASON 2		
	VINE DAMAGE (SCORE)*		ROOT YIELD LOSS (%)	VINE DAMAGE (SCORE)*		ROOT YIELD LOSS (%)
	EXTERNAL	INTERNAL		EXTERNAL	INTERNAL	
Masindi North (Pakanyi + Miirya), n = 22	1.50 ± 0.19a	1.50 ± 0.19b	43.40 ± 8.71ab	1.64 ± 0.13a	1.93 ± 0.16a	28.70 ± 5.94ab
Masindi South (Bwijanga + Nyangahya) n = 25	1.50 ± 0.13a	1.69 ± 0.12ab	35.81 ± 5.24b	1.89 ± 0.11a	2.11 ± 0.20a	25.12 ± 7.95b
Buliisa upper (Biiso + Kihungya), n = 34	1.47 ± 0.12a	1.59 ± 0.12ab	56.53 ± 4.16a	1.18 ± 0.10b	1.12 ± 0.08b	47.54 ± 5.40a
Buliisa lower (Buliisa + Ngwedo), n = 38	1.74 ± 0.10a	1.89 ± 0.07a	36.13 ± 4.94b	1.65 ± 0.17a	1.70 ± 0.13a	8.12 ± 4.16c
Total mean	1.57 ± 0.06A	1.70 ± 0.06A	42.80 ± 2.85A	1.55 ± 0.08A	1.65 ± 0.08A	26.64 ± 3.36B

*Basal segment vine damage scores: 1 = 0%; 2 = 1–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100%; Means followed by the same letter within a column (small letter) and within a row (capital letter) are not significantly different ($P < 0.05$).

Table 4. Parasitism rates of *Acraea acerata* in sweetpotato crop in 2012.

PARASITOID TAXA	PARASITISM RATE (%)							
	MASINDI NORTH (PAKANYI + MIIRYA), n = 6		MASINDI SOUTH (BWIJANGA + NYANGAHYA), n = 11		BULIISA UPPER (BIISO + KIHUNGYA), n = 4		BULIISA LOWER (BULIISA + NGWEDO), n = 0	
	SEASON							
	I	II	I	II	I	II	I	II
Hymenoptera: Ichneumonidae *Charops* spp.	0.0(0)	6.1 (18)*	11.1 (33)	6.3 (21)	15.1 (11)	0.0 (0)	0.0 (0)	0.0 (0)
Diptera: Tachinidae *Caricelia* spp.	0.0 (0)	0.0 (0)	0.3 (1)	0.0 (0)	1.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)
Diptera (unidentified sp.)	4.8 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Total larvae	21	297	296	333	73	0	0	0

n = number of fields; * = number of parasitoids in parentheses.

pest of sweetpotato in Eastern Kenya. Management of *Synanthedon* spp. in Uganda had been reported to not be necessary, however this was probably because Buliisa district was never surveyed or may have changed due to other factors such as climate change.[11,20]

Parasitism, parasitoid diversity, and distribution. Out of the 21 fields infested with *A. acerata* larvae, 56% of the fields had larvae which were parasitized. All the fields in Buliisa upper had larvae that were parasitized while fields in Buliisa lower had no *A. acerata* larvae and therefore no parasitoids. Eighty six parasitoids emerged out of the 1,020 *A. acerata* larvae (parasitism rate of 8.43%) collected from 15 sweetpotato fields during the two cropping seasons. Three different parasitoid species were recorded in this study, belonging to two orders: Hymenoptera (1 sp.) and Diptera (2 spp.) (Table 4). One of the dipteran parasitoids was not identified. *Charops* spp. (Hymenoptera: Ichneumonidae) was the most dominant parasitoid identified in this survey (96.51%). This species represented 93.62% and 100% of the three parasitoids reared in the first and second cropping seasons, respectively. Larval parasitoid *Charops* sp. was also the most dominant species in Buliisa upper, Masindi North, and Masindi South.

Improper use of broad-spectrum insecticides such as cypermethrin, dimethoate, and permethrin against *A. acerata* (Okonya & Kroschel, unpublished) could be responsible for the low parasitoid diversity and abundance recorded in this study as some farmers practice routine insecticide applications. Low parasitism of *A. acerata* larvae is consistent with the observation of Azerefegne et al[3] in Ethiopia and Lugojja et al[21] in Uganda. Although no mycosis tests were carried out on larvae dead due to fungal infections in this study, Lugojja et al[21] observed the entomopathogenic fungi *Beauveria bassiana* (Bals.-Criv.) Vuill. to be responsible for the death by factors other than parasitism. Also, handling of larvae might have increased larval mortality.

Conclusion and Recommendations

A. acerata and *Cylas* spp. are significant insect pests in Masindi and Buliisa districts. Pest pressure of the previously neglected or underestimated *Synanthedon* spp. is significantly higher in Ngwedo and Buliisa subcounties and requires a detailed study. This information should aid the decision-making process for insect pest management in the two districts and surrounding districts with similar agro-ecologies, such as Hoima, Kiryandongo, Kibaale, Mubende, Kiboga, Bundibugyo, Kyenjojo, Kabarole, and Kamwenge.

Suggestions for an integrated pest management (IPM) strategy aiming at reduction of damage from insect pests include: a) adequate cultural practices and proper sanitation involving removal of any infested crop roots and vines from the field and its surroundings to prevent re-infestation; b) use of healthy planting material; c) regular monitoring of pest populations, for example through the use of pheromone traps for *Cylas* spp. or the occurrence of *A. acerata* larvae on the foliage; d) avoidance of calendar insecticide spraying as this would worsen the situation especially for *A. acerata* as in years without outbreaks, *A. acerata* pest populations and infestation would not require any intervention as shown in this study; e) use of biopesticides such as *Bacillus thuringiensis* sp. *kurstaki* to control larvae of *A. acerata*; and f) as the last option, use of less-toxic insecticides considering all safety measures during application and storage of the insecticide. It would be extremely useful to activate a basic education program on essential elements of IPM, such as increased crop rotation duration of at least 12 months since adult females of *C. puncticollis* can live for up to 309 days (Okonya & Kroschel, unpublished), the basics of insect pest biology, and the use of biological control.

Acknowledgment

The authors wish to thank James DJ Gilbert for comments on the manuscript, Katja Syndikus and Robert OM Mwanga for helpful discussions, Zaamu Ssempa for assistance with laboratory work, and Esther L Nampeera, and agricultural extension workers of the surveyed subcounties for assistance with fieldwork.

Author Contributions

Conceived and designed the survey protocol: JSO, JK. Analyzed the data: JSO. Wrote the first draft of the manuscript: JSO. Contributed to the writing of the manuscript: JSO. Agree with manuscript results and conclusions: JSO, JK. Jointly developed the structure and arguments for the paper: JSO, JK. Made critical revisions and approved final version: JSO, JK. Both authors reviewed and approved of the final manuscript.

DISCLOSURES AND ETHICS

As a requirement of publication the authors have provided signed confirmation of their compliance with ethical and legal obligations including but not limited to compliance with ICMJE authorship and competing interests guidelines, that the article is neither under consideration for publication nor published elsewhere, of their compliance with legal and ethical guidelines concerning human and animal research participants (if applicable), and that permission has been obtained for reproduction of any copyrighted material. This article was subject to blind, independent, expert peer review. The reviewers reported no competing interests.

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