ENTOMOLOGY

Occurrence of the sweet potato hornworm *Agrius convolvuli* (Lepidoptera: Sphingidae) in the Haut-Katanga province, Democratic Republic of the Congo

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Abstract

Agrius convolvuli (Lepidoptera: Sphingidae) is a pest that feeds on young sweet potato leaves causing severe plant defoliation. This study was designed to report for the first time on the occurrence of the pest in the Haut-Katanga province in DR Congo. Survey and observations were conducted during the growing season in ten cities of the Haut Katanga province to detect the presence of *A. convolvuli*. Fifty-two sweet potato fields were inspected during the season. Larvae and pupae were collected in each city and reared in the laboratory at the University of Lubumbashi, DR Congo. Results revealed that the pest occurs in the province with Lubumbashi and Kasumbalesa being the most highly infested with 18.80±11.36 and 18.71±8.13% of infestation, respectively. The highest number of larvae per field and per plant was recorded in Lubumbashi alone with 18.80±8.04 and 3.80±1.48, respectively. Classification of sweet potato leaf damage indicated that Kasumbalesa, Sakania and Lubumbashi had high levels of damage. Positive relationships were observed between infestation rate and number of larvae per field (R^2=0.3069; t=4.705; p<0.0001) but also between infestation rate and number of larvae per plant (R^2=0.4478; t=6.368; p<0.0001). The findings of the current study suggest that *A. convolvuli* could be a potential threat to sweet potato production in the Haut-Katanga province.

Introduction

Sweet potato (*Ipomoea batatas* L.) is an important food security crop and cash crop in tropical and sub-tropical regions where it is mainly grown for both home consumption and to supplement household income (Mutuura *et al.,* 1992; Bashaasha *et al.,* 1995; Capinera, 2001; Stathers *et al.,* 2003; Andrade *et al.,* 2009). It is a dicotyledonous plant that belongs to the bindweed or morning glory family, Convolvulaceae. The crop ranks the seventh most consumed food in the world (CIP, 2010; FAO, 2015). In developing countries, including DR Congo, sweet potato is a major staple crop that offers food security during times of food shortage (Andrade *et al.,* 2009). It is used as a staple food, vegetable (fleshy roots, tender leaves and petioles), snack food, animal feed, for industrial starch extraction and fermentation, and for processed products (Andrade *et al.,* 2009). The leaf contains large amounts of protein, minerals, vitamin B, ß carotene, zinc, lutein and antioxidants (Liu & Regen, 2018).

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Many insect pests attack sweet potato, and their importance varies between agro-ecological regions (Ames *et al.,* 1996; Adhanom *et al.,* 1985; Ferdu *et al.,* 2009). *Agrius convolvuli* (Lepidoptera: Sphingidae), the pink spotted hawkmoth (or sweet-potato hornworm) is a lepidopteran pest that feeds on sweet potato leaves (Ames *et al.,* 1996; Capinera, 2001; Okonya *et al.,* 2014). Sweet potato and morning glory are the main hosts of this species; however, it may feed on some other crops or weeds (Sorensen *et al*., 2003). The Latin name *convolvuli* refers to the genus *Convolvulus*, to which the plants that usually host the larvae of the pest belong. The pest is widely distributed in Africa, Asia, and Europe (Wen, 2004). It is partly a migratory moth, belonging to a family containing 203 genera and 1348 species distributed worldwide (Dai *et al.,* 2016). Damage is mostly caused by the larvae that feed on leaf surface of sweet potato, causing irregular holes. Some other caterpillars start feeding on the leaf edges, and eventually eat the entire leaf leaving only the petiole (Vasquez & Sajise, 1990). In most cases, caterpillars, prefer young succulent leaves, but they will consume all leaves if population numbers are high. Larvae vary in colour from green to brown and are marked with distinct striped patterns (Ames *et al.,* 1996).

Based on a report from smallholder farmers mentioning serious infestations of sweet potato production areas in Haut-Katanga province during January to Mid-May 2020, the Faculty of Agricultural Sciences of the University of Lubumbashi led an investigation in ten different sweet potato production sites in order to identify the insect and the levels of its damage. Thus, the objective of this study was to investigate the distribution of *A. convolvuli* in the main cities of the Haut-Katanga province and to describe its crop damage.

Materials and Methods

Study area

Sweet potato fields were inspected in ten cities in the southern Haut-Katanga province, *i.e.,* Lubumbashi (11.6876°S, 27.5026°E), Kipushi (11.7602°S, 27.2500°E), Likasi (10.9884°S, 26.7379°E), Kambove (10.8779°S, 26.5964°E), Tenke (10.6038°S, 26.1212°E), Kasumbalesa (12.2516°S, 27.8018°E), Kansenya (10.6228°S, 26.7583°E), Mulungwishi (10.7738°S, 26.6347°E), Sakania (12.7496°S, 28.5594°E), and Fungurume (10.6197°S, 26.3190°E) (Figure 1). The province is located in extreme south of the country. It was formed from the Haut-Katanga district and the independently administered cities of Likasi and Lubumbashi. The latter city retained its status as a provincial capital.

Identification of hornworm in sweet potato fields

Larvae with morphological characteristics like *A. convolvuli* were collected from sweet potato fields and identified using published identification guides (Hodges, 1971; Talekar, 1988; Vasquez & Sajise, 1990; Ames *et al.,* 1996; Sorensen *et al.,* 2003; Ekman & Lovatt, 2015). Distinguishing marks of this species include the size of the mature caterpillar with prominent posterior horn (Amalin & Vasquez, 1993; Ames *et al.,* 1996; Sorensen *et al.,* 2003). Although

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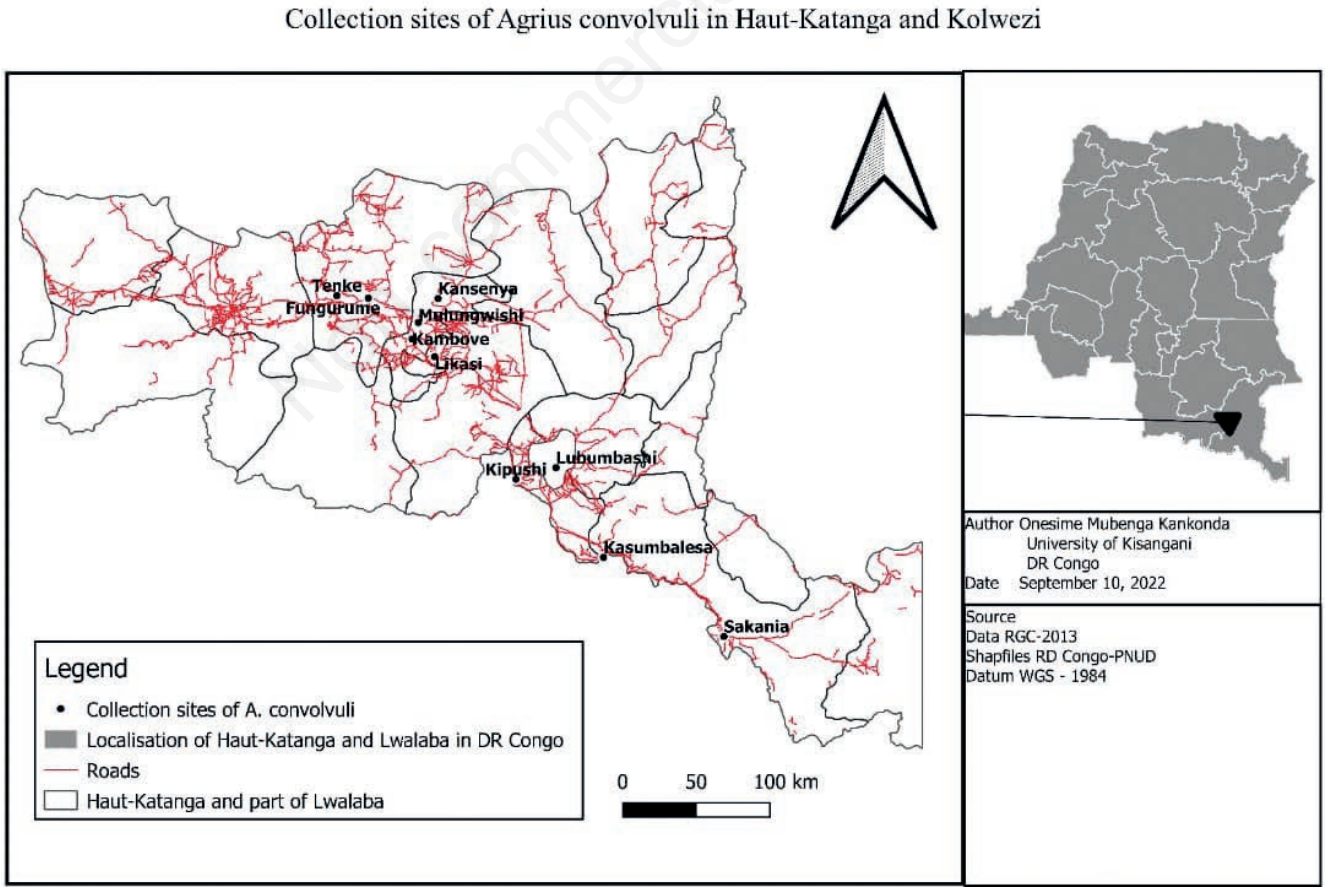

Figure 1. Surveyed sites around Haut-Katanga province.

characteristic marks on the larvae were distinct to the naked eye, a portable magnifying glass (PMS-054 of 6x magnification) was used for better visualization and confirmation of the species, especially of the first and second instars (Amalin & Vasquez, 1993). For identification, collections of larvae and pupae were brought to the crop production laboratory of the University of Lubumbashi (UNILU) and reared at room temperature (25.2 ± 0.3ºC) in plastic vials fitted with metal mosquito netting to ensure air circulation (Kankonda *et al.,* 2014). Larvae were fed with sweet potato leaves. The pupae (collected from both soil and after rearing) were kept in plastic bottles containing moist soil until moth or parasites emergence. The emerging moths were identified according to keys by Ames *et al.* (1996) and Aljaf (2020).

Assessment of hornworm incidence

Surveys were conducted from Mid-January to the end of the May 2020 growing season in ten cities of the province. Five fields measuring about 15×25 m were selected randomly in each city. A total of 52 sweet potato fields were inspected in the province. In each sampled field, four randomly selected quadrats of 5×5 m each were set by the W pattern sampling method (McGrath *et al*., 2018; Cokola *et al*., 2021). Within the quadrat, the total number of plants and that the number of infested plants were recorded, which allowed to determine the infestation rate which is the ratio of the number of attacked plants divided by the total number of plants in the quadrat and multiplied by 100. Leaves showing symptoms of large holes or young leaves with faeces (droppings) of caterpillars were thoroughly checked for the presence of *A. convolvuli* larvae. The number of larvae per plant and the number of larvae in each quadrat were determined by counting. An average of the number of larvae per field was considered based on the larval density in each quadrat. The degree of attack was determined solely in each quadrat from 15 randomly selected plants based on the lesions observed on sweet potato leaves. Visual scoring for damage developed by Stathers *et al.* (2003) was used to get the degree of attack. This scale has ratings from 1 to 5 where 1=0%; 2=1-25% damage, 3= 26-50% damage; 4=51-71% damage and 5=76-100% damage on leaves.

Statistical analysis

All data collected during this study were submitted to Shapiro and Wilk's normality test. In case the data are not normally distributed as it was the case for the infestation rate, the larval density per plant and per field and the degree of attack, a generalized linear model (GLM) with Poisson distribution was applied to compare incidence by cities. The comparison of means was performed by the Tukey Honestly Significant Difference (HSD) test at the 5% significance level. Simple linear regression was applied to test the relationship between infestation rate and *Agrius convolvuli* population density. All these analyses were performed using the XLSTAT 2015 statistical Software.

Results

The pest insect *Agrius convolvuli* and its damage on sweet potato leaves

Agrius convolvuli was found infesting sweet potato in all sampled cities. The last (fifth) larval instar is basically brown with black angled marks down each side with black anal horn. The head is also brown greenish with black stripes on each side. Most of infestations of *A. convolvuli* were observed on tender leaves of sweet potato plants. Larvae at the fifth instar were 10±0.7 cm in length (Figure 2a). The caterpillars feed on the lead blades, causing irregular holes, or may eat the entire blade, leaving only the petiole (Figure 2b). The pupation takes place in the soil at a depth up to 15 cm. The pupa is large (6±0.5 cm), reddish brown mostly characterized by a prominent proboscis, which is curved downward (Figure 2c). Adults are large, gray hawkmoths with black lines on the wings. On the abdomen they are distinctive black, pink and white bands. Wingspan can reach 8-12 cm (Figure 2d).

Agrius convolvuli abundance in sweet potato growers' fields

Results in relation to the infestation rate of *Agrius convolvuli* are presented in Figure 3. The infestation rate of *Agrius convolvuli* varied significantly by site according to the Poisson model (df=9; *LR Chi*^{2}=138.52; p<0.0001). Lubumbashi and Kasumbalesa sites had a high infestation rate compared to the other sites with 18.80±11.36 and 18.71±8.13, respectively. According to the Poisson model, there was no difference between the Lubumbashi and Kasumbalesa sites (*Wald Chi*^{2}=0.001; p=0.973). The lowest value of infestation rate was recorded in Sakania (4.20±0.83). When compared with the Lubumbashi site with regard to infestation rate according to the Poisson model, a significant difference was observed (*Wald Chi*^{2}=38.559; p<0.0001).

Larval density parameters are presented in Figure 4. Larval density is reported both as number of *Agrius convolvuli* per field and per plant depending on the study sites. Significant differences were observed between sites in the number of larvae per field (Figure 4a) (df=9; *LR Chi*^{2}=110.54; p<0.0001). The highest number of larvae per field was recorded in Lubumbashi (18.80±8.04) while the lowest value was observed in Sakania (4.20±1.09). When comparing the site of Lubumbashi with the one of Sakania, a significant difference was observed in the larval density per field (*Wald Chi*^{2}=38.559; p<0.0001).

Regarding the number of larvae per plant, a significant difference was observed between sites (df=9; *LR Chi*^{2}=21.53; p<0.0001). The Lubumbashi site had a high value of larvae per plant, 3.80±1.48. Only one larva per plant was observed at the Mulungwishi and Sakania sites. By comparison with the Poisson model between the Lubumbashi site with a high average number of larvae per plant and the two sites (Mulungwishi and Sakania) with a low average, a significant difference was observed (*Wald Chi*^{2}=5.889; p=0.015 and *Wald Chi*^{2}=7.055; p=0.008 respectively). The sites of Kambove, Kasenga, Kipushi, Mulungwishi and Sakania have the low values of the means, which are not statistically different according to the Tukey HSD test.

The results of *Agrius convolvuli* attack degree in sweet potato fields are shown in Figure 5. Depending on the sites, a significant difference was observed (df=9; *LR Chi*^{2}=27.131; p<0.0001). Higher damage score was observed in Kasumbalesa, Sakania and Lubumbashi with scores 5, 4, 4, respectively. These scores indicate attack levels of *Agrius convolvuli* from 51 to 100% of leaves completely defoliated. Only veins remain on the entire attacked leaf. The lowest score (score 1) was recorded only in the Mulungwishi site with no leaf damage in some investigated fields.

The results on the relationship between infestation rate and population density of *Agrius convolvuli* are presented in Figure 6. The trend lines in Figures 6a and 6b reflect the relationship between infestation rate and the number of *Agrius convolvuli* larvae per field and the number of larvae per plant, respectively. Positive relationships were observed between infestation rate and number of larvae per field (df=51; R^2=0.3069; t=4.705; p<0.0001) but also between infestation rate and number of larvae per plant (df=51; R^2=0.4478; t=6.368; p<0.0001). The results indicate that

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the infestation rate increases with increasing number of larvae per field and per plant.

Discussion

The study revealed for the first time the occurrence of *A. convolvuli* in Haut-Katanga province, DR Congo. The ease of retrieval of its main food, the capacity to adapt to any environment and the very high prolificacy are the winning points of this moth (Amalin & Vasquez, 1993; Ames *et al.,* 1996). *Agrius convolvuli* is extremely sluggish when feeding in the field; moving only enough to reach a new sweetpotato leaf after one has been consumed. The larvae of the pest display armyworm-like habits when feeding on sweet potato leaves. A similar situation was observed in Florida, USA (Sorensen *et al.,* 2003). The study revealed high infestation rate in Kasumbalesa and Lubumbashi indicating the presence of large numbers of *A. convolvuli* larvae eating the entire leaf blade, leaving only the petiole. Besides, in highly infested fields a distinct odour from the frass found near the infested plant part can be perceived (Dietz, 1915). Caterpillars of *A. convolvuli* are distinguished from others lepidopteran species feeding on sweet potato by the size and a major posterior horn (Ames *et al.,* 1996; Sorensen *et al.,* 2003). A large caterpillar can defoliate a plant on its own, and a large population of late instar larvae can defoliate completely a field overnight (Ames *et al.,* 1996). The defoliation causes yield loss depending on the severity of infestation and the plant growth stage in which it occurs (Ames *et al.,* 1996; Sorensen *et al.,* 2003; Ntambo *et al.,* 2015).

The phytophagous larvae are mainly nocturnal and generally eat the younger leaves of the hosts, often stripping growing shoots. If the young plants are healthy and growing well the damage is not too great, because sweet potato plant has remarkable powers to recover from the attack (Ntambo: personal communication with sweet potato growers). However, damage to the leaves delay harvest, increasing the likelihood of attack by the sweet potato weevil, *Cylas* spp (Cock, 2006). The study revealed higher damage score varying between 51 to 100% of leaves completely defoliated in three sites including Kasumbalesa, Sakania and Lubumbashi. In Asia and many African countries sweet potato growers consume the leaves as a vegetable. The leaves contain several nutrients and bioactive compounds, should be consumed as leafy vegetable in an attempt to reduce malnutrition, especially in developing countries (Liu & Regen, 2018). Since sweet potato is grown in DR Congo for its foliage and roots; the presence of leaf feeders such as *A. convolvuli* can represent a threat to food security.

Generally, in the Haut-Katanga province the larvae of the pest

Figure 2. Sweet potato hornworm occurred in the Haut Katanga province. a) Caterpillar, b) Damage of the larvae of sweet potato hornworm, c) Pupa hornworm, d) Adult Hawkmoth of sweet potato hornworm.

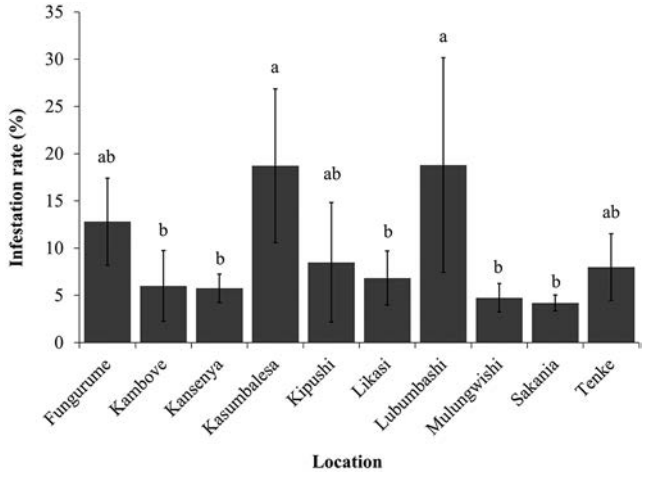

Figure 3. Infestation rate of *Agrius convolvuli* within field in the Haut Katanga. Means ± Standard deviation (SD) sharing similar letters are not significantly different according to HSD test at p=0.05.

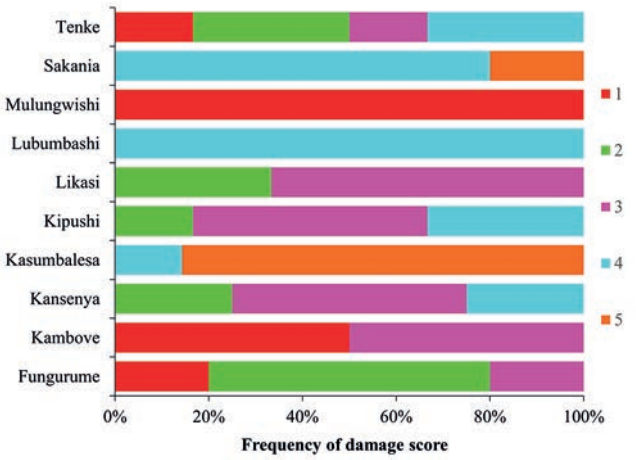

Figure 5. Degree of attack of *Agrius convolvuli* given as scores at the different sites. 1: 0%; 2: 1-25% damage, 3: 26-50% damage; 4: 51-71% damage and 5: 76-100% damage on leaves.

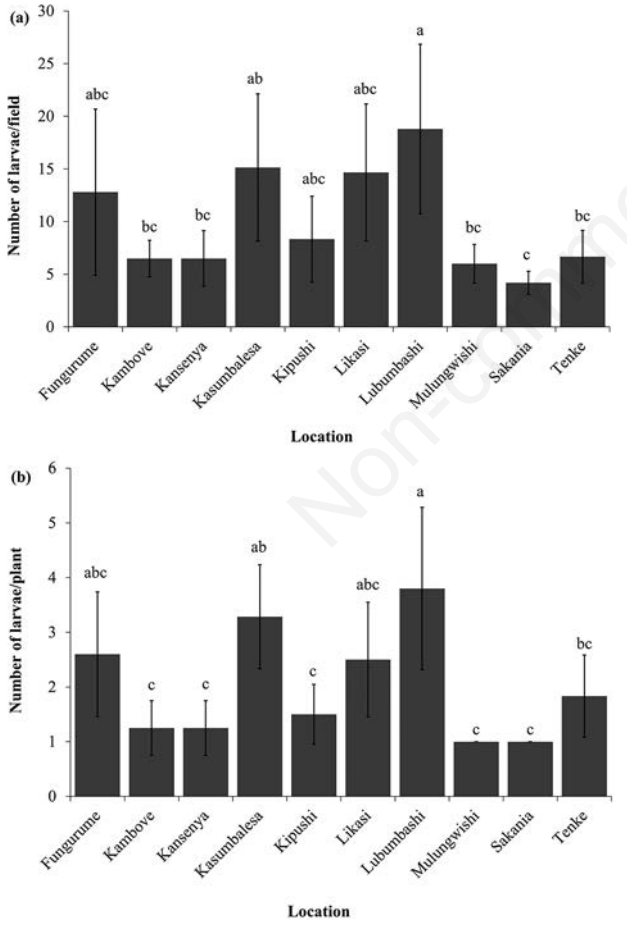

Figure 4. Population density of *Agrius convolvuli* in different sites of the Haut Katanga province. Means ± Standard deviation (SD) sharing similar letters are not significantly different by HSD test at p=0.05. a) variation in larval density per field; b) variation in larval density per plant.

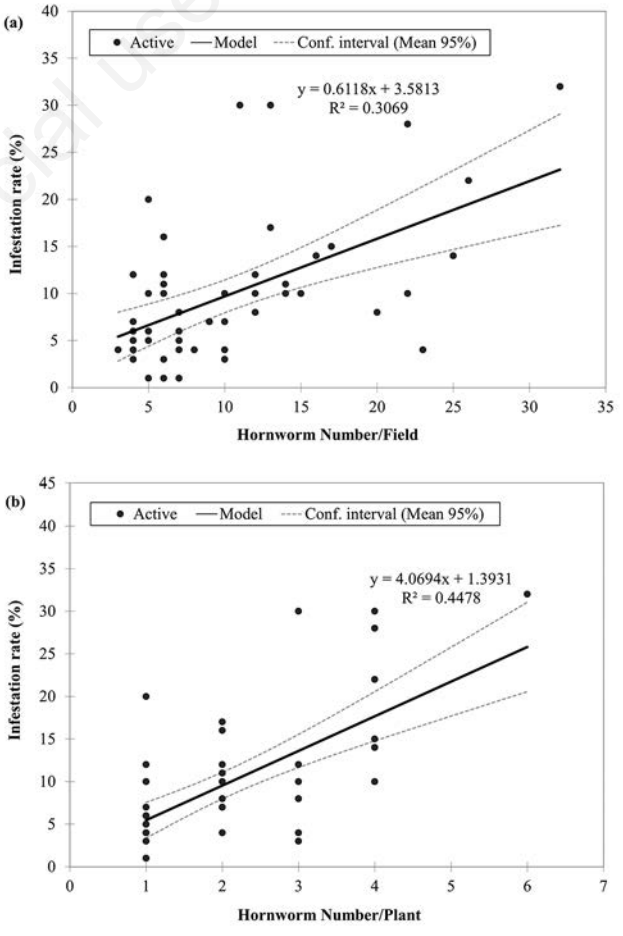

Figure 6. Relationships between infestation rate and population density of *Agrius Convolvuli* evaluated across different sites. Simple linear regression plotted with R2 value and confidence intervals at 5% significance level. a) relationship between infestation rate and number of larvae per field; b) relationship between infestation rate and number of larvae per plant.

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start feeding on sweet potato leaves late in January, reach the peak in mid-February and decline in mid-March. The decline is related to pupation when most of the larvae go under the soil. However, during unfavorable conditions, the larvae often hide under large leaves near the base of the plants (Ames *et al.,* 1996). Besides, the pest occurs occasionally in the province by escaping one growing season and infests the next sweet potato growing season. The occasional appearance of this pest in 2013 and 2020 in the Haut-Katanga province caused severe damages on sweet potato leaves (Ntambo: Personal communication with sweet potato growers). A similar situation was also observed in Uganda in the districts of Gulu and Soroti (IPC, 2010).

In this study we could not measure sweet potato root loss resulting from foliar feeding of the caterpillars during the period of inspection. However, in several reports, small sized roots were harvested in Bangladesh following *A. convolvuli* infestation (Halder *et al.,* 2018). Besides, high defoliation of fields of *Vigna* (*V. radiata* and *V. mungo*) resulted in complete loss of the crop (Dietz, 1915; Aherkar *et al.,* 1993). Within the province, sweet potato growers prevent the build-up of the sweet potato hornworm population by manual removal, while others plow the land between crops to expose the pupae to the heat from the sun and predators (Ames *et al.,* 1996; Sorensen *et al.,* 2003).

Conclusions

This study has reported for the first time the presence of the sweet potato hornworm causing damage in the Haut-Katanga province in the DR of the Congo, Africa. *Agrius convolvuli* is an unknown species in the Haut Katanga province and represents a serious threat to the sweet potato crop. In view of the visible damage on sweet potato leaves, some farmers use pesticides to control the pest. However, this practice is not recommended for this crop since sweet potato leaves are used as vegetable. Also, pesticides affect the action of natural enemies. The presence of this pest on sweet potato represents important information in the development of an integrated management strategy for this pest in the future. It would be important to invest in research to develop additional control measures for this pest. Therefore, training about the biology and ecology of this pest can help farmers to make informed crop management decisions.

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