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Survey of sweetpotato weevils (*Cylas* spp.) and white grub (*Phyllophaga* spp.) in Malawi

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Abstract Sweetpotato weevils (*Cylas* spp.) and white grub (*phyllophaga* spp.) are among the most common and important sweetpotato pests in sub-Saharan Africa. This study presents results of comprehensive national sweetpotato field surveys of the African sweetpotato weevils, *Cylas puncticollis* Boheman and *C. brunneus* F. infestation and damage as well as infestation of *phyllophaga* spp. The pests' surveys were conducted from May to July, 2021 with the aim of determining the infestation, occurrence and distribution of *Cylas* spp. and *phyllophaga* spp. in Malawi. A total of 187 sweetpotato fields in twelve districts were sampled. Sweetpotato field infestation rates and root yield loss were assessed. Outside weevil damage (OWD) and inside weevil damage (IWD) were assessed and their intensity of infestation compared. There were significant variations in weevil damage among the sampled districts with Salima having the highest occurrence of OWD *(OR = 37.61, P = <0.001, Df = 11)*. There were also significant differences OWD among sweetpotato varieties (P value please). Among improved varieties, Zondeni was the variety that was heavily infested while Mugamba was the least infested variety. Analysis of deviance showed that there were significant differences *(p <0.001)* in the way weevil damaged sweetpotato, with OWD being more severe than IWD. The survey has documented continuous threat that *Cylas* spp. has on sustainable sweetpotato production in Malawi. The information generated is key in determinationof pest management strategies in the country.

Keywords: *Sweetpotato, infestation, Sweetpotato weevil, pest, epidemiology*

Introduction

Sweetpotato (*Ipomoea batatas* L.) is one of the most widely grown root crops and an important economic crop in many countries with a production of more than 133 million tonnes worldwide (FAO, 2016). In terms of annual production, sweetpotato ranks as the fifth most important food crop in the tropics and the seventh in the world food production after wheat, rice, maize, potato, barley, and cassava (FAO, 2016; Mukhopadhyay et al., 2011). It is an important food and vegetable crop in most developing countries where it fulfils a number of basic roles in the global food system, all of which have fundamental implications for meeting food requirements, reducing poverty, and increasing food security (Amagloh et al., 2021; Low et al., 2017, 2020; Low & Thiele, 2020; Tumwegamire et al., 2014). In sub-Saharan Africa (SSA), it is grown on about 2.1 million ha, providing 9.9 million tons of storage root (Placeholder1). In Malawi, sweetpotato comes second after cassava as a food security root crop and is more widely grown in the country (Chipungu et al., 2012).

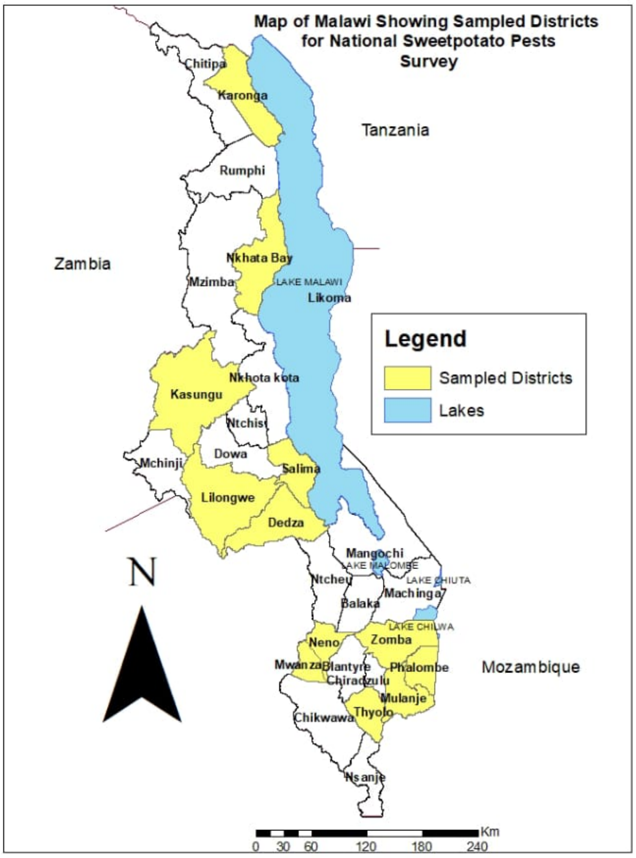
Production of sweetpotato is hindered among others by the existence of abiotic and biotic factors (Fite et al., 2014; Gurr et al., 2021; Okonya et al., 2014). Sweetpotato weevil (*Cylas* spp.) is known as the biggest pit fall for production and productivity of the crop in Sub-Saharan Africa (SSA). Various species of sweetpotato weevils are found in almost all sweetpotato-growing regions of the world (Kagimbo et al., 2018; Stathers et al., 2003; Sutherland, 1986; Thompson et al., 2019). One species, *Cylas formicarius* commonly called 'sweet potato weevil' and internationally called 'sweet potato root borer' mainly attacks sweetpotatoes (Invasive Species Compendium, CAB International, www.cabi.org/isc). There are various other sweetpotato species (Kyereko et al. 2019) that attack other crops such as okro, coffee, sesame, cowpea, and maize (Biovision foundation, Infonet, http://www.infonet-biovision.org/node/28501). In addition to damage caused directly by tunneling, larvae also cause indirect damage by facilitating entry of soil-borne pathogens (Sanderson, 1902), which renders the product unsuitable for consumption (Azerefegne & Solbreck, 2010; Ebregt et al., 2005). Losses can be severe both in storage facilities and in the field, where yield losses due to *C. formicarius* may range from 60 to 97% (Reddy et al., 2012). Sweetpotato white grub (*phyllophaga* spp.) are also a big problem in sweetpotato production systems (Chilipa et al., 2021; Paik et al., 2007). The pest has been associated with tuber damages of up to 80% (Paik et al., 2007). Despite the serious threat to sweetpotato production by *Cylas* spp. and *phyllophaga* spp., detailed information on their abundance and infestation is not largely documented for Malawi. The current study was designed to determine occurrence and distribution of *Cylas* spp. and *phyllophaga* spp. as well as infestation and losses they cause in sweetpotato in the country. This information is key as it lays a foundation in understanding pest ecology, thus will be novel in determination of suitable control management strategies which will be based on pest distribution and severity.

Materials and methods

Survey sites and protocol

The surveys were conducted between May and July in 2021 in twelve districts that represent the most important sweetpotato-growing areas of the country, viz., Dedza, Karonga, Kasungu, Lilongwe, Mulanje, Mwanza, NKhatabay, Neno, Phalombe, Salima, Thyolo, and Zomba (Figure 1). The first field in each district was sampled randomly while consecutive fields were sampled within 5 km interval along motorable roads traversing each district depending on the availability of sweetpotato fields as described previously (Mbewe et al., 2021). Sweetpotato fields ready for root harvesting (≥ 3 months after planting) were targeted as these are ideal for weevil surveys (Okonya & Kroschel, 2013).

Figure 1: Map of Malawi showing districts where the study was conducted.



Sweetpotato field infestation rates and root yield loss by *Cylas* spp. were assessed based on the methodology recently reported in Okonya & Kroschel (2013). Destructive sampling was used in the assessment of root damage by the pests. 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.*

Sampling domain, data collection and analysis

In each sampled field, twenty sweetpotato plants were randomly selected along two diagonal transects across each field. The tubers were visually inspected and scored for external physical weevil damage (here-in defined as outside weevil damage (OWD)) using a scale of 1 to 5, as where 1 represented 0 % weevil damaged and 5 represented 76 – 100% weevil damage as described previously (Stathers et al., 2003). Thereafter, each tuber was cut open to reveal internal physical weevil damage (inside weevil damage (IWD) which was also assessed using the same scale as OWD. In total, 3760 sweetpotato tubers were assessed for weevil damage.

In the process of analysis, it was observed that some of the clones were sampled only once, in order to avoid bias, all the clones that were sampled only once were ignored during the analysis. This resulted on working with data of 3558 sweetpotato tubers of 67 clones. Of the remaining filtered data, Thyolo provided the highest number of sweetpotato sampled (944 tubers) in a district while Kenya variety was among the most sampled variety across the country and was used as baseline data.

For OWD, generalized linear model (logistic regression) fitting the quasibinomial family was used for analysis. Prior to logistic regression OWD data were transformed to fit binary range of 0 – 1. Transformation involved taking each score (1 – 5) subtracting each score by one and then dividing the outcome by four. This led into change of score of one which denotes for clean (free) to zero, whereas five that represents most severe score to one as shown below.

$$\text{TransformedScore} = \frac{(\text{out} - \text{inside sweetpotato weevil damage} - 1)}{4}$$

Logistic regression was also done on sweetpotato *phyllophaga* spp. score fitting binomial family without transformation, as its data was already in binary 0's which denotes absence and 1's for presence of white-grab. The model residuals were standardized in order to test for possible outliers and influential cases, which were assessed using Cook's distance and Hat values (leverage) (Cook, 1977; Li & Valliant, 2009) which showed that there was no major influence on the bias of the model. Significant estimate (coefficient) of Logistic regression were changed to odds ratios (OR).

Results

Sweetpotato weevil damage

The study revealed occurrence and distribution of *Cylas* spp. across all sampled districts. Sweetpotatoes were infested with weevils both outside (OWD) and inside (IWD) (Figure 2). The damage was higher in outside than inside (*p <0.001*). Analysis of deviance showed that there were significant differences between OWD and IWD *(p <0.001)* in the way weevil damaged sweetpotato. Sweetpotato tubers were heavily damaged outside than inside *(p <0.001).*

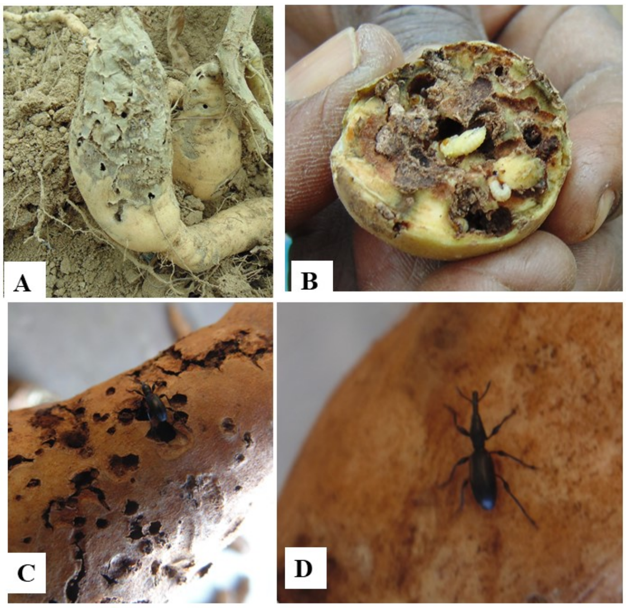


Figure 2: A). Outside sweetpotato weevil damage, B). Inside sweetpotato weevil damage, C & D). Sweetpotato weevil (Courtesy W. Mbewe).

(a). Outside weevil damage

Among districts, Salima had the highest occurrence of OWD ($p < 0.001$), followed by Kasungu ($p < 0.001$), Lilongwe ($p < 0.001$), Neno ($p < 0.001$), Zomba ($p < 0.001$) and Nkhata-Bay ($p = 0.004$). On the other hand, there were no significant differences in the occurrence of OWD to Thyolo (baseline), among the districts; Mulanje ($p = 0.93$), Dedza ($p = 0.22$), Karonga ($p = 0.22$), Phalombe ($p = 0.86$) and Mwanza ($p = 0.98$). The study documented significant differences in occurrence of OWD among the sampled varieties and tests clones. It was observed that clone BV12/114 had the highest likelihood of being attacked by *Cylas* spp (Table 1). Among improved varieties, Zondeni was the variety that was heavily damaged (Table 1). Some varieties were least damaged by *Cylas* spp. as compared to Kenya (baseline). These include; Mugamba ($p < 0.001$), unknown local ($p = 0.006$), and test clone BV12/88 ($p = 0.02$) (Table 1). It was also observed that outside sweetpotato weevil damage among other varieties was not significantly different (Table 1).

Table 1: Outside sweetpotato weevil (OWD) damage among the most sampled varieties

Variety	Flesh colour	Odds Ratios	95 % CI	*P-values*
Improved varieties				
Mugamba	Yellow	0.49	0.32 – 0.72	***<0.001***
Kaphulira	Orange	0.82	0.59 – 1.13	0.226
Kadyaubwerere	Orange	2.49	1.27 – 4.67	***0.006***
Semusa	White	0.57	0.24 – 1.18	0.165
Zondeni	Orange	3.85	1.66 – 8.37	***0.001***
Unimproved varieties (local)				
Unknown	White	0.50	0.30 – 0.81	***0.006***
Chikhomeni	White	0.19	0.04 – 0.61	***0.016***
Makwawa	White	0.00	0.00 – 0.00	0.992
Makanjira	White	0.00	0.00 – 0.00	0.992
Kasanza	Orange	0.00	0.59 – 1.13	0.990
Test clones				
BV12/15B	White	0.48	0.26 – 0.83	***0.013***
Sumaia	Orange	0.38	0.18 – 0.72	***0.005***
Victoria	Orange	0.52	0.27 – 0.94	***0.036***

BV12/114	White	18.85	8.79 – 39.14	***<0.001***
BV12/88	White purple	0.34	0.17 – 0.64	***0.002***

R^2measures Hosmer and lemmeshow (R_L^2) = 0.50, Cox and Snell = 0.15, Nagelkerke = 0.54

There was variation in susceptibility of sweetpotato weevil damage among sampled districts as evidenced in Figure 3 below.

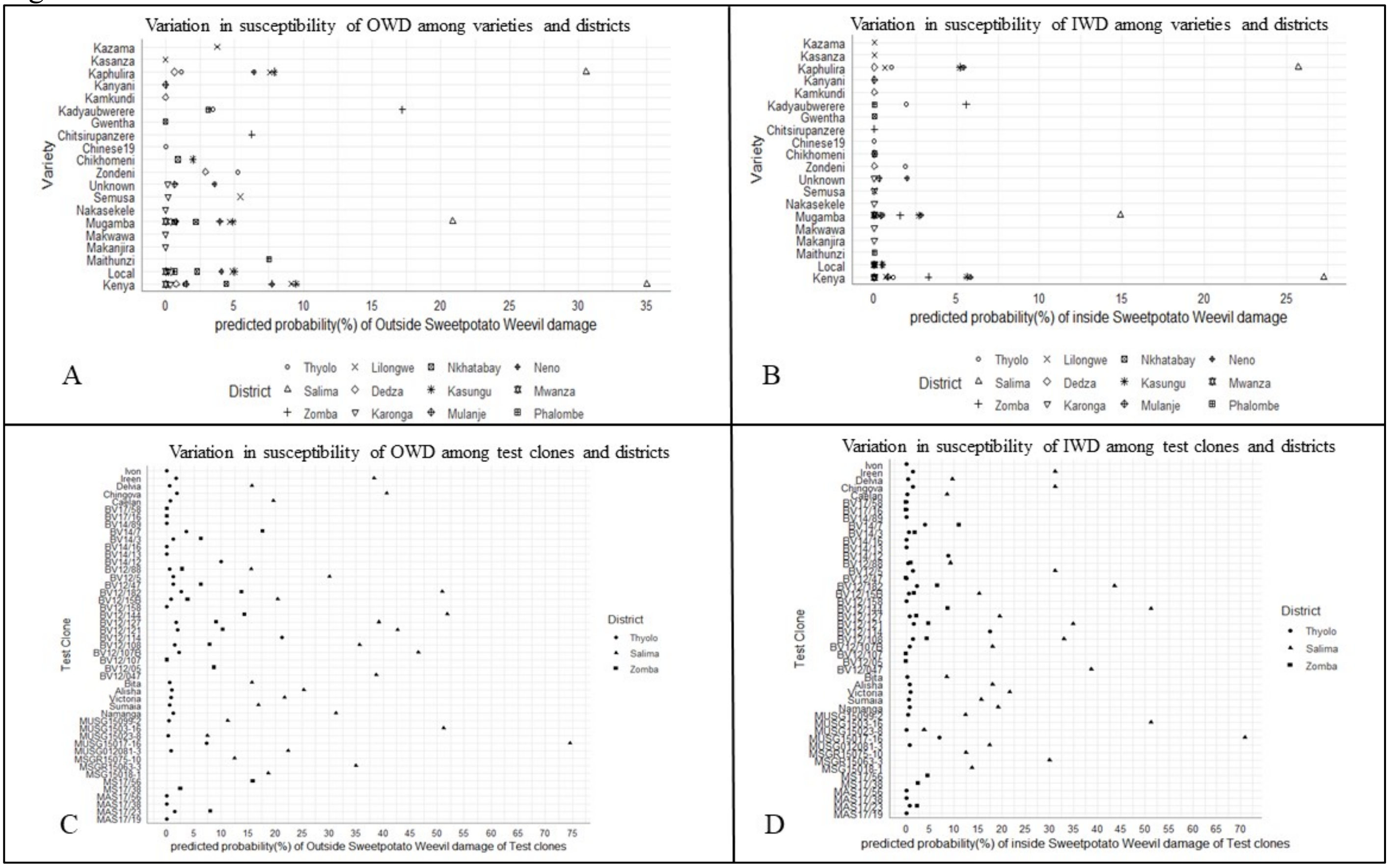


Figure 3. Variation in susceptibility of sweetpotato weevil damage among sampled districts. Figures A (top left) and B (top right) are for IWD and OWD versus varieties sampled, while Figures C (bottom left) and D (bottom right) are for OWD and IWD versus tests clones.

(b). Inside sweetpotato weevil damage (IWD)

The results showed significant differences ($p < 0.001$) in IWD by *Cylas* spp. There was significantly higher occurrence of IWD in Salima ($p < 0.001$), followed by Neno ($p < 0.001$), Kasungu ($p < 0.001$) and Zomba ($p < 0.001$). It was also observed that IWD did not differ significantly between Thyolo (baseline) and remaining districts (Lilongwe, Dedza, Karonga, Nkhata-Bay, Mulanje, Mwanza and Phalombe).

Table 2: Inside sweetpotato weevil damage among the most sampled varieties

Variety	**Fresh colour**	**Odds Ratios**	**95 % CI**	***P-values***
Improved Varieties				
Mugamba	Pale yellow	0.47	0.28 – 0.76	***0.003***
Kaphulira	Orange	0.92	0.62 – 1.36	0.687
Kadyaubwerere	Orange	1.74	0.61 – 4.14	0.250

Semusa	White	0.00	0.00 – 0.00	0.992
Zondeni	Orange	1.69	0.36 – 5.27	0.427
Unimproved varieties				
Unknown	White	0.08	0.01 – 0.28	***0.001***
Chikhomeni	White	0.00	0.00 – 0.00	0.992
Makwawa	White	0.21	0.00 – 35.00	1.000
Makanjira	White	0.21	0.00 – 80.00	0.992
Kasanza	Orange	0.00	0.00 – 0.00	0.996
Test clones				
BV12/15B	White	0.48	0.25 – 0.88	***0.024***
Sumaia	Orange	0.50	0.25 – 0.93	***0.037***
Victoria	Orange	0.74	0.40 – 1.30	0.313
BV12/114	White	18.72	8.42 – 40.49	***<0.001***
BV12/88	White purple	0.27	0.11 – 0.56	***0.001***

R^2measures Hosmer and Lemmeshow (R_L^2) = 0.59, Cox and Snell = 0.15, Nagelkerke = 0.62

Among varieties, BV12/114 (Test clone) had highest likelihood of IWD (*OR = 18.72, p < 0.001)* and was significantly different to Kenya (baseline). On the other angle it was observed that some of varieties, like Mugamba (*p = 0.003*)*,* Local (*p = 0.001)* and BV12/88 (*p = 0.001)* had the lowest likelihood of IWD as compared to Kenya (baseline) (Table 2). There were also
no significant differences among of most the varieties to inside sweetpotato weevil damage.

White grub (Phyllophaga* spp*)

There was significant improvement on the model fitting district and variety on trying to explain difference in occurrence of white-grab on sweetpotato *(p <0.001*). Among the district, sweetpotato that was sampled in Zomba registered highest white-grab occurrence (*OR = 2.84 p < 0.001)* and was significantly different to Thyolo (baseline). At the same time, it was also observed that sweetpotato sampled from Salima (*OR = 0.10, p < 0.001)*, Lilongwe (*OR = 0.39 p < 0.001*), Dedza (*OR = 0.12, p < 0.001)* and Mwanza (*OR = 0.18, p value = 0.001*) registered the least white-grub incidences and were significantly different to Sweetpotato that were sampled from Thyolo (baseline). There was no defined significant deference to white-grab on the samples that were sampled in Karonga, Nkhata-Bay, Kasungu, Mulanje, Neno and Phalombe to that of Thyolo (baseline).

Table 3: Sweetpotato damage to white-grab among most sampled varieties

Variety	**Fresh colour**	**Odds Ratios**	**95 % CI**	***P-values***
Improved varieties				
Mugamba	Pale yellow	0.42	0.26 – 0.66	***<0.001***

Kaphulira	Orange	0.78	0.44 – 1.38	0.398
Kadyaubwerere	Orange	0.84	0.42 – 1.68	0.627
Semusa	White	0.00	0.00 - ∞	0.988
Zondeni	Orange	0.46	0.29 – 1.41	0.269
Unimproved (local) varieties				
Unknown	Pale yellow	0.30	0.14 – 0.62	***0.001***
Chikhomeni	White	0.54	0.00 - ∞	1.000
Makwawa	White	0.32	0.00 - ∞	1.000
Makanjira	White	0.32	0.00 - ∞	1.000
Kasanza	Orange	0.00	0.00 - ∞	0.994
Test clones				
BV12/15B	White	3.50	1.68 – 7.29	***0.001***
Sumaia	Orange	0.45	0.14 – 1.41	0.170
Victoria	Orange	0.10	0.01 – 0.75	***0.026***
BV12/114	White	0.36	0.10 – 1.32	0.125
BV12/88	White purple	0.97	0.43 – 2.18	0.938

R^2measures Hosmer and Lemmeshow (R_L^2) = 0.32, Cox and Snell = 0.24, Nagelkerke = 0.41

Alisha (test clone) recorded the highest log-likelihood (*OR = 13.24, p < 0.001)* followed by other test clones like MUSG1503-16 (*OR = 11.42, p < 0.001)*, MUSG012081-3 (*OR = 7.48, p <0.001)*, BV12/15B (*OR = 3.5, p = 0.001)* were significantly different to Kenya. On the other hand, some of the improved varieties like Mugamba (*OR = 0.42, p < 0.001)*, unimproved local varieties (*OR = 0.3, p = 0.001)* and test clones like Victoria (*OR = 0.10, p = 0.026*) registered the least white grub attack. However, there were no significant differences in white grub attack to Kenya (baseline) and some other sweetpotato varieties like Kaphulira and Kadyaubwere (improved), Kasanza and Makanjira (local) and Sumaia and BV12/114 (test clones).

Discussions

Our current field study has revealed significant infestation of *Cylas* spp. and *phyllophaga* spp in Malawi. However, it is not surprising to see variations in infestation of pest damage among the sampled districts. Studies elsewhere have shown that sweetpotato weevil infestation has a strong relationship with geographical location. Reports have concluded that higher temperature may increase the growth rate of insect's population as well as the risk and severity of the outbreaks (Gomi et al., 2007; Ladányi & Hufnagel, 2006). Thus, it is therefore not surprising to see Salima, a district with fairly higher temperatures, having high pests' infestations among all the sampled districts.

Variations in pests' infestations among varieties is also not surprising. Different varieties react differently to weevil attack. The variation in level of infestation in different sweetpotato genotypes was previously reported to be related to the concentration of kairomones in the periderm of the tubers. Kairomones are compounds produced by one organism and sensed by and beneficial to another organism. For example, boehmeryl acetate, a kairomone identified in sweetpotato tubers surface, acts as an ovipositional stimulant for female weevils (Son et al., 2019). Earlier studies discovered triterpenol acetate on the root surface of the genotype "Centennial" which has shown similar function to other kairomones (Nottingham et al., 1989). This suggests that selection of sweetpotato genotypes with increased deterrents or decreased concentration of kairomones such as boehmeryl acetate and triterpenol acetate may significantly facilitate sweetpotato resistance to weevils (Korada et al., 2012; Praveen Rao, 2018).

Variations in infestations of pests among different genotypes could also be explained based on root morphology and structure. Studies elsewhere reported that deep-rooting and early maturing varieties (90 to 120 days) are about four times less susceptible to infestation than shallow-rooting and late maturing varieties (180 days or more). As a result, both deep storage roots and early maturing varieties tend to reduce the severity of weevil damage (Hue & Low, 2015). More than 95% of oviposition by female weevils happens in the first 35 cm of vines and planting of infested cuttings is one of the ways of distributing sweet potato weevils (WT et al., 2019).

Thus, weevil infestation can be reduced by proper planning of planting and harvesting time as well as the planting location. Generally, sweetpotato weevil relies strongly on cracks in dry soil to reach the storage roots, as they cannot tunnel into the soil but rely on the cracked or dry soil that allows the insect pest reach the fully grown tubers (Hue & Low, 2015). Hence, weevils cannot reach roots which are well buried under the soil. The enlargement of roots near the soil surface and the stress from soil moisture can increase the chances of producing cracks and exposure of roots to the weevils. This is why one of the best control measures for weevil damage is cultivation in wet season as the absence of cracks hinders weevils from accessing the roots (Korada et al., 2012; Thompson et al., 2019). It should also be noted that nutritional quality, the physical attributes of sweetpotato, including its flesh colour, neck length, shape, thickness, and skin colour, influence the infestation by sweetpotato weevils. Earlier studies also suggested that root size, shape, hardness and arrangement may play an important role in affecting *Cylas* spp (Stathers et al., 2003).

Conclusions

Cylas spp. and *phyllophaga* spp. are significant insect pests in Malawi. This information should aid the decision-making process for insect pest management in the country. 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 especially in research stations. 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 (Korada et al., 2010; Okonya & Kroschel, 2013), the basics of insect pest biology, and the use of biological control.

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