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RESEARCH PAPER

Incidence, spatial distribution and damage severity by the sweet potato weevils in sweet potato producing areas of Central Tanzania

Lucas P. Mkuki[1, 2] and Gration M. Rwegasira[1]*

[1]Department of Crop Science and Horticulture, Sokoine University of Agriculture, P.O. Box 3005, Morogoro, Tanzania
[2]Department of Economics and Production, Singida Regional Secretariat P.O. Box 5, Singida, Tanzania

***Corresponding author:** Gration M. Rwegasira (grwegasira@sua.ac.tz)

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Key Message: This study evaluates the pest status and distribution of weevils in Gairo and Ikungi districts of central Tanzania. It reports that the average field incidence of the pest was higher in Gairo (68%) than that of Ikungi (5%).

Abstract: Sweet potato (*Ipomoea batatas* (L.) Lam) is an important staple food and commercial crop in central Tanzania and most of the tropical countries. The on-farm crop productivity in the country is low estimated at 9.5 t ha^{-1}. Of this, the proportion of marketable yield is even lower due to substantial damages inflicted by the sweet potato weevils, the *Cylas spp*. A study was conducted to establish the pest status and distribution of weevils in Gairo and Ikungi districts of central Tanzania. A diagnostic survey covered a total of 600 farmers' randomly selected in 20 villages through interviews and the actual assessment of their fields. In each sweet potato field, a 600 m^2 area was marked with pegs for data collection. Results revealed that 80% of the fields were infested with weevils albeit at varied incidences and severities. The average field incidence of the pest was higher in Gairo (68%) than that of Ikungi (5%). Ranking of sampled roots based on the damage severity scale suggested more severely damaged roots (index 5) in Gairo than that of Ikungi district (with index 3). Despite the remarkable presence of the pest and substantial losses inflicted, limited attention is paid to the pest by the farmers. The pest abundance data was used to establish pest distribution maps in the study area that would guide focused management strategies. Extensive education on the pest identification and management strategies is paramount to minimize the ever increasing losses inflicted by weevils.

Keywords: *Cylas spp*, Economic loss, Weevil incidence, Yield

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Introduction

Sweet potatoes are grown for food and feed in many developing countries (Low et al., 2009). It is an important food security crop, often crucial during famine periods because of its excellent drought tolerance and rapid production of storage roots (Mukhopadhyay et al., 2011). In East Africa, the sweet potato plays an important role in the diet and food security of the population as indicated by high per capita consumption (Mwanga, 2001). The crop production is often considered as a means for generating income among the poorer segments of the rural population (Low et al., 2009). The average on-farm sweet potato fresh root yield in Tanzania is only 9.5 t ha^{-1} (FAOSTAT, 2015; RAC, 2012). This yield is very low compared to the yield potential of 20–50 t ha^{-1} attainable on research experiments (Benjamin et al., 2014). Low productivity arises from several biotic, abiotic and socio-economic constraints. Sweet potato weevils, elegant grasshoppers, white grubs, stem borer and sweet potato leaf beetles have been found to cause damage to sweet potato storage roots and leaves (Stathers et al., 2005; Gajanayake et al., 2015). Several other constraints such as traditional potato production systems, shortage of clean planting materials of improved varieties, limited knowledge on postharvest handling of the produce, and poor technology transfer systems also hinder the crop productivity worldwide (Gebru et al., 2017). Among the insects, particularly, the sweet potato weevil (*Cylas puncticollis* and *Cylas brunneus*) is a priority problem. Poor yielding varieties of low nutritive value (low or no ß-carotene), shortage of high quality planting materials, marketing problems (Mwanga, 2001), as well as limited range of processing and utilization options leading to high postharvest losses estimated between 30-35% (Woolfe, 1992), are also important constraints to the crop.

The sweet potato weevils have been implicated to largely cause poor quality of roots (Kapinga et al., 1995; RAC, 2012), particularly in Central Tanzania where intermittent drought during crop growth is a common scenario. More specifically, *C. puncticollis* has been recorded to be the most prevalent species in Central Tanzania. Weevil damage to roots is reported to be high even at low levels of infestation, and can significantly reduce root quality rendering them non-marketable. Weevil damage results mainly from their larvae

(Mansaray et al., 2013) which feed within tuberous roots. Among the sweet potato weevils, *Cylas spp.* is one of the most destructive species worldwide (Sefasi et al., 2012). Its presence even in small numbers is viewed as economically important and warrants intensive management (Rees et al., 2001). Damage caused by the weevil on the vines occurs due to the behavior of the adult female weevils to lay eggs on the crown after which the hatched larva feeds on the vines causing tunnels or holes. Furthermore, in response to the weevil feeding, larval tunneling storage roots produce trepan which imparts a bitter taste and makes the sweet potato roots unsuitable for human consumption (Sefasi et al., 2012; Kibrom et al., 2015). Feeding inside the vines causes malformation, thickening and cracking of the vine (Reddy et al., 2012). According to Mansaray et al. (2013), plants may wilt or even die because of extensive stem damage, and damage to the vascular system can reduce the size and number of storage roots. According to Emana (1990) the infestation may increase from 29 to 68 % when harvesting is delayed from five to six months. Moreover, growing sweet potato on the same plot of land for four consecutive years can result in over 70 % infestation and where rotation of crops is practiced less than 20 % infestation can occur (Emana, 1990). Yield loss is high towards the dry season due to low soil moisture, low biomass yield and high soil cracks (Shonga et al., 2013). Yield losses caused by weevils have been estimated to range from 15% to 73% in Tanzania and Uganda (Kapinga et al., 1997; Smit, 1997; Shonga et al., 2013).

The weevils are generally nocturnal, but may also fly in response to a pheromone source (Reddy et al., 2012) and be found on Ipomoea plants during daytime. Adult weevils fly freely during the warm part of the year and are capable of ranging at least 1.6 kilometer per season (Gajanayake et al., 2015). Jansson et al. (1990) reported that approximately 80-90% of the weevil population is below the soil surface. Thus, it is difficult to determine infestation levels or root damage without uprooting the plant. The severity of infestations can only be accurately determined by digging up and dissecting the storage roots (Munyiza et al., 2007). This is not only a difficult process, but it also destroys a portion of the crop. Available literature indicates that distribution and incidences of weevils varies between regions worldwide (Wolfe, 1991). Reports on the abundance and distribution of sweet potato weevils in Central Tanzania are scarce and inconsistent. Lack of reliable information on the pests grossly affects development of its management strategy for ultimate improvement of the crop yield at farmers' level. The specific objectives of this study were; 1) to determine the sweet potato weevils' incidences farmers' fields in Central Tanzania, 2) to establish the temporal distribution of sweet potato weevils across the two districts that commercially grow sweet potato, and 3) to determine the damage severities inflicted by sweet potato weevils on grown sweet potato crops. Obtained results were presented in the form of graphs and maps for ease of interpretation and uses. The study findings in the current study will create a basis for management of sweet potato weevils to improve production and quality of sweet potato roots in Central Tanzania.

Materials and Methods

Identification of the study area

The research team travelled to Morogoro and Singida Regional administrative offices (Regional secretariat) to familiarize themselves with the sweet potato crop production and distribution of the crop in the regions. Morogoro, Dodoma and Singida are three main regions that form the central Tanzania zone but sweet potato is not a priority crop in Dodoma hence the region was not considered in the current study. The discussion held between the research team and Regional Agricultural Advisors in each region led to the detailed mapping of the crop production and identification of the key districts where the study should be prioritized. Selection criteria were; sweet potato being a the mostly grown in terms of land area, the crop being either staple or cash crop, the crop being produced by both male and female farmers, area having being reported to be affected by sweet potato weevils and readiness of farmers to participate in the study. Based on the criteria, Gairo district was selected to represent Morogoro region and Ikungi district selected to represent Singida Region.

Pre testing the interview questions

A checklist of interview questions were established and pre-tested before conducting the actual survey. Three randomly selected farmers in each district were interviewed for the questions pre-testing exercise. Discussions were also made with extension officers, researchers, input suppliers and key informants (retired officers and religion leaders) to test responses to questions and cross-examine the general knowledge about sweet potatoes. Determination of the area to be covered was based on advice at district levels and pre-survey observational visit of few target areas through transect walks in each agro-ecological zone. This was meant to ensure that all the information intended to be collected were relevant to sweet potato production in Central Tanzania. During pre-testing it was observed that the common local variety planted in Ikungi across the district was Gudugudu, which helped to compromise that the study should consider one variety instead of two as it was earlier proposed. In Gairo district, Simama variety was the most grown hence considered for the study.

Diagnostic survey

Survey was conducted in twenty villages in Gairo and Ikungi districts, in Morogoro and Singida Regions respectively, from April to June, 2016. Gairo district lies on the geographical coordinates of 06° 08′ S, 36° 52′ E and Ikungi district on 05° 08′ S, 34° 46′ E. These districts were selected because sweet potato is the highest produced crop and it serves both as food and cash crop (Kisetu & Honde, 2014). The areas are characterized by predominantly non-modal rain patterns (average annual range of 400 to 800 mm) followed by prolonged dry spells of five to six months. Gairo district is a hill (class T-Hypsographic) located at an elevation ranging between 1230 and 1370 meters above sea level (masl), with a minimum temperature of about 22 °C (Rees et al., 2001). Its soil is predominantly highly weathered red clay that tends to crack when dry. Ikungi is of sandy loam texture, almost flat with slightly sloping elevation of 1540 masl (district Economic Profile, 2016).

Sampling procedure

Purposive sampling was employed to identify regions, districts, villages and farmers for the interview and field assessment. Ten villages per district were selected based on their accessibility and production records. Thirty farmers among sweet potato producers were randomly selected in each village with the help of agricultural extension officers. In each village, the selected farmers were interviewed and their fields intensively assessed for weevil infestation. Care was taken to allow coverage of a large proportion of the village area.

Field assessment for weevil infestation

A field area of 30 by 20 meters in size was earmarked using a measuring tape at random in each farmer's field and used for assessment and data collection. In each of the earmarked "600m^{2}" area three quadrants were made diagonally to obtain three replications per field; one placed at the bottom, the second at the middle and the third at the top of a diagonal to avoid biasness. A quadrant of "3 m^{2}" in size was used. The farmers' fields were visited and assessed for weevil incidences and severity. During the visits discussions and detailed explanations of the weevil problem were made. Closed and open ended questions were used to collect general information on history of the crop in the area and perception of pests during the past two seasons.

Data collection and analysis

Infestation data were collected based on plants which fell in the quadrant. The centimetre long vines immediately from soil surface were considered for above ground infestation assessment of five plants in each quadrant that is fifteen plants per plot. Incidence and severity of sweet potato damage on vines were recorded. Then, data was recorded on the roots after digging the fifteen plants. Marketable and non-marketable roots were separated according to Titus et al. (2010). Marketable roots were those with bigger size and less infested ones while non-marketable roots were smaller in size and severely infested. Sweet potato weevil incidence on above ground and below ground were established by counting the numbers of vines and roots that showed signs of weevils' infestation divided by total number of harvested vines and root multiplied to 100.

$$\text{Incidence (\%)} = \frac{\text{Total numbers of infested vines of roots}}{\text{Total numbers of plants in the assessed area/quadrats}} \times 100$$

Severity of the weevils damage on both above and below ground was assessed by using a scale of 1 through 5 whereby; 1 = 0%; 2 = 1 – 15%; 3 = 16 – 50%; 4 = 51 – 65%; 5 = 66 – 100%. Consequently, "category 1" was assigned to vines and roots that were not damaged, "category 2: slightly damaged;" Category 3: moderately damaged", "category 4: highly damaged" and "category 5: severely damaged". The scale used was according to Rees et al. (2001) with slight modifications on categories 2 and 5 to allow un-biased rating on small roots, to accommodate all roots colors and to allow a wide range of severity indices.

Statistical analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) for descriptive and non-descriptive statistics and Microsoft Excel (Windows Office-2007). Location coordinates were obtained using a GPS based upon which maps for weevil incidence and distribution was established using ArcGIS (Geographical Information System) software.

Results

Spatial distribution of sweet potato weevils in the study area

The maps constructs of coordinates of all surveyed fields in the respective villages entails the distribution of weevils and their incidences across the study area whereby comparatively higher weevils populations were recorded in Gairo compared to Ikungi district (Fig. 1 & 2). Varied infestation levels were recorded which subsequently implied varied distribution of the pest. None of the surveyed villages was free from the pest suggesting an extensive distribution of the pest across Central Tanzania. Weevils' incidences in Gairo district were higher compared to Ikungi district as six out of ten covered villages in the former had incidences higher than 50% while only one out of ten villages in the later had incidences greater than 50%. Only Ukwamani, Tabuhoteli and Mtumbatu and nine out of ten villages (except Siuyu) in Ikungi had damage incidence of less than 50%. Suggestively, fields with high damage incidences had relatively high population density of weevil and vice versa.

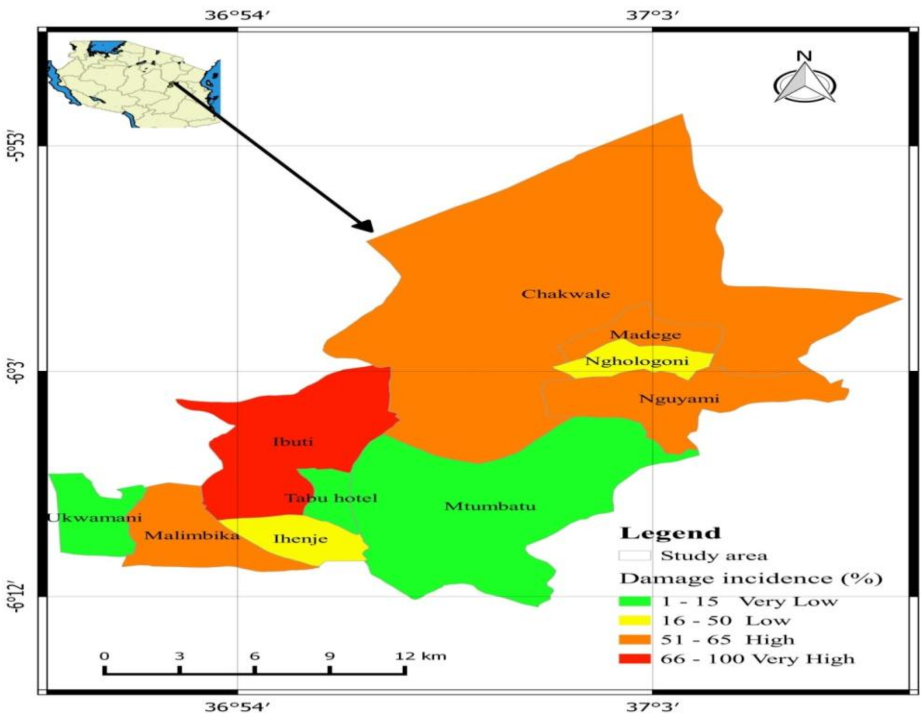

Fig. 1 Sweet potato weevils' distribution in Gairo district, Morogoro

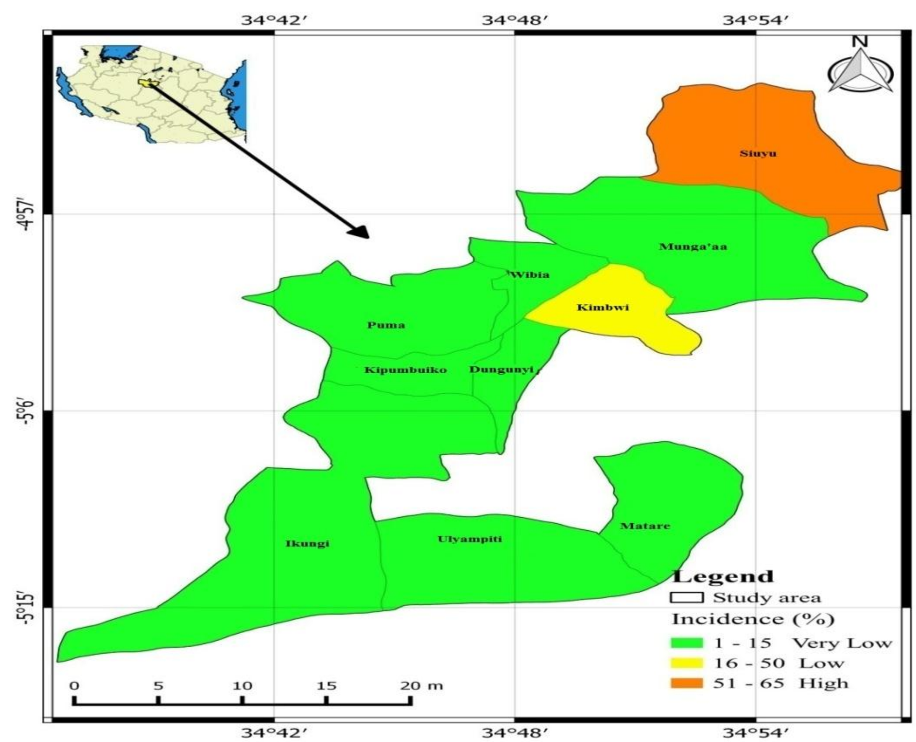

Fig. 2 Sweet potato weevils' distribution in Ikungi district

Village-specific incidence of the sweet potato weevils in the study area

Sweet potato weevils were recorded in all the surveyed villages and were indicated to be a known pest by all respondents. Incidences were varied among and within villages. Recorded incidences were as presented (Fig. 3 & 4). Highest incidences were recorded in Gairo district with Ibuti village recording the highest mean incidence (68.27%). Generally high weevils' incidences were recorded in Ibuti, Madege, Malimbika, Nguyami, Chakwale and Ngolongoni villages while Ihenje, Tabuhoteli, Ukwamani and Mahemu villages had relatively low incidences (Fig. 3). The categorical differences in incidences among the highly and lowly infested villages were statistically significant ($P \leq 0.05$) between Ibuti and Malimbika villages on the highest side and Ihenje, Tabuhoteli, Ukwamani and Mahemu villages on the lowest side. The Ikungi district data presented (Fig. 4) indicated that the highest weevil' incidences were recorded in Siuyu (53%) village followed by Kimbwi (38.118%) and the lowest was in Wibia (2.01%). Majority of the villages in Ikungi had incidences lower than 15%.

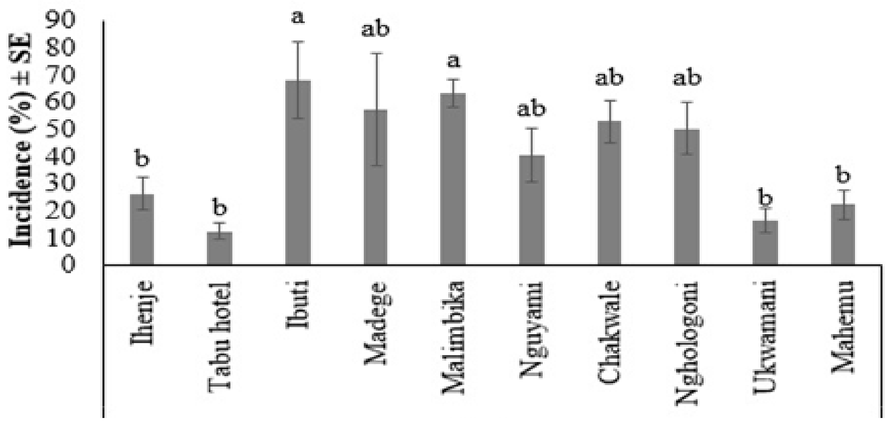

Fig. 3 Mean incidence of weevils in sweet potato fields across villages in Gairo district. Bars with different letters as data labels represent means that are significantly different as per Turkey's test

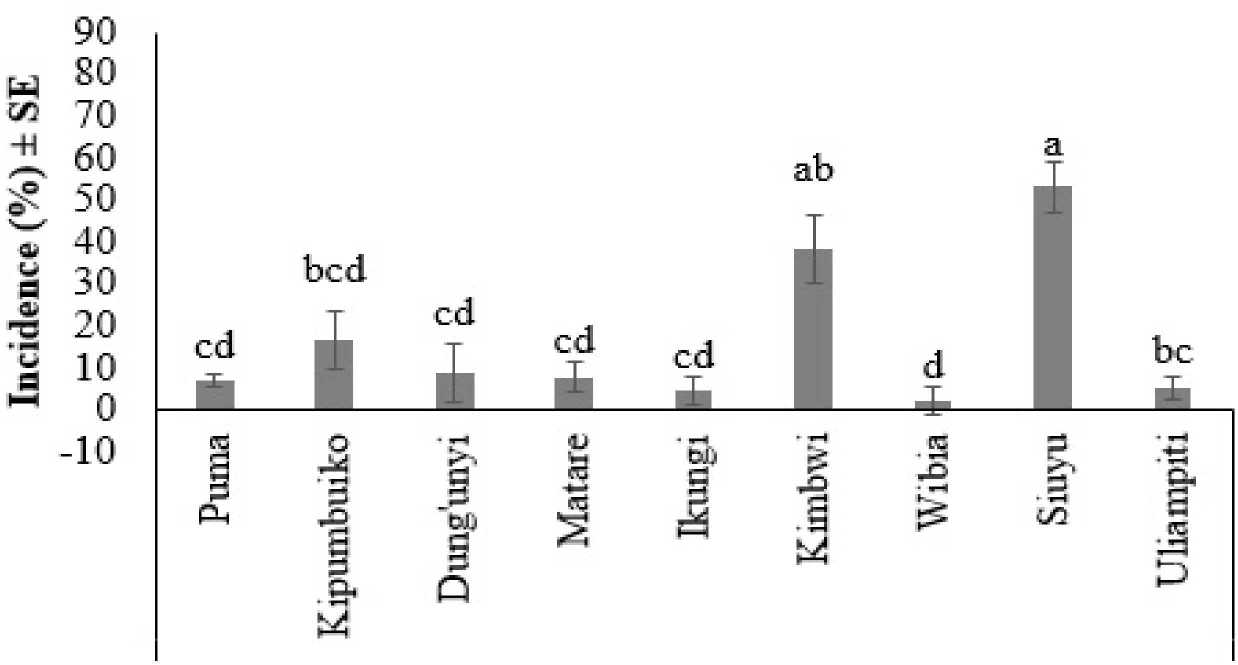

Fig. 4 Mean incidence of weevils in sweet potato fields across villages in Ikungi district. Bars with different letters as data labels represent means that are significantly different as per Tukeys' statistical test

Root damage severity

The severity of potato weevil damage from Gairo and Ikungi was as presented (Fig. 5 & 6). The severity of weevil damages was not significantly different among villages (P > 0.05). Most assessed fields had damage severity in the score 1 category implying that a substantial amount of crop yield can still be obtained from the grown sweet potato crop. However, a significant distribution of severity from score 2 through 5 suggests that the significance of the pest is increasing particularly in Gairo district. Ikungi district still commands a notable healthy crop and with exception of Siuyu village, worries about weevils' infestation may be non-paramount.

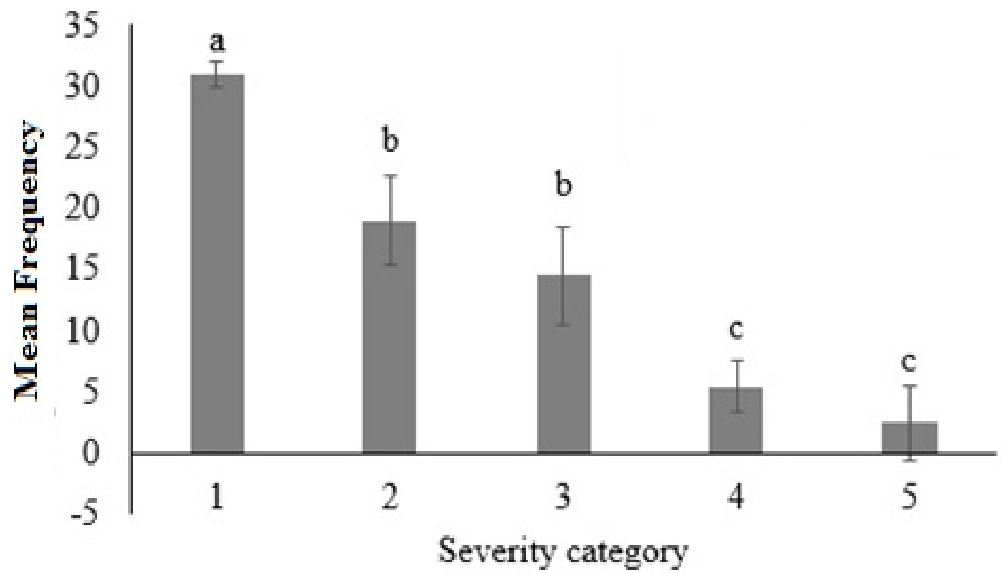

Fig. 5 Average number of roots per severity score of weevils' damage severity indices in surveyed Sweet potato fields in Gairo district. Bars followed by the same letters are not statistically different at (P<0.05) Tukey's test

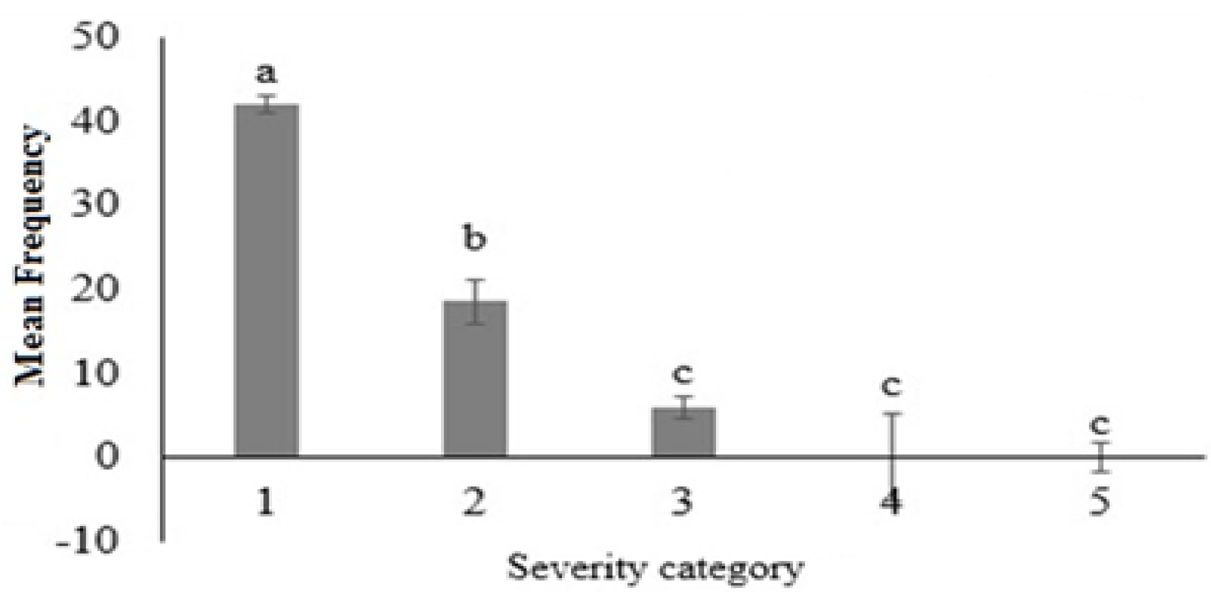

Fig. 6 Average numbers of roots per weevils' damage severity indices in surveyed sweet potato fields in Ikungi district. Bars followed by the same letters are not statistically different at (P<0.05) Tukey's test

Discussion

The highest damage incidences were encountered in most villages in Gairo district compared to those in Ikungi district. One of the reasons for higher infestation may be the use of unclean or infested planting materials. Gairo district is dominated by prolonged dry spell of up to five months which causes shortages of planting materials forcing farmers to use whatever is available during planting season however unclean it might be. Scarcity of planting materials triggers the use of the lowest basal portion of sweet potato stem which are inevitably infested with weevils' eggs and some adults colonizing the stems as reported by other workers (Shonga et al., 2013). This ensures perpetuation of the pest into a newly planted crop with subsequent presence of the pest foci in almost every field. Hue & Low (2015) pointed out that planting of infested vines is one of the ways for sweet potato weevils' distribution in a given area including the originally un-infested ones. Scarcity of planting materials in Gairo has led to commercialization of sweet potato vines. During the dry season, vines are usually conserved in river valleys at high concentration such that even the clean harvested vines would end up infested not only with weevils but also other pests like whiteflies, aphids and sweet potato virus disease. It is during this time when weevils migrate from existing alternative plant species to infest the sweet potato crop concentrated in one location near irrigation water or swamps (Kibrom et al., 2015). At the beginning of planting season the vines demand is usually high and almost everybody enters the rush of money making business caring the less about qualities of vines. Planting materials introduced from other places might have been infested too (Emana, 1990; Hue & Low, 2015).

The scarcity of vines forces farmers to travel distances to buy planting materials making traded vines the most prominent mechanism through which weevils are spread. Repeated planting of sweet potato on the same piece of land has also been reported to contribute to making sweet potato weevils endemic in many locations. Persistence of the pest has been recorded in fields where continuous or repeated planting is practiced. According to Emana (1990) growing sweet potato on the same plot of land for four consecutive years can result in over 70% incidence while an average of 20% incidence has been reported where rotation of crops is practiced. The use of sprouted planting materials from previously infested fields without any protective treatment was also considered to be among the causes for higher incidences in Gairo. The rooting characteristics of the grown varieties possibly contributed to the high weevils incidences recorded in Gairo.

Mansaray et al. (2013) reported that varieties that set their roots superficially on top soils are prone to weevils attack while deep rooted sweet potato suffers less from the pest. The commonly grown varieties in Gairo are Simama and Sinia which set their roots on top soils rendering them exposed to weevils attack. On the centrally, the commonly grown variety in Ikungi is Gudugudu which is deep rooted making it hard for the weevils to access roots. Subsequently, the weevils surviving on this variety often take refuge on vines and few accidentally exposed roots.

Physical characteristics of the soil have also been reported to deter or promote the infestation with sweet potato weevils (Munyiza et al., 2007). Gairo district is dominated by clay soils characterized by extensive cracking during the dry season or in periods of intermittent drought during the growing season, which enables weevil entrance into the soil to access the sweet potato roots. As such, crops growing in such soils suffer much from the weevils' infestation as was the case with Gairo. Conversely, the soils in Ikungi district are predominantly sandy loam with no cracking which ensures continued cover of the subsoil limiting access of weevils to the sweet potato roots. Added to the characteristics of the dominantly grown Gudugudu variety which is deep rooted, the weevils' incidence must be inevitably low as was recorded in the present study as similarly observed by Tesfaye (2002). Munyiza et al. (2007) reported high infestation levels recorded under dry conditions due to many cracks associated with drying of soils. Ashebir (2006) reported that the extent of yield loss was high towards the dry season due to low soil moisture, low biomass yield and high soil cracks. The pest is particularly serious under dry conditions (in clay loam soil) because the insect can reach the roots more easily through the cracks which occur as the soil dries out.

On the other hand, the differences in damage incidences may have resulted from temperature variation. Apart from soils being not conducive, the predominantly cool temperatures in Ikungi particularly during the dry season limit breeding and perpetuation of weevils in the area. According to Badii et al. (2015), temperature variation may constitute unfavorable ecological niches for some insect species. The dominant weevil species in Gairo and Singida is *Cylas punticollis* which is sensitive to temperatures below 17.5 °C. The suitable temperature range for survival and perpetuation of the species is 17.5 °C – 35 °C. Suggestively, the predominantly less than 16 °C temperature in Ikungi may have supported limited development and spread of weevils in the area which led to the recorded low incidences. Likewise, the related species *Cylas brunneus* which has been reported to occur at limited incidences in Central Tanzania, cannot develop, survive or reproduce at temperature conditions less than 15°C and above 35 °C (Musana et al., 2013).

The higher root damage severity recorded in Gairo district compared to Ikungi district suggests that the weevils population is high in the area and the grown crops often sustain longer time of exposure to the pest. Although known to be destructive, the weevils would require an appreciable time of exposure to the root to inflict severe damages. Very often the magnitude of damage is usually related to the population density of the pests (Munyiza et al., 2007). Some weevil species have been reported to be more highly destructive than others in the same area. While *Cylas formicarius* is known to be the most destructive sweet potato weevil worldwide (Sefasi et al., 2012), *Cylas puncticollis* is the most destructive in sub-Saharan Africa (Munyiza et al., 2007). Its presence even in small numbers is viewed as economically important and warrant intensive management (Rees et al., 2001). The lowest damage severity in most villages in Ikungi district was not only attributed to low weevil incidences but also the soils and commonly grown local variety, Gudugudu with deeper root setting compared to most of varieties particularly those grown in Gairo.

Conclusion

Conclusively, the study indicated that sweet potato weevils are predominantly abundant in Central Tanzania and extensively distributed wherever sweet potato is grown particularly in Gairo district in Morogoro Region. Rampancy of the pest in Gairo is attributed to susceptibility of the commonly grown varieties and cracking nature of the soils that are predominantly clay. Ikungi district on the other hand had limited incidences of sweet potato weevils mainly attributed to the deep rooted nature of the commonly grown Gudugudu variety and the non-cracking soils. Trade in sweet potato planting material is the main mechanism through which weevils are spread. Farmers' and agricultural extension officers' knowledge on sweet potato weevils is limited and there are limited attempts to manage the pest. Successful management of sweet potato weevil should consider planting of deep rooted varieties, adherence to phytosanitary requirements for planting materials and timely planting to avoid maturing of the crop during the dry season, the conditions that attract infestation, breeding and perpetuation of weevils. Investment in education to farmers, proper and well managed sweet potato seed systems, and enforcement of standard weevils' management practices to every farmer should be prioritized.

Authors Contribution: G.M.R. conceptualized the research idea, solicited for research funds, supervised the data collection and analysis, reviewed the draft text, wrote the final manuscript and proofread for submission. L.P.M. undertook the study, field collection of data, organized and analyzed data and wrote the draft manuscript.

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Conflict of Interest: Authors have no conflict of interest of any form and declare no compromise between and among any other parties.

References

Ashebir, T. (2006). Sweet potato weevil *Cylas puncticollis* (Boh.) (Coleoptera: Curculionidae) in southern Ethiopia: Distribution, farmers' perception and yield loss. Thesis for Award degree of Master of Science in Alemaya University of Agriculture, School of Graduate Studies. Alemaya. Ethiopia. Available from URL: https//:docsdrive.com /pdfs/knowledgia/ajar/0000/57578-57578.pdf.

Badii, K. B., Billah, M. K., Afreh-nuamah, K., & Obeng-ofori, D. (2015). Species composition and host range of fruit-infesting flies (Diptera: Tephritidae) in Northern Ghana. *International Journal of Tropical Insect Science*, *35*, 137-151.

Benjamin, M. K., Francis, J. M., Stephen, M. G., Graig, G. Y., & Julia, S. (2014). Assessment of production constraints and farmers' preferences for sweet potato genotypes. *Journal of Plant Breeding*, *2*(1), 15-29.

Emana, G. (1990). Integrated Approach to control the Sweet potato weevil. In: Committee of Ethiopian Entomologists (eds.) *Proceeding of the 10th Annual Meeting*. 7-9 February, 1990, Addis Ababa, Ethiopia.

FAOSTAT. (2015). Available from URL: https://faostat.fao.org/ site/567/default.aspx#ancor]

Gajanayake, B., Reddy, K. R., Shankle, M. W., & Arancibia, R. A. (2015). Growth, development, and physiological responses of two sweet potato cultivars to early season soil moisture deficit. *Science in Horticulture Crops*, *168*, 218–228.

Gebru, H., Mohammed, A., Dechassa, N., & Belew, D. (2017). Assessment of production practices of smallholder potato (*Solanum tuberosum* L.) farmers in Wolaita zone, southern Ethiopia. *Agriculture and Food Security*, *6*, 31; doi: 10.1186/s40066-017-0106-8

Hue, S., & Low, M. (2015). An insight into sweet potato weevils management. *Journal of Entomology*, *5*, 1-11.

Jansson, R. K., Hunsberger, A. G. B., Lecrone, S. H., & Hair, S. K. (1990). Seasonal abundance, population growth, and within-plant distribution of sweet potato weevil (Coleoptera: Curculionidae) on sweet potato in Southern Florida. *Environmental Entomology*, *19*, 313-321.

Kapinga, R., Peter, K., Ewell, T., Jeremiah, S. J., & Kileo, R. (1995). Sweet potato in Tanzania farming and food systems. Implication for research; International Potato Center (CIP) and Ministry of Agriculture, Tanzania. 47pp.

Kapinga, R., Peter, K., Ewell, T., Jeremiah, S. J., & Kileo, R. (1997). *Sweet potato In Tanzania Farming and Food Systems.* International Potato Center (CIP) and Ministry of Agriculture, Tanzania. 57pp.

Kibrom, B., Amsalu, N., & Merkeb, G. (2015). Effect of Number of Nodes and Storage Duration of Vine Cuttings on Growth, Yield and Yield Components of Sweet potato (Ipomoea batatas L.) at Jimma, Southwest Ethiopia.

Journal of Biology, Agriculture and Healthcare, *5*(22), 1-15.

Kisetu, E., & Honde, C. (2014). Incubation of selected Tanzanian Chromic Acrisol with Minjingu Mazao fertilizer, cattle and poultry manures and their effects on phosphorus availability. *Asian Journal of Agricultural Research*, *8*, 30-41.

Low, J., Lynam, J., Lemaga, B., Crissman, C., Barker, I., Thiele, G., Namanda, S., Wheatley, C., & Andrade, M. (2009). Sweet potato in Sub-Saharan Africa. In: Loebenstein, G., & Thottappilly, G. (eds.) *The sweet potato.* Springer Netherlands 359-390pp.

Mansaray, A., Sundufu, A. J., Yilla, K., & Fomba, S. N. (2013). Evaluation of cultural control practices in the management of sweet potato weevil (*Cylas puncticollis*) Boheman (Colepotera: Curculionidae). *QScience Connect, 44,* doi: 10.5339/connect.2013.44.

Mukhopadhyay, S. K., Chattopadhyay, A., Chakraborty, I., & Bhattacharya, I. (2011). Crops that feed the world. Sweet potato. Sweet potatoes for income and food security. *Food Security, 3,* 283–305.

Munyiza, H., Stevenson, P., Mwanga, R., Talwana, H., Murumu, J., & Odongo, B. (2007). The relationship between stem base and root damage by *Cylass spp* on sweet potato. *Africa Crop Science Journal, 8,* 955-957.

Musana, P., Okonya, J. S., Kyamanywa, S. & Kroschel, J. (2013). Effect of temperature on the development, reproduction and mortality of the sweet potato weevil *cylas brunneus* (Fabricius) (Coleoptera: Brentidae). *Uganda Journal of Agricultural Sciences*, *14*, 77-84.

Mwanga, R. O. M. (2001). Nature of resistance and response of sweet potato to sweet potato virus disease. PhD dissertation for Award degree of doctorate of Kampala University of Uganda 145pp.

RAC. (2012). Reaching Agency for Change: Orange-fleshed sweet potato situation analysis and needs assessment. *Tanzania Report*. 40pp.

Reddy, G. V. P., Badilles, A. E., & McConnel, E. (2012). Estimation of the population density of the sweet potato weevils on Mariana Islands. *Journal of Entomological and Acarological Research*, *44*, 20-23.

Rees, D., Kapinga, R., Mtunda, K., Chilosa, D., Rwiza, E., Kilima, M., Kiozya, H., & Munisi, R. (2001). Effect of damage on market value and shelf-life of sweet potato in urban markets of Tanzania. *Tropical Science*, *41*, 1–9.

Sefasi, A., Kreuze, J., Ghislain, M., Manrique, S., Kiggundu, A., Ssemakula, G., & Mukasa, S. B. (2012). Induction of somatic embryogenesis in recalcitrant sweet potato (*Ipomoea batatas* L.) cultivars. *African Journal of Biotechnology*, *11*(94), 16055-16064.

Shonga, E., Gemu, M., Tadesse, T., & Urage, E. (2013). Review of entomological research on sweet potato in Ethiopia. *Journal of Agriculture and Food Sciences*, *1*(5), 83-92.

Smit, N. E. J. M. (1997). The effect of the indigenous cultural practices of in-ground storage and piecemeal harvesting of sweet potato on yield and quality losses caused by sweet potato weevil in Uganda. *Agriculture Ecosystems and Environment*, *64*(3), 191–200.

Stathers, T. E., Rees, D., Kabi, S., Mbilinyi, L., Smith, N., Kiozya, H., Jeremiah, S., Nyango, A., & Jeffries, D. (2005). Sweet potato infestation by *Cylas* spp in East Africa. Cultivar differences in field infestation and the role of plant factors. *International Journal of Pest Management*, *49*, 131-140.

Tesfaye, B. (2002). *Development of management practice for sweet potato weevil, in southern Ethiopia* (Master's thesis). Alemaya University of Agriculture, Ethiopia.

Titus, P., Lawrence, J., Adams, H., Iton, A., Pilgrim, R., & Robin, G. (2010). *Sweet potato Technical Manual.* CARDI Root and Tuber Commodity Group. Caribbean Agricultural Research and Development Institute (CARDI) 47pp.

Wolfe, G. W. (1991). The origin and dispersal of the pest species of *Cylas* with a key to the pest species groups of the world. In: RK. Jansson and KV. Roman (eds). *Sweet potato Pest Management: A Global Perspective West View* 13-14pp.

Woolfe, J. A. (1992). Sweet Potato*: An Untapped Food Resource, Cambridge, UK*: Cambridge University Press 389pp.