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Efficacy of plant extracts in the control of rodent infestations and their effects on the nutritional contents of sweet potato tuber

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Abstract
The use of plant extracts has been described as credible alternative to synthetic insecticides in the protection of field crops. This research work was conducted at Teaching and Research Farm, Ladoke Akintola University of Technology during the planting seasons of 2015 and 2016 to determine the efficacy of plant extracts – Tephrosia vogelii, Moringa oleiferia, Petiveria alliacea and Annona squamosa in the control of rodent infestation. The experiment was arranged in a randomized complete block design and each treatment was replicated three times. Synthetic insecticide (Lambdachyalothrin) and control were included in the experiment for comparison. Data were collected on plant stands attacked, vine length, yield and nutritional components of sweet potato tuber. The result showed that plant extracts treated sweet potato plants had significant lower rodent infestations when compared with unsprayed plant stands. Also, applied treatments had no negative effect on the vine length meanwhile yield obtained from botanical insecticides treated plants was two times higher than that of untreated plants which had the least tuber yield (0.90 t/ha). The tested plant extracts significantly improved the proximate contents of the harvested sweet potato tubers. Therefore, these plant extracts can be used in the field management of rodent infestation without any adverse effects on the nutritional components of the sweet potato tuber.

Keywords*: Sweet potato, Rodent, Tephrosia vogelii, Moringa oleiferia, Petiveria alliacea, Annona squamosa*

Introduction

Sweet potato (*Ipomoea batata* Lam) belongs to the family of Convolvulaceae and it is cultivated in over 100 countries (FAOSTAT, 2012). Consumption of sweet potato does not involve much processing in most of the tropics. This is a root crop that provides food to a large segment of the world population, especially in the tropics where the bulk of the crop are cultivated and consumed (Kocklar, 1981, Opeke, 2000, Padamaja *et al*., 2012). Sweet potato is high in nutritive value, outranking most carbohydrate foods in vitamins, minerals, protein and energy content (Watt and Merrill, 1975; Onuh *et al*., 2004). Sweet potato serves as a staple food vegetable (fleshy roots and tender leaves), snack food, weaning food, animal feed, as well as a raw material for industrial starch and alcohol. It is processed into diverse products (Bouwkamp, 1985, Lin *et al*., 1985, Udensi, 2000).

Cultivation of sweet potato is wide spread in Nigeria but the major limitation factor aside from soil fertility is pest infestation such as sweet potato weevils, *Cylas puncticollis,* (Coleoptera: Curculionidae); sweet potato butterfly, *Acraea acerata* (Lepidoptera: Nymphalidae), sweet potato hornworm, *Agrius convolvuli* (Lepidoptera: Sphingidae), tortoise beetles, *Aspidomorpha spp*., *Laccoptera spp*. (Coleoptera: Chrysomelidae); and virus transmitters *Aphis gossypii* (Homoptera:

Aphididae) and *Bemisia tabaci* (Homoptera: Aleyrodidae). In developing countries, rodent infestation poses a serious threat in the cultivation of this crop thereby leading to the wide spread shortage of sweet potato tubers (Stenseth *et al*., 2001). However serious attention has not been paid to this problem by crop protectionists.

In view of the above facts, control of pests especially rodents become necessary. Most of the farmers in developing countries apply synthetic insecticides indiscriminately and this has led to environmental pollution and human toxicity (Damalas and Koutroubas, 2015, Kumari *et al*., 2014). Literature also has it that most insect pests develop resistance and resurgence after the persistent application (Shabana *et al*., 2017). Non availability is another discouraging factor among our local farmers. Therefore, alternatives to the synthetic insecticides has become imperative. Biological control, use of plant resistance and botanical insecticides have been advocated and found to be effective in the management of insect pests. However, the cost of using biological control and plant resistance is beyond the reach of our local farmers but use of secondary metabolites is affordable due to the availability of plant materials and little technology involved in the preparation of the plant extracts (Alao, 2015). Meanwhile, plant extracts have been reported to have had significant control of some insect pests of different field crops but there is dearth of information on the use of plant extracts in the control of rodent infestations on the field especially sweet potato tuber.

Less than 1% of pesticides applied as herbicides of pest control reached the target plants (Pimental, 1995) while the rest go into the environment which are eventually absorbed and translocated to plant parts (Joy *et al*., 2013). However, the absorbed pesticides by the plants may have persistent biological effects on germination, growth, yield and alteration on biochemical constituents and antioxidant enzymes (Williams *et al*., 1995). Insecticides have been reported to have had effects on plant growth, for instance, rice seeds treated with fipronil had lowest germination percentage (76%) while untreated seeds had 80% germination whereas diazinon had 85% germination (Moore and Kroger, 2010). Also, Imidachloprid has been described as plant growth enhancer despite the fact that it is an insecticide (Steven *et al*., 2008). On the contrary, Dimethoate which is an insecticide reportedly reduced growth root and shoot length of the treated plants (Mishra *et al*., 2008). This is an indication that insecticides when applied to the plants can have either negative or positive effects on the treated plants. Therefore, this experiment was designed to determine the insecticidal efficacy of *P. alliacea*, *M. oleifera*, *A. squamosa* and *T. vogelii* against the rodent infestations and their effects on the proximate contents of harvested sweet potato tubers.

Materials and methods

Study site: The field experiment was conducted during cropping season of 2015 and 2016 at Ladoke Akintola University of Technology (LAUTECH) Teaching and Research Farm, Ogbomoso, Oyo state. This region is on longitude 403’E and latitude 1005’N. The region can be described as humid tropical and falls under Southern Guinea Savannah of Nigeria.

Experimental Design and Management

Experimental land was ploughed and harrowed once. Eighteen plots were arranged and demarcated in a Randomized Completed Block Design with three replicates. The plot size was 3 m x 3 m with a planting space of 1 m x 1 m between and within the plant rows respectively. The sweet potato stems (Orange fleshed sweet potato) were planted. Manual weeding was done fortnightly.

Preparation of Plant extracts

The leaves of *M. oleifera T. vogelii A. squamosa and* root of *P. alliacea* respectively were washed to remove sand, dust and chemical contaminants, the plant extracts were air dried for seven days to reduce the moisture content. 500 g of the crushed plant materials were weighed separately with sensitive scale after which each of the paste was put into a separate 10-litre plastic buckets containing 1000 ml of water. The soaked materials were allowed to stay overnight. The filtration was done with muslin cloth and filtrates collected were stored in a 5-litre plastic keg as stock solution. 1000 ml of each of the plant extracts was measured out from the stock solution. This method was in line with the established procedures by Alao and Adebayo (2011)

Formulation of Botanical Insecticides

The filtrate collected was stored separately in a refrigerator which was used as an active ingredient in the formulation of botanical insecticide. The 33.3% of active ingredient (filtrate) was separately diluted with adjuvant substances such as Texapon (11.11%), Nitrosol (22.22%), Salt (22.22%) and Black soap (11.11%). Hence, the mixture was equivalent to 100 ml. The unsprayed plots and synthetic insecticide (karate) treated at 0.5 ml per plot were included for comparison. Each concentration of both synthetic and botanical insecticides was diluted with 1000 ml of water to achieve the same spraying volume.

Treatment Application

One hundred (100 ml) was measured from stock solution which was later diluted with 900 ml of water. Foliar application was done with hand-held sprayer (2-litre capacity) and ensured it had contact with root of the tested crop. The spraying was done early in the morning to avoid photo degradation of the extracts (Adebayo, 2003). Some plots were left unsprayed to serve as control. Four-weekly application was done at seven days interval.

Data Collection

Data were collected on the number of sweet potato tubers attacked and this was determined by estimation of number of plants attacked and undamaged plant stands on a weekly basis. The morphological data collected were based on number of plants per stand, length of vines and yield was calculated in kg/ha which was later converted to ton per hectare (t/ha).

Samples Preparation and Proximate Analysis

The sweet potato tubers were sorted, washed and chopped into smaller pieces with stainless steel knife and the samples were air-dried at room temperature separately for two months. The dried materials obtained were ground to a fine powder with electric blender and finally packed into airtight polyethylene plastic bottles and stored in the desiccator until required for analysis. The dry samples were analysed for proximate composition. Moisture, ash, crude fat and crude fibre were determined in accordance with (AOAC, 2016), while nitrogen was determined by the micro-kjeldahl method (Pearson, 1976) and the percentage nitrogen was converted to crude protein by multiplying by 6.25. Carbohydrate was determined by difference. The result was expressed in percentage and determinations were carried out in duplicate. This analysis was carried out at Crop and Environmental Protection Laboratory, Ladoke Akintola University of Technology, Ogbomoso.

Data Analysis

The data collected were subjected to Analysis of variance (ANOVA) and significant means were separated with Duncan multiple range text at 5% probability level using SAS package software, 2002.

Results

Response of Rodent Infestations to the Applied Treated and Untreated Plant Stands

Data were collected on the level of rodent infestation on potato tuber before the application of the treatments and no significant variation was observed in the level of rodent attack (Fig. 1). The results presented in Table 1 showed that untreated plants had highest plants attacked (35.1%) at week 1. Among the plant extracts, *P. alliacea* significantly performed better in the control of rodent attack than other plants extract. However, *P. alliacea* had the same efficacy as observed in the Lambdachyalothrin treated plants at first week of spraying. At 2 weeks after treatment, incidence of rodent attack was drastically reduced among the sweet potato plants treated with *P. alliacea* and Lambdachyalothrin but the highest rodent infestation was detected in the untreated plots. Significant differences ($P<0.05$) were not detected among the plants sprayed with *T. vogelii, M. oleifera* and *A. squamosa*. Untreated plants had highest significant ($P<0.05$) rodent attack (22.3%) when compared with treated plants at 3 weeks after treatment. Among the plant extracts treated plants, *A. squamosa* significantly failed (12.5%) to repel the rodent infestations when compared with other tested plant extracts. However, all the tested plant extracts compete effectively with Lambdachyalothrin in the control of rodent attack on sweet potato tubers except *A. squamosa* extracts (3 WAT).

Effects of insecticides on sweet potato vine length (m)

The result presented (Figure 2) clearly showed that the applied treatments did not have any effect on the vine length of the target crop when compared with untreated plants but *A. squamosa* treated plants had highest vine length (1.77 m) followed by Lambdachyalothrin treated plants (1.72 m). The least vine length was observed in the plants sprayed with *P. alliacea* extracts.

Effects of Insecticides on Tuber Yield (t/ha)

The result presented in Table 2 indicated that the applied treatments had significant effects on the yield of sweet potato tuber yield. Among the plant extracts, *A. squamosa* treated plants had the least tuber yield (1.47 t/ha). No significant difference ($P< 0.05$) was detected among other plant extract treated plants from the yield obtained but none of the plant extracts compete effectively with Lambdachyalothrin which had highest tuber yield.

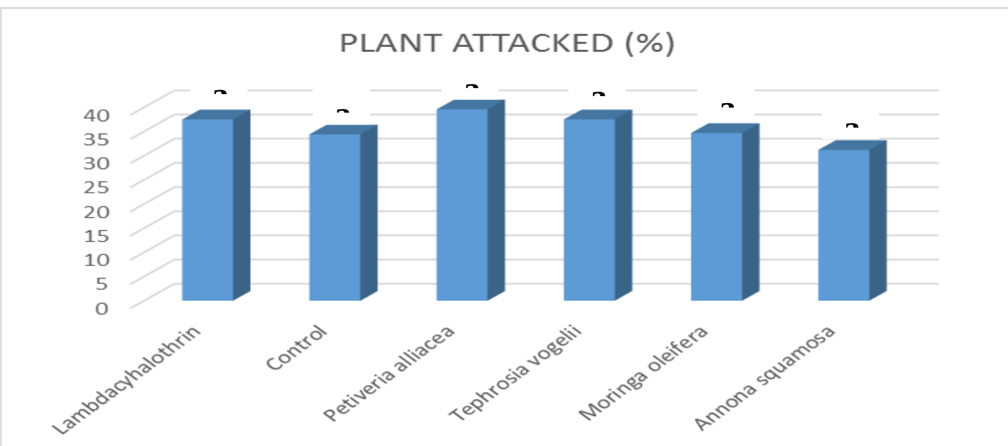

Figure 1: Plant attacked by rodents before application of treatments.

Table 1: Plants attacked by rodents after application of treatments (%)

Treatments	Week After Planting		
	1	2	3
Lambdachyalothrin	8.33[b]	4.2[b]	0.00[d]
Control	35.1[a]	27.9[a]	22.3[a]
Petiveria alliacea	10.1[b]	8.3[b]	2.08[c]
Tephrosia vogelii	20.2[ab]	2.72[ab]	2.25[c]
Moringa oleifera	22.2[ab]	17.1[ab]	4.17[c]
Annona squamosa	26.2[ab]	18.8[ab]	12.5[b]

Means with the same alphabet(s) along the column are not significantly different at 5% probability using DMRT.

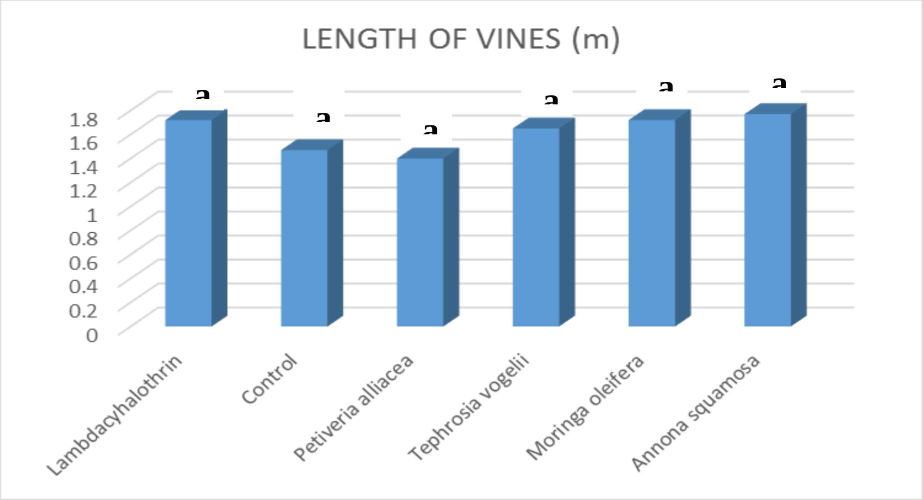

Figure 2: Effects of insecticides on sweet potato vine length (m)

Table 2: Effect of the application of the treatment on yield (t/ha)

Treatments	YIELD (t/ha)
Moringa oleifera	1.57[b]
Control	0.90[c]
Annona squamosa	1.47[b]
Petiveria alliacea	1.90[c]
Tephrosia vogelii	1.83[ab]
Lambdachyalothrin	2.13[a]

Means with the same alphabet(s) along the column are not significantly different at 5% probability

Proximate content of harvested sweet potato tubers

Among the botanical insecticides, *P. alliacea* treated fruits had highest moisture content (9.80%) followed by *A. squamosa* treated fruits (9.55%). There was no significant difference in the moisture content of *M. oleifera* and *T. vogelii* treated fruits. Meanwhile, highest moisture content was discovered in the untreated fruits (9.93%) while Lambdachyalothrin had the least moisture content (8.28%) (Table 3). The–ash content in the untreated fruits was higher (5.68%) than that of treated fruits. *A. squamosa* treated fruits had higher ash content (5.60%) than other botanical treated fruits. The ash content observed in the *T. vogelii* was statically comparable with Lambdachyalothrin but *M. oleifera* treated fruits had the least ash contents (4.46%). In respect to fat content, Lambdachyalothrin treated fruits had highest fat content while the least was discovered in the *T. vogelii* and *A. squamosa* treated fruits. Untreated fruits had more fat content (19.5%) than the botanical sprayed fruits. Among the botanical insecticides, *M. oleifera* treated fruits had highest fat content (18.2%) than other plant extracts treated fruits (Table 3). *A. squamosa* had highest fibre content when compared with treated and untreated fruits. Meanwhile, the least fibre content was discovered in *M. oleifera* treated fruits. All the plant extracts significantly improved the fibre content except *M. oleifera* when compared with Lambdachyalothrin. Fruits treated with *P. alliacea* and *T. vogelii* had the same significant effects ($P < 0.05$) on protein content as it was observed in Lambdachyalothrin. Untreated fruits had highest protein content (9.75%) meanwhile the application of M. oleifera resulted into low protein content (9.22%). In respect to carbohydrate, *A. squamosa* and *P. alliacea* statistically performed low compared with other treated and untreated fruits while *T. vogelii* sprayed fruits had highest carbohydrate content followed by *M. oleifera* treated fruits. No significant difference was detected between Lambdachyalothrin and untreated fruits (Table 3).

Table 3: Proximate analysis of the treated and untreated sweet potato tubers (%)

Treatments	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Moringa oleifera	8.85^{d}	4.46^{e}	18.20^{c}	3.70^{f}	9.22^{d}	55.6^{b}
Control	9.93^{a}	5.68^{a}	19.5^{b}	7.90^{b}	9.75^{a}	47.2^{e}
Annona squamosa	9.55^{c}	5.60^{ab}	16.7^{e}	8.30^{a}	9.40^{c}	50.5^{d}
Petiveria alliacea	9.80^{b}	5.50^{bc}	17.5^{d}	5.88^{c}	9.58^{b}	51.8^{d}
Tephrosia vogelii	8.82^{d}	5.40^{d}	13.2^{e}	4.55^{d}	9.60^{b}	58.4^{a}
Lambdachyalothrin	8.28^{e}	5.30^{d}	19.7^{a}	4.29^{e}	9.24^{b}	53.2^{c}

Means with the same alphabet(s) along the column are not significantly different at 5% probability using DMRT.

Discussion

Sweet potato has been reported by farmers in Africa to have been attacked by insects such as sweet potato butterfly and sweet potato weevil (Joshua *et al*., 2014). Throughout the experimental trial, no insect infestation was observed although this experiment was set up with a view to controlling the insect attack. Eight weeks after planting, rodent infestation was observed and this revealed that rodent attack might have been the major problem in the cultivation of sweet potato in this agroecological zone. Application of the treatments commenced when over 8% of the plant stands have been attacked by the rodents.

It was observed that the tested plant extracts (*P. alliacea, T. vogelii, M. oleifera and T. vogelii*) effectively reduced the level of rodent attack when compared with unsprayed plant stands. Also, the number of plants stand attacked were drastically reduced as the week after treatment increased. This might be attributed to the active ingredients reportedly derived from the tested plant extracts. Also, the active ingredients might have interfered with the central nervous system of the rodents which accidentally deterred them from the treated plants. However, no rodents were found dead throughout the experimental trials, thus it could be another indication that the applied treatments acted as repellant action against rodents. Lambdachyalothrin which has been reported by the manufacturer as insecticides turned out to be rodenticide, based on the data collected, Lambdachyalothrin can be used as an alternative to commercially formulated rodenticides in sweet potato cultivation though the efficacy was comparable to that of tested plant extracts. This clearly shows that Lambdachyalothrin and plant extracts have dual purposes in the cultivation of sweet potato. The results revealed that rodent infestation drastically cause economic yield loss to root tuber crops which can be attributed to the reason why unsprayed plants had the least tuber yield (0.90t/ha). Although there was significant difference in the yield obtained among the botanical treated plants but none of the yield was not comparable to that of synthetic insecticide treated plants (2.13 t/ha).

Based on the nutritional contents, the ash content of the harvested sweet potato tubers ranged from 4.46 to 5.68% which was higher than the reported ash content of sweet potato tubers (0.87–1.32%) by Antonius *et al*., (2016). This is an indication that that the applied plant extracts improved nutritional contents of the sweet potato tubers. Meanwhile, all the tested plant extracts except *M. oleifera* treated harvested tubers had lower ash contents (4.46%) than harvested tubers from Lambdachyalothrin which had 5.30%. Ash had been described as major source of mineral elements which plays a vital role in the metabolic processes of man and animals (Surani and Firmansah, 2005). Islam (2006) reported that the fat content of sweet potato tubers falls between 0.06 – 0.48%, meanwhile the observed fat content was higher than this. The reported fat contents by Antonious *et al*., (2016) was also lower than the observed fat contents. This shows that the tested insecticides influenced the fat content of sweet potato tubers. However, variation was detected in the fat contents of the harvested tubers, for instance harvested tubers from treated *T. vogelii* and *A. squamosa* extracts had the least significant fat contents (13.2 and 16.7% respectively) while the highest value (19.7%) was reported from the tubers harvested from plots treated with Lambdachyalothrin. Meanwhile, fats are the components of energy content and sources of essential fatty acids (Antonius *et al*., 2016).

In respect to fibre contents, harvested tubers from the sweet potato plants treated with *A. squamous* extracts had significant highest fibre contents (8.30%) while the least fiber content (3.70%) was observed from the harvested tubers treated with *M. oleifera* extracts. This suggests that application of *A. squamosa* is a means of improving the fibre contents of sweet potato tubers. However, the observed fibre contents of sweet potato tuber ranged from 3.70 to 8.30% which were higher than the value (1.6%) reported by Hartoyo (2004). This showed that the tested plant extracts did not have negative effects on the fibre contents of the harvested sweet potato tubers. Fibre contents are responsible for easy digestibility of food products (Piliang, 2006). The observed protein content ranged from 9.22 to 9.75% which was considerably higher than

0.91 to 1.44% reported by Antoniou *et al*., (2016). However, harvested tubers from plants sprayed with *P. alliacea* and *T. vogelii* extracts had the same significant effects on protein contents as it was observed on harvested tubers from Lambdachyalothrin treated plants while the least protein content (9.22%) was recorded from potato tubers harvested from plants sprayed with *M. oleifera* extracts. This suggested that *P. alliacea* and *T. vogelii* extracts are excellent sources of protein enhancers in the cultivation of sweet potato. According to Dirjen-Kasehatan (2005), the standard carbohydrate content in sweet potato tubers is 27.9% and this value is extremely low compared to the observed carbohydrate content (47.2 – 58.4%). Meanwhile, the highest carbohydrate content (58.4%) from the sweet potato tubers treated with *T. vogelii* extracts while the least carbohydrate content (47.2%) was discovered in the sweet potato tubers from the plants treated with *A. squamosa* extracts.

Variation in the observed proximate contents among the applied insecticides is clear evidence that the insecticides applied to the target plant were absorbed and metabolized in the plant tissue which might have caused variation in the biochemical constituents of the treated plants. This suggests that the tested insecticides did not have negative effects on the photosynthetic activities of the target plant thereby improved the growth and the quality of the harvested tubers. This observation goes in line with earlier report that rate of photosynthetic activities determines the rate of production and the quality of the harvested products (Nwadinigwe, 2010)

Conclusion and REcommendations

Management of insect pests with plant extracts has been reported in the literature but very few have been tested in the control of rodents in root tuber crop and their effects on nutritional compounds of the target crop. This experiment therefore showed that the plant extracts and Lambdachyalothrin can be used in the management of rodent infestation of sweet potato tuber. Based on these findings, the plant extracts are better alternatives in the control of rodents and protection of the environment due to environmental hazards resulting from the use of synthetic insecticides. The tested plant extracts also improved proximate contents of the harvested sweet potato tuber except M. oleifera which had the least efficacy in the improvement of proximate contents of sweet potato tuber.

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