Pesticidal evaluation of teak and almond ethanol leaf extracts against two insect pests of sweet potato (*Ipomea batatas* L.)

Sa'adat Yetunde Yusuf[1], Abdulrasak Kannike Musa[1], Suleiman Mustapha[1*] and Mujidat Temidayo Lawal[1]

[1]*Department of Crop Protection, University of Ilorin, Ilorin, Nigeria.*

**Corresponding author email*: juniorsuleiman78gmail.com

The cultivation of sweet potatoes is constrained by insect pests. This had led to the use of synthetic insecticides which are unsafe for humans and the environment. Although various studies have investigated the single application of plant material to control pests, this study employed the combination of two botanicals to suppress them. The aim was to evaluate the pesticidal effectiveness of teak and almond ethanol leaf extracts against *Phyllotreta cruciferae* and *Cylas puncticollis* infesting sweet potato. The experiment was arranged in a randomised block design with three replications. The various treatments employed were single applications of almond (AL) and teak leaf (TL) extracts at 15% and 25% concentrations; mixed application of AL and TL extracts at AL15% + TL15%, AL15% + TL25%, AL25% + TL15% and, AL25% + ATL25% respectively, cypermethrin (0.15%) and a control. Data were collected on the number of the insect pests after treatments, sweet potato yield, and phytochemical screening of the botanicals. Analysis of variance indicated that the combination of AL and TL at 25% each significantly ($P \leq 0.05$) lowered the population of insect pests to a level comparable to cypermethrin and lower than the single applications of the botanicals. There was a significant increase in yield on plots treated with AL + TL at 25% concentration each. Phytochemical analysis indicated the presence of some bioactive compounds in the botanicals. The combination of different botanicals may be a plausible sustainable alternative to synthetic pesticides in pest management.

Keywords: Sweet potato, synthetic chemicals, botanicals, *Phyllotreta cruciferae, Cylas puncticollis,* plant extracts

Sweet potato (*Ipomoea batatas* (L.) is known to be a short cycle growing species in warm and hot climate regions and an annual plant in the temperate zone. This species is characterised as having delicate tubers with a sweetish taste and pleasant aromatic smell. It has a 50% higher nutritional value than Irish potato and plays a major role in the diet of consumers (Ofori et al. 2009). Sweet potato tubers are the main part used for food and other purposes, although the leaves can also be used. Tubers are characterised by a high unit mass (1 – 3 kg and even 5 kg); diverse shapes from spherical, oval, spherical-oval to fusiform; skin and flesh: white, cream, yellow, orange, red, claret and even purple, depending on the cultivar planted (Maloney et al. 2012). The main nutritional components in sweet potato tubers are protein, carbohydrates (starches and simple sugars), fat and fat-soluble vitamins. Moreover, cultivars with yellow flesh contain substantial amounts of carotenes (Allen et al. 2012). The tubers exhibit anti-oxidant, anti-proliferative and anti-diabetic properties due to the presence of valuable nutritional and mineral components in addition to having a low glycemic index (Jaarsveld et al. 2005; Abubakar et al. 2010; Ludvik et al. 2004; Allen et al. 2012).

Unfortunately, despite the nutritional and health benefits derived from sweet potato, its cultivation is plagued with a lot of constraints, insect pests posing a major problem in its production. Two of the most important insect pests affecting sweet potato in the tropics are the sweet potato weevils (*C. puncticollis* Boheman, Coleoptera: Curculionidae) and the flea beetles (*P. Cruciferae* Goeze, Coleoptera: Chrysomelidae) which cause drastic reductions in yield (Hue and Low 2015). Although efforts to curb their destructiveness have been extensively dependent on the usage of chemical pesticides, the practice is unsafe and poses a lot of threats. When pesticides are

0041–3216/2022/020121–130

used, they do not always stay in the target location where they are applied and moving as run-offs, they come in contact with non-target organisms reducing their population and thus favouring the pest complex (Cunningham 2018). Pesticides have also been shown to drastically alter the natural balance of the ecosystem. In addition to causing harm to wildlife, pesticides are known to cause serious harm to humans. Human exposure to pesticides has caused poisonings, the development of cancer, and the deaths of between 20,000 to 40,000 people worldwide each year (Cunningham 2018). Therefore, an alternative method of pest control has to be sought.

The search for insect control substances of plant origin has recently attracted great interest throughout the world, even though the utilisation of botanical extracts for pest control purposes is as old as mankind (Nancy and Wendy 1991; Ware 2000). Botanical pesticides are an important group of naturally occurring, often slow-acting crop protectants that are usually less harm to humans and the environment than conventional pesticides and with minimal residual effects (Pavela 2009). Ivbijaro (2012) reported that the system of using botanicals in plant protection against pests is very promising due to several distinct advantages. Insecticides that are botanically produced have long been in use as attractive substitutes to synthetic insecticides for insect pest management because they pose little or no threat to the environment and ecosystem at large and also are relatively safer if ingested by humans (Isman 2006; Asawalam and Onu 2014). Emphasis has been laid on studying plant derivatives as protectants to prevent the toxic or adverse effects of synthetic chemicals (Yang et al. 2010).

The objective of this research was to evaluate the pesticidal effectiveness of teak and almond leaf ethanol extract against two insect pests of sweet potato viz: *C. puncticollis* and *P. cruciferae*. The combination of these two botanicals at varying levels of concentration was also studied. Because botanicals have been thought of as safer alternatives to synthetic chemicals, the study was imperative.

Methods

Preparation of plant materials

Fully grown leaves of both almond (*Prunus dulcis* L.) and teak (*Tectona grandis* L.) were obtained from the parent trees, separately washed and air-dried for 6 - 10 days depending on the moisture content. The dried leaves were ground using a Eurolex electric blender. After grinding, the powders were passed through a 1 mm sieve to obtain particles of uniform size, then 1 kg of each of the powders was soaked in 3 L of ethanol (b.p. 56°C) and then allowed to stand for 72 hours, with occasional stirring. The solvent extraction procedure was carried out in the laboratory at ambient temperature (25 ± 2°C) and relative humidity (65 ± 3%). The solution of each plant sample was filtered using separate muslin cloths. The filtrates were evaporated to dryness (paste-like) using a rotary evaporator under reduced pressure and kept in their respective vials until required for use. The 15% concentrations were made by soaking 150 g of the paste in 1 L of water and the 25% concentrations were made by soaking 250 g of the paste in 1 L of water. A pyrethroid, cypermethrin, was used at a concentration of 0.15 L to 1 L of water as a synthetic check.

Phytochemical screening of ethanol plant extracts of almond and teak leaves

The air-dried leaves were ground into powder form in a Eurolex blender, 1 kg of blended materials were soaked in 3 L of ethanol for 72 hours and filtered through a clean, white muslin sieve. The filtrates were next concentrated into dryness (paste-like) with the use of a rotary evaporator. The ethanol plant extracts of almond and teak leaves were screened for phytochemical constituents according to the method of Sofowora (1993).

Study site

The experiment was carried out at the Faculty of Agriculture, University of Ilorin Teaching and Research Farm, Nigeria. The soil consisted of a sandy-loamy nature suitable for the cultivation of sweet potato. Planting of the sweet potato vines was done during the rainy season, in March, and harvesting commenced in June.

Experimental layout and procedures

The experimental field was prepared by clearing, ploughing and harrowing. A total land area of 1000 m^2 was used for cultivation and each treatment plot was in a spacing of 5 × 5 m with an inter-plot spacing of 1 m. Healthy planting vines of sweet potato with a varietal name of UMOSPO 3 were obtained from the Agricultural and Rural Management Training Institute (ARMTI), Ilorin – Idofian, Kwara State, Nigeria. The apical vines of the sweet potato were cut into 30 cm sections and healthy cuttings with 8 – 12 nodes were propagated at a spacing of 65 x 35 cm on well-ridged beds in all the treatment plots with each plot containing a total of 70 stands of sweet potato. Poultry droppings cured for 6 months were applied at a rate of 500 g per ridge by ring placement method at 2 and 5 weeks after planting to serve as organic fertiliser. To assist in the establishment of the plants, watering was done as necessary for the first 3 weeks after planting. After this, the sweet potato plants were well-established and required no further artificial irrigation. Spaces between plants and replicates were weeded manually every 2 weeks.

Almond (AL) and teak leaf (TL) extracts at concentrations of 15% and 25%; combinations (almond + teak) of AL15% + TL15%, AL15% + TL25%, AL25% + TL15% and AL25% + TL25%; cypermethrin EC at 0.15% and control were the various treatments employed. The botanical extracts and cypermethrin were sprayed on the foliage of sweet potato leaves using knapsack sprayers of 10 L capacity bi-weekly from 21 days after planting (DAP) just when the insect pest populations were at a considerable level to cause visible damage on the sweet potato. The application of treatments was done early in the morning from 7:00 am. (Owolade et al. 2004; Oparaeke 2005).

Sweet potato plants were monitored every 2 weeks after treatment to assess flea beetle and sweet potato weevil feeding damage (George et al. 2019). The flea beetle and sweet potato weevil populations at the study site were assessed by carefully inspecting the foliage and vines of the plant and by collecting and counting the insect pests in pitfall traps and on yellow sticky traps as described by George et al. (2019). Five sweet potato plants were randomly selected for assessment from each treatment plot by carefully uprooting them using a hoe. Next, tagging and labelling were done and the uprooted samples were taken to the laboratory where the assessment of the insect pest population was carried out by splitting up the vines and roots (tubers) of sweet potato longitudinally using a sharp knife to investigate for the presence of adults, eggs, larval and pupal stages of the insects which were counted and recorded.

Data collection and analysis

The experiment was laid out in a randomised block design with three replications. From each treatment plot 25 sweet potato plants were randomly selected and data were collected on the number of flea beetles, the number of sweet potato weevils, and the total yield weight of sweet potato. Statistical analysis was done using a two-way analysis of variance and significant treatment means were separated using the Duncan's New Multiple Range Test at $P \leq 0.05$.

Results

Effect of ethanol extract of teak and almond leaves in the control of sweet potato weevil (C. puncticollis) infesting sweet potato

Table 1 shows the effect of teak and almond leaves ethanol extract against *C. puncticollis* affecting sweet potato. Throughout the period of the study, the untreated control was heavily infested by the insect pest and recorded the highest level of damage. Cypermethrin treated plants, on the other hand, had the lowest mean number of trapped *C. puncticollis* within the two sampling periods. There were significant ($P \leq 0.05$) differences between the botanical extracts and the control with all the plant extracts having a significantly lower population of *C. puncticollis* when compared to the control. The treatment combination of both almond and teak leaf extract at 25% gave the least amount of the insect pests recorded from 30 - 100 days DAP and thus was effectively able to suppress the insect. Post hoc analysis also revealed that there was no difference between the treatment combination of both almond and teak leaf extract at 25% each and the cypermethrin treatment from 30 - 72 DAP and thus was as effective as the chemical treatment cypermethrin.

The total effect of the treatments revealed that cypermethrin and the treatment combinations of AL and TL (25 + 25%, 25 + 15%, 15 + 25% and 15 + 15% respectively) had the least insect pest infestation when compared to the control that had the highest.

Table 1: Effect of ethanol plant extracts on the mean number of *C. puncticollis* infesting sweet potato

	Days after planting (DAP)					
Treatment (%)	**30**	**44**	**58**	**72**	**86**	**100**
TL 15	2.33^{ab}	2.67^{b}	1.67^{b}	2.67^{bc}	1.67^{b}	2.67^{bcd}
TL 25	1.33^{bc}	1.67^{bcd}	1.67^{b}	2.67^{bc}	1.33^{bc}	2.67^{bcd}
AL 15	2.33^{ab}	2.67^{b}	1.67^{b}	3.33^{b}	2.00^{b}	4.00^{b}
AL 25	1.67^{bc}	1.67^{bcd}	1.00^{b}	2.67^{bc}	1.33^{bc}	3.33^{bc}
AL 15 + TL 15	2.00^{bc}	2.33^{bc}	1.67^{b}	2.33^{bc}	0.67^{bc}	2.33^{bcd}
AL15 + TL 25	1.33^{bc}	1.00^{cd}	1.00^{b}	1.33^{bcd}	0.67^{bc}	2.00^{cd}
AL 25 + TL 15	1.33^{bc}	1.33^{bcd}	1.00^{b}	1.33^{bcd}	0.67^{bc}	1.67^{cd}
AL 25 + TL 25	0.67^{c}	1.00^{cd}	0.67^{b}	0.67^{cd}	0.00^{c}	1.00^{de}
CP 0.15	0.67^{c}	0.67^{d}	0.00^{b}	0.00^{d}	0.00^{c}	0.00^{e}
Control	$3.33^{a} \pm$	5.33^{a}	4.33^{a}	8.67^{a}	9.33^{a}	8.67^{a}
	Total treatment effect					
Tl	1.83^{b}	2.67^{b}	1.67^{b}	2.67^{bc}	1.50^{b}	2.67^{bc}
AL	2.00^{b}	2.17^{b}	1.33^{b}	3.00^{b}	1.67^{b}	3.67^{b}
AL + TL*	1.33^{bc}	1.67^{bc}	1.17^{b}	1.50^{bcd}	0.33^{c}	1.67^{c}
AL + TL**	1.33^{bc}	1.17^{bc}	1.00^{b}	1.33^{cd}	0.67^{bc}	1.83^{c}
CP	0.67^{c}	0.67^{c}	0.00^{b}	0.00^{d}	0.00^{c}	0.00^{d}
Control	3.33^{a}	5.33^{a}	4.33^{a}	8.67^{a}	9.33^{a}	8.67^{a}
SEM	0.18	0.26	0.27	0.45	0.49	0.43

Means in the same column with the same superscript(s) are not significantly different at $P \leq 0.05$ using Duncan`s New Multiple Range Test.
Key: TL = teak leaf extract, AL = almond leaf extract, CP = cypermethrin, SEM = Standard error of mean, * = 15 + 15/25 + 25, ** = 15 + 25/25 + 15

Effect of ethanol extract of teak and almond leaves in the control of flea beetle (P. cruciferae) infesting sweet potato

Table 2 shows the effects of the botanicals against *P. cruciferae* affecting sweet potato leaves. The result indicated that there were significant differences between the various treatments and the control. The untreated sweet potato plants had significantly (P ≤ 0.05) higher numbers of the insect pest infestations on the leaves from 30 - 100 DAP when compared to the treated plants.

Amongst the various treatments, sweet potatoes treated with cypermethrin had the lowest mean numbers of perforated leaves by the insect pest. This was followed by the ethanol plant extracts combination of almond and teak leaf extracts at the concentration rate of 25% each which had no significant differences from the cypermethrin administered dosage at 30, 44, 58, 86, and 100 DAP and as such was effectively able to suppress the insect pest on the sweet potatoes. Observations also revealed that the almond + teak leaf extracts at 25% each had a significantly (P ≤ 0.05) lower mean numbers of the insect pest perforations of sweet potato leaves at 86 and 100 DAP with the mean numbers 4.00 and 4.33 respectively when compared to the other botanical treatments. Whereas, the single usage of the plant extracts (TL 15% and 25% and AL 15% and 25%) had more insect populations when compared to the use of almond and teak leaf extracts at 25% each.

Result for the total treatment effect indicated the cypermethrin based treatment along with the treatment combination of AL and TL (25 + 25%, 15+ 25% and 15 + 15% respectively) to have offered the most control against the insect pest.

Table 2: Effect of ethanol plant extracts on the mean number of *P. cruciferae* infesting sweet potato

	Days after planting (DAP)					
Treatment (%)	**30**	**44**	**58**	**72**	**86**	**100**
TL 15	5.00^{b}	6.00^{b}	7.33^{b}	8.33^{b}	9.67^{b}	10.67^{b}
TL 25	4.33^{bc}	6.00^{b}	7.00^{b}	7.33^{bc}	8.33^{cd}	9.00^{c}
AL 15	4.33^{bc}	5.33^{bc}	6.67^{b}	7.33^{cd}	9.00^{bc}	10.00^{b}
AL 25	4.00^{bcd}	4.67^{bcd}	5.00^{c}	6.33^{cd}	8.00^{d}	9.00^{c}
AL 15 + TL 15	3.33^{cde}	4.00^{de}	4.33^{cd}	5.67^{de}	6.33^{e}	6.67^{d}
AL15 + TL 25	3.33^{cde}	4.00^{cde}	4.00^{cd}	5.00^{ef}	5.33^{f}	5.67^{e}
AL 25 + TL 15	3.33^{cde}	4.33^{cd}	4.67^{c}	5.67^{de}	6.33^{e}	6.67^{d}
AL 25 + TL 25	2.67^{de}	3.33^{de}	3.33^{de}	4.00^{f}	4.00^{g}	4.33^{f}
CP 0.15	2.33^{e}	2.67^{e}	2.67^{e}	2.67^{g}	2.67^{h}	2.67^{g}
Control	7.0^{a}	8.33^{a}	10.00^{a}	11.67^{a}	14.00^{a}	15.67^{a}
			Total treatment effect			
TL	4.67^{b}	6.00^{b}	7.17^{b}	7.83^{b}	9.00^{b}	9.83^{b}
AL	4.17^{bc}	5.00^{bc}	5.83^{c}	6.83^{c}	8.50^{b}	9.50^{b}
AL + TL*	3.00^{cd}	3.67^{de}	3.83^{d}	4.83^{d}	5.17^{d}	5.50^{c}
AL + TL**	3.33^{bcd}	4.17^{cd}	4.33^{d}	5.33^{d}	5.83^{c}	6.17^{c}
CP	2.33^{c}	2.67^{e}	2.67^{e}	2.67^{e}	2.67^{e}	2.67^{d}
Control	7.00^{a}	8.33^{a}	10.00^{a}	11.67^{a}	14.00^{a}	15.67^{a}
SEM	0.28	0.31	0.41	0.45	0.57	0.65

Means in the same column with the same superscript(s) are not significantly different at P ≤ 0.05 using Duncan`s New Multiple Range Test.

Key: TL = teak leaf extract, AL = almond leaf extract, CP = cypermethrin, SEM = Standard error of mean, * = 15 + 15/25 + 25, ** = 15 + 25/25 + 15

Effect of ethanol extract of teak and almond leaves on the yield of sweet potatoes (Ipomea batatas)

There were significant differences amongst all the various treatments administered and the control on the yield of sweet potato (Table 3). Observation of both the numbers and weight of the sweet potato tubers showed that the untreated plants (3.00), and the single applications of teak at 15% (3.00) and 25% (4.67) and almond leaves at 15% (3.00) and 25% (3.00) ethanol extracts had a significantly ($P \leq 0.01$) lower mean number of tubers and also the lowest tuber weights of 1.73, 2.47, 3.50, 2.07 and 2.23 kg respectively.

On the other hand, sweet potatoes treated with cypermethrin had significantly ($P \leq 0.01$) the highest mean number of tubers (16.67) followed by the treatment combination of almond and teak leaf ethanol extracts at 25% each (14.67).

Even though the treatment combinations of almond and teak leaf extracts at the rate of 15% + 15%, 25% + 25%, 25% + 15%, and 15% + 25% respectively were effective in increasing yield compared to the single application of the treatments and the control, it was the treatment combination of both almond and teak leaf ethanol extracts at 25% each that was most significant ($P \leq 0.05$), having the highest number and weight of sweet potato tubers amongst all the botanical concentrations.

Table 3: Effect of teak and almond leaf ethanol extracts on the mean yield weight of sweet potato

	Yield	
Treatment (%)	**No. of tubers**	**Weight of tubers (kg)**
TL 15	3.00^{e}	2.47^{d}
TL 25	4.67^{e}	3.50^{cd}
AL 15	3.00^{e}	2.07^{d}
AL 25	3.00^{e}	2.23^{d}
AL 15 + TL 15	9.33^{c}	7.40^{b}
AL15 + TL 25	10.67^{c}	8.17^{b}
AL 25 + TL 15	7.33^{d}	6.00^{c}
AL 25 + TL 25	14.67^{b}	13.10^{a}
CP 0.15	16.67^{a}	14.13^{a}
Control	3.00^{e}	1.73^{d}
	Total treatment effect	
TL	3.83^{d}	2.98^{d}
AL	3.00^{d}	2.15^{d}
AL + TL*	12.00^{b}	10.25^{b}
AL + TL**	9.00^{c}	7.08^{c}
CP	16.67^{a}	14.13^{a}
Control	3.00^{d}	1.73^{d}
SEM	0.92	0.84

Means in the same column with the same superscript(s) are not significantly different at $P \leq 0.05$ using Duncan`s New Multiple Range Test.

Key: TL = teak leaf extract, AL = almond leaf extract, CP = cypermethrin, SEM = Standard error of mean, * = 15 + 15/25 + 25, ** = 15 + 25/25 + 15

Phytochemical analysis of almond and teak leaf

Quantitative analysis indicated that the various phytochemical components in both almond and teak leaf varied slightly. Saponins, alkaloids, and tannins were detected to be a little bit more in almond leaf than in teak leaf. Whereas flavonoids, phenols, glycosides, terpenoids, and oxalates were found to be slightly increased in teak leaf (Table 4).

Table 4: Quantitative phytochemical constituents of almond and teak leaf ethanol extracts

Compounds	**Almond leaf (mgl^{-1})**	**Teak leaf (mgl^{-1})**
Tannins	0.52	0.50
Saponins	3.15	2.99
Flavonoids	0.36	1.01
Phenols	0.44	0.63
Alkaloids	1.38	1.29
Glycosides	6.24	6.73
Terpenoids	0.10	0.13
Oxalates	0.98	1.02

Discussion

Botanical pesticides are safer alternatives to the use of synthetic pesticides that leave off toxic residues in food crops (Pavela 2009). The present study was an investigative approach in the use of two botanical extracts to control the insect pests of sweet potato: *C. puncticollis* and *P. cruciferae*. Previous findings have reported *Cylas* spp. and the flea beetle as major pests of sweet potato (Uwaidem et al. 2018). In some parts of the world, yield loss in the range of 90-100% in stored roots has been documented due to insect pest infestations (Munyuli et al. 2017)

It was observed that the combination of the extracts of almond and teak leaves at 25% w/v recorded the least number of both sweet potato weevil (*C. puncticollis*) and flea beetle (*P. cruciferae*). This indicates that the application of these plant extracts at the given concentration was sufficient to bring the insect population below economic damage. The study was unique in that it revealed that the combination of these two extracts was as efficient as cypermethrin which is a chemical-based pesticide. However, the single applications of the botanicals were not as effective. Other studies have evaluated the effectiveness of single-use of plant-based materials as insecticides (Rajendran and Sriranjini 2008; Ivbijaro 2012; Isman 2006), but the current investigation showed that a single application of these botanicals may not be sufficient in the control of insect pests in replacing the use of chemicals. The effectiveness of the botanical mixture (at 25%) may be due to the combined quantity of the phytochemicals in both the almond and teak leaves which played a significant role as pesticides and in the protection of the plant against insect pests. Some of these phytochemicals have been shown to alter the behaviour, growth, and development of insects affecting host plants (Katie and Thorington 2006; Nukmal et al. 2017). In a study by Sathyan et al. (2015), the combination of teak leaf and neem seed kernel extract at 5% each was effectively used to control leafhoppers in cotton plants, thus showing that the mixture of two or more botanicals could drastically improve on the insecticidal potentials of plant materials.

The main aim of controlling insect pests is to ultimately increase yield in a sustainable manner. Sweet potatoes that are severely infested or have inefficient treatment by the single usage of botanicals show negative impacts on tuber quality and yield (Stathers et al. (2003). Defoliation is common sight in such treatments and this inhibits cell multiplication, amino-acid synthesis and energy formation thus affecting the photosynthetic ability of the plant (Eifediyi and Remison 2010). Our experiment indicated that the almond and teak extract combination of 25% each gave the most yield and did not vary from the yield observed when treated with chemical pesticide thus showing its potential to serve as a chemical alternative. The botanical extracts could have possibly acted or served not only as an insecticide but also as amendments in improving the yield of the plant (Opara and Agugo 2014). In another finding, Osei et al. (2010) reported that the potential of botanical treatments to protect sweet potato foliage from insect damage might have permitted higher photosynthetic rates resulting in high tuber production. Mochiah et al. (2011) observed that vegetables in which botanicals were applied produced the highest mean fruit weight and fruit numbers of okra and eggplant. This is in support of what was found in this work, that the synergistic action of two different botanicals can greatly improve its insecticidal components and also increase the yield of crops.

Conclusion

The method of using plant extracts shows promising results in the management of insect pests of sweet potato. Although the use of synthetic pyrethroid cypermethrin achieved a reduced pest status and an increase in yield of sweet potato, the practice is not sustainable therefore, this has necessitated the search for other alternatives. In this study, almond leaf ethanol extract at 25% concentration in combination with teak leaf ethanol extract at 25% concentration was identified to give a satisfactory level in the management of the two insect pests of sweet potato encountered namely flea beetles and sweet potato weevils. Based on the results from this study, teak and almond leaf extracts could be incorporated in the control of field insect pests of sweet potato thus reducing the dependency on toxic chemicals. Some important observations can also be drawn from this study; first that the combination of two or more botanicals can enhance the potency of pesticides in pest control and secondly, the enhanced pesticide could invariably increase crop yield. Recommendations could be further made based on the findings of this study to carry out further investigations on the combined effects of almond and teak plant extracts in the control of pests in place of the use of toxic chemicals.

References

Abubakar, H.N., I.O. Olayiwola, S.A. Sanni, and M.A. Idowu. 2010. “Chemical Composition of Sweet Potato (*Ipomoea batatas* (L.) Lam) Dishes as Consumed in Kwara State, Nigeria.” *International Food Research Journal* **17:**411−416.

Allen, J.C., A.D. Corbitt, K.P. Maloney, M.S. Butt, and V.D. Truong. 2012. “Glycemic Index of Sweet Potato as Affected by Cooking Methods.” *The Open Nutrition Journal* **6:**1−11.

Asawalam, E. and I. Onu. 2014. “Evaluation of Some Plant Powders against Khapra Beetle (*Trogoderma granarium* Everts) (Coleoptra: Dermestidae) on Stored Groundnut.” Advancement in Medicinal Plant Research **2 (2):** 27–33.

Cunningham, M. 2018. Use of Pesticides: Benefits and Problems Associated with Pesticides. DSST Environmental Science: Study Guide.

George, D., G. Port, and R. Collier. 2019. “Living on the Edge: Using and Improving Trap Crops for Flea Beetle Management in Small-Scale Cropping Systems.” Insects **10 (9):** 286. https://doi.org/10.3390 /insects10090286

Eifediyi, E.K., and S.U. Remison. 2010. “The Effects of Inorganic Fertilizer on the Yield of Two Varieties of Cucumber (*Cucumis sativus* L.).” *Report and Opinion* **2 (11):** 1–5.

Hue, S., and Low, M. 2015. “An Insight into Sweet Potato Weevils Management: A Review.” *Psyche* **2015**:1–11.

Isman, M.B. 2006. “The Role of Botanical Insecticides, Deterrents, and Repellents in Modern Agriculture and an Increasingly Regulated World.” *Annual Review of Entomology* **51:**45–66.

Ivbijaro, M.F. 2012. *Natural Pesticides from Nigeria in Poverty Alleviation from Biodiversity Management.* Ibadan, Nigeria: Book Builders Editions of Africa, 431.

Jaarsveld, P.J., M. Faber, S.A. Tanumihardjo, P. Nestel, C.J. Lombard, and B.J. Spinnler. 2005. "Beta-Carotene – Rich Orange-Fleshed Sweet Potato Improves the Vitamin A Status of Primary School Children Assessed with the Modified-Relative-Dose-Response Test." *American Journal of Clinical Nutrition* **81:**1080−1087.

Katie, E.F., and R.W. Thorington. 2006. *Squirrels: The Animal Answer Guide.* Baltimore: Johns Hopkins University Press. p. 91.

Ludvik, B., B. Neuffer, and G. Pacini. 2004. "Efficacy of *Ipomoea batatas* (Caiapo) on Diabetes Control in Type 2 Diabetic Subject Treated with Diet." *Diabetes Care* **27:**436−440.

Maloney, K., V.D. Truong, and J.C. Allen. 2012. "Chemical Optimization of Protein Extraction from Sweet Potato (*Ipomoea batatas*) Peel." *Journal of Food Science* **77:**306−312.

Mochiah, M.B., B. Banful, K.N. Fening, B.N. Amoabeng, K. OffeiBonsu, S. Ekyem, H. Braimah, and M. Owusu-Akyaw. 2011. "Botanicals for the Management of Insect Pests in Organic Vegetable Production." *Journal of Entomology and Nematology* **3 (6):** 85−97.

Munyuli, T., Y. Kalimba, E.K. Mulangane, T.T. Mukadi, M.T. Ilunga, and R.T. Mukendi. 2017. "Interaction of the Fluctuation of the Population Density of Sweet Potato Pests with Changes in Farming Practices, Climate and Physical Environments. A 11-year Preliminary Observation from South-Kivu Province, Eastern DR Congo." *Open Agriculture* **2 (1):** 495−530.

Nancy, M., and C.M. Wendy. 1991. "Alternatives to Synthetic Chemical Insecticides for Use in Crucifer Crops." *Biological Agriculture and Horticulture* **8:**33–52.

Nukmal, N., E. Rosa, A. Apriliyani, and M. Kanedi. 2017. "Insecticidal Effects of the Flavonoid-rich Fraction of Leaves Extract of Gamal (*Gliricidia sepium*) on the Coffee Mealybugs (*Planococcus citri* Risso.)." *Annual Research & Review in Biology* **16:**1−9. 10.9734/ARRB/2017/36209.

Ofori, G., I. Oduro, W. Ellis, and H. Dapaah. 2009. "Assessment of Vitamin A Content and Sensory Attributes of New Sweet Potato (*Ipomoea batatas*) Genotypes in Ghana." *African Journal of Food Science* **3:**184−192.

Opara, E., and A. Agugo. 2014. "Application of Organic Amendments and Botanical Foliar Sprays against Bacterial Diseases of Mungbean (*Vigna radiata* L.) in South Eastern Nigeria." *Greener Journal of Agricultural Sciences* **4:**052−057.

Oparaeke, A.M. 2005. "Studies on Insecticidal Potential of Extracts of *Gmelina arborea* L. Products for Insect Pests' Control on Cowpea, *Vigna unguiculata* (L.) Walp-1. The Legume Flower Bud Thrips, *Megalurothrips sjostedti* Tryb." *Archives of Phytopathology and Plant Protection* **24:** 54−60.

Osei, K., S.R. Gowen, B. Pembroke, D.L. Bradenburg, and D.L. Jordan. 2010. "Potential of Leguminous Cover Crops in Management of a Mixed Population of Root-Knot Nematode (*Meloidogyne* spp.)." *Journal of Nematology* **42:**173–178.

Owolade, O.F., B.S. Alabi, Y.O.K. Osikanlu, and O.O. Odeyemi. 2004. "On-Farm Evaluation of Some Plant Extracts as Biofungicide and Bioinsecticide on Cowpea in Southwest Nigeria." *Agriculture and Environment* **22 (22):** 237–240.

Pavela, R. 2009. "Effectiveness of Some Botanical Insecticides against *Spodoptera littoralis* Boisduvala **(**Lepidoptera: Noctuidae**),** *Myzus persicae* Sulzer **(**Hemiptera: Aphididae**)** and *Tetranychus* *urticae* Koch **(**Acari: Tetranychidae).” *Plant Protection Science* **45:**161−167.

Rajendran, S., and V. Sriranjini. 2008. “Plant Products as Fumigants for Stored - Product Insect Control.” *Journal of Stored Products Research* **44:**126–135.

Sathyan, T., N. Murugesan, K. Elanchezhyan, J. Arokia Stephen Raj, and G. Ravi. 2015. “Evaluation of Botanicals, Microbials and Non - Synthetic Insecticides for the Management of Leafhopper, *Amrasca devastans* Distant in Cotton.” *Journal of Entomology and Zoology Studies* **3 (6):** 180 – 182

Sofowora, A. 1993. *Medicinal Plants and Traditional Medicine in Africa*. 2nd ed. Spectrum Books Limited. pp. 134−156.

Stathers, T.E., D. Rees, A. Nyango, H. Kiozya, L. Mbilinyi, S. Jeremiah, S. Kabi, and N. Smit. 2003. “Sweet Potato Infestation by Cylas spp. in East Africa: II. Investigating the Role of Tuber Characteristics.” *International Journal of Pest Management* **49 (2):** 141−146.

Uwaidem, Y.I., O.A. Borisade, R.A. Essien, and E.A. Akpan. 2018. “Insect Pest Complex and Beneficial Insects Associated with Sweet Potato (*Ipomoea batatas*) (Lam.) in Southern Nigeria and Key Pests to Consider in Control Programmes.” *Journal of Agriculture and Ecology Research International* **16 (2):** 1−9.

Ware, G.W. 2000. *The Pesticide Book.* 5th ed. Fresno, California: Thomson Publications. p. 415.

Yang F.I., F. Zhu, and C.L. Lei. 2010. “Garlic Essential Oil and its Major Component as Fumigants for Controlling *Tribolium castaneum* (Herbst) in Chambers Filled with Stored Grain.” *Journal of Pest Science* **83:**311−317.