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An Evaluation of Insecticidal Properties of Extract from Pyrethrum (*Chrysanthemum cinerariaefolium*) in Controlling Cylas (*Cylas puncticolis*) an Insect Pest of Sweet Potatoes in Nigeria

Lawrence A. Ugbe[1*], Patrick O. Ukatu[2], Akinmola Solomon Morebise[3]

[1]Department of Agriculture, Federal College of Education Obudu, University of Calabar, Calabar, Nigeria
[2]Department of Crop Science, University of Calabar-Calabar, Calabar, Nigeria
[3]Department of Plant Production, State University of Santa Cruz, Ilhéus, Brazil
Email: *ugbeahmed@gmail.com

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Abstract

This experiment was carried out in 2023 and 2024 farming seasons at the teaching and research farm of Federal College of Education, Obudu in Cross River State of Nigeria. The study was to evaluated the insecticidal properties of extract from flowers of Pyethrium (*Chrysanthemum cinerariaefolium*) in controlling *Cylas punticolis*, a predominant insect pest of sweet potato in Nigeria. The experiment was established in a piece of fallow land measuring 25.0 × 25.0 m. The design of the experiment was a Completely Randomized Design (CRD) with a 3 by 5 factorial layout. 3 sweet potato varieties were cultivated on 5 beds measuring 4 m × 2 m each. There were 5 beds per plots, 15 beds in the 3 plots representing a block. The experiment was replicated 3 times with 45 beds in the entire experimental plot. Sweet potato cuttings were planted at 30 cm within rows and 75 cm between rows, giving a plant population of 26 stands per bed, 130 stands per plot, 390 stands per replicate and 1,170 stands in the entire farm. Extract from the flowers of pyrethrum were prepared into a solution and applied at 0, 2, 4, 6 and 8 litres per hectare to the sweet potato stands on the beds with the help of a knapsack sprayer at 12 weeks after planting, to control activities of *Cylas spp*. The sweet potato variety was the main plot, while the volume of application of the plant extract was the sub-plot. Data for the number of tubers per stand, tuber weight in grammes (g) per stand and tuber yield in tonnes per hectare (t/ha) were taken. The average of all data generated in each parameter were subjected to analysis of variance (ANOVA) and

means separated by Least Significant Difference (LSD) at 0.05 level of probability. Findings revealed that extract from flowers of Pyrethrum has the efficacy to effectively control *Cylas spp* in sweet potato farm, thereby resulting to higher yield of the crop. It was recommended that the extract should be applied at 8 litre /a.i/ per hectare to sweet potato plants in the field to control *Cylas spp*. The application should be preventive.

Subject Areas

Agricultural Science

Keywords

Pyrethrum, Extract, Experimental Design, Variety, Insecticidal, Insect Pest

1. Introduction

Sweet potato *(Ipomoea batatas)* are perennial herbs with Vine-like trailing stem [1]. They belong to the family called Convolvulaceae. They originated in the Andes from northern part of South America down to Mexico [2]. From here, they were taken to Southeast Asia and to Africa. Nowadays, they are grown everywhere in the tropics and subtropics [3]. In some areas of production, they are the major source of food [4]. The tuber is eaten boiled, fried, baked or made into syrup. They serve as raw materials for the manufacture of starch, glucose, and alcohol. The leaves are used as vegetables, while the vines are used as livestock feeds [1].

Many cultivars of sweet potatoes are existing however, the most popular ones are the white, light yellow, to deep arrange coloured flesh., the light ochre, brown, red, to deep violet blue skins., the short, almost round, oblong roots, long root (tuber) and the short, medium or long growing time type: short growing (3 months), medium growing (4 - 6 months) and long growing type (9 months) [5].

The production of sweet potatoes like any other crop is constrained by damage caused to the tubers in addition to the leaf eating insect pests. Pests attacks on sweet potatoes and recorded everywhere in the world including tropical Africa, hence Nigeria [5]. [1] reported that the commonest insect pest of sweet potatoes in the tropics is *Cylas formicarius*. [6] reported that *Cylas puncticolis* is the commonest pest in Nigeria. [7] had earlier on reported that the commonest special of cylas in Africa is *Cylas punticolis*.

Cylas species are commonly known as "sweet potato weevil" a complete life cycle of *Cylas puncticolis* requires just one to two months with 35 to 40 days being common in rainy season. The generations are indistinct, and the number of generations occurring annually are estimated to be between 5 and 8 [8]. Adults of *Cylas spp* do not undergo a period of diapause in the dry season, but seeks shelter and remain inactive until the weather is favourable. All stages can be found throughout the year if suitable host materials are available [9]. *Cylas* species are very active, especially during the rainy season, when sweet potato plants develop

tubers.

Symptoms of infestation by sweet potato weevil include; yellowing of the vines, but a heavy infestation is usually necessary before this becomes apparent [5]. Thus incipient problems are easily over looked, and damage not apparent until tubers are harvested. The principal form of damage to sweet potato is mining of the tubers by the larvae of *Cylas spp* [5]. The infested tuber is often riddle with cavities, becomes spongy in appearance, and dark in colour [7]. In addition to the damage caused directly by tunnelling, the larvae cause damage indirectly by facilitating entry of soil-borne pathogens [9]. Even low levels of feeding induced a chemical reaction that imparts a bitter taste and terpene odor to the tuber. Larvae also mine the vine of the plant, causing it to darken, Crack or collapse. The adult may feed on the tubers, creating numerous small holes that measure about the length of its head. However, adults *Cylas* usually have limited access to the potato tubers; however, damage at this stage is less severe than that of larvae. Adult feeding on the foliage is seldom [9].

For several years now organophosphate and organochlorine insecticides have been used as affective substances in controlling insect pests of crops [10]. In control of *Cylas spp*, synthetic insecticides are commonly applied to the soil during planting time to prevent injury to slips or cuttings. Either granular or liquid formulations are used and systemic insecticides are preferred [5]. Post plant applications are sometimes made to the foliage for adult control [9] especially, if fields are likely to be invaded from adjacent areas. But if systemic insecticides are applied, some suppression of larvae developing in the vine may also occur. Due to the long duration of the plant growth period, it is not uncommon for preplant or planting time applications to be followed by one or more insecticide applications to the plant or soil at mid-season [5]. Insecticides are also applied to tubers being placed into storage to prevent re-infestation and inoculation of nearby field [9].

However, research has shown that using the synthetic chemicals continuously in insect pest control, will result in the development of resistant to the chemicals [11]. In addition, a recent re-assessment of the ecotoxicity of these chemicals, revealed that, they are no longer safe for use because of their hazards to the environment [12]. Therefore, it has become necessary to develop alternative means of controlling insect pests of crops, rather than the continuous use of chemical pesticides. One of the best alternative means, is the use of plant based extracts [13]. Extracts from plants control pests through non-toxic mechanisms. The United State Environmental Protection Agency (USEP) called them 'Biopesticides' and defined them as pesticides dervised from natural materials such as animals, plants, bacteria and minerals. [14] reported that Biopesticdes are environmentally sound and efficacious products. According to them, Biopesticides are non-toxic to non-target organisms, including beneficial insects and wildlife.

Small holder farmers in many parts of the world have been using products from some indigenous plants to protect insect pests infestations of their agricultural

produce [15]. Plant materials such as the leaves, fruits, barks, roots, seeds, processed powders etc, have been in use for the protection of insect pests of crops [15].

In this experiment, extract from pyrethrum (*Chrysanthemum cinerariaefolium*) was used. Pyrethrum is a daisy like perennial plant of the genus chrysanthemum belonging to the family compositae. The white flower heads possess insecticidal properties [16].

Pyrethrum originated in former Yugoslovia and its cultivation has now spread all over the world. The plant thrives better in semi-arid regions and requires a rainfall of about 1200 mm. In places with humus-rich loams and heavier rainfall, the plant grows more profusely, but the insecticidal content is less than when it grows in poorer, drier situation [16]. In Nigeria, the plant grows wild on its own, while in some cases, it is planted as an ornamental plant [17]. According to Gaby [16] through the effect of pyrethrum as a nerve poison, it produces erratic movement, excitement and finally paralysis (knock-down effect). The insects can recover from the amount required to produce the knock-down effect within 24 hours. Larger doses are usually needed to bring about total death of the insect. The insecticidal flowers of pyrethrum are effective against insects such as *Aphids*, *Cylas spp*, *Coffee bugs*, *Colorado Beetles etc*. Extract from pyrethrum can be effective against insect pests, especially in crops such as Lygus species, Pieris, Rapae, Aspodydia, Sweet potato and Empoasia devastans [18].

2. Statement of the Problem

The need to produce food in large quantities through the use of agro-chemicals in order to feed the increasing human populations, has continued to put pressure on the intensive use of pesticides and fertilizers. However, research globally has documented the contamination and negative impact of agrochemical residues in soils, terrestrial and aquatic ecosystems including coastal marine systems. Also documented most importantly is their toxic effect on humans. It has become necessary to seek alternative paths to the intensive use of chemicals in crop protection, through the use of plant base extracts that are more biodegradable in order to produce better quality food. Pyrethrum extract as a biological extract, is safe on non-target organisms. It is easily biodegradable in the soil health and the environment [19]. [20] had earlier reported that biocontrol agents have no adverse effect on soil microorganisms, but that rather, some of them can contribute positively to soil nitrogen content.

3. Objective of the Study

The main objective of the study is to develop an alternative means of controlling insect pests of crops through the use of plant base extract. This will reduce the hazards caused by synthetic pesticides to the environment. The specific objectives include;

1) To prepare an aqueous solution from flowers of pyrethrum (*Chrysanthemum cinerariaefolium*).

2) To test the efficacy of the aqueous solution in controlling *Cylas puncticols* in sweet potatoe tubers.

3) To demonstrate the efficacy of the aqueous solution in controlling *Cylas punticolis* to sweet potato farmers in the study area.

4. Materials and Methods

The study was conducted in April 2023 and April 2024 at the research and experimental farm of the Department of Agriculture, Federal College of Education Obudu, Cross River State in Nigeria. Obudu Local Government Area is bounded by Obanliku Local Government Area to the East, Bekwarra Local Government Area to the West and Vandeikya Local Government Area of Benue State to the North. The climate in Obudu Local Government Area is rainforest from southern to western parts, then, it is guinea Savannah from eastern to the northern parts. The College farm shares the guinea savannah climate which extends from Vandeikya Local Government Area of Benue State. About 60 % of the population of the people of Obudu Local Government Area, is made up peasant farmers, who cultivate various crops like; yam, cassava, rice, oil palm, cocoa, sweet potatoes etc (Source: Ministry of Agriculture, Obudu Local Government Area).

The design of the experiment was a Completely Randomized Design (CRD) on a 3 by 5 factorial. A plot of land measuring 25.0 m × 25.0 m was used as experimental plot. The plot was cleared, packed and beds constructed. The beds were inter-spaced 0.05 m apart and each bed measured 4 m × 2 m. Each bed represented a sub-plot. There were 5 beds in each plot planted to a single cultivar of sweet potato. Altogether, three cultivars were used; the long white to light fellow tubers (TIS 3057), the long, brown to deep violet blue tubers (TIS. 3030) and the round or oblong white to light yellow tubers (TIS 2532). The 5 beds in each of the 3 plots received the application of crude extract of Pyrethrum *(Chrysanthemum cinerariaefolium)* at different volumes of 0, 2, 4, 6 and 8 lit/ha, applied at 12 weeks after planting to protect both the leaves and the developing tubers from attacks by adult and larvae of *Cylas spp*. The experiment was replicated 3 times. There were 15 beds in a replicate, and 45 beds in the entire experimental farm. The application of the plant extract was carried out in the evening when the temperature had gone down. It is reported [16] that high temperatures will accelerate the rapid decomposition of plant mixture, thereby reducing the efficacy of the mixture as a biopesticides.

Cuttings of sweet potato vines were planted at a distant of 30 cm within rows, and 75 cm between rows. There were 26 stands per bed, 130 stands per plot, 390 stands per replicate and 1,170 stands in the entire plant population of the experimental plot.

5. Preparation of Aqueous Solution of Pyrethrum

Mature flowers of Pyrethrum plant were harvested when fully opened. They were

spread 3 - 4 cm thick on mats under the sun in an airy, shady place to dry. About a 100 g of the flowers were pounded into powder in a mortar. 20 g of the powder was dissolved in 10 litre of water in which 10 g of soap was initially dissolved. Soap enhances the dissolution of Pyrethrum in water, thereby increasing the toxicity [16]. The solution was vigorously stirred well together, filtered in a clean white cloth or filter of tiny mesh and kept at room temperature and humidity (26˚C - 30˚C) and (80% - 82%) respectively in ampoules, till evening, according to the methods of Gaby (1998) before it was loaded in a 16 litre knapsack sprayer and applied to the potato stands in the field, from the bed through the leaves of the potato stands at 0, 2, 4, 6 and 8 lit /ai/ha to control activities of *Cylas spp*. The zero application was taken as control where no spray was done.

Data collected on the number of tubers per stand, tuber yield in tonnes per hectare and tuber weight in grammes per stand were taken at maturity, while observing the incidence of pests' attacks on the tubers. Ten stands were randomly selected per sub-plot. The tubers were counted at maturity and the average calculated as the number of tuber per stand. The tuber weight in grammes (g) obtain, were later converted to tonnes per hectare by extrapolation on treatment basis per sub-plot to obtain tuber yield in tonnes per hectare (t/ha). Data recording for each item was an average of the data from the two year cultivation.

All data generated were analysed using analysis of variance (ANOVA) procedure and the means were separated by Least Significant difference (LSD) at (p = 0.05) level of probability).

6. Results

Table 1. Insecticidal effect of extract from Pyrethrum (*Chrysanthemum cinerariaefolium*) on *Cylas punticolis* and on the number of tubers per stand of sweet potato varieties during harvesting.

Variety	Application rate lit/ha	Replicates			Σx	x
		1	2	3		
TIS 3057	0	7.3	8	6.5	21.8	7.27
	2	8.5	7.6	7.8	23.9	7.76
	4	8.3	7	8.62	23.92	7.97
	6	10.22	10.5	10	30.72	10.24
	8	12.34	12.66	13	38,00	12.66
Total		**46.66**	**45.76**	**45.92**		
TIS 3030	0	6.55	6	5.21	17.76	5.92
	2	6.62	7.2	7	20.82	6.94
	4	6.72	8.22	7.6	22.54	7.51
	6	7.23	7.34	6.8	21.37	7.12
	8	7.62	7.5	7.65	22.77	7.59

Continued

Total		**34.74**	**36.26**	**34.26**		
	0	6.71	6.53	6.66	19.9	6.63
	2	7.23	6.82	7.88	21.93	7.31
TIS 2532	4	7.65	8.61	8.53	24.79	8.26
	6	8.71	8.34	9.32	26.37	8.79
	8	10.62	9.88	10.26	30.76	10.25
Total		**40.92**	**40.18**	**42.65**		

Table 2. Analysis of variance (ANOVA) for the effect of extract from *(Chrysanthemum cinerariaefolium)* on *Cylas punticolis* and on the number of tubers per stand of sweet potato varieties.

Source of variance	Df	SS	MS	F-cal	F-tab
Replicate	2	286.42			
Factor (A) (s/potato variety)	2	88.23	44.12	6.66	2.22*
Error (a)	4	26.46	6.62		
Factor B (Rate of application of plant extract)	4	148.22	37.10	14.37	10.32*
Interaction (A × B)	7	360.21	51.50	19.96	16.54*
Error	14	36.22	2.58		

* = Significant at 0.05 level of probability.

Table 2 above presents analysis of variance (ANOVA) for the number of tubers per stand of sweet potato varieties during harvesting. The number of tubers per stand differ significantly ($p < 0.05$) amongst the varieties. The F-calculated value of 6.66 was greater than the F-tabulated value of 2.22 at (0.05) level of significance. The highest number of tubers per stand was recorded in the variety TIS. 3057, where between 10.00 and 13.00 tubers per stand were recorded. This was followed by the variety. TIS 2532 where between 9.32 and 10.62 tubers per stand were recorded (Table 1). The rate of application of plant extract was equally significant ($p < 0.05$), with the F-calculated value of 14.37 greater than the F-tabulated value of 10.32. The interaction effect (AB) between the sweet potato variety and the rate of application of the extract from pyrethrum flowers was also significant ($p < 0.05$) F-calcultated valud of 19.96 was greater than F-tabulated value of 16.54 (Table 2).

Table 4 above shows the analysis of variance (ANOVA) test for the effect of extract from pyrethrum on *Cylas spp* and on the weight of tubers in grammes (g) per stand of sweet potato varieties. The tuber weight in grammes (g) per stand was significantly ($p < 0.05$) different amongst the sweet potato varieties. The F-calculated value of 21.95 was greater than the F-tabulated value of 12.03 at (0.05) level of significance (Table 4). The variety TIS. 2532 recorded the highest weights in grammes of between 22.42 g and 25.22 g. Followed by TIS. 3057 with recorded

weights of between 19.81 g and 20.32 g, then by TIS. 3030 with tuber weight of between 14.22 g and 15.63 g (Table 3). The rate of application of the plant extract was also significant ($p < 0.05$) as F-calculated value of 7.85 was greater than F-tabulated value of 5.22. The interaction effect (AB) between the sweet potato variety and the rate of application of plant extract was significant at (0.05) level of significance F-calculated value of 7.82 was greater than F-tabulated value of 6.32 (Table 4).

Table 3. Insecticidal effect of extract from Pyrethrum (*Chrysanthemum cinerariaefolium*) on (*Cylas punticolis* and on the tuber weight in grammes per stand of Sweet potato varieties.

Variety	Application rate lit/ha	Replicates			Σx	X
		1	2	3		
TIS. 3057	0	1051	12.22	10.36	33.09	11.03
	2	15.23	16.24	16.62	48.09	16.03
	4	18.25	16.62	18.14	53.01	17.67
	6	19.22	18.65	19.31	57.18	19.06
	8	20.1	19.81	20.32	60.23	20.07
Total		**83.31**	**83.54**	**84.75**		
TIS. 3030	0	11.5	10.32	11.26	33.08	11.03
	2	12	11.59	10.82	34.41	11.47
	4	11.68	12.55	12.36	36.59	12.19
	6	13.25	13.86	14.22	41.33	13.77
	8	15.63	14.82	15.55	46	15.33
Total		**64.06**	**63.14**	**64.21**		
TIS. 2532	0	10.35	10.61	11.25	32.21	10.73
	2	10.86	12.32	12.11	35.29	11.76
	4	13.52	13.46	14.22	41.2	13.73
	6	20.12	20.51	20.32	60.95	20.32
	8	22.42	24.23	25.22	71.87	23.95
Total		**77.27**	**81.13**	**83.12**		

Table 4. Analysis of variance (ANOVA) for the effect of extract from Pyrethrum (*Chrysanthemum cinerariaefolium*) on *Cylas punticolis* and on the tuber weight in grammes per stand of sweet potato varieties.

Source of variance	Df	SS	MS	f-cal	F-tab
Replicate	2	422.32			
Factor (A) (s/potato variety)	2	243.31	121.65	21.95	12.03*
Error (a)	4	22.15	5.54		

Continued

Factor B (Rate of application of plant extract)	4	126.34	31.58	7.85	5.22*
Interaction (A × B)	7	220.10	31.43	7.82	6.32
Error (b)	14	56.32	4.02		

* = Significant at 0.05 level of probability.

Table 5. Insecticidal effect of extract from Pyrethrum (*Chrysanthemum cinerariaefolium*) on *Cylas punticolis* and on the tuber yield in tons per hectare (t/h) of sweet potato varieties

Variety	Application rate lit/ha	Replicates			Σx	X
		1	2	3		
TIS. 3057	0	6.21	5	4.8	16.01	5.33
	2	6.5	5.82	5.64	17.96	5.98
	4	7.22	7.32	6.84	21.38	7.13
	6	6.88	7.22	7.64	21.74	7.25
	8	7.63	7.84	7.86	23.33	7.77
Total		**34.44**	**33.2**	**32.78**		
TIS. 3030	0	3.21	3.43	3.22	9.86	3.28
	2	4.22	4.3	4.1	12.62	4.21
	4	3.62	3.84	3.88	11.34	3.78
	6	4.24	4	3.87	12.11	4.04
	8	5.21	4.92	5	15.13	5.04
Total		**20.5**	**20.49**	**20.07**		
TIS. 2532	0	5.24	5.63	5.51	16.38	5.46
	2	5.82	5.84	6.2	17.86	5.95
	4	8.42	8.22	8.63	25.27	8.42
	6	8.62	9.62	10.22	28.46	9.48
	8	10.65	12.41	12.56	35.62	11.87
Total		**38.75**	**41.72**	**43.12**		

Table 6. Analysis of variance (ANOVA) for the effect of extract from pyrethrum *(Chrysanthemum cinerariaefolium)* on *Cylas punticolis* and on the tuber yield in ton per hectare of sweet potato varieties.

Source of variance	Df	SS	MS	F-cal	F-tab
Replicate	2	110.26			
Factor (A) (s/potato variety)	2	64.42	32.21	12.73	10.09*
Error (a)	4	10.12	2.53		
Factor B (Rate of application of plant extract)	4	76.22	19.10	3.10	1.82*

Continued

Interaction (A × B)	7	56.43	8.10	1.31	0.90*
Error (b)	14	86.32	6.16		

* = Significant at 0.05 level of probability.

Table 6 is the result of analysis of variance test for the effect of extract from pyrethrum on *Cylas spp* and on the tuber yield in ton per hectare of sweet potato varieties. The yield in ton per hectare (t/ha) of the tubers was significant ($p < 0.05$) as F-calculated value of 12.73 was greater than F-tabulated value of 10.09 at (0.05) level of significance. The highest yield in tons per hectare of tubers was recorded in the variety TIS. 2532 which recorded between 10.22 and 10.65 (t/ha). This was followed by the variety TIS. 3057 with yield in (t/ha) of between 7.22 and 7.86. Then TIS. 3030 with tuber yield of between 5.00 t/ha and 5.21 t/ha (Table 5). The rate of application of the plant extract was also significant ($p < 0.05$) as the F-calculated value of 3.10 was greater than F-tabulated value of 1.82 at (0.05) level of significances. The interaction effect (AB) between the sweet potato variety and the rate of application of the plant extract was equally significance, F-cal of 1.31 was greater than F-tab of 0.90 ($p < 0.05$) (Table 6).

7. Discussion

The number of tubers per stand of sweet potato varieties differed significantly ($p < 0.05$) amongst the three varieties cultivated here (Table 2). The numbers of tubers per stand was higher in the variety TIS. 3057 where between 10.00 and 13.00 tubers were recorded on application of between 6 to 8 lit/ha of the extract from pyrethrum *(Chrysanthemum cinerariaefolium)*. The higher number of tubers recorded in TIS. 3057 was followed by between 9.32 and 10.62 recorded in TIS. 2532 (Table 1). [1] had earlier reported that the variety TIS. 3057 produces higher number of tubers than other varieties. The application of extract from pyrethrum was more active in higher doses of 6 and 8 lit/ha than the lower doses of between 2 and 4 lit/ha. This was in line with the views of [16] who earlier reported that the extract from pyrethrum is a nerve poison which produces erratic movement and excitement on the insect and finally paralysis it (knock-down effect). He added that the insect can however, recover from the knock-down effect if the amount of extract used was small. Larger doses are needed to bring about death.

The number of tubers per stand were as low as between 6.00 and 7.30 in control experimental plots in all the varieties (Table 1). This is a confirmation of the fact that because no extract was applied in the control plots, many of the tubers might have been destroyed by sweet potato weevil (*Cylas spp*) which resulted in a remarkable reduction of the number of tubers per stand. Evidence of Cylas infestations were seen on most of the Sweet potato stands in the control plots. The leaves become discoloured and wilting occurred. The vines were undergoing dieback. Most of the tubers harvested from the control plots become riddled, spongy and blackish in colour with cavities or tunnel on them which might have been created

by the weevils. Tubers from plots treated with 2 and 4 lit /ai/ha also showed similar symptoms but were less severed and not as much as in control plots. This also is in line with the report of [5] that sweet potato tubers are significantly destroyed by *Cylas spp* if kept unchecked. [4] earlier reported massive destruction of sweet potato tubers by *Cylas spp* in Papua New Guinea.

The interaction between the sweet potato variety and the rate of application of the plant extract was also significant ($p < 0.05$) (**Table 2**). TIS. 2532 and TIS. 3037 varieties were more responsive to the plant extract than TIS. 3030 in terms of number of tubers per stand.

On the effect of the plant extract on the weight in grammes per stand of the sweet potato tubers, the weight in grammes (g) per stand of the tubers was significant ($p < 0.05$) amongst the potato varieties (**Table 4**). The highest tuber weights (g) per stand were recorded in TIS. 2532, between 20.12 to 25.22 g per stand were recorded (**Table 3**). This was followed by the variety TIS. 3057 with tuber weight per stand of between 18.14 and 20.32 g per stand. Although the highest number of tubers per stand was recorded in the variety TIS 3057 (**Table 1**), the highest weight of tuber in grammes per stand was rather recorded in TIS. 2532. [5] earlier described the tubers of TIS 2532 as being round or oblong in shape, white to light yellow in colour and contained more starch than the other varieties. The fact that they contain higher amount of starch than other varieties here, may have been responsible for why they are heavier in grammes weight than others. The effective control of *Cylas spp* by the extract from pyrethrum here, may also have been responsible for why the tubers were able to develop to their full weight size.

The interaction effect (AB) between the sweet potato variety and the rate of application of the plant extract was also significant ($p < 0.05$) in terms of tuber weight in grammes per stand (**Table 4**). Higher weights in grammes were recorded in all the three varieties here, on application of between 6 and 8 lit/ha of the crude extract of pyrethrum than on application of 2 and 4 lit/ha (**Table 3**). This confirmed the earlier observation that the extract is more effective as a knock-down substance at higher doses than at lower doses [16]. Tuber weights in grammes per stand were relatively lower in all the varieties on zero application where no crude extract was applied (**Table 5**). The lower weight recorded here might be attributed to subsequent attacks by *Cylas spp* on the tubers since no preventive measures were taken. This observation was in line with that of [6] who reported that attacks on sweet potato tubers by *Cylas spp* can render the tubers poor in quality, since they will lose weight, become shrank and generally unmarketable and unsuitable for human consumption.

The yield in ton per hectare (t/ha) of the sweet potato tubers was equally significant ($p < 0.05$) amongst the three varieties of the sweet potato cultivated here (**Table 6**). The highest yield in tonnes per hectare were recorded in the variety TIS. 2532 where between 8.22 and 12.56 t/ha were recorded.

The highest yield (t/ha) was followed by that of TIS. 3037, which recorded between 6.88 and 7.84 t/ha. The highest yield in t/ha by TIS. 2532 here was in line

with the report of [1]. According to the report, TIS. 2532 was high yielding than other varieties of sweet potatoes in Nigeria. [6] also reported that TIS. 2532 and TIS. 3057 are high yielding in tropical Africa. The higher yields recorded in TIS. 2532 and TIS. 3057 were not unconnected with the effective control of *Cylas spp*. with the plant extract applied in the sweet potato farm.

The interaction effect (AB) between the sweet potato variety and the rate of application of the plant extract was significant ($p < 0.05$). The interaction showed that TIS 2532 responded to the application of the plant extract more than other varieties (**Table 6**). This was followed by TIS. 3057 and then TIS 3030. The application of 6 and 8 lit/ha were more effective in controlling *Cylas spp* than 2 and 4 lit/ha (**Table 5**). In zero application (control) where no plant extract was applied, the yields were as low as between 3.21 and 6.21 t/ha (**Table 5**). The yield of between 3.21 and 6.21 t/ha in the control, was as a result of the little resistance the sweet potato plants put against the potato weevil attacks. [4] reported that some varieties of Sweet potatoes, especially the yellow skin varieties exhibit natural resin glycosides which are biochemical compounds that can scare the insects away from attacking them.

8. Conclusions

Researchers all over the world have proven that most synthetic chemicals routinely used in conventional agriculture are associated with alarming health problems and environmental hazards. From human ecological health impacts, there are growing concerns about how farmers conduct their farming activities. However, sustainable agricultural practices which requires a more cautious use of agrochemicals through prior testing and careful risk assessment is the answer.

Sustainable agriculture include the use of alternative means of pests control order than the continuous use of synthetic chemicals. The use of plant base extract is one of the best alternatives to synthetic pesticides in Integrated Pest Management (IPM) programmes. Small holder farmers in many parts of the world including Nigeria, have been using extracts from indigenous plant parts such as leaves, fruits, barks roots, seeds, processed powders etc to protect insect pests infestations of their agricultural produce, especially during storage [21]. Therefore, the use of extract from flowers of Pyrethrum *Chysanthemum cinerariaefolium* here for the control of *Cylas punticolis* in sweet potato cultivation was in line with the scientific innovation of sustainable agriculture.

9. Recommendations

Based on the findings from the research study, the following recommendations were made;

1) Farmers should adopt the use of plant base extract in controlling insect pests of crops rather than depending much on synthetic pesticides;

2) Extract from flowers of pyrethrum should be prepared into solutions and used for controlling sweet potato weevil (*Cylas spp*), since it is found to be very

effective.

3) The recommended dosage of the pyrethrum for effective control of *Cylas spp* in sweet potato should be 8 litres per hectare. Though in some cases, 6 lit/ha could be effective too;

4) The use of synthetic pesticides should only be encouraged when a pest infestation has occurred (therapeutic) and has not reached the damage threshold.

5) The use of plant extracts should be preventive (prophylaxis) to keep *Cylas spp*. and other insect pests away from the crop;

6) If synergistic substances such as sesame oil or Piperonyl butoxide are available, the pyrethrum extract should be dissolved in any of them as this will enhance the utilization of the toxic substances in the pyrethrum by increasing or prolonging the effect. Kerosene is also said to increase the dissolution of the active substance in the pyrethrum by 73% in 48 hours [16]. Similarly, [22] had earlier reported the effective dissolution of Pyrethrum in water by up to 65% with the addition of sesame oil (0.25% - 0.5%) and this increased the efficacy of the pyrethrum in controlling beans beetles (Maruca vitrata).

Again, [23] reported an increase in the efficacy of pyrethrum extract solution as an insecticide with the addition of about a litre of Piperonyl butoxide (a pesticide synergist).

Conflicts of Interest

The authors declare no conflicts of interest.

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