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An Evaluation of the Insecticidal Properties of Custard Apple (*Annona Squamosa L.*) for Controlling Green Peach Aphid (*Myzus persicae*: Sulzer) in EggPlant Cultivation in Southern Part of Nigeria

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Abstract

A two year experiment was conducted in 2023 and 2024 on a pre-fallowed piece of land at the Teaching and Research Farm of the Department of Agriculture, Federal College of Education Obudu Cross River State of Nigeria. The main objective was to evaluate the insecticidal properties of extract from the seeds of Custard Apple (*Annona squamosa L*) for controlling Aphid spp. in Eggplant cultivation. An experimental farm was established on a plot measuring 18.5 m x 18.5 m, for two growing seasons (2023 and 2024). The design of the experiment was Completely Randomized Design (CRD) on a 3x5 factorial layout. 3 cultivars of Eggplant (*Solanum aethiopicum*) (Gilo), *S. aethiopicum* (shum) and *S.aethiopicum* (kumba) were cultivated per plot, with 5 beds in each plot, 15 beds in a block, 45 beds in a replicate. A bed represented a subplot, there were 3 plots in a block, 3 blocks in a replicate. The entire layout was replicated 3 times with each replicate having 45 beds in all. Eggplant seedlings were transplanted from a 4-week nursery to the beds in the main field at a planting distance of 60 cm between rows and 45 cm within rows. There were 6 stands of egg plants per bed, 30 stands per plot, 90 stands per block, 270 stands per plot in a replicate, and 810 stands in the entire experimental farm. A solution of extract from custard apple (*Annona squamosa* L) seeds was prepared through simple solvent extraction and was applied immediately in 5 different levels (volumes) of 0,2,4,6 and 8 liter per hectare (lit/ha) to the eggplant seedlings, 2 weeks after transplanting to prevent aphids attacks. The main plot treatments were the eggplant cultivars, while the subplot treatment were the different volumes of plant extract applied. Data were taken for plant establishment at 4 weeks after transplanting, number of fruits per stand, and fruit yield in tons per hectare both in 2023 and 2024 planting seasons. All data generated in the 2 year planting seasons were pooled together and the average calculated. The data was subjected to analysis of variance (ANOVA) and the means separated by Least Significant Difference (LSD) at 0.05 level of probability. Findings revealed that the crude extract from custard apple seeds applied at 6 to 8 (lit/ha) has the efficacy to effectively repel Aphids spp. from crops in the field. It was recommended that farmers should adopt the use of the custard apple seed extract in managing Aphids infestation in eggplant cultivation. The dosage should be 6 to 8 (lit/ha). Gilo and shum cultivars were also recommended as high yielding cultivars to be selected for cultivation.

Keywords: Custard Apple; Plant Extract; Eggplant; Efficacy; Biopesticide; Aphid

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1. Introduction

Eggplants (*Solanum spp.*) are one of the most widely cultivated vegetables in Africa including Nigeria. They yield what is popularly called garden egg (Eggplant) and are of many varieties and cultivars, with fruits that vary in size, shape, color ,and in use [1]. The crop is a popular salad often cherished in snacks form all over the world. Leading producers of eggplant globally include, China, India, Iran, Egypt and Turkey. Some of the Countries that produce eggplants most in Africa are Nigeria, Ghana, and Senegal. South American Countries and the Caribbean Islands also grow Eggplants [1]. Global output of eggplants as at 2022 was put at 59.31million tons [2]. Eggplants are propagated by seeds and sometimes by cuttings from mature stems. They grow well in full sunlight but can tolerate shade to a limited level. They can withstand drought quite well. However, yields are low when water is scarce. They are grown both in gardens and in farms, in pure stands and in associations. Eggplants grow vigorously in shade of other crops. However, fruit production is increased by exposure to full sunlight during flowering and fruiting [3].

Many varities of eggplants exist, such as *Solanum athiopicum*, *S. leucopersicum*, *S.macrocapon*, *S.melongena* and *S. nigrum* complex. The varieties *Solanum aethiopicum* and *S.nigrum* are different cultivars. For instance, *S.nigrum* complex is made up of the following cultivars;*Solanum americanum*, *S.eldoretti*, *S.retroflexum*, *S.scabrum* and *S.vilosum* [4]. *Solanum aethiopicum* has the following cultivars: *S.aethiopicum* (Gilo Raddi) the Gilo group. "They are popularly called in Kenya as white brinjals" They constitute most of the eggplants sold in markets in the humid West Africa, Central, East and Southern Africa [5]. It is cultivated a great deal in Uganda, Tanzania, and Democratic Republic of Congo (DRC) [6]. The brinjals have large fruits, which maybe white or cream in color, with green to red stripes. They are eaten raw or cooked. The leaves are hairy and are not used as a vegetable [5]. *Solanum aethiopicum* (the shum group), has relatively smaller, nearly round, greenish fruits that turn red upon ripening. The leaves are not hairy, therefore are used as a vegetable, especially in Uganda where they are widely grown [5]. They are also grown in Nigeria and other West African countries. *Solanum aethiopicum* (the kumba group) have large leaves and usually with cream to yellow fruits that are broader than long with marked longitudinal ridges like those of a pumpkin fruit. The fruits as well as the leaves are used as a vegetable [4], [5].

Eggplant like any other crops is attacked naturally by several pests. In tropical Africa, common pests of Eggplants include; flower borer (*Scrobipalpa*), Fruit Borer (*Lencinodes orbonalis*), stem Borer (*Euzophera vilora*) sucking buds (*Corrythuca planaris*) and Aphids (*Aphis tabae* and Green peach Aphis) [7]. Aphids colonized the plant in sucking sap especially around the stem growing points and leaves, thereby resulting in yield reduction.

Large population of Aphids on Eggplant causes curling, yellowing and distortion of leaves. They can also cause stunting of shoots; they produce large quantities of a sticky exudates known as honeydew which often turns black with growth of a sooty mold fungus [8]. Aphids inject toxin into the Eggplant which distorts the plant growth and sometimes form gall. They also transmit plant viruses from one eggplant to the other [8].

Several organophosphorus and organochlorine insecticides such as fenitrothion,chloropyrifos-methyl, malathion etc. have been used in dealing with the problem of insect pest of crops [9].Research has shown that the continuous use of these synthetic chemicals in agricultural production will lead to the development of resistance to the chemicals by the target insects [10]. The Eco-toxicity of these chemicals also shows that they are no longer safe for us even to the users and the consumers of the food [11].

Recent research focus has been on finding alternative means of managing insect pest of crops rather than the continuous use of the hazardous chemicals. The use of biopesticides has been seen as the best alternative means of dealing with insect pests of crops. Biopesticides are derived from natural substances such as animals, plants, bacteria and minerals [12].

Biospesticides according to United States Environmental Protection Agency (US.E.P.A) are environmentally sound and efficacious products. They are non-toxic to non-target organisms, including beneficial insects and wildlife. Many of them are easily biodegradable, decomposed quickly and do not negatively impact on surface and underground water [13]. Small holder farmers in many parts of Africa have been using products from some indigenous plants to protect insect pests' infestation of their agricultural produce [14]. Plant materials such as leaves, fruits, barks, roots, seeds, processed powders etc. have been in use for the protection of insect pests of crops [12].

Extract of custard apple (*Annona squamosa* L) was used in this experiment to evaluate its efficacy for control of Aphis spp. in eggplant cultivation. The toxicity of extract from Annona seeds with ether or petroleum ether will increase its toxicity by 50 to 100 times [15]. *Annona squamosa* L (Annonanceae) is a tropical endemic species of the West Indies, South and Central America, Ecuador, Peru, Brazil, India, Mexico, Bahamas, Bermuda and Egypt [16]. It is also found

growing as a wild shrub in different forest areas in Nigeria. Indian Council of Agricultural Research (ICAR) reported the extensive cultivation of *Annona squamosa* L in different states of India. Extracts from various sections of the *Annona squamosa* L plant such as its bark, root, leaf, stem, fruit, peel and seed, have been utilized in traditional pharmacological applications in different countries to cure a variety of diseases such as dysentery, epilepsy, hemorrhage, fever, and tumor [17].

Annona squamosa L leaves possess valorization potential owing to their extensive pharmacological properties and biological activities, such as antioxidant, antimicrobial, antidiabetic, antiviral, anticancer and hepatoprotective activities [18]. *Annona squamosa* L seed powder is utilized to abolish lice [19]. Therefore, *Annona squamosa* L should have bioactivity and insecticidal properties against insect pests of crops.

1.1. Statement of the problem

The need to increase the production of food through the use of Agro-chemicals in order to feed the rapidly growing human populations, has continued to put pressure on the intensive use of pesticides and fertilizers all over the world. Research the world over has shown the contamination and hazardous impact of agrochemical residues in the soil, aquatic and terrestrial ecosystems.

These include, coastal marine system and their toxic effect on humans and non-human biota. Although organic chemicals that are persistent have been phased out and replaced by the more biodegradable chemicals, contamination by legacy residues and recent residues still impact significantly on the quality of human food, water and environment.

It has become imperative to seek alternative paths to the intensive use of chemicals in crop protection, in order to produce food with better quality and reduce toxic contaminants.

Therefore, the use of plant extracts such as extracts from the seeds of custard apple (*Annona squamosa*) is one of the most acceptable alternatives to the use of hazardous agrochemicals.

1.2. Objective of the study

The main objective of the study is the establishment of an alternative means of controlling insect pest of crops through the adoption of the use of biopesticides, in order to reduce environmental degradation, chemical food poisoning, and the destruction of the ecosystem arising from the continuous use of synthetic pesticides. The specific objectives include to:

- Extract a crude solution from custard apple seeds,
- Test the efficacy of the solution in controlling Aphids (Aphis spp.) in Eggplant cultivation,
- Demonstrate the efficacy of the plant extract to farmers in the study area.

2. Materials and methods

The two years experiment was conducted in 2023 and 2024 on a pre-fallowed piece of land belonging to the Teaching and Research Farm of the Department of Agriculture, Federal College of Education Obudu, Cross River State of Nigeria. The design of the experiment was a Completely Randomized Design (CRD) on a 3 x 5 factorial. A plot of land measuring 18.5 m x 18.5 m was used for the purpose of the experiment.

The plot was cleared, the trash packed and burnt on the 4th of March 2023 and on the 5th of April 2024. Nurseries of three cultivars of eggplant (*Solanum aethipicum*) (Gilo group) *S. aethiopicum* (shum group) and *S. aethiopicum* (kumba group) were prepared. Four weeks after the seedlings were transplanted to already prepared beds at the main plot. The beds were each 3 m x 2 m with interspacing of 0.5 m between the beds. The transplanting was done on the 7th and 8th of April, 2023 and on the 3rd and 4th of April 2024 at a spacing of 60 cm between rows and 45 cm within rows.

Each bed in a plot represented a subplot, there were 5 beds in each plot and planted to a single cultivar of eggplant, 15 beds in each of the 3 plots in a block, 45 beds in a replicate, and 135 beds in the entire experimental plot.

Six stands of eggplant were planted in each bed, 30 stands in a plot, 90 stands in block, 270 stands in a replicate and 810 stands in the entire field. Each of the five beds received application of crude extract of custard apple at different volumes of 0,2,4,6,8 (lit/ha), the zero application as control. The experiment was replicated three types. The eggplant cultivars were the main plot treatments while the volumes of application of the plant extract were the subplot treatments.

2.1. Preparation of crude extract solution of custard apple

100g of wet seeds of custard apple (*Annona squamosa* L) were pounded in a mortar into a paste. The paste was dissolved completely in 50 litres of cool water at room temperature. The solution was filtered with clean white cloth or with a filter of tiny mesh. The residues were kept aside while the filtrate was mixed with about 3 to 5 liters of petrol or kerosene to facilitate solubility and rapid extraction of the active ingredient of the custard apple seeds. More so, this was to increase the toxicity of the extract [15]. The crude extract was loaded in a knapsack sprayer for spraying on the eggplant during flowering and tender stage of the plant at 4 weeks after transplanting (establishment stage). And during flowering and fruiting stages of the eggplant to control the activities of Aphids. Data collection on the plant establishment 4 weeks after transplanting, number of fruit per stand, and the fruit yield in tons per hectare (t/ha) were taken. The ten stands of egg plants were randomly selected per subplot at maturity, the fruits were harvested, counted and the average taken as the number of fruits per stand. The fruit weights obtained in grams (g) were later converted to tones per hectare by extrapolation on treatment basis per subplot to obtain fruit yield in tons per hectare (t/ha). All data collected were analyzed using Analysis of Variance (ANOVA) procedure and the means were separated by least significant different (LSD) at ((p=0.05) level of probability.

3. Results

Table 1 Insecticidal effect of extract from seeds of custard apple (*Annona squamosa* L) on plant establishment per plot at 4 weeks after transplanting of eggplant cultivars

Cultivar	**Rate of application**	**Replicates**			**∑x**	**x̄**
		1	**2**	**3**		
S.aethiopicum(Gilo)	0	50.0	56.0	52.0	158.0	52.66
	2	66.0	63.0	60.0	189.0	63.00
	4	74.0	77.0	76.0	227.0	75.66
	6	77.0	78.0	85.0	240.0	80.00
	8	92.0	95.0	94.0	281.0	93.66
Total		**359.0**	**367.0**	**375.0**		
S.aethiopicum(shum)	0	52.0	50.0	56.0	158.0	52.66
	2	66.0	64.0	60.0	190.0	63.33
	4	76.0	78.0	78.0	232.0	77.33
	6	78.0	80.0	85.0	243.0	81.00
	8	93.0	90.0	92.0	275.0	91.66
Total		**365.0**	**362.0**	**371.0**		
S.aethiopicum(kumba)	0	56.0	55.0	50.0	161.0	53.66
	2	60.0	65.0	68.0	190.0	63.33
	4	72.0	76.0	78.0	226.0	75.33
	6	80.0	86.0	88.0	254.0	84.66
	8	91.0	95.0	96.0	282.0	94.00
Total		**357.0**	**377.0**	**380.0**		

Table 2 Analysis of variance for the insecticidal effect from custard apple (*Annona squamosa* L) on plant establishment per plot at 4 weeks after transplanting of eggplant cultivars

Source of variance	**DF**	**SS**	**MS**	**F-Cal**	**F-Tab**
Replicate	2	654.22			
Factor(A);Eggplant cultivar	2	886.14	443.07	28.34	12.20*
Error(A)	4	62.54	15.63		
Factor(B): Rate of application of extract	4	684.22	171.10	29.09	18.62*
Interaction(AXB)	8	120.32	15.04	2.55	1.23*
Error (B)	14	82.42	5.88		
Total	**34**	**2,489.86**			

*Significant at 0.05 level of probability.

Table 2 above shows the analysis of variance (ANOVA) for testing the insecticidal effect of extract from custard apple on Eggplant establishment percentage at four (4) weeks after transplanting from nursery. Plant establishment percentage differ significantly ($p<0.05$) amongst the eggplant varieties (F-calculated value of 28.34 was greater than F-tabulated value of 12.20) (Table 2). There was high percentage establishment in kumba cultivar, followed by Gilo cultivar and then shum cultivar (Table 1).

Kumba cultivar recorded between 91 % and 96 % plant establishment, the Gilo cultivar recorded between 92% and 94%, while the shum cultivar recorded between 90 % and 93 % plant establishment at 8 lit/ha of plant extract (Table1). Factor (B) rate of application of extract from custard apple was significant, ($p<0.05$) as F-calculated value of 29.09 was greater than F-tabulated value of 18.62 (Table2). Application of between 4 and 8 lit/ha was more effective than application of 0 and 2 (Table1). The interactive effect between the eggplant cultivar and the rate of application of the plant extract was also significant ($p<0.05$) at 0.05 level of significance (F-Cal 2.55>F-tab1.23) (Table2).

Table 3 Insecticidal effect of extract from custard apple (*Annona squamosa L)* on Aphid spp. and on the number of fruits per stand of eggplant cultivars

Cultivar	**Rate of application**	**Replicates**				
		1	**2**	**3**	**∑x**	**x̄**
S.aethiopicum(Gilo)	0	10.0	11.0	09.00	30.00	10.00
	2	22.0	25.0	23.00	70.00	23.33
	4	28.0	26.0	28.00	82.00	27.33
	6	32.0	30.0	33.00	95.00	31.66
	8	42.0	41.0	45.00	128.00	42.66
Total		**134.00**	**133.00**	**138.00**		
S.aethiopicum(shum)	0	8.00	10.00	12.00	30.00	10.00
	2	25.00	26.00	28.00	79.00	26.00
	4	36.00	36.00	38.00	110.00	36.66
	6	38.00	37.00	37.00	112.00	37.33
	8	45.00	43.00	46.00	134.00	44.66
Total		**152.00**	**152.00.0**	**161.00**		
S.aethiopicum(kumba)	0	10.00	11.00	10.00	31.00	10.33
	2	20.00	22.00	18.00	60.00	20.00

	4	24.00	25.00	26.00	75.00	25.00
	6	30.00	36.00	35.00	101.00.0	33.66
	8	38.00	37.00	38.00	113.00.0	37.66
Total		**122.00**	**137.00**	**127.00**		

Table 4 Analysis of variance for the insecticidal effect of extract from custard apple (*Annona squamosa* L) on Aphids spp. and the number of fruits per stand of eggplant cultivars

Source of variance	**DF**	**SS**	**MS**	**F-Cal**	**F-Tab**
Replicate	2	762.51			
Factor(A);Eggplant cultivar	2	482.32	241.16	51.86	22.10*
Error(A)	4	18.62	4.65		
Fcator(B):Rate of application of plant extract	4	326.16	81.54	24.71	18.24*
Interaction(AxB)	8	286.23	35.77	10.84	8.36*
Error (B)	14	46.22	3.30		
Total	**34**	**1,922.06**			

*Significant at 0.05 level of probability

Table 4 represents the analysis of variance (ANOVA) for testing the insecticidal effect of extract from custard apple (*Annona squamosa* L) on Aphid spp. and on the number of fruits per stand of eggplant cultivars. The number of fruits per stand differ significantly ($p<0.05$) amongst the different cultivars of eggplant (F-calculated value of 51.86 was greater than F-tabulated value of 22.10 (Table 4). The number of fruits per stand was significantly higher in shum cultivars than in other cultivars. Between 38 and 46 fruits per stand were recorded in the shum variety, followed by 33 and 45 fruits per stand in the Gilo variety and between 36 and 38 fruits per stand in the kumba variety (Table 3). The rate of application factor (B) of plant extract was significant ($p<0.05$) as the F-calculated value of 24.71 was greater than F-tabulated value of 18.24 at 0.05 level of significance (Table 4). The number of fruits per stand were higher in application of between 4 and 8 lit/ha than in others (Table 3). The interaction effect between the plant variety and the rate of application of the aqueous extract was equally significant ($p<0.05$) at 5 % level of probability (F-cal value of 10.84>F-tab. 8.36) (Table 4).

Table 5 Insecticidal effect of extract from custard apple (*Annona squamosa* L*)* on Aphid spp. and on the fruits yield in tons per hectare of eggplant cultivars

Cultivar	Rate of application	Replicates 1	2	3	∑x	x̄
S.aethiopicum(Gilo)	0	2.20	2.20	1.82	6.02	2.00
	2	3.21	3.00	2.90	9.11	3.04
	4	3.82	4.26	4.52	12.60	4.20
	6	10.12	12.22	11.51	33.85	4.20
	8	12.42	13.11	15.00	40.53	13.51
Total		13.77	34.79	35.75		
S.aethiopicum(shum)	0	1.26	2.23	3.10	6.59	2.19
	2	3.88	4.36	4.78	13.02	4.32
	4	8.24	8.71	7.85	24.80	8.26
	6	9.35	10.62	10.56	30.53	10.17

	8	12.88	12.26	11.72	36.86	12.28
Total		35.61	38.18	38.01		
S.aethiopicum(kumba)	0	2.20	2.15	2.31	6.66	2.22
	2	3.00	2.86	3.32	9.18	3.06
	4	3.86	4.20	3.88	11.94	3.98
	6	5.62	5.00	6.22	16.84	5.61
	8	5.61	8.61	8.82	23.04	7.68
Total		**20.29**	**22.82**	**24.55**	**61.10**	

Table 6 Analysis of variance for the insecticidal effect of extract from custard apple (*Annona squamosa* L) on Aphid spp. and on the fruit yield in tons per hectare of eggplant cultivars

Source of variance	**DF**	**SS**	**MS**	**F-Cal**	**F-Tab**
Replicate	2	124.21			
Factor(A);Eggplant cultivar	2	86.34	43.17	13.93	11.05*
Error(A)	4	12.26	3.10		
Factor(B): Rate of application of extract	4	206.21	51.55	19.82	14.36*
Interaction(AXB)	8	138.46	17.31	6.65	5.91*
Error (B)	14	36.44	2.60		
Total	34	603.92			

*Significant at 0.05 level of probability.

Table 6 above gives the result of analysis on variance (ANOVA) test for the insecticidal effect of extract from custard apple (*Annona squamosa* L) on Aphid spp. and on the yield in tons per hectare of fruits of eggplant cultivars. The yield in tons per hectare (t/ha) was significantly ($p<0.05$) different amongst the three eggplant cultivars used here. The F-calculated value of 13.93 was greater than the F-tabulated value of 11.05 at 5 % of probability. The fruit yield in tons per hectare (t/ha) was higher in Gilo cultivars than in others. Between10.12 to 15.00 (t/ha) were recorded in Gilo while between 10.56 to12.88 (t/ha) were recorded in the shum variety (Table 5). Finally, between 5.00 and 8.61(t/ha) were recorded in kumba variety (Table 5). The rate of application of plant extract (Factor B) was also significant ($p<0.05$) F-cal of 19.82>F-tab of 14.36 (Table 6). Higher rates of between 6 and 8 lit/ha were more effective in Gilo, and kumba while between 4 and 8 lit/ha were more effective in shum cultivar (Table 5).

Similarly, the interaction effect (AB) between the eggplant variety and the rate of application of the aqueous plant extract was significant ($p<0.05$) at 5 % level of probability. F-cal value of 6.65>F-tab value of 5.91(Table 6). The yield in tons per hectare (t/ha) in zero application (control) were relatively very low compared with those from treated plots. (Table 5).

4. Discussion

The significant difference ($p<0.05$) in the percentage establishment of the eggplant at 4 weeks after transplanting (Table 2) indicated that there were Aphids attacks on some of the eggplant seedlings. This is most obvious in control subplots where no crude extract was applied and in other subplots where lesser volumes of the extract were applied. For instance, higher percentage establishment of between 76 and 96 were recorded in subplots that received 4, 6 and 8 lit/ha in all the three cultivars of the eggplant (Table1). Control plots where no plant extract was applied, recorded as low as between 50 and 56 % plant establishment. However, subplots that received only 2 lit/ha of the plant extract, recorded between 60 % and 68 % plant establishment. The low plant establishment in control plots and in low volume application of plant extract, was attributed to Aphids attacks on the crops thereby reducing the plants' population (Table1).

The higher plant percentage establishment of between 91 and 96 was recorded in the kumba cultivar where 8 lit/ha of the crude extract were applied. This was followed by the Gilo cultivar that recorded between 92 % and 95 % in subplots that also received 8 lit/ha of the crude extract (Table1). The high percentage establishment of the plant seedling here was in line with the views of [15]who stated that early treatment of crops with plant extract will prevent early attacks by insect pests on the crops, thereby resulting in the increase crop growth. The low percentage establishment in plots that received zero application and in low volume application of 2 lit/ha, shows that Aphids attacks here were prevalent. This also is in line with the observations of [7] who reported that early attacks on crops by insect pests can significantly reduce the plants' ability to establish themselves very well on the soil at the early stage of growth. This will result in eventual death of most crops, few weeks after germination.

The number of fruits per stand of the eggplant cultivars differ significantly ($p<0.05$) among the cultivars (Table 4). The number of fruits per stand in control plots and in plots that received low volume (2 lit/ha) application of the crude extract, was relatively low, compared to the number of fruits per stand in other plots for all the cultivars (Table 3). The highest number of fruits per stand of between 43 and 46 was recorded in the shum cultivars in subplots that received 8 lit/ha of the crude extract. This was followed by the subplots that received 6 lit/ha of the crude extract with between 37 and 38 fruits per stand. Gilo cultivar also recorded between 41 and 45 fruits per subplot, on application of 8 lit/ha (Table 3). The higher number of fruits per stand recorded in plots that received between 4 and 8 lit/ha in all the cultivars here was attributed to the prevention of Aphids' attacks by adequate volumes of extract of custard apple (*Annona squamosa* L). The crude extract was applied to the plants at early stage of 4 weeks after transplanting and during fruiting. The ability of the crude extracts to effectively control Aphids' attacks here is in line with the observation of [15] who reported that extracts of custard apple seeds and leaves have the efficacy to suppress insect pest activities. According to him, this can be achieved especially when it is mixed with small quantities of kerosene or petrol [15].

The higher number of fruits per stand recorded in the shum cultivar over other cultivars (Table 3) may also be attributed to the fact that the fruits of the shum cultivar contain bitter sap in the cells, which may have prevented the Aphids from sucking the sap from fruits. The observation may be in line with the views of [20]. Who reported that some Solanaceous plants produce poisonous alkaloids that protect them from being easily attacked by pests.

The fruits yield of eggplant in tons per hectare (t/ha) differ significantly ($p<0.0$) amongst the different cultivars used here (Table 6). Although the highest number of fruits per stand was recorded in the shum cultivar, generally higher yields in tons per hectare were rather recorded in the Gilo cultivar. Between 12 and 15 tones per hectare and between 10 and 11.5 (t/ha) were obtained in subplots that received 6 and 8 lit/ha respectively in the Gilo cultivar (Table 5). This was followed by 11 and 12 t/ha, then 9 and 10.56 t/ha) for subplots that received 6 and 8 lit/ha respectively in shum cultivar. The kumba cultivar recorded between 7 and 8.61 t/ha in the subplots that received 8 lit/ha and between 5.62 and 6.22 lit/ha in subplots that received 6 lit/ha of the crude extract of custard apple (Table 5). The trend of the yield in tons per hectare of the eggplant cultivars used here is as follows; Gilo (between12 to 15) t/ha > shum (between11 to 12) t/ha > kumba (between 7 and 8.61) t/ha. The highest yield of 15.00 t/ha recorded in the Gilo cultivar was in line with the report of [4], [21] that, of all species of eggplant (*Solanum aethiopicum, S. leucopersicum, S. macrocarpon, S. melongena and S. nigrum), S. aethiopicum* cultivars are more high yielding than the rest of other species. [20] reported that the Gilo cultivar is high yielding than shum and kumba cultivars of *S.aethiopicum*. [7] had earlier reported a yield of up to 50 metric tons per hectare of *Solanum spp.* With proper management practices, including pests control.

5. Conclusion

Global research has proven that majority of agricultural pesticides which are routinely used in conventional agriculture have detrimental effect on the health of humans and the entire environment. From the ecological perspective, there are growing concerns about how the people should farm. However, sustainable agriculture is the solution. It describe a robust and balance agricultural system, requiring prior testing and careful risk assessment and the need for the farmers and agrochemical users generally, to adopt measures that will ensure the protection of ecosystem. This will enhance good practices for sustainable development in agriculture, fisheries and aquaculture [13]

Finding an alternative to the use of highly toxic pesticides is very imperative. The use of plant base extract is an important alternative to the use of synthetic pesticides in an Integrated Pests Management (IPM). Biopesticides are least harmful to natural enemies of pests, generally, they are environmentally friendly and sustainable, since they are extracted from plant materials. The application of crude extract from custard apple (*Annona squamosa* L) seed in controlling Aphid spp., especially *Aphis gossypii* (Aphidadae) in eggplant cultivars here, is one important search for alternatives to the use of synthetic pesticides.

Recommendations

Based on the findings of this research work, the following recommendations were made;

- Farmers and fruit growers should adopt the use of crude extract from custard apple seeds in controlling Aphids spp. in eggplant and other vegetables.
- Synthetic pesticides should be used only when pest infestations have reached economic threshold levels (Therapeutic treatment).
- The use of botanical pesticides such as the crude extract from custard apple here, should be prophylaxis, to prevent insect pest infestations of crops.
- The recommended dosage for the crude extract of the custard apple seeds should be between 6 and 8 lit/ha for effective control of Aphid spp.
- Gilo and shum cultivars of *Solanum aethiopicum* produce higher yields in tones per hectare of fruits than most other species of eggplant. Emphasis should therefore be given to the two cultivars in eggplant cultivation.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest

Statement of ethical approval

The present research work did not involve the use of animals/humans, by any of the authors. Neither did it involve information about individual(s) by way of case study, survey or interview.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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