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An Evaluation of the Insecticidal Properties of Neem (*Azadirachta indica*) In Controlling Diamondback Moth (*Plutella xylostella*. (L) In Cabbage Cultivars in Obudu Cattle Ranch Resort, Cross River State, Nigeria

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Abstract

An experiment was conducted at Obudu Cattle Ranch in northern Cross River State of Nigeria, to evaluate the insecticidal properties of extract from neem seeds in controlling the deleterious activities of diamond back moth (*Plutella xylostella*) in cabbage farms. An experimental farm was established in a 30 by 10m plot of land, and the design of the experiment was a Completely Randomized Design (CRD) with a 3 by 5 factorial lay out. 3 cultivars of headed cabbage (*B. Oleracea* germmifera: white, Green and Red) were cultivated one to a plot with 5 beds per plot. A bed represented a subplot. There were 15 beds in a plot, 3 plots in a block and 3 blocks in a replicate, with each replicate having 45 beds. The entire lay out was replicated 3 times. Cabbage seedlings of 3 cultivars were transplanted from a 30 day nursery to already prepared beds at the planting distance of 70 cm within and 0.5 m between rows. There were 5 stands in a bed, 25 stands in a plot, 75 stands in a block, 225 stands in a replicate and 675 stands in the entire experimental plot. A solution of extract from neem seeds was prepared and applied in five different volumes (0, 2, 4, 6 and 8 liters ai/ha) to the cabbage cultivars, 2 weeks after transplanting to prevent early attacks on the fresh leaves of the cabbage by Diamond Back Moth (DBM). The main treatments were the cultivars while the sub-treatments were the 5 volumes of neem seed extract applied. Data were taken at maturity of the crop for the number of fruits per plot, weight of fruit in grammes per plot and the fruit yield in tons per hectare (t/ha). All data generated were subjected to analysis of variance and the main separated by least significant difference at (p=0.05) level of probability. Findings revealed that the crude extract of neem seeds at 6 and 8 lit/ha has the efficacy to repel Diamond back month effectively, thereby resulting to higher yields of the crop, especially the white cultivar. It was recommended that farmers should adopt the use of biopesticides such as neem seed extract at volumes of 6 and 8 liters ai/ha in controlling DBM in cabbage farms. They are safer and environmentally friendly.

Keywords: Crude extract; Cultivars; Efficacy; Diamondback; Bio-pesticide; Biodegradable and evaluation

1. Introduction

Cabbage is an annual temperate crop which belongs to the family Cruciferae, generally referred to as *Brassicas.* The crop originated from the Mediterranean region where large quantities are currently produced. In Nigeria, they are produced in cooler regions of Jos Plateau State and in limited quantities in Obudu Cattle Ranch in Cross River State. Cabbage are produced for their leaves, heads, buds, flowers or stems depending on the variety. Some of them can be fed to livestock. In places like Germany and Russia, the leaves of Cabbage are used in preparing a popular food called sauerkraut. It is a favourite food in which slice of cabbage are fermented in cabbage juice together with salt [1]. The crop is rich in vitamin B and C as well as in minerals such as K, Ca, P and Mg. Many varieties of *Brassica oleracea* exist, however, this paper will

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only dwell on five cultivars that are cultivated in Nigeria and in this study area in particular. These include; *Brassica oleracea* L. Var. (Capitata), *B*. *oleracea* L. Var (acephala), *B*. o*leracea* L. Var (botrytis), *B. oleracea* L. Var (germmifera), and *B. oleracea* L. Var. (sabauda).

According to [2], cabbage are grown mainly for the local markets and for domestic use. As earlier mentioned, cabbage are valuable sources of vitamins and minerals, as well as a source of cash for small scale farmers in rural and peri-urban areas. However, production is often constrained by damage caused by a range of pests (insects, diseases, nematodes and weeds) [2]. [1] also reported that insects, especially their caterpillars, cause severe damage to cabbage. They added that insects such as *Plutella xylostella* and *Hellula phidilealis* lay eggs on the leaves of cabbage. The eggs hatch after ten days to release the caterpillars which feed ferociously on the leaves before reaching their final stage within 10-15 days. The cabbage leaves become completely defoliated after two life-cycles of the insect pests. [2] had earlier reported that the range of pests attacking the different Brassicas is similar, but the relative importance of individual pest species varies between the different crops. They listed insects like Diamondback moth (DBM), cabbage aphids, the head borer (Hellula) and Bagrada bugs as the predominant pests of cabbage.

In the study area here Diamondback moth (DBM) is the predominant pest of cabbage. According to [2] Diamondback moth is a serious pest of brassicas and attacks all Brassica species. The insect is said to be cosmopolitan, tolerating tropical, subtropical and temperate climatic conditions. [3] reported that the insect is the predominant pest of cabbage in Eastern and southern Africa.

The adult is a small greyish-brown moth about 8 mm in length, with a wingspan of about 15 mm 4]. The insect has a characteristic diamond pattern on its back, which can be seen when the wings are closed at rest. This is what earns the insect the name diamondback [2]. [5] reported that the insect lays its eggs on the surface of leaves of its primary host (cabbage). The eggs are tiny, flat, white in color and overall in shape [2]. The authors added that the eggs are usually laid single or in small group and that a single female is capable of laying up to 400 eggs. After 3 to 8 days, pale green larvae which are widest in the middle part of the body emerged. The larvae which measure about 12 mm in length are voracious feeders. Their feeding on the leaves of cabbage leave severe damage on the leaves resulting to yield loses. The newly hatched larvae often feed on the underside of the cabbage leaves, penetrating the epidermis and mining through it [2]. [6] reported earlier on that infestations of Diamond back moth tends to be more severe during dry periods as rainfall has negative effect on the activities and population of the insect.

For several years now organophosphate and organo-chlorine insecticides such as fenitrothion, chloropyrifos-methyl, malathion, pirimiphos - methyl and dichlorvos have been used as effective substances in controlling insect pests [7] however, research has shown that using these chemicals continuously in controlling insect pests will results in the development of resistance to the chemicals[8]. In addition, a recent re-assessment of the ecotoxicity of these chemicals, showed that they are no longer safe to be used [9, 10] therefore, there is an urgent need to develop alternative means of controlling insects pests of crops rather than the continuous use of chemical pesticides. The best alternative means is the use of biopesticides.

Biopesticides are naturally occurring substances that control pests by non-toxic mechanisms [11]. The United States Environmental Protection Agency (US. EP) defined biopesticides as pesticides derived from natural materials such as animals, plants, bacteria and minerals. Biopesticides, according to researchers are environmentally sound and efficacious products, [12]. Biopesticides are nontoxic to non-target organisms, including beneficial insects and wildlife. Many of them are easily biodegradable. In terms of decomposition, they decompose easily and readily without imparting negatively on surface and underground water [12]. Biopesticides are typically effective in small quantities, which eliminate pollution concerns, sometimes usually associated with the traditional synthetic chemicals [13]. In addition, they are manufactured from naturally occurring raw materials in an environmentally responsible and sustainable manner [14].

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 [16].

In this experiment, extract of neem was used. Neem (*Azadirachta indica A. Juss)* is a fast growing, scleraphyllous tree which is native to the Indian subcontinent, but which is now distributed throughout southeast-Asia, East and sub-sahelian Africa, Fiji, Mauritius and parts of central America [17]. Neem grows well in climates from semi-arid to semi-humid and will thrive even in places with less than 500 mm of rainfall per year. The soil requirements are modest and the plant grows equally well on poor, shallow, sandy or stony ground. The tree bears fruits when it is 4-5 years old, on

average giving 30-50 kg of fruits per tree [17]. Research has shown that the effective ingredient of the tree are present in all parts of the three, but appear more highly concentrated in the seeds [18].

Research has shown that neem preparations have the efficacy to kill or render ineffective over 200 insect species [19]. [17] has earlier reported that the plant parts are effective as insecticidal, repellent, antifeedant, growth inhibiting, fungicidal, and nematicidal. [19] further reported that neem tree as a wonder plant has seeds and leaves which contain compounds with possible antiseptic, antiviral, and antifungal properties. He added that, there are indications the plant also has the efficacy as anti-inflammatory, hypotensive, and anti-ulcer.

1.1. Statement of the problem

The need to increase food production through the use of agrochemicals to feed the rapidly growing human population, has maintained constant pressure on the intensive use of pesticides and fertilizers. However, worldwide surveys have documented the contamination and impact of agrochemical residues in soils, terrestrial and aquatic ecosystems including coastal marine systems and their toxic effect on human and non-human biota. Although persistent organic chemicals have been phased out and replaced by the more biodegradable chemicals, contamination by legacy residues and recent residue still impact on the quality of food, water and environment. Therefore alternative paths to the intensive use of chemicals in crop protection must be adopted in order to produce food with better quality and with less toxic contaminants. The use of plants extracts such as extracts from neem *(Azadirachta indica)* is one of the acceptable alternatives.

1.2. Objective of the study

The main objective of the study is to establish an alternative means of controlling insect pests 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;

- prepare an aqueous extract from neem seeds
- test the efficacy of the aqueous extract in controlling Diamondback moth (*Plutella xylostella)*
- demonstrate the efficacy of the aqueous extract to cabbage farmers in the study area

2. Material and methods

This study was, conducted at the Obudu Cattle Ranch in Obudu/Obanliku Local government Areas of Cross River State. Obudu Cattle Ranch is bounded with Cameroon to the East, Obanliku to the West and Benue State to the North. The Ranch is situated at approximately 6.6 degrees north latitude and 9.2 degrees east longitude. The elevation of the Ranch varies between 1, 524 to 1, 829 meters (5000 to 6000 feet) above sea level. The ranch is renowed for its diverse flora and fauna. The region is rich in plant species including tropical rainforest trees, orchids and unique vegetation. In terms of wildlife, there are birds butterflies and mammals (Drills and Leopards).

The climate at the Ranch is a blend of tropical and temperate characteristics which makes it unique. There are two seasons in the Ranch; the dry season and the rainy season. The dry season spans from November to February. During this time, the Ranch experiences lower humidity and relatively cooler temperatures. Day time temperatures usually range from 18^{o} C to 25^{o} C.

The rainy season starts from March to October. This is the period when nature shows its vibrant and lush beauty. Rainfall is abundant, nourishing the fertile soil and encouraging the growth of vegetation. Humidity levels rise during the rainy season and daytime temperatures typically range between 20^{o} C and 26^{o} C. The rainy season has a distinct pattern, with most of the precipitation occurring between April and September. Annual rainfall averages around 2000 mm, ensuring a thriving ecosystem and a beautiful landscape.

During dry season, the relative cooler temperatures and drier weather create ideal conditions for cultivation of a variety of crops. Farmers in the ranch take advantage of this period to grow crops such as maize, potatoes and cabbage which thrive in these conditions. The milder temperatures during this season provide a comfortable environment for both plant growth and farm work. The rainy season brings abundant rainfall to the region, which sustain the lush vegetation. This period is particularly suitable for crops like tomatoes, lettuce and other vegetables which require consistent moisture. The fertile soil in the ranch, coupled with the regular rainfall, leads to robust yields of these crops (Ministry of Agriculture, Obudu Local Government Area Office).

2.1. Experimental design

The design of the experiment was a Completely Randomized Design (CRD) on a 3 x 5 factorial. A plot of land measuring 30 m x 10 m was used as the experimental plot. The plot was cleared packed and then beds were constructed. The beds were measuring 1.5 m x 0.5 m wide, with inter-bed spacing of 0.5 m. All together there were 5 beds in each plot, with each bed representing a subplot. There were 3 plots in a block, therefore, there were 15 beds in a block of 3 plots, and 3 blocks in a replicate, giving a total of 45 beds in a replicate. Meanwhile, the entire experimental set up was replicated 3 times with 135 beds in the 3 replicates of the experimental plot.

Cabbage seedlings of 3 cultivars were transplanted from a 30 day nursery to the beds, at a spacing of 70 cm within rows and 0.5 m between rows. There were 5 stands of cabbage in each bed, 25 stands in each plot of 5 beds, 75 stands in each block, 225 stands in each replicate and 675 stands in the entire experimental farm. Each plot was planted to a separate cultivar of headed cabbage. Three cultivars were used in the experiment; *Brassica oleracea* L. gemmifera (Green), *B. oleracea* L. gemmifera (Red), and *B. oleracea* L. gemmifera (white).

2.2. Preparation of aqueous solution of neem

Aqueous solution of neem was prepared by removing the flesh from about 100 g of mature seeds of neem. The seeds were washed and dried to avoid fungal growth. The seeds were shelled and finely grated, then steeped overnight in a cloth suspended in water at the rate of 50 g/liters of cool water. Some quantity of soap (10 g) was added to the solution to facilitate the solubility of the neem in water. The aqueous solution was filled in 16 capacity backpack knapsack sprayer and applied on the leaves of cabbage seedlings 2 weeks after transplanted from nursery to the mean field. The aqueous solution was randomly distributed to the crops at five different levels of volumes, 0, 2, 4, 6 and 8 liters/ai/hectare to control the damaging activities of Diamond back moth *(Plutella xylostella).* The main treatments were the three cabbage varieties while the sub-treatments were the five levels of volumes of application of aqueous solution of neems, each bed represented a sub-plot.

Data was taken on, the number of fruit per plot, fruit weight in grammes (g) and fruit yield in tons per hectare (t/ha) during maturity of the cabbage. The fruit weights obtained in grammes (g) were later converted to tons per hectare by extrapolation on treatment basis per sub-plot to obtain fruit yield in tons per hectare (t/ha). 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.

3. Results

Table 1 Insecticidal effect of extract from neem (*Azadirachta indica*) on Diamond back moth (*Plutella xylostella*) and on the number of fruits per plot of cabbage cultivars

Cultivar	**Applications rate (lit/ha)**	**R1**	**R2**	**R3**	**∑x**	**$\overline{X}$**
C (1) *B. oleracea* gemmifera (Green)	0	14.0	15.0	15.0	44.0	14.66
	2	16.0	15.0	15.0	46.0	15.33
	4	18.0	19.0	19.0	56.0	18.66
	6	19.0	21.0	22.0	62.0	20.66
	8	23.0	22.0	24.0	69.0	23.00
Sub-total		**90.0**	**92.0**	**95.0**		
C (2) *B. oleracea* gemmifera (Green)	0	13.0	15.0	14.0	42.0	14.00
	2	14.0	17.0	16.0	47.0	15.66
	4	16.0	16.0	17.0	49.0	16.33
	6	18.0	19.0	18.0	55.0	18.33
	8	18.0	16.0	17.0	51.0	17.00
Sub-total		**79.0**	**83.0**	**82.0**		
	0	12.0	14.0	15.0	41.0	13.66

C (3) *B. oleracea* gemmifera (Green)	2	16.0	15.0	16.0	47.0	15.66
	4	18.0	18.0	17.0	53.0	17.66
	6	20.0	22.0	24.0	66.0	22.00
	8	24.0	25.0	25.0	75.0	25.00
Sub-total		**90.0**	**95.0**	**97.0**		

Table 2 Analysis of variance for effect of extract from Neem (*Azadirachta indica*) on Diamondback moth (*Plutella xylostella*) and on number of fruits per plot of cabbage

Source of variance	**Df**	**Sum of squares**	**Mean of squares**	**f-cal**	**f-tab**
Replicate	2	248.34			
Factor (A) cabbage cultivation	2	68.62	34.31	6.20	2.43*
Error (a)	4	22.24	5.56		
Factor (B) (Rate of application)	4	160.22	40.10	12.15	10.64*
Interaction (A x B)	7	320.15	45.74	13.86	11.52*
Error	14	46.21	3.30		

*significant at 0.05 level of significance

Table 2 above shows the analysis of variance (ANOVA) for effect of extract from neem on Diamondback moth and the number of fruits per plot of cabbage cultivars during harvest. The number of fruits per plot differ significantly ($p<0.05$) amongst the cultivars of the cabbage (F-calculated volume of 6.20 was greater than F-tabulated value of 2.43). the cultivar 3 (*B. oleraceae*: gemmifera) (white) recorded the highest number of fruits per plot. Between 20 and 25 fruits per plot were recorded here. This was followed by cultivar 1 (*B. oleraceae*: gemnifera) (Green) which recorded between 19 and 24 fruits per plot (Table 1). Factor (B), the rate of application of aqueous solution of neem was also significant ($p<0.05$) as 6 and 8 liters per hectare were effective in controlling Diamondback moth than other volumes of 2 and 4 lit/ha. 8 liters per hectare was more effective than all other volumes. The inter action effect (AB) between cabbage variety and the rate of application of neem extract was significant ($p<0.05$) at (0.05) level of probability (Table 2).

Table 3 Insecticidal effect of extract from neem (*Azadirachta indica*) on diamondback moth (*Plutella xylostella*) and on the fruit weight in grammes (g) per hectare (g/ha) of cabbage

Cultivar	**Applications rate (lit/ha)**	**R1**	**R2**	**R3**	**∑x**	$\overline{\mathbf{X}}$
C (1) *B. oleracea* Gemmifera (Green)	0	30.0	22.21	25.32	77.53	25.84
	2	49.0	47.34	48.22	144.56	48.18
	4	49.62	48.92	48.81	147.35	49.12
	6	50.22	49.98	51.23	151.43	50.47
	8	52.10	50.52	51.86	154.48	51.49
Sub-total		**230.94**	**218.97**	**225.44**		
C (2) *B. oleracea* Gemmifera (Red)	0	23.40	26.22	30.62	80.24	26.75
	2	32.41	34.32	33.22	99.95.0	33.32
	4	34.52	35.26	32.81	102.59	34.20
	6	35.88	36.31	34.72	106.91	35.63
	8	36.22	36.35	35.88	108.45	36.15
Sub-total		**162.43**	**168.48**	**167.25**		

C (3) *B. oleracea* Gemmifera (Green)	0	32.11	34.23	31.56	97.90	32.63
	2	41.22	44.28	43.23	128.73	42.91
	4	56.31	48.22	52.61	157.14	52.38
	6	58.21	57.34	56.28	171.83	57.27
	8	59.22	58.91	57.86	175.99	58.66
Sub-total		**247.07**	**242.98**	**241.54**		

Table 4 Analysis of variance for the effect of extract from neem (*Azadirachta indica*) on Diamondback moth (*Plutella xylostella*) and the weight in grammes per hectare (g/ha) of cabbage fruits

Source of variance	**Df**	**Sum of squares**	**Mean of squares**	**f-cal**	**f-tab**
Replicate	2	342.26			
Factor (A) (cabbage cultivar)	2	98.23	49.12	8.82	2.64
Error (a)	4	22.28	5.57		
Factor (B) (Rate of application)	4	142.36	35.59	10.27	6.42
Interaction (A x B)	7	426.25	60.89	17.49	6.42
Error	14	48.74	3.48		

* Significant at 0.05 level of significance

Table 4 above represents the analysis of variances (ANOVA) for the effect of extract of neem on Diamondback moth and the weight in grammes (g) of cabbage cultivars. The weight in grammes differ significantly ($p<0.05$) amongst the cabbage cultivars (F- calculated value of 8.82 was greater than F-tabulated value g 2.64) (Table 4). The highest weight in grammes per stand was record in cultivar 3 (*B. oleraceae*: germmifera) (white) where between 52.61 and 59.22g were recorded. The second highest weights in grammes were recorded in cultivar 1 (*B.oleraceae*: gemmifer) (green) where between 47.34 and 51.86 grammes were recorded, then finally by cultivar 2 (*B.oleraceae*: gemmifera) (red) with grammes weights of between 32.81 and 36.35g (Table 3). The rate of application of neem extract was significant ($p<0.05$) as application at between 4 and 8 liters hectare of the aqueous solution was more effective in controlling the Diamondback moth than application at 2.0 lit/ha. The interaction effect (AB) between the cabbage cultivar and the rate of application of the plant extract was equally significant ($p<0.05$) as the higher rate of application of the aqueous solution were more effective in some cultivars than others (Table 3)

Table 5 Insecticidal effect of extract from neem (*Azadirachta indica*) on diamondback moth (*Plutella xylostella*) and on the yield in tons per hectare of cabbage fruits.

Cultivar	**Applications rate (lit/ha)**	**R1**	**R2**	**R3**	**∑x**	**X**
C (1) *B. oleracea* gemmifera (Green)	0	5.00	6.21	8.22	19.43	6.67
	2	8.62	7.51	8.46	24.59	8.19
	4	10.21	9.65	10.82	30.68	10.23
	6	11.52	10.88	12.62	35.02	11.67
	8	14.24	12.68	12.92	39.84	13.28
Sub-total		**49.59**	**46.93**	**53.04**		
C (2) *B. oleracea*	0	4.62	5.28	4.34	14.24	4.75
	2	4.84	5.31	4.88	15.03	5.01
	4	5.21	4.62	5.64	15.47	5.20

gemmifera (Red)	6	6.32	5.84	5.72	17.88	5.96
	8	6.41	7.32	6.45	20.18	6.73
Sub-total		**27.40**	**28.37**	**27.03**		
C (3) *B. oleracea* gemmifera (Green)	0	10.21	9.88	10.34	30.43	10.14
	2	15.34	15.64	16.35	47.33	15.77
	4	18.56	17.68	18.150	54.24	18.08
	6	25.42	28.41	28.52	82.35	27.45
	8	27.18	29.43	30.53	87.14	29.05
Sub-total		**96.71**	**101.04**	**103.74**		

Table 6 Analysis of variance for the effect of extract from neem (*Azadirachta indica*) on Diamondback moth (*Plutella xylostalla*) and on the fruit yield in tons per hectare (t/ha) of cabbage cultivars

Source of variance	Df	Sum of squares	Mean of squares	f-cal	f-tab
Replicate	2	168.20			
Factor (A) cabbage cultivation	2	46.35	23.17	5.52	2.32*
Error (a)	4	16.62	2.20		
Factor (B) (Rate of application)	4	120.20	30.10	11.62	10.12*
Interaction (A x B)	7	220.0	31.43	12.13	10.11*
Error	14	36.32	2.59		

Significant at 0.05 level of probability

Table 6 above shows the result of analysis of variances (ANOVA) for the effect of extract of neem on Diamondback moth and on the yield of cabbage in tons per hectare (t/ha). The result shows that the yield in tons per hectare (t/ha) was significant ($p<0.05$) amongst the cabbage cultivars (F-calculated values of 5.52 was greater than F- tabulated values of 2.32). The highest yield in tons per hectare of 25 to 30 tons were obtained in cultivar 3 (*B.oleraceae*: gemmifera) (white). This was followed by between 11.00 and 12.92 (t/ha) in cultivar 1 (*B. oleraceae*) (Green) (Table 5). Factor (B) the rate of application of neem extract was also significant ($P<0.05$) (F-calculated value of 11.62 was greater than F-tabulated value of 10.12. Volumes of between 6 and 8 lit/ha were more effective than other volumes of 0, 2 and 4 (Table 5). The interaction effect (AB), the cabbage cultivar and the rate of application of the aqueous neem extract was also significant ($p<0.05$) at 0.05 level of significance (Table 6).

4. Discussion

The number of fruits of cabbage per plot differs significantly ($p<0.05$) amongst the three cultivars of cabbage cultivated in this experiment (Table 2). Cultivar 3, (*Brassica oleraceae*: gemmifera) (white) recorded the highest number of fruits per plot. Between 20 and 25 fruits per plot were recorded in plots that received 6 and 8 liters ai/ha respectively of the aqueous solution of neen (*Azadirachta indica*) (Table 1). This was only followed by cultivar 1, *B. oleracea* gemmifera (Green) which recorded between 19 and 24 fruits per plot, on application of 6 and 8 litre ai/a respectively of the neem extract. The red cultivar (cultivar 2) *B. oleracea* gemmifera (red) recorded only between 16 and 19 fruits per plot on application of 4, 6 and 8 liters of the aqueous solution of neem (Table 1). The high yield of number of fruits per plot of the white cultivar here is in line with the report of [20] who reported that the white cultivar was a high yielding cultivar more than other cultivars of the headed cabbage. The high number of fruits per plot by the white and Green. Cultivar was not unconnected with the fact that the neem solution effectively repel the insect pest, Diamondback moth (*Plutella xylostella*) thereby giving way for the growth of fresh green leaves leading to good fruit production. The control plots where zero application was done (no application of the neem extract), there was low record of the number of fruits per plot for all the three cultivars of the cabbage cultivated here. The leaves were seen tattered in control plots as they were heavily attacked by Diamondback moth (*Plutella xylostella*), thereby reducing fruit yield drastically. The highest number

of fruits recorded in control plots was 15 in all the three cultivars (Table 1). The weight of fruits in grammes per hectare of the cabbage cultivars was significantly different ($p<0.05$) amongst the cabbage cultivars (Table 4). The white cultivar recorded the highest weight of 59 g/ha. This was followed by the green cultivar with the weight of 52 g/ha. The red cultivar only recorded the highest weight of 36 g/ha (Table 3). The highest weights of between 58 and 59 g/ha in the white cultivar, and between 51 and 52 g/ha in the green cultivar, were recorded in plots that received between 6 and 8 liters per hectare of the aqueous solution of neem (Table 3). The higher fruit weights recorded by the white and green headed cabbage here is in line with the views of [20] that some cultivars of the headed cabbage (*B. oleracea*: gemmifera) bear bigger fruits than others, hence higher weights. The yield in tons per hectare (t/ha) of the cabbage cultivars was significantly different ($p<0.05$) amongst the three cultivars (Table 6). The highest yield in tons per hectare of between 28.52 and 30.53 t/ha was recorded by the white cultivar in plots treated with 6 and 8 liters/ha respectively of the aqueous solutions of neem (Table 5). This was followed by the Green cultivar which recorded between 12.62 and 14.24 t/ha in plots treated with 6 and 8 liters/ha respectively of the aqueous neem solution. The red cultivar recorded only between 6.32 and 7.32 t/ha in plots treated with 6 and 8 liters ai/ha respectively, of the aqueous solution (Table 5). The higher yields in tones/ha were recorded in plots that received between 6 and 8 litre/ha of the aqueous solution of neem. This revealed the fact that the ideal volumes of the aqueous solution of the neem extract that can be effective against Diamondback moth (DBM) are 6 and 8 liters ai/ha. The aqueous neem solution as a biopesticide is safer to use and easily biodegradable, compared to the synthetic insecticides. However, the biopesticides are needed in greater quantities in order to the effective against the insect pests, whereas, the synthetic pesticides are effective against insect pests even in small quantities [21]. The higher volumes of 6 and 8 litres ai/ha of the neem solution for effective control of DBM here is in line with the observation of [17] who reported that plant extracts are more effective against insect pests in larger doses than in small quantities. The synthetic pesticides are effective even in small quantities. For instance [1] reported the application of 2 to 3 liters ai/ha of Diaginon or Cypermenthrine, which was effective in controlling *Plutella xylostella* and *Hellula phidilealis* in cabbage.

5. Conclusion

Researchers globally are sending signals confirming the fact that some chemicals which are routinely used in conventional agriculture are associated with alarming health and environmental hazards. From human ecological health impacts, there are growing concerns about how farmers carry out their farming activities. On the other hand, sustainable agriculture describes a robust and balanced agricultural system which requires a more cautions use of agrochemicals. This is often done through testing and careful risk assessment and the need for the farmers and the agrochemical users in general to adopt measure for better protection of the ecosystem. This include good practices for sustainable development of agriculture, fisheries and aquaculture. The use of botanical pesticides in controlling insect pests of crops is a better alternative to the use of synthetic pesticides which have adverse effects on the environment and the ecosystem. Botanical pesticides such as crude extracts of neem used where, are easily biodegradable, ecosystem and environmentally friendly, and typically effective with broad spectrums of efficacy in the management of a wide range of insect pests. Since they are extracted from plant materials, they are environmentally friendly for sustainable agricultural production.

Recommendations

From the findings of the research work, it was recommended as follows:-

- Cabbage farmers should embrace the use of crude extract from neem seeds in controlling Diamond Back Moth (DBM). Plant extracts are cheaper and less expensive to prepare.
- The use of botanical pesticides will reduce the over dependence on synthetic pesticides which have toxic effects on the user and the environment.
- Synthetic pesticides should be used only when a pest's infestation has reached economic threshold level (Therapeutic treatment).
- The use of botanical pesticides such as crude extract of neem seeds should be used prophylaxis to prevent insect pest's infestations.
- The recommended dosage of the crude extract should be between 4 and 8 litre ai/ha. The dosage should not be below 4 litres ai/ha, as this may not be effective against the insect pest. Dosage above 8 litres ai/ha may be over dosage and can result to other adverse effect.
- The white cultivar of cabbage *(Brassica oleracea:* gemmifera) is higher yielding amongst the three cultivars of the headed cabbage. Its cultivation should be given emphasises

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed. Reference to the attached cover letter.

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