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Aqueous extract of *Moringa oleifera* leaf in the management of insect pest of cabbage plant both in the laboratory and field

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Abstract
Cabbage is an important vegetable, eaten and grown worldwide. It is a rich source of vitamin A, B and C, fiber and beta-carotene. However, a wide spectrum of insect pest affects the production of cabbage causing considerable damage to the plant. To manage these insect pests, farmers have resulted in the massive use of synthetic insecticides, leaving residues in cabbage heads, contamination of water bodies, hazardous effect on human and livestock. Especially since cabbage is eaten almost raw as salads, then the production process becomes a matter of importance. The diamondback moth *Plutella xylostella* L. (Lepidoptera: Plutellidae) and cabbage aphids *Brevicoryne brassicae* L. (Hemiptera: Aphididae) are the two most important insect pest of cabbage. Botanicals have shown to be effective against many insect pests and are cheap, always available, easily degradable and environmentally friendly. Therefore, the bio-insecticidal effect of aqueous extract of *Moringa oleifera* leave was assayed against insect pest complex of cabbage in the laboratory and field at various concentrations (90, 45, 22.5, 11.3, and 5.6 µL/mL). In the laboratory, *P. xylostella* larvae and apterous *B. brassicae* adult were assayed by direct application and leaf dip assay respectively. At 90 µL/mL, *Moringa oleifera* leave, recorded 86.7% and 83.3% mortality after 6 days of exposure against *P. xylostella* larvae and *B. brassicae* respectively. Also 90% and 80% residual mortality were obtained against *P. xylostella* larvae and *B. brassicae* respectively after 10 days of exposure. At 90 µL/mL, repellency of 93.94% and 87.88% against *P. xylostella* and *B. brassicae* were recorded respectively. Larval damage on leaves treated with *M. oleifera* leave extract was as low as 3.33%. *M. oleifera* leave extract had the lowest LD_{50} of 21.71 and 29.10 µL/mL for *P. xylostella* and *B. brassicae* respectively. In the field, botanical treated plots were observed to have reduced number of insect infestation and damage. Higher yield were recorded on botanical treated plots compared to the control while the yield recorded at 90 µL/mL were not significantly different from the standard check Lambda-cyhalothrin. This study have shown the potential of aqueous *M. oleifera* leave extract as a good alternative for the control of cabbage insect pests.

Keywords: botanical control, aqueous extract, *moringa oleifera* leaf, cabbage pest, *Plutella xylostella*, *Brevicoryne brassicae*

Introduction
Cabbage (*Brassica oleracea*) is a leafy green, white, pale green or red (purple) biennial plant grown as an annual vegetable crop for its thick-leaved heads. It is derived from the wild cabbage, *B. oleracea* var. *oleracea*, and closely related to broccoli and cauliflower; Brussels sprouts; and savoy cabbage [1]. Cabbage is high in nutritional value [1]. Cabbages are prepared different ways for consumption; they can be eaten raw, pickled, fermented (for dishes such as sauerkraut), stewed, steamed, sautéed, or braised [2]. Cabbage is a good source of vitamin A, B, C, K, beta-carotene and dietary fiber [2]. The Food and Agriculture Organization of the United Nations (FAO) in 2017[3] reported that world production of cabbage and other brassicas was 71.4 million metric tonnes, led by China with 47% of the world total. Other major producers were India and Russia.

However, a wide spectrum of insect pest affects the production of cabbage causing economic damage to the stems, leaves, growing points, and inflorescences [4]. The diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutellidae), and the cabbage aphids *Brevicoryne brassicae* L. (Hemiptera: Aphididae), are considered the most destructive insect pest causing major losses to cabbage production and other cruciferous crop in Africa and other areas of the world were cabbage is grown [5]. It has been reported that heavy infestation with DBM can cause up to 80-90% losses to cabbage production if insecticide is not applied [6]. The rapid rate of development and breeding makes DBM particularly serious in the tropics [7]. In severe infestation, the entire plant could be lost. There effect is not limited only to large-scale production but also to small-scale production making their economic impact difficult to assess [8]. The global cost of control and yield loss by DBM is estimated to be US$ 5 billion per annum [9].

The damage done by the cabbage aphid is similar to that of DBM. It's a cosmopolitan pest of cabbage, cauliflower and Brussels sprouts in the temperate, tropical and sub-tropical climates [7]. Large colonies of the aphid feed on the underside of the leaves, flowers and stems causing leaf curl, leaf discolouration, Stunted growth and in severe cases, death of the infested plants [7]. They also secrete sticky honey-dew on which sooty mould grow on, causing further damage [7]. In areas where cabbage is grown in Nigeria, it is believed and popularly said, No insecticide No cabbage. In Nigeria, insecticides such as Malathion, karate, Actellic, Emamectic benzoate and cypermetrin are heavily used throughout the growing season. Although, chemical

insecticides are effective in the control of these pest but they increase cost of production and pose health hazard to its consumers due to the problem of residue and considering that cabbage is mostly consumed raw as a vegetable. Therefore, it has become important to find other alternative measures that are more ecologically friendly, cheap and easily accessible while its efficacy is not compromised, hence the use of botanicals. The study is aimed at evaluating the effects of aqueous extract of *Moringa oleifera* leaf against insect pest complex of cabbage.

Materials and methods

Experimental sites

Laboratory trials were conducted at the Department of Biology/Microbiology/Biotechnology laboratory, Alex Ekwueme Federal University Ndufu-Alike, Ebonyi State, Nigeria while field studies were carried out at Abakaliki, Ebonyi State, (Lat. 6.322922, Long. 8.082848) during the wet (Major: May – August 2017) and dry (Minor: November 2017 – February 2018) growing seasons.

Plant part collection and powder preparation

Moringa oleifera leaves were collected from a farm at Aguleri, Anambra East in Anambra State, Nigeria and air dried for 3 weeks under shade. The dried leaves were then pulverized into powder using a mechanical blender and the powder sieved with a mesh size of 710 µL to obtain fine powder for the extraction.

Preparation of plant extracts

The plant powder (100 g) was weighed and put into a non-transparent reagent bottle. Then 750 mL of distilled water was added and allowed to stand in a dark cupboard for three days. The setup was then filtered through a muslin cloth to obtain a uniform extract which was further evaporated using a rotary evaporator. Five concentrations of each extracts were serially diluted to obtain 9.0%, 4.5%, 2.25%, 1.13% and 0.56% using acetone, thus, yielding 90 µL/mL, 45 µL/mL, 22.5 µL/mL, 11.3 µL/mL, and 5.6 µL/mL respectively.

Laboratory Experiment

Collection and culturing of insects

Cabbage aphids were collected together with infested leaves from Elechi experimental farm at Abakaliki, Ebonyi State. The aphids were provided with fresh tender leaves in the laboratory till the completion of the experiment. The DBM larvae and pupae were also collected from infested cabbage using fine camel hairbrush into petri dishes lined with filter paper. The collected larvae and pupae were placed separately in plastic containers and the larvae provided with fresh cabbage leaves until adults emerge. Adults that emerge were allowed to mate at random and provided with cabbage leaves for oviposition. Eggs laid on leaves were transferred into plastic containers lined with filter paper and covered until larvae emerged. The 1st instar larvae that emerged were fed with fresh tender leaves until the 2nd and 3rd instars of F_2 larvae from the population were then used for the assays. Insect colonies were established under controlled laboratory condition of 27 ± 2.0^0C, 65 – 70% relative humidity and photoperiod of 12h:12h (L:D) and were fed on insecticide-free cabbage.

Contact toxicity

Toxicity method described by Maa and Liao (2000)[10] with slight modification was adopted. The various concentrations of the plant extracts were topically applied on 10 larvae of DBM using a pipette. After which the treated insects were then transferred into a transparent plastic container with cabbage leaf disc while for cabbage aphids, leaf dip assay (no choice method) was used as described by Birhanu *et al.* (2011)[11] with slight modification. 10 apterous aphids on the infested leaf were counted using a hand lens. After which the leaf containing the apterous aphids was dipped in the extracts and placed in a transparent plastic container lined with filter paper. Each treatment had 3 replicates with distilled water used as control and Lambda Cyhalothrin (at the recommended dose of 50 ml per 16 L of water) as standard checks. Mortality was counted after 24 hours. An insect was considered dead when it doesn't respond to probing using a blunt probe.

Residual toxicity

The method used by Ogbonna *et al*. (2014) [12] was adopted with slight modification. Cabbage leaf disc 8.0 ± 1.0 cm were treated with various concentrations of the plant extract and placed in petri dishes lined with moist filter paper and allowed to air dry for 3 hours. 10 larvae of DBM were introduced into the petri dishes while for the aphids, 10 apterous aphids were introduced. Each treatment was replicated 3 times with distilled water as control and Lambda Cyhalothrin was used as standard check. Mortality was counted after 24 hours. An insect was considered dead when it doesn't respond to probing using a blunt probe.

Repellency test

Cabbage leaf disc treated with various plant extracts and untreated leaf were placed in lined petri dishes for each treatment. 10 apterous aphids and 10 larvae of DBM were introduced into separate petri dish and left for 24 hours. The numbers of aphids and DBM found on the treated and untreated leaves were recorded. Percentage repellency (PR) was calculated using the formula:

$$\% \text{ repellency (PR)} = \frac{Nc - Nt}{Nc + Nt} \times 100$$

Where:
Nc- Number of insect pests on untreated leaves (control)
Nt- Number of insects on the treated leaves
NB: all negative numbers implied was zero repellency.

Damage assessment

Damage on leaves caused by DBM larvae were assessed by counting the damage on the leaves and then scoring on a scale of 0 – 10 where 0 is no damage and 10 is total damage and then converted to percentages.

Field Experiment

Nursery trays filled with sterilized soil were used to raise the cabbage seedlings. Cabbage seeds were nursed in a black seed tray filled with fertile soil and covered with a nylon mesh net. Seedlings were watered daily to keep the soil moisture constant. All nursery practices were carried out for three weeks until seedlings were fully ready for transplanting. A stock solution composed of 97.5 g of Urea, 45 g of Muriate of Potash and 112.5 g of potassium nitrate

mixed in 130 L of water were applied two times. Thirty (30) beds were raised 1.6 m wide, 20 m high and 2 m long. On each plot, holes were dug with a hoe and well decomposed poultry manure was placed into each hole at a rate of 200 g/hole. The holes were covered and the whole field was watered using a watering can. Transplanting was done at a distance of 0.4 m × 0.6 m. Application of fertilizer (NPK 15-15-15) was carried out after the first two weeks and four weeks after transplanting at a rate of 8 g per plant.

Field application of extracts

Aqueous *Moringa oleifera* leaf extract was used for the field application with distilled water used as the control and Lambda Cyhalothrin used as the standard checks at the recommended concentration of 50 ml per 16 L of water. Treatment applications of the different concentrations of the extracts started two weeks after transplanting using hand held sprayer. For each concentration of each extract 3 plants were sprayed.

Data collection

Data collection started 2 weeks after transplanting. Three plants for each concentration of the different treatments were sampled. Sampling of insects were done every 10 days for 11 weeks.

Parameters for the data collection on the field were:

- Presence and number of DBM larvae on both treated and untreated plots
- Presence and abundance of cabbage aphids on treated and untreated plot
- Presence and number of other insect pests of cabbage

Damage and yield assessment

At harvest the 3 cabbage heads for each concentrations were harvested and taken to the laboratory for damage and yield assessment and the control and standard check plots were also harvested for damage and yield assessment. Damage index were scored as follows:

Damage 1 = 0 – 20% damage to the leaves (D1)
Damage 2 = 21 – 40% damage to the leaves (D2)
Damage 3 = 41 – 60% damage to the leaves (D3)
Damage 4 = 61 – 100% damage to the leaves (D4)

Cabbage with no head and those with split heads were also counted. Each cabbage head was weighed using Scout-Pro (Ohaus) digital scale and equally measured with a measuring tape

Data analysis

Data collected from the field and laboratory were analysed using GenStat Statistical Package 9.2 (9th edition). Statistical designs was Complete Randomized Design (CRD) for laboratory and Randomized complete block design (RCBD) for field trials but since the blocks were not significantly different they were analysed using CRD. Count data were transformed into percentages and analysed at 5% probability level. Means were separated with LSD test at 5% level of significance. Probit analysis was also done and used to determine the LD_{50} of the different treatments while Mortality in the control was corrected using Abbots [13] formula:

$$= \frac{\text{No of Survival in control} - \text{No of Survival in treatment}}{\text{No of survival in control}} \times 100$$

Results

Contact toxicity effect of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae* in the laboratory

The effect of aqueous extract of *Moringa oleifera* leave on the mortality of *P. xylostella* and *B. brassicae* is summarized in Figures 1 and 2. After 6 days of exposure, the highest percentage mortality of 86.7% and 83.3% was recorded at 90 µL/mL against *P. xylostella* and *B. brassicae* respectively while the least concentration of 5.6 µL/mL recorded lowest mortality of 16.7% and 13.3% respectively. Control in both assay gave 0.00% mortality while the standard check, lambda cyhalothrin recorded a mortality of 93.3% and 80% respectively. The analysis of variance showed that the concentrations were significantly different in both assay (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL of aqueous extract was significantly higher than the control while the standard check, lambda cyhalothrin was not significantly different from the highest concentration of 90 µL/mL in both assays. The LD_{50} and LD_{90} of aqueous extract were 21.71 and 110.69 µL/mL against *P. xylostella* and 29.10 and 153.18 µL/mL against *B. brassicae* respectively (Figure 3).

Residual toxicity effect of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae*

The residual toxicity effect of aqueous extract of *Moringa oleifera* leave on *P. xylostella* and *B. brassicae* is summarized in Figures 4 and 5. After 10 days of application of the extract, the highest percentage mortality of 90% and 80% was recorded at 90 µL/mL while the least concentration of 5.6 µL/mL recorded lowest mortality of 10% and 5.33% against *P. xylostella and B. brassicae* respectively. Control gave 0.00% mortality for both assays while the standard check, lambda cyhalothrin recorded a mortality of 83.3% and 63.3% against *P. xylostella* and *B. brassicae* respectively. The analysis of variance showed that the concentrations were significantly different (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL of aquoues extract was significantly higher than the control while the standard check, lambda cyhalothrin was not significantly different from the highest concentration of 90 µL/mL.

Repellency effect of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae*

Table 1 shows the repellency effect of aqueous *M. oleifera* leave extracts against *P. xylostella* and *B. brassicae*. Mean percentage repellency increased with increase in concentration of the different extracts. The highest concentration of 90 µL/mL recorded a repellency of 93.94% and 87.88% while the least concentration of 5.6 µL/mL gave a repellency of 25.33% and 17.92% against *P. xylostella* and *B. brassicae* respectively. The analysis of variance showed that there is a significant difference (ANOVA: F.pr < 0.001, P < 0.05) in the different concentrations used. The mean separation showed that the highest concentration of 90 µL/mL was significantly higher than the least concentration of 5.6 µL/mL but not significantly higher than the standard check, Lambda cyhalothrin against both insects.

Damage on cabbage leaves caused by *P. xylostella* larva treated with aqueous extract of *Moringa oleifera* leave

Aqueous extract of *Moringa oleifera* leaf at the highest concentration of 90 µL/mL recorded a damage of 3.33% while the least concentration of 5.6 µL/mL recorded the highest damage of 59.67%. Control recorded a 100% damage while the standard check, Lambda cyhalothrin recorded a damage of 23.33% (Table 2). The analysis of variance showed that there is a significant difference (ANOVA: F.pr < 0.001, P < 0.05) in the concentrations used. The mean separation showed that the highest concentration of 90 µL/mL was significantly lower than the control and standard check, Lambda cyhalothrin (Table 2).

Field Experiment

Effect of aqueous extract of *M. oleifera* leave on *P. xylostella* and *B. brassicae* in the field

The mean number of *P. xylostella* larvae and *B. brassicae* adults in the plots treated with aqueous extract of *M. oleifera* leave is summarized in Table 3. The highest concentration of 90 µL/mL recorded the least population of 0.33 and 0.00 against *P. xylostella* larvae and 2.67 and 2.33 against *B. brassicae* in the major and minor seasons while the least concentration of 5.6 µL/mL recorded a mean population of 4.33 and 3.67 in the major and minor seasons against *P. xylostella* larvae and 21.00 and 17.67 against *B. brassicae* in the major and minor seasons respectively. The control recorded the highest population of 9.00 and 6.00 in the major and minor seasons against *P. xylostella* larvae and 40.33 and 28.00 against *B. brassicae* while the standard check, Lambda cyhalothrin recorded a population of 1.33 and 1.00 in the major and minor seasons against *P. xylostella* larvae and 3.00 and 2.33 against *B. brassicae* respectively. The analysis of variance showed that population of *P. xylostella* larvae and *B. brassicae* found in the plants at the different concentrations were significantly different (ANOVA: Major-F.pr < 0.001, P < 0.05; Minor-F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL was significantly lower than the controls in both seasons but not significantly different from the standard check, Lambda cyhalothrin in both seasons.

Effect of the plant extracts on other cabbage insect pests and their abundance

Apart from *P. xylosyella* and *B. brassicae* found in the field, other insect pests such as the cabbage flea beetle (*Phyllotreta spp*), cabbage webworm (*Spodoptera littorali*) and variegated grasshopper (*Zonocerus variegatus*) were equally seen in the major growing season while in the minor season only *P. xylosyella* and *B. brassicae* were found to be of pest status.

Effect of aqueous extract of *M. oleifera* leave on *Phyllotreta spp, Spodoptera littoralis* and *Zonocerus variegatus* in the field

The mean number of *Phyllotreta spp, Spodoptera littoralis* and *Zonocerus variegatus* in the plots treated with the aqueous extract of *M. oleifera* leave is shown in Table 4. At the highest concentration of 90 µL/mL, a population of 0.00 was recorded for the 3 insect species while the least concentration of 5.6 µL/mL recorded a population of 1.67 for both *Phyllotreta spp, Spodoptera littoralis* and 1.33 for *Zonocerus variegatus*. The control recorded the highest population of 4.00, 3.33 and 2.33 for *Phyllotreta spp, Spodoptera littoralis* and *Zonocerus variegatus* respectively, while the standard check, Lambda cyhalothrin recorded a population of 0.67, 1.00 and 0.67 respectively. The analysis of variance showed that the population of the three species of insects found in the plants at the different concentrations were significantly different (ANOVA: F.pr = 0.012, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL was significantly lower than the control but not significantly different from the standard check, Lambda cyhalothrin.

Damage assessment of cabbage heads treated with aqueous extract of *Moringa oleifera* leave in the major and minor season

The mean percentage damage on cabbage leaves caused by leave feeders treated with aqueous extract of *Moringa oleifera* leave in the major and minor seasons is shown in Table 5. The damage recorded in the cabbage heads treated with the concentrations of 90, 45 and 22.5 µL/mL of the aqueous extract in the major season fell within the damage 1 and 2 categories while at the least concentration 5.6 µL/mL, damage 4 category was recorded in the major season and damage 3 category recorded in the minor season. The controls all fell within the damage 4 category. The analysis of variance showed that the aqueous extract were significantly different (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the concentration of 90, 45 and 22.5 µL/mL of the aqueous extract were significantly lower than the control in both seasons. Only the highest concentration of 90 µL/mL was significantly lower than the standard check, lambda cyhalothrin in both seasons.

Yield assessment of cabbage head weight and diameter treated with aqueous extract of *Moringa oleifera* leave in the major and minor season

The mean weight and size of cabbage heads treated with aqueous extract of *Moringa oleifera* leave in the major and minor seasons is shown in Table 6. The highest concentration of 90 µL/mL recorded a head weight of 385.67 g and a diameter 38.67 mm in the major season while in the minor season a head weight of 399.00 g and a diameter of 40.33 mm was recorded. Compared to the control that recorded the lowest head weight and diameter of 21.33 g and 2.33 mm in the major season and 35.33 g and 4.33 mm in the minor season respectively. The standard check, lambda cyhalothrin recorded a head weight of 244.67 g and a diameter of 24.00 mm in the major season and a head weight of 254.00 g and diameter of 25.33 mm in the minor season. The analysis of variance showed that aqueous extract of the cabbage head weight and diameter of both the major and minor seasons were significantly different (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the concentration of 90 µL/mL of the head weight and diameter was significantly higher than the control and standard check, lambda cyhalothrin both in the major and minor seasons.

Discussion

Contact toxicity of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae* in the laboratory

The different concentrations of aqueous extracts of *M. oleifera* leave showed some bio-insecticidal properties

against *P. xylostella* and *B. brassicae*. Generally, it was observed that increase in concentration and time led to increased mortality of both insects.

The high mortality recorded when aqueous extract of *M. oleifera* leave was used could suggest that more of the active ingredients found in *M. oleifera* leave dissolves far much better in water. This is consistent with the work done by Alao and Adebayo (2015) [14] were aqueous extract of *M. oleifera* leave was tried against insect pest of water melon, *Phyllotreta cruciferae* and a reduction of 62% of the pest was achieved in the field trial. From the phytochemical analysis done by Ramesh *et al*. (2016) [15], it was revealed that the damage protective property of *M. oleifera* leave is attributed to the presence of the functional bioactive compounds, such as phenolic acids, flavonoids, alkaloids, phytosterols and organic acids, as these functional bioactive compounds might be attributed to the high percentage mortality recorded in this study.

The result also suggest that the effectiveness of *M. oleifera* leave depend on the concentration applied. Insects treated with 90 µL/mL recorded higher mortality than insect treated with 5.6 µL/mL. This might have been due to the quantity of the bioactive compound in the extract applied in the management of these insects. This agrees with earlier report by Seljasen and Meadow (2006) [16] who reported the effectiveness of plant extracts as insecticides are dose dependent. The LD_{50} of 21.71 µL/mL recorded against *P. xylostella and* LD_{50} of 29.10 µL/mL recorded against *B. brassicae* also proves the potency of aqueous extract of *M. oleifera* leave. This is more potent compared to the LD_{50} (208.35 µL/mL) obtained when *M. oleifera* seed oil was tried against *Aedes aegypti* larva [17]. Although, in the work done by Ogbonna *et al*. (2021) [32] where *Carica papaya* seed oil was tried against same insects, it was shown that *C. papaya* seed oil recorded a lower LD_{50} of 16.14 and 27.62 µL/mL for *P. xylostella* and *B. brassicae* respectively.

Residual toxicity of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae* in the laboratory

The different concentrations led to an increase in the mortality of *P. xylostella* larvae and adult *B. brassicae*. This may be attributed to the toxicant, antifeedant and repellent effect of the extracts. This is consistent with the work done by Talukder (2006) [18] were four plant extracts were tried against several stored product insects and they were found to be potent.

It was observed that *P. xylostella* larvae had a higher percentage mortality as compared to adult *B. brassicae.* This buttress the fact that the hard cuticle of adult *B. brassicae* might have been one of the factors that aided in the blockage of toxins from entering into the insect compared to that of *P. xylostella* larvae, thus making *P. xylostella* larvae more susceptible. This is consistent with the work done by Nyamador *et al*. (2010) [19], where *Cymbopogon nardus* extracts were used against *C. maculatus* and *C. subinnotatus* and it was observed that at 40 µL/L of the oil, 47.5% mortality was recorded for *C. maculatus* while 10% mortality was recorded for *C. subinnotatus* which was concluded that *C. maculatus* is more susceptible than *C. subinnotatus*. Also the work done by Ogbonna *et al*. (2016) [20], showed that despite same concentration of *Z. officinale* rhizome oil were tried on *P. truncates* and *C. maculatus* adult, *C. maculatus* recorded a lower percentage survival than that of *P. truncates* and it was concluded that *C. maculatus* was more susceptible than *P. truncates* and it was attributed to the harder cuticle of *P. truncates* as compared to that of *C. maculatus.*

Also the high percentage mortality recorded when aqueous extracts of *M. oleifera* leave were applied on the cabbage leave shows that the active substance in the plant extracts is high enough and can stick to the leaves at a more lethal dose since after treatment the leaves were air dried for 3 hours and only 2 mL of each concentration was used for the treatment. This suggest that a higher mortality may have been recorded if introduction of the insects were done immediately after treatment (that is without air drying) and if more than 2 mL of each concentration was used for the treatment of the cabbage leaves. This is also consistent with the work done by Eziah *et al.* (2013) [21] where methanol extract of roots of *Z. xanthoxyloides* and *S. longependuncata* were used against *P. truncatus* and *T. castaneum* in treated grains and it is also consistent with the work done by Ogbonna *et al*. (2016) [20] where residual toxicity of *Z. officinale* rhizome extract was tried on *C. maculatus* and a lower percentage survival was recorded after 3 days of air drying the grains before introduction of the adult insects.

Repellency effect of aqueous extract of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae* in the laboratory

The different concentrations of aqueous extracts of *M. oleifera* leave showed some level of repellent effect to *P. xylostella* larvae and adult *B. brassicae* at the different concentrations used. Most of the insects were found on the untreated leaves due to the repellent effect of the plant extracts. This is an indication of the presence of chemical substances contained in the plants that made the insect move away from the source of the stimulus. This is consistent with the work done by Eziah *et al*. (2013) [21] where *Zanthoxylum xanthoxyloides and Securidaca longependuncata* extracts were tried against *Prostephanus truncatus* and *Tribolium castaneum* and it was concluded that some plant extracts emit certain chemicals that makes insect move away from them. Although it is known that plants like *Z. officinale, M. oleifera* and *C. annuum* are normally planted with other plants to serve as insect repellent. This study has confirmed that this plant parts used constitute repellent substances and hence, help in repelling of insects when planted amongst other plants.

The result also showed that higher concentration recorded higher percentage repellency when compared to lower concentrations. This implies that the higher level of repellency exhibited by the plant extracts shows a higher amount of chemical compound that can cause repellency as compared to the lower concentration. The presence of alkanoids and flavonoids and other metabolites in the bark, seed, leaves and roots of these plants used may be the cause of the repellency observed in this study [20].

The highest concentration of the plant extract that recorded higher repellency had no larval damage on the cabbage leaf. This indicates that any plant that has the ability to repel insects also has the ability to exhibit an antifeedant property. This is consistent with the study carried out by Ukeh and Umoetok (2011) [22] that showed that different ginger extract were repellant to *T. castaneum* and *R. dominica*. Also, the extract of *Artemisisa annua* L. was equally found to repel *C. maculatus* thereby causing less damage to cowpea [23].

Effect of aqueous extract of *Moringa oleifera* leave against population of *P. xylostella* and *B. brassicae* in the field

Despite similar infestation levels of *P. xylostella* larvae and *B. brassicae* in both treated and untreated plots, there was a significantly lower infestation level of insects on treated plots compared to untreated plots. Population of *P. xylostella* larvae and *B. brassicae* was found to be reduced on plots treated with aqueous extract of *Moringa oleifera* leave in both minor and major seasons. This reduction may be due to the toxic effect of the plant extracts. This is in agreement with the works done by Sanda *et al*. (2006)[24]; [25]; [26] where it was observed that several plant extracts lead to significant reduction in insect population of *P. xylostella* and other insect pest under field conditions. The performance of aqueous extract of *M. oleifera* leave in the field also confirms the laboratory fielding although that of the laboratory had slightly lower damage and this is due to fewer insect species that was tried in the laboratory as against the field where we had no control on the species of insect that visited the plants.

Apart from the toxic effect of the plant extract that was used that resulted in the low population of *P. xylostella* and *B. brassicae* in the treated plots as against the untreated plots, one could also deduce that repellency effect of the extracts might have also contributed in the lower population of *P. xylostella* and *B. brassicae* found in the treated plots. This is also consistent with the works done by Sanda *et al*. (2006)[24]; [25]; [26] where it was concluded that the repellency effect of the botanicals used must have also contributed to the lower population of insects under study.

Also it was observed that higher concentrations of aqueous extract of *M. oleifera* leave recorded lower population of *P. xylostella* and *B. brassicae* as compared to the higher population of insects found in the plots treated with lower concentrations. This goes further to confirm that higher concentration of the plant extracts contain higher dissolved active ingredients as compared to lower concentrations. It was equally observed that *P. xylostella* and *B. brassicae* population found in the highest concentration of aqueous extract of *M. oleifera* leave was not significantly different from the standard check, lambda-cyhalothrin used at its recommended concentration. This indicates their effectiveness in the management of insect pests of cabbage when incorporated into integrated pest management.

Effect of aqueous extract of *Moringa oleifera* leave against population of other insect pests of cabbage in the field

It was observed that apart from *P. xylostella* and *B. brassicae,* other insect pest of cabbage were found on both treated and untreated plots and their presence and abundance did not differ among plots. Although the infestation levels of these insects were similar but the plots treated with the different concentrations of aqueous extract of *Moringa oleifera* leave were observed to have a reduced population of the insects. The insect pest found in the cabbage farm for the major seasons were cabbage flea beetle (*Phyllotreta spp*), cabbage webworm (*Spodoptera littorali*) and variegated grasshopper (*Zonocerus variegatus*) while in the minor season only *P. xylosyella* and *B. brassicae* were found to be of pest status. Similarly, Mochiah *et al*. (2011) [27] confirm that the above mentioned insects are found in the cabbage ecosystem.

It was equally observed that more insect pest visited the cabbage field in the major season than in the minor season. This shows that the presence and abundance of insect in an ecosystem is highly affected by seasonal changes. This is also consistent with the work done by Chalfant *et al.* (1979)[28]; [27] and [29] were it was observed that about 7 different species of insect pest of cabbage were found in the major season while only 3 species were found in the minor season.

Effects of the aqueous extract of *Moringa oleifera* leave on the damage and yield assessment of the cabbage

The extent of insect pest damage on cabbage leaves and heads were significantly reduced on plots treated with the different concentrations of aqueous extract of *Moringa oleifera* leave as compared to the control plot. The highest concentration used were not significantly different from the standard check, Lambda Cyhalothrin. This confirms the laboratory findings where the leaves treated with the plant extract were less damaged by *P. xylostella* larvae compared to untreated leaves. This is consistent with the work done by Oparaeke and Bunmi (2006) [30] where it was reported that seed of Bambara groundnuts treated with several plant extracts protected it from damage by *Callosobruchus subinnotatus.* Plant-based insecticides contain some active compounds that act as feeding deterrent and repellents to insects. As this might have contributed to the reduced damage observed in the plots treated with the different plant extracts. The repellency, toxicity and the reduced larval damage effects exhibited by the different plant extracts in the laboratory confirm the reason for the reduced number of damage on cabbage heads in the field.

Higher yield of cabbage head was recorded on treated plots with aqueous extract of *M. oleifera* leave recording the highest weight and size of cabbage heads. The cabbage heads harvested on the treated plots were bigger and less damaged than those of untreated plots. These findings indicate that cabbage cannot be cultivated without the control of insect pests because like other crucifers, they contain mustard oil and glucosides [31] which make them more susceptible to insect pest attack especially *P. xylostella* and *B. brassicae.*

Cabbage is prone to insect pest attacks and likelihood of producing a healthy and quality cabbage heads with low insecticide residue to meet consumers demand has been a problem that is yet unsolved. The study has shown that aqueous extract of *M. oleifera* leave contain chemical compounds which are responsible for bioactivities such as toxicity, repellency, antifeedants, oviposition deterrent, growth regulators and ovicidal properties against insect pests. This study has also shown that the plant extracts were most active against pest of cabbage especially the major insect pest of cabbage which are *P. xylostella* and *B. brassicae,* increasing their mortality, repelling them and deterring them from feeding.

The current study suggests that aqueous extract of *M. oleifera* leave has the potential to significantly reduce insect pests of cabbage and could serve as efficient plant based insecticides when included in integrated pest management for cabbage production.

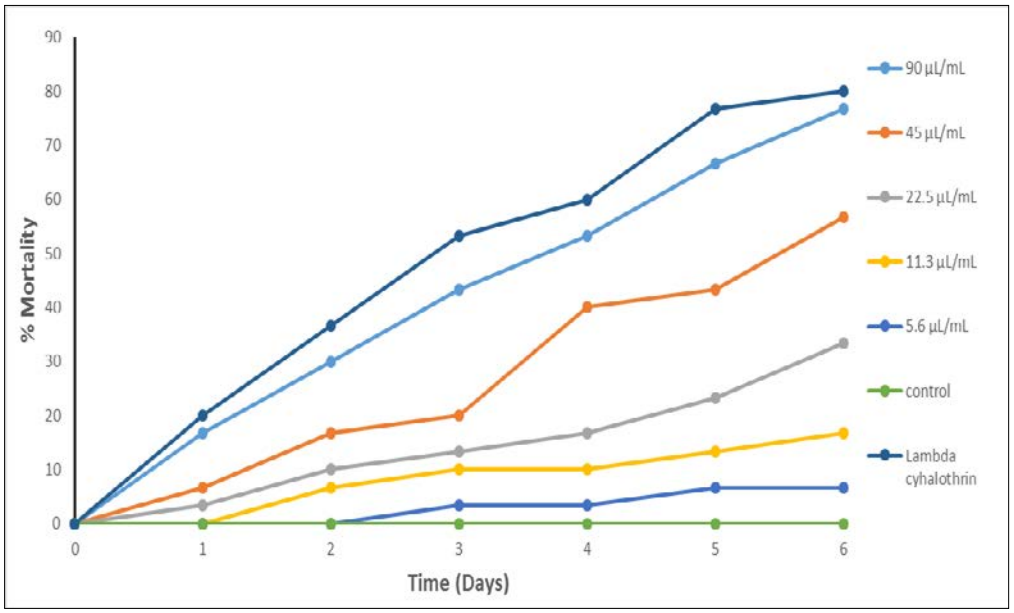

Fig 1: Percentage mortality of *P. xylostella* after 6 days of exposure to aqueous extract of *Moringa oleifera* leaves

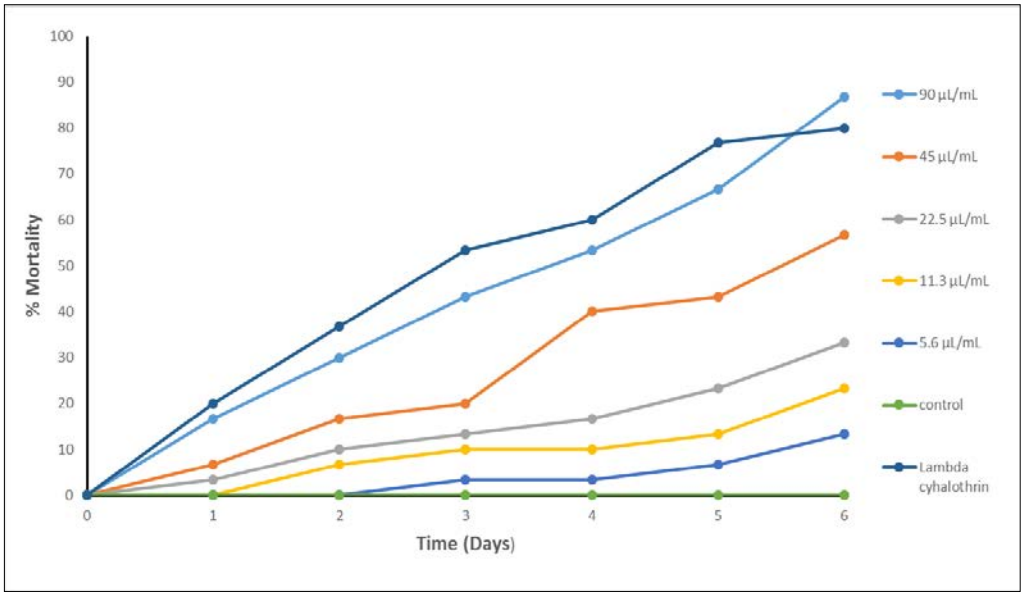

Fig 2: Percentage mortality of *B. brassicae* after 6 days of exposure to aqueous extract of *Moringa oleifera* leaves

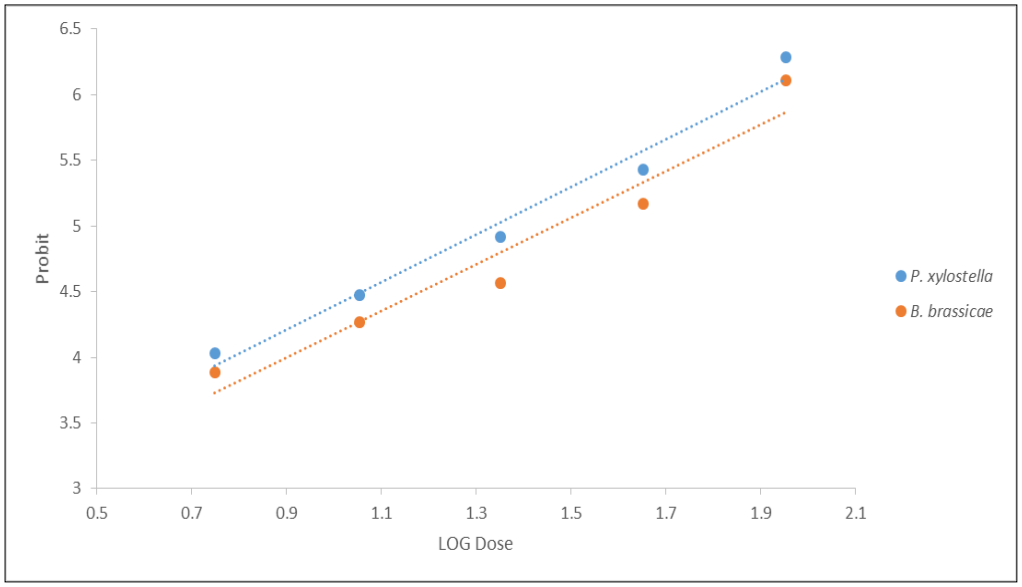

Fig 3: Probit mortality of *P. xylostella* and *B. brassicae* exposed to aqueous extract of *Moringa oleifera* leav

P. xylostella
y = 1.8095x + 2.5812
R^2 = 0.9773, **LD_{50} = 21.71 µL/mL, LD_{90} = 110.69 µL/mL**

B. brassicae
y = 1.7747x + 2.4019
R^2 = 0.9451, **LD_{50} = 29.10 µL/mL, LD_{90} = 153.18 µL/mL**

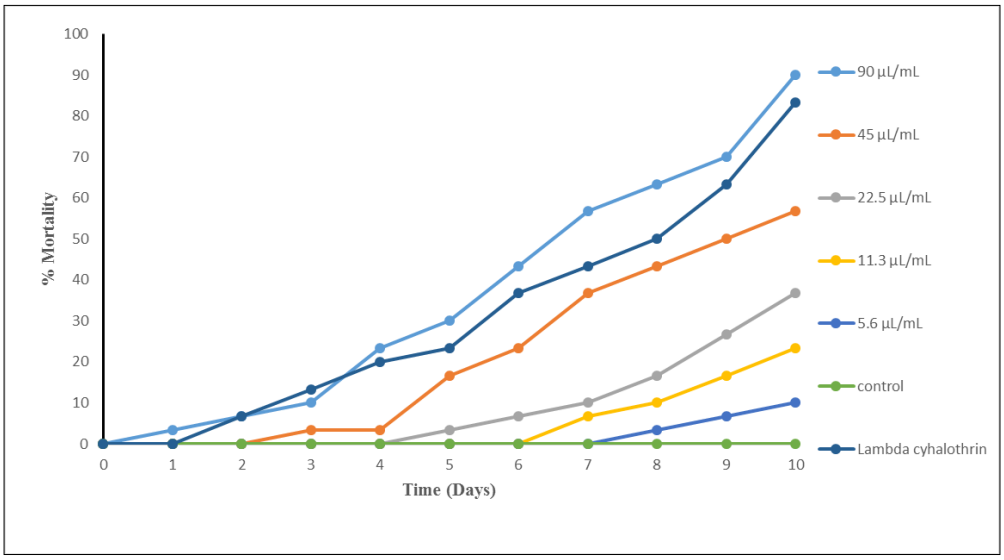

Fig 4: Percentage mortality of *P. xylostella* after 10 days of exposure to aqueous extract of *Moringa oleifera* leave

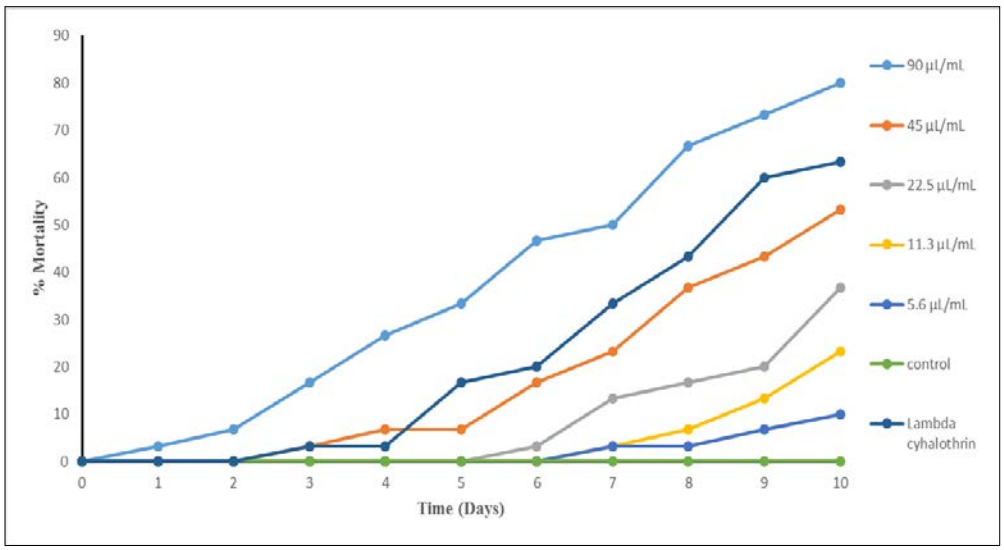

Fig 5: Percentage mortality of *B. brassicae* after 10 days of exposure to aqueous extract of *Moringa oleifera* leave

Table 1: Mean percentage repellency effect of aqueous *Moringa oleifera* leave extracts against *P. xylostella* and *B. brassicae*

Conc. (µL/mL)	Mean % Repellency ± SE *P. xylostella*	*B. brassicae*
90	93.94 ± 6.06	87.88 ± 6.06
45	58.12 ± 4.27	54.46 ± 6.88
22.5	43.35 ± 5.93	39.68 ± 3.18
11.3	27.78 ± 2.78	22.55 ± 2.45
5.6	25.33 ± 4.53	17.92 ± 4.01
Lambda cyhalothrin	87.88 ± 6.06	71.72 ± 5.05

P. xylostella*:** L.S.D.: 15.67 ***B. brassicae: L.S.D.: 14.98

Table 2: Percentage damage on cabbage leaves caused by *P. xylostella* larva treated with aqueous extract of *Moringa oleifera* leave

Conc. (µL/mL)	R1	R2	R3	Mean % Damage ± SE
90	0.00	0.00	10.00	3.33 ± 3.33
45	20.00	20.00	30.00	23.33 ± 3.33
22.5	30.00	30.00	40.00	33.33 ± 3.33
11.3	50.00	60.00	50.00	53.33 ± 3.33
5.6	60.00	60.00	70.00	63.33 ± 3.33
control	100.00	100.00	100.00	100.00 ± 0.00
Lambda cyhalothrin	20.00	30.00	20.00	23.33 ± 3.33

L.S.D.: 12.08

Table 3: Number of *P. xylostella* and *B. brassicae* sampled per plant in the field treated with aqueous extract of *Moringa oleifera* leave for major and minor seasons

Conc. (µL/mL)	Mean larvae/plant ± SE *P. xylostella B. brassicae*			
	Major Season	Minor season	Major Season	Minor season
90	0.33 ± 0.33	0.00 ± 0.00	2.67 ± 0.33	2.33 ± 0.33
45	1.33 ± 0.33	0.67 ± 0.33	5.33 ± 1.53	5.00 ± 1.16
22.5	2.33 ± 0.33	1.33 ± 0.33	12.00 ± 1.16	9.67 ± 1.45
11.3	4.00 ± 0.58	2.67 ± 0.67	16.00 ± 1.73	13.67 ± 1.45
5.6	4.33 ± 0.33	3.67 ± 0.33	21.00 ± 1.73	17.67 ± 1.20
control	9.00 ± 1.16	6.00 ± 0.58	40.33 ± 2.91	28.00 ± 1.53
Lambda cyhalothrin	1.33 ± 0.00	1.00 ± 0.33	3.00 ± 1.16	2.33 ± 0.33

P. xylostella L.S.D (Maj: 1.666; Min: 1.267); *B. brassicae* L.S.D (Maj: 5.070; Min: 3.544)

Table 4: Number of *Phyllotreta spp*, *Spodoptera littoralis* and *Zonocerus variegatus* sampled per plant in the field treated with different extract of *M. oleifera* leave for major season

Conc. (µL/mL)	Mean ± SE Adult/plant		
	Phyllotreta spp	*Spodoptera littoralis*	*Zonocerus variegatus*
90	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.33 ± 0.33	0.33 ± 0.33	0.33 ± 0.33
22.5	0.67 ± 0.33	0.67 ± 0.33	0.67 ± 0.33
11.3	1.00 ± 0.00	1.33 ± 0.33	1.00 ± 0.00
5.6	1.67 ± 0.33	1.67 ± 0.67	1.33 ± 0.33
control	4.00 ± 0.58	3.33 ± 0.67	2.33 ± 0.33
Lambda cyhalothrin	0.67 ± 0.33	1.00 ± 0.00	0.67 ± 0.33

LSD: 0.936 1.267 0.855

Table 5: Percentage damage on cabbage leaves caused by leave feeders treated with aqueous extract of *Moringa oleifera* leave in the major and minor season

Conc. (µL/mL)	Mean % Damage ± SE	
	Major season	Minor season
90	3.33 ± 3.33 – D1	0.00 ± 3.33 – D1
45	26.67 ± 3.33 – D2	20.00 ± 3.33 – D1
22.5	40.00 ± 5.77 – D2	30.00 ± 5.77 – D2
11.3	56.67 ± 5.77 – D3	43.33 ± 3.33 – D3
5.6	70.00 ± 3.33 – D4	60.00 ± 6.67 – D3
control	100.00 ± 0.00 – D4	80.00 ± 3.33 – D4
Lambda cyhalothrin	26.00 ± 3.33 – D2	16.67 ± 3.33 – D1

Major season: L.S.D.: 17.51
Minor season: L.S.D.: 13.24

Table 6: Mean of cabbage head weight and diameter recorded in the plot treated with aqueous extract of *Moringa oleifera* leave in the major and minor season

Conc. (µL/mL)	Mean of cabbage yield ± SE Head weight (g)		Head diameter (mm)	
	Major season	Minor season	Major season	Minor season
90	385.67 ± 32.83	399.00 ± 32.04	38.67± 3.28	40.33 ± 3.28
45	221.33 ± 26.74	236.67 ± 27.39	22.33 ± 2.52	24.00 ± 2.73
22.5	197.67 ± 6.12	203.33 ± 4.93	19.67 ± 0.88	20.67 ± 0.58
11.3	112.67 ± 7.97	196.67 ± 8.97	11.33 ± 0.67	19.33 ± 0.88
5.6	92.67 ± 14.17	121.00 ± 13.65	9.67 ± 1.20	12.00 ± 1.45
control	21.33 ± 9.94	35.33 ± 9.53	2.33 ± 0.58	4.33 ± 0.88
Lambda cyhalothrin	244.67 ± 19.06	254.00 ± 19.14	24.00 ± 2.08	25.33 ± 1.76

L.S.D.: 57.96; 57.60; 5.67; 5.77

Conclusion

The study has proven the contact toxicity of aqueous extracts of *Moringa oleifera* leave against *P. xylostella* and *B. brassicae* both in the laboratory and in the field. Generally, it was observed that the highest concentration of 90 µL/mL of the extract was not significantly different from the standard check, lambda cyhalothrin used.

It also showed the residual toxicity and repellency of aqueous extracts of *M. oleifera* leave, against *P. xylostella* and *B. brassicae* both in the laboratory and in the field.

In the field, the study also proved that apart from *P. xylostella* and *B. brassicae*, the extracts can also protect the cabbage plant from other insect pest that visits the cabbage ecosystem thereby leading to increase in yield of cabbage heads that should have been destroyed by these insect pests.

Recommendation

From the findings of this study, the following recommendations can be made:

- The highest concentration of 90 µL/mL of the extract can be used in the control of insect pest of cabbage.
- Further studies are needed to establish the effect of the

plant extracts on the growth and development of *P. xylostella* and *B. brassicae*
- Test for active ingredients of the plant extracts used should equally be carried out.
- Finally, residual analysis should be carried out in order to determine the level of active ingredient residue in the cabbage head.

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