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Carica papaya seed oil extract in the management of insect pest of cabbage plant both in the laboratory and field

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Abstract
Recently, the cultivation of cabbage in the Eastern part of Nigeria is increasing due to the nutritional and financial importance of cabbage. However, a wide range of insect pest cause considerable damage to cabbage production. The diamondback moth *Plutella xylostella* L. (Lepidoptera: Plutellidae), and the cabbage aphids *Brevicoryne brassicae* L. (Hemiptera: Aphididae), are considered the most economical. The petroleum ether extract at various concentrations (90, 45, 22.5, 11.3, and 5.6 µL/mL) were assayed in the laboratory against *P. xylostella* larvae and *B. brassicae* adult by direct application and leaf dip assay respectively. At 90 µL/mL, *C. papaya* seed oil, recorded 100% and 83.3% mortality after 6 days of exposure against *P. xylostella* larvae and *B. brassicae* respectively. Also similar results were obtained for the residual toxicity after 10 days of exposure. At 90 µL/mL, repellency of 93.94% and 82.83% against *P. xylostella* and *B. brassicae* were recorded respectively. There was no larval damage on leaves treated with *C. papaya* seed oil extract. *C. papaya* seed had the lowest LD_{50} of 16.14 and 27.62 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 *C. papaya* seed oil extract as a good alternative for the control of cabbage insect pests.

Keywords: botanical control, *Carica papaya* seed oil, cabbage pest, *Plutella xylostella, Brevicoryne brassicae*

Introduction

Cabbage (*Brassicae oleracea var capitate*) is one of the most important vegetables grown and eaten worldwide belonging to the family, Cruciferae (Obeng-Ofori *et al*., 2007) [14]. The edible portion is called the head which consist of overlapping thin leaves covering a small terminal bud. Cabbage is a cold season crop believed to have originated from Europe where the wild types are still found in Denmark, North-Western France and Eastern England but is presently cultivated all year round throughout the world including African countries (Obeng-Ofori *et al*., 2007) [14].

Based on the conscious effort to improve man's dietary intake, cabbage is now added in majority of foods that should have normally been eaten without it. This is because cabbage is an important source of vitamin A, B and C, fiber and beta-carotene. For every 100 g of uncooked cabbage, it contains 21 Kcal energy, 1.2 g protein, vitamins and minerals such as potassium, magnesium and sodium (Baidoo and Adam, 2012) [4]. Cabbage is eaten raw in salads or as boiled vegetable. It is also used in making soup and stew. Recently around the Temporary site of Nnamdi Azikiwe University, Awka in Anambra state, Nigeria, cabbage is now used to prepare sauce by women who sale fried yam and plantain which has led to a surge in sales, as people now prefer sauces made with cabbage than others made without them.

However, a wide spectrum of insect pest affects the production of cabbage causing considerable damage to the leaves, stems, growing points, inflorescences and fruits (CPC, 2001). Among these insects, the diamondback moth (DBM) *Plutella xylostella* L. (Lepidoptera: Plutellidae), and the cabbage aphids *Brevicoryne brassicae* L. (Hemiptera: Aphididae), are considered the most economically important insect pest causing major losses to cabbage production and other cruciferous crop in Africa and other areas of the world were cabbage is grown (Furlong *et al*., 2008) [9]. It has been reported that heavy infestation with DBM can cause up to 80-90% losses to cabbage production in the absence of insecticidal application (Zhao *et al*., 1996) [25]. The rapid rate of development and breeding makes DBM particularly serious in the tropics (Obeng-Ofori *et al*., 2007) [14]. 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 (Talekar and Shelton, 1993) [22]. The global cost of control and yield loss by DBM is estimated to be US$ 5 billion per annum (Wei *et al*., 2013) [24].

The damage done by the cabbage aphid is not far from that of DBM. It's a cosmopolitan pest of cabbage, cauliflower and Brussels sprouts in tropical, sub-tropical and temperate climates (Obeng-Ofori *et al*., 2007) [14]. Large colonies of the aphid feed on the underside of the leaves, stems and flowers, causing leaf curl, leaf discolouration, stunted growth and even death of the infested plants in severe cases (Obeng-Ofori *et al*., 2007) [14]. They also secrete sticky honey-dew on which sooty mould may grow on, causing further damage (Obeng-Ofori *et al*., 2007) [14]. 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 inevitable 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 Pawpaw seed (*Carica papaya*) 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

The seed of *C. papaya* were collected from a pawpaw farm at Nri, Anaocha LGA in Anambra State, Nigeria and air dried for 3 weeks under shade. The dried plant part 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 powders (100 g) each were weighed and put into a non-transparent reagent bottle. Then 750 mL of 100% Petroleum ether were added separately and allowed to stand in a dark cupboard for three days. Extracts were then filtered through a muslin cloth to obtain a uniform extracts 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 in stars 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^{0}C, 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) [11] with slight modification was adopted. The various concentrations of each plant extracts was 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) [5] 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 acetone 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) [15] was adopted with slight modification. Cabbage leaf disc 8.0 ± 1.0 cm were treated with various concentrations of the plant extracts 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 acetone 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. Ten 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.

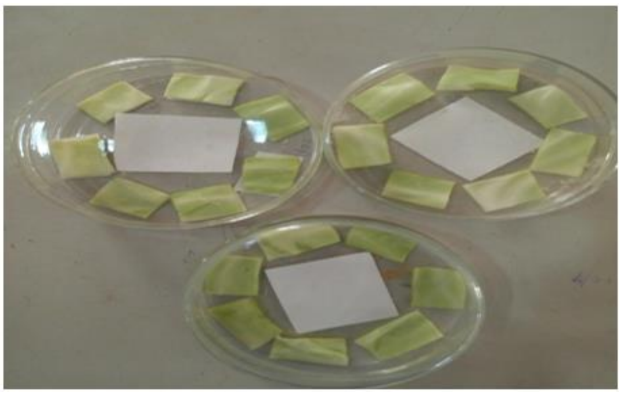

Plate 1: Set up for repellency test

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
Carica papaya seed (CPS) oil extract was used for the field application with acetone used as the control and Lambda Cyhalothrin was 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 (9^{th} 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} and LD_{90} of the different treatments while Mortality in the control was corrected using Abbots (Abbott, 1925) formula:

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

Results and Discussion
Contact toxicity effect of *Carica papaya* seed oil extract against *P. xylostella* and *B. brassicae*
C. papaya seed oil extract showed various levels of toxicity against *P. xylostella* and *B. brassicae.* Percentage mortality of *P. xylostella* and *B. brassicae* increased with increase in concentration and time. This is suggestive of the fact that higher concentrations contain higher level of the active substance. This is consistent with the studies done by Ogbonna *et al*. (2016) [16] and Eziah *et al.* (2013) [8] where it was equally shown that increased concentration also led to increase mortality.
The highest concentration of 90 µL/mL exhibited the highest mortality of 100% and 83.3% against *P. xylostella* and *B. brassicae* respectively after 6 days of exposure. The control recorded no mortality while the standard check, lambda cyhalothrin exhibited a mortality of 93.3% (Figure 1 and 2). This agrees with the work done by Rawani *et al*. (2012) were it was observed that aliphatic amide isolated from *C. papaya* seed oil brought about high mortality of adult mosquitoes; this might have contributed to the reduced survival recorded in the present study.
Also the result showed that larvae of *P. xylostella* recorded higher mortality compared to that of adult aphids of *B. brassicae* at the same concentration. This shows that insect instar that possess harder cuticle can aid in the blockage of toxins from entering the insects, since the larvae of *P. xylostella* possesses a softer cuticle than adult *B. brassicae*. This is in agreement with the work done by Nyamador *et al*. (2010), where *Cymbopogon nardus* oil was used against *Callosobruchus maculatus* and *Callosobruchus 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.*
The analysis of variance showed that there was a significant difference (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL was significantly higher than the control while there was no significant difference between the highest concentration of 90 µL/mL with the standard check, lambda cyhalothrin for both *P. xylostella* and *B. brassicae*. The LD_{50} and LD_{90} for *P. xylostella* were 16.14 and 35.79 µL/mL respectively while for *B. brassicae* were 27.62 and 167.11 µL/mL respectively (Figure 3). This shows that as low 16.14 µL/mL can kill up to 50% of *P. xylostella*

population while as low 35.70 µL/mL can kill up to 90% this could be compared to that of adult *B. brassicae* where the LD_{50} was 27.62 µL/mL and LD_{90} was 167.11 µL/mL, which is higher than that of *P. xylostella*. This is also consistent with the work done by Adhikari *et al*. (2012) were the LD_{50} and LD_{90} obtained from the mortality of pupae *Culex quinquefasciatus* was shown to be higher than that of its larvae.

Residual toxicity effect of *Carica papaya* seed oil against *P. xylostella* and *B. brassicae*

The highest concentration of 90 µL/mL exhibited the highest mortality of 88.7% and 70% against *P. xylostella* and *B. brassicae* respectively after 10 days of exposure. The control recorded no mortality while the standard check, lambda cyhalothrin exhibited a mortality of 83.3% (Figure 4 and 5). This may be attributed to the toxicant, antifeedant and repellent effect of the extracts. This is consistent with the work done by Talukder (2006) were four plant extracts were tried against several stored product insects and they were found to be potent.

Also the higher percentage mortality of *P. xylostella* larvae as compared to adult *B. brassicae* further 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.

The analysis of variance showed that there was a significant difference (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL was significantly higher than the control while there was no significant difference between the highest concentrations of 90 µL/mL with the standard check, lambda cyhalothrin. This 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 consistent with the work done by Ogbonna *et al*. (2016) [16] where residual toxicity of *Z. officinale* rhizome extract was tried *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 *Carica papaya* seed extracts against *P. xylostella* and *B. brassicae*

C. papaya seed extracts exhibited some form of repellency against *P. xylostella* and *B. brassicae.* However, mean percentage repellency increased with increase in concentration of the different extracts. The highest concentration of 90 µL/mL against *P. xylostella* and *B. brassicae* recorded a repellency of 93.94% and 82.83% respectively. 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) [8] 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. 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 of petroleum ether extract was significantly higher than the least concentration while the standard check, Lambda cyhalothrin was not significantly different from the highest concentration of 90 µL/mL (Tables 1 and 2). The higher repellency recorded with the highest concentration when compared to lower concentrations 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 (Ogbonna *et al*., 2016) [16].

Damage on cabbage leaves caused by *P. xylostella* larva treated with *Carica papaya* seed

Carica papaya seed oil at the highest concentration of 90 µL/mL recorded no damage (0.00%) while the least concentration of 5.6 µL/mL recorded the highest damage of 70%. The control recorded a 100% damage while the standard check, Lambda cyhalothrin recorded a damage of 23.33%. This shows that the active ingredient in the *C. papaya* seed oil also possess antifeedant properties. 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 3). This is consistent with the study carried out by Ogbonna *et al*. (2011) that showed that different *Carica papaya* seed oil isolate possessed antifeedant property against *P. truncates* and caused no damage to maize grain used at the highest concentration of 700 µL/mL.

Effect of *C. papaya* seed oil extract on *P. xylostella* and *B. brassicae* in the field

Generally, infestation level was higher in the major season (May – August, 2017) than in the minor season (November 2017 – February 2018). After treatment application, the level of infestation was reduced on treated plots but higher on the control plot in both the major and minor seasons. Also, it was observed that cabbage aphids were the most abundant insect pest in the field both in the major and minor growing seasons.

The level of *P. xylostella* and *B brassicae* reduced with increase in concentration of *C. papaya* seed oil extract. At concentration of 90 µL/mL of, 0.00 population of *P. xylostella* larvae was recorded both in the major and minor season while 2.00 and 1.33 population of *B brassicae* were recorded in the major and minor seasons respectively. The control recorded the highest population of 7.67 and 5.33 in the major and minor seasons respectively against *P. xylostella* larvae and 41.33 and 28.67 of *B brassicae* in the major and minor seasons respectively while the standard check, Lambda cyhalothrin recorded a population of 1.67 and 0.33 of *P. xylostella* larvae in the major and minor seasons respectively and 3.00 and 1.67 of *B brassicae* in the major and minor seasons respectively (Table 4). 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) [20]; Ogendo *et al*. (2008) [17]; Agboka *et al*. (2009) [4] 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 analysis of variance showed that population of *P. xylostella* larvae and *B brassicae* found in the plants at the different concentrations were significantly different both for major and minor seasons (ANOVA: Major-F.pr < 0.001, P < 0.05; Minor- F.pr < 0.001, P < 0.05). The mean separation of *P. xylostella* larvae and *B brassicae* showed that the highest concentration of 90 µL/mL was significantly lower than the controls in both seasons while highest concentration of 90 µL/mL was significantly different from the standard check, Lambda cyhalothrin in the major season and not significantly different from that of the minor season for *P. xylostella* larvae while for *B brassicae,* standard check, Lambda cyhalothrin was not significantly different from the highest concentration of 90 µL/mL in both seasons (Table 4). The performance of *C. papaya* seed oil extract in the field 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.

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.

The highest concentration of 90 µL/mL recorded the least population of 0.00 to *Phyllotreta spp*, *S. littorali* and *Z. variegatus* while the least concentration of 5.6 µL/mL recorded a population of 2.00, 1.67 and 0.67 to *Phyllotreta spp*, *S. littorali* and *Z. variegatus* respectively. The control was observed to have recorded the highest population of 3.33, to both *Phyllotreta spp* and *S. littorali* and 2.67 to *Z. variegatus* while the standard check, Lambda cyhalothrin recorded a population of 0.67 to *Phyllotreta spp* and 0.33 to both *S. littorali* and *Z. variegatus*. The analysis of variance showed that the population of *Phyllotreta spp, S. littorali* and *Z. variegatus* found in the plants at the different concentrations were significantly different (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the highest concentration of 90 µL/mL was significantly lower than the control but not significantly lower than the standard check, Lambda cyhalothrin (Table 5). Similarly, Mochiah *et al*. (2011) [12] 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) [6]; Shelton and Nault (2004) [21] and Mochiah *et al*. (2011) [12] 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.

Damage assessment of cabbage heads treated with *Carica papaya* seed oil extract in the major and minor season

Generally, the severity of damage was lower in the minor season compared to that of the major season. The damage recorded in the cabbage heads treated with the concentrations of 90 µL/mL in the major and minor season fell within the damage 1 (0 – 20%) category but the standard check, lambda cyhalothrin fell within the damage 1 (0 – 20%) category only in the minor season and damage 2 (21 – 40%) category in the major season while the control fell within the damage 4 (61 – 100%) category. The analysis of variance showed that the C. papaya oil extract was significantly different both in the major and minor seasons. (ANOVA: F.pr < 0.001, P < 0.05). The mean separation showed that the concentration of 90 µL/mL was significantly lower than the control and standard check, lambda cyhalothrin in both seasons (Table 6). This confirms the laboratory findings where most of 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) [18] 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 plant extract. 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.

Yield assessment of cabbage head weight and diameter treated with *Carica papaya* seed oil extract in the major and minor season

Generally, cabbage heads treated with the higher concentrations were significantly higher than the control and standard checks. Also, the minor season recorded higher cabbage weight and size than the major season. The highest concentration of 90 µL/mL recorded the highest head weight of 399 g and a diameter 39.33 mm in the major season while in the minor season a head weight of 410 g and a diameter of 41.67 mm was recorded. This could be compared to the control that recorded the lowest head weight and diameter of 16.67 g and 2.67 mm in the major season and 36.33 g and 4.67 mm in the minor season respectively. The standard check, lambda cyhalothrin recorded a head weight of 239 g and a diameter of 24.33 mm in the major season and a head weight of 258 g and diameter of 26.67 mm in the minor season. The analysis of variance showed that 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. (Table 7). Most of 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 trying to control insect pests because like other crucifers, they contain mustard oil and glucosides (Grontved and Pittler, 2000) [10] which make them more susceptible to insect pest attack

especially *P. xylostella* and *B. brassicae*.
The study has shown that *C. papaya* seed oil contain chemical compounds which are responsible for bioactivities such as toxicity, repellency, antifeedants, oviposition deterrent, growth regulators and ovicidal properties against insect pests of cabbage. The current study suggests that *C. papaya* seed oil extracts 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.

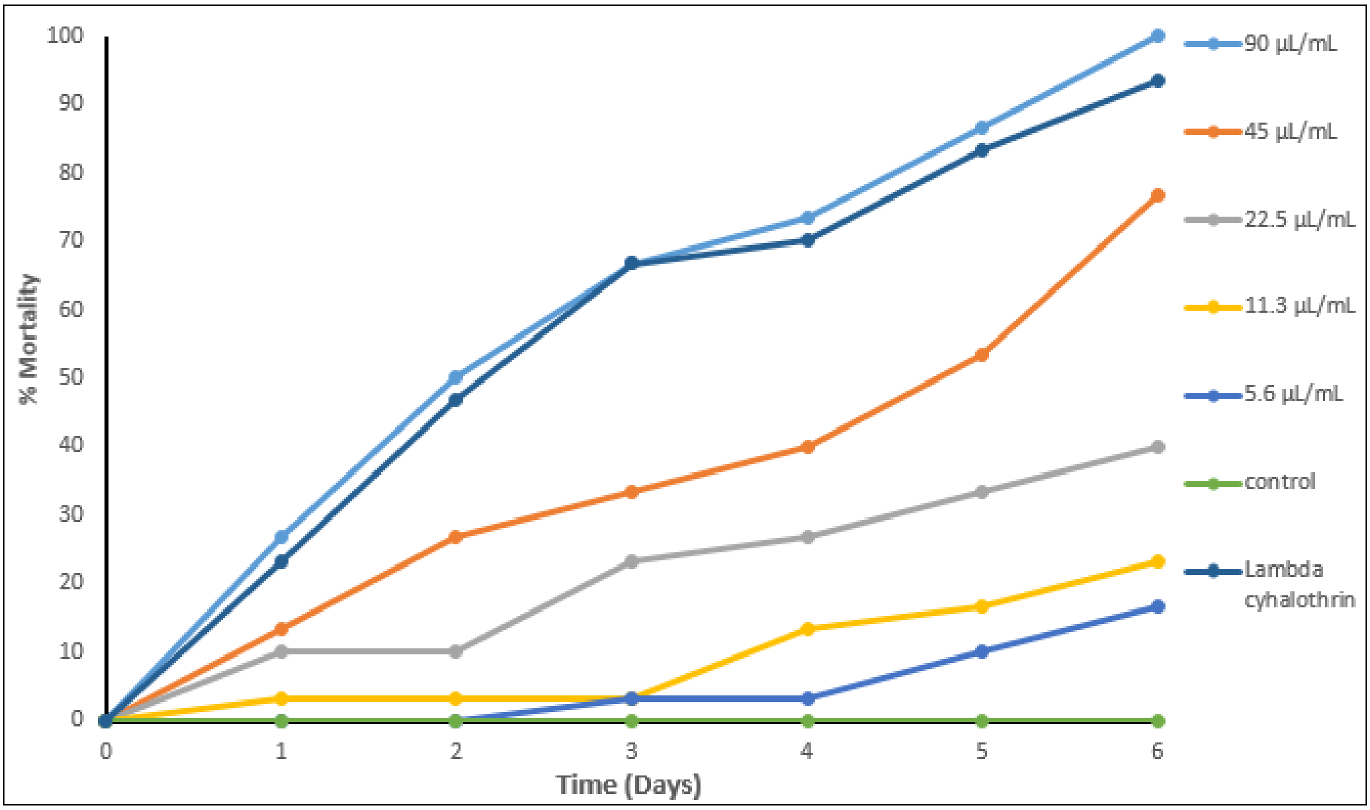

Fig 1: Percentage mortality of *P. xylostella* after 6 days of exposure to petroleum ether extract of *Carica papaya* seed

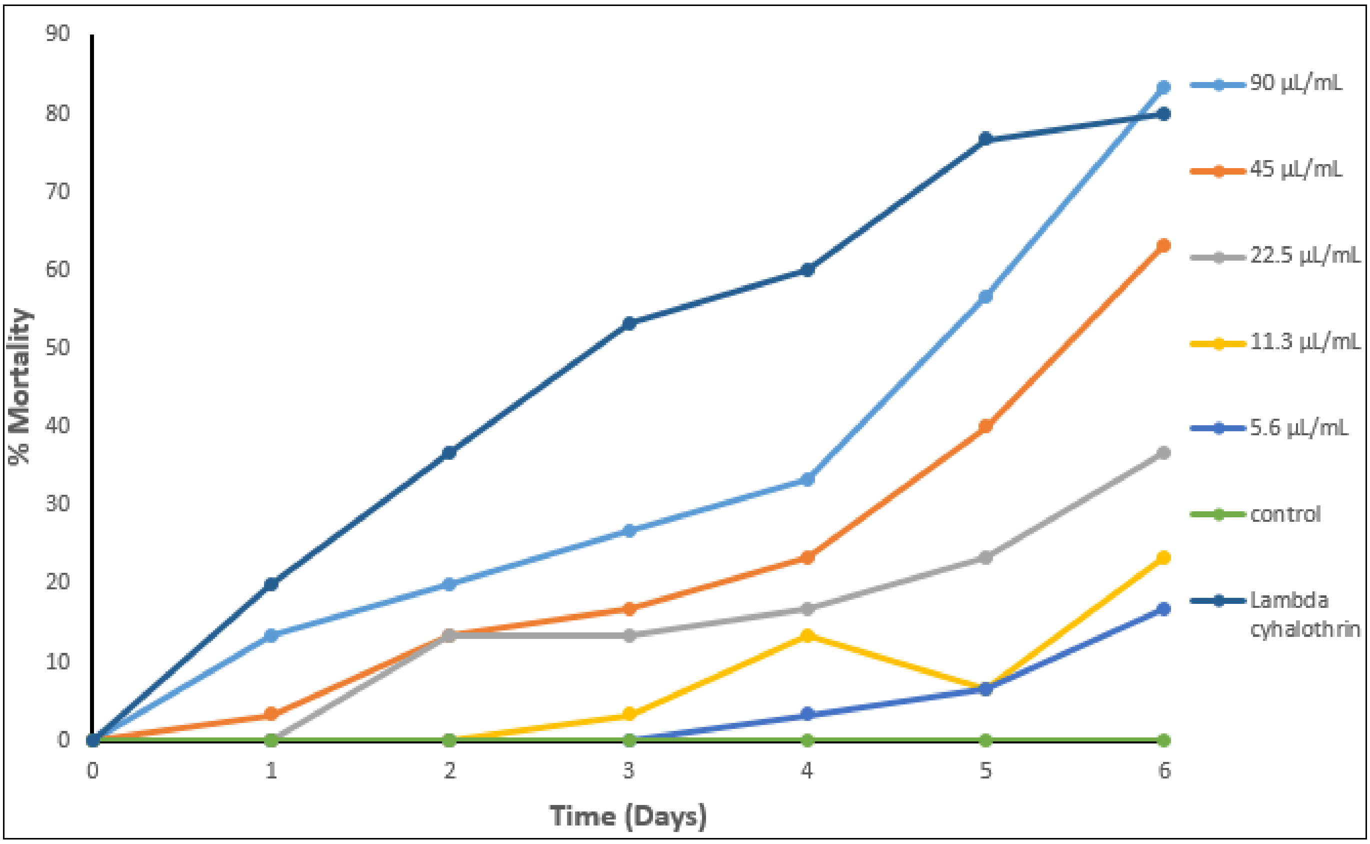

Fig 2: Percentage mortality of *B. brassicae* after 6 days of exposure to petroleum ether extract of *Carica papaya* seed

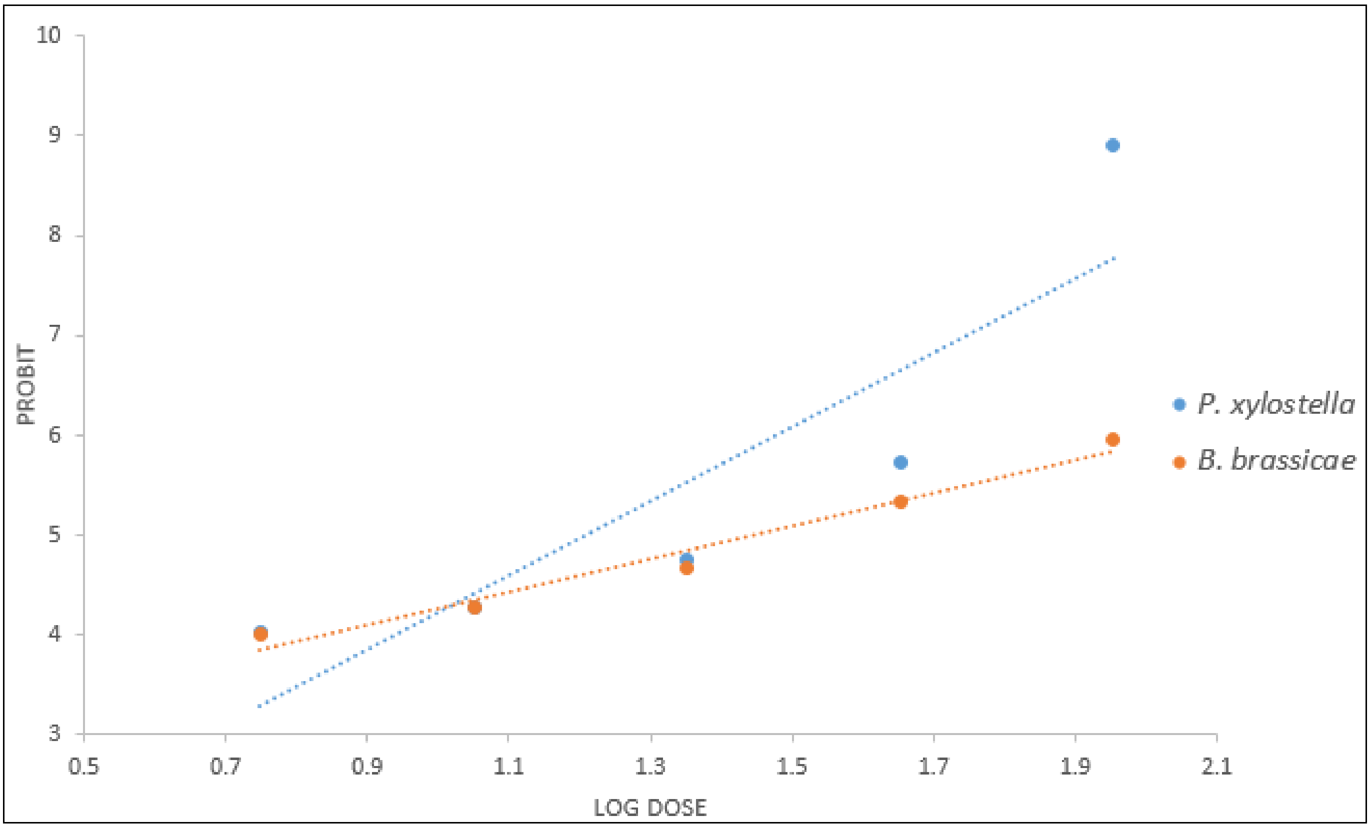

Fig 3: Probit mortality of *P. xylostella* and *B. brassicae* exposed to the different extract of *Carica papaya* seed oil extract

B. brassicae
Y= 1.6372x + 2.6405
R^2 = 0.964, LD_{50} = 27.62 µL/mL, LD_{90} = 167.11 µL/mL

P. xylostella
y = 3.7116x + 0.5169
R^2 = 0.7902, LD_{50} = 16.14 µL/mL, LD_{90} = 35.70 µL/mL

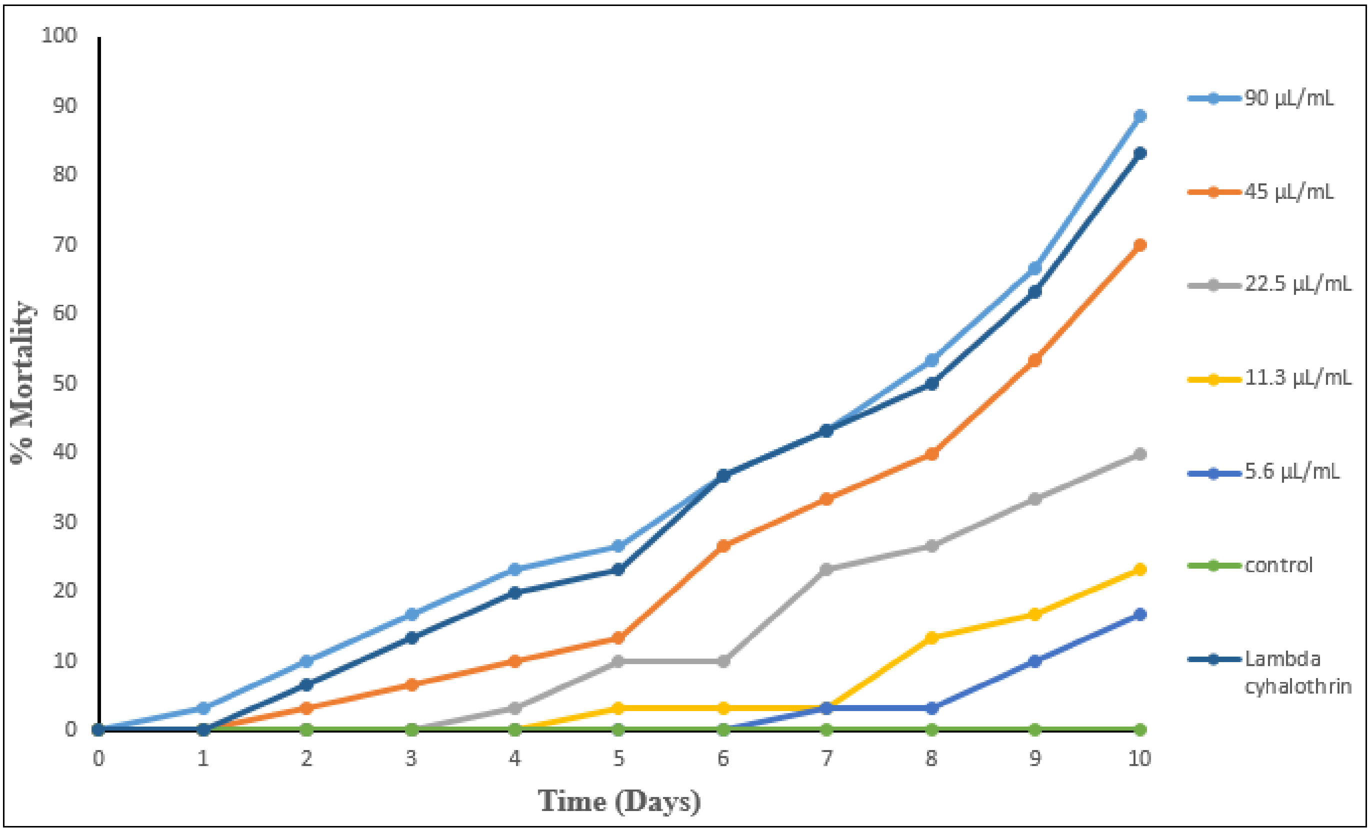

Fig 4: Percentage mortality of *P. xylostella* after 10 days of exposure to petroleum ether extract of *C. papaya* seed

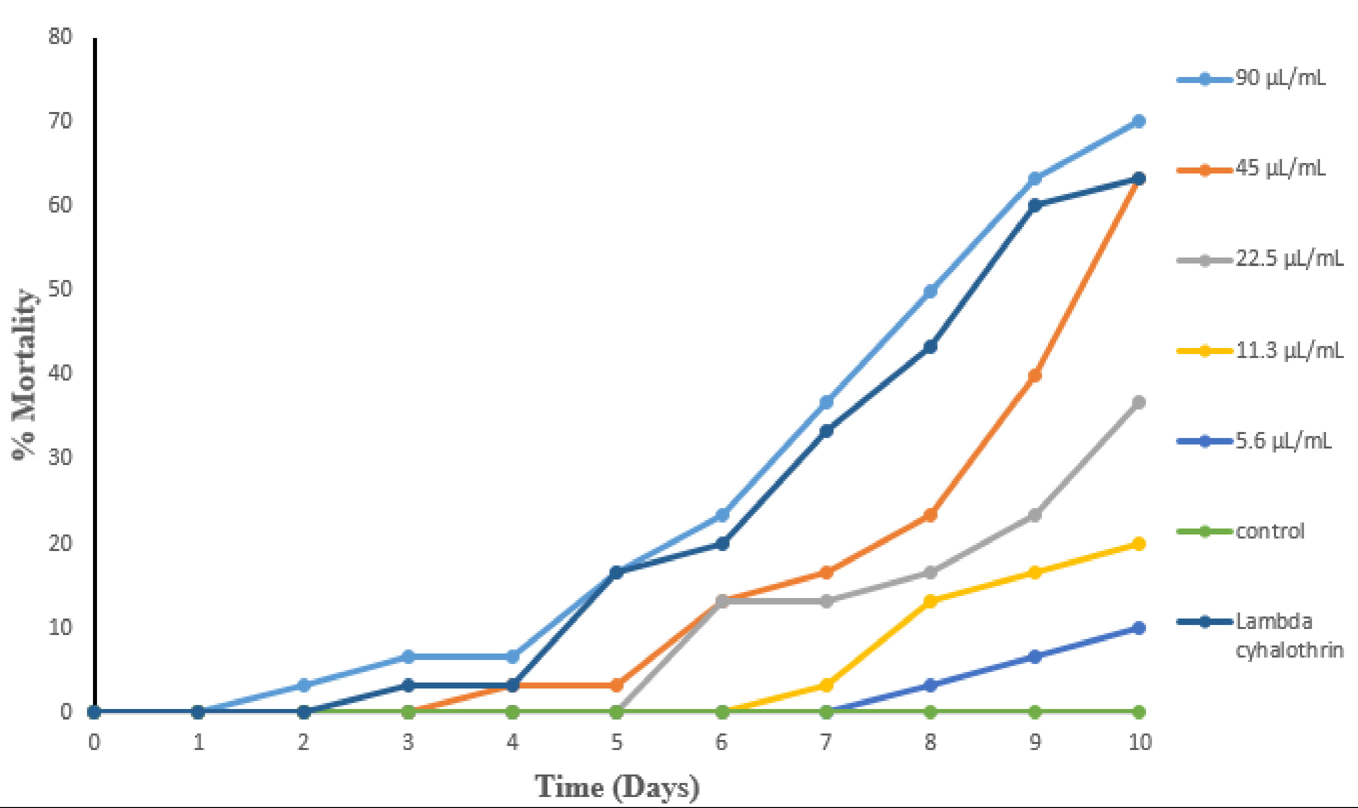

Fig 5: Percentage mortality of *B. brassicae* after 10 days of exposure to petroleum ether extract of *C. papaya* seed

Table 1: Mean percentage repellency effect of *Carica papaya* seed oil extracts against *P. xylostella*

Conc. (µL/mL)	% Repellency			Mean % Repellency± SE
	R1	R3	R2	
90	100.00	100.00	81.82	93.94
45	53.85	66.67	66.67	62.39
22.5	42.86	42.86	53.85	46.52
11.3	33.33	25.00	25.00	27.78
5.6	17.65	17.65	25.00	20.10
Lambdacyhalothrin	100.00	81.82	81.82	87.88

L.S.D (P< 0.001) = 13.71

Table 2: Mean percentage repellency effect of *Carica papaya* seed oil extracts against *B. brassicae*

Conc.(µL/mL)	% Repellency			Mean % Repellency± SE
	R1	R3	R2	
90	81.82	100.00	66.67	82.83
45	42.86	53.85	42.86	46.52
22.5	33.33	42.86	25.00	33.73
11.3	17.65	17.65	11.11	15.47
5.6	17.65	11.11	5.26	11.34
Lambdacyhalothrin	66.67	66.67	81.82	71.72

L.S.D (P< 0.001) = 16.69

Table 3: Mean percentage damage on cabbage leaves caused by *P. xylostella* larva treated with *Carica papaya* seed oil extract

Conc.(µL/mL)	% Damage			Mean % Damage ± SE
	R1	R2	R3	
90	0.00	0.00	0.00	0.00
45	10.00	20.00	10.00	13.33
22.5	30.00	40.00	40.00	36.67
11.3	40.00	50.00	60.00	50.00
5.6	70.00	80.00	60.00	70.00
Control	100.00	100.00	100.00	100.00
Lambda cyhalothrin	20.00	30.00	20.00	23.33

L.S.D (P< 0.001) = 11.46

Table 4: Number of *P. xylostella* and *B. brassicae* sampled per plant in the field treated with petroleum ether extract of *C. papaya* seed for major and minor season

Conc.(µL/mL)	*P. xylostella* (Mean ± SE)		*B. brassicae* (Mean ± SE)	
	Major	Minor	Major	Minor
90	0.00 ±0.00	0.00±0.00	2.00 ± 0.21	1.33 ± 0.33
45	1.33 ±0.33	1.00±0.00	5.00 ± 0.57	3.33± 0.88
22.5	2.67 ±0.33	2.33±0.33	9.00 ± 0.58	7.00 ±0.58
11.3	3.33 ±0.88	2.67±0.71	13.33±0.88	11.00±0.58
5.6	5.00 ±0.58	4.00±0.33	17.33±0.52	13.00±0.58
control	7.67 ±0.33	5.33±0.33	41.33±5.81	28.67±2.65
Lambdacyhalothrin	1.67.00±0.33	0.33±0.33	3.00 ± 0.58	1.67 ±0.67

Major: L.S.D=1.480; Minor: L.S.D=1.267 Major: L.S.D=6.942; Minor: L.S.D=3.502

Table 5: Number of other cabbage insect pests sampled per plant in the field treated with the *C. papaya* seed extract for major season

Conc.(µL/mL)	*Phyllotreta spp*	Mean ± SE Adult/plant	*Zonocerus variegatus*
		Spodoptera littoralis	
90	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.33 ± 0.33	0.33 ± 0.33	0.00 ± 0.00
22.5	1.00 ± 0.00	1.00 ± 0.00	0.33 ±0.33
11.3	1.33 ± 0.33	1.33 ± 0.33	0.33 ± 0.33
5.6	2.00 ± 0.58	1.67 ± 0.33	0.67 ± 0.33
control	3.33 ± 0.88	3.33 ± 0.33	2.67 ± 0.33
Lambdacyhalothrin	0.67 ± 0.33	0.33 ± 0.33	0.33 ± 0.33

LSD: 1.378 0.855 0.855

Table 6: Mean percentage damage on cabbage leaves caused by leave feeders treated with *Carica papaya* seed extracts in the major season

Conc.(µL/mL)	Mean % Damage ± SE	
	Major season	**Minor season**
90	00.00 ± 0.00 – D1	00.00 ± 0.00 – D1
45	23.33 ± 3.33 – D2	16.67 ± 3.33 – D1
22.5	46.67 ± 3.33 – D3	40.00 ± 5.77 – D2
11.3	62.00 ± 5.77 – D4	53.33 ± 6.67 – D3
5.6	81.00 ± 5.77 – D4	76.67 ± 5.77 – D4
control	100.00 ± 0.00 – D4	80.00 ± 3.33 – D4
Lambdacyhalothrin	26.67 ± 3.33 – D2	16.67 ± 3.33 – D1

Major season: L.S.D. 11.46; Minor season: L.S.D. 13.24

Table 7: Mean of cabbage head weight and diameter recorded in the plot treated with petroleum ether extract of *Carica papaya* seed 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	399.00±28.10	410.00±27.50	39.3±2.85	41.67 ±3.00
45	233.33±21.87	249.67±25.15	23.00±2.40	25.33 ± 2.65
22.5	177.33 ± 8.82	194.00 ± 9.29	17.67±1.16	20.33 ± 0.88
11.3	118.00 ± 8.89	132.00 ± 8.89	11.67±0.88	14.00 ± 0.88
5.6	103.33±10.87	115.67±10.73	10.00±1.20	12.67 ± 1.20
control	16.67 ± 8.84	36.33 ± 4.91	2.67 ± 2.19	4.67 ± 0.58
Lambdacyhalothrin	239.00±24.21	258.33±24.06	24.33±1.20	26.67 ± 2.65

L.S.D. 53.86; 54.655. 585.88

Conclusion

The study has proven the contact toxicity of *Carica papaya* seed oil extract against *P. xylostella* and *B. brassicae* both in the laboratory and in the field. It was observed that the highest concentration of 90 µL/mL of *Carica papaya* seed oil extract were not significantly different from the standard check, lambda cyhalothrin used.

It also showed the residual toxicity and repellency of *Carica papaya* seed oil extract 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

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