International Journal of Agricultural Science Research Vol. 7(3), pp. 018-027, July 2018
Available online at http://academeresearchjournals.org/journal/ijasr
ISSN 2327-3321 ©2018 Academe Research Journals

Full Length Research Paper

Evaluating the insecticidal potential of aqueous plant extracts from *Zanthoxylum zanthoxyloides* and *Anacardium occidentale* against insect pest complexes of cabbage in an open field experiment.

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Accepted 21 June 2018

Cabbage production and consumption have drastically increased in both rural and urban dwellings in Ghana. Although the plant is susceptible to insect pests, the tendency to produce quality with low insecticide cabbage head has been a problem yet to be fully resolved. The study was to evaluate the insecticidal activity of some Ghanaian botanicals: *Zanthoxylum zanthoxyloides* leaf and stem bark, *Anacardium occidentale* leaf and nutshell against insect pest complexes of cabbage in an open field conditions during 2013 major and minor rainy seasons. Infestation level of reduced *P xylostella* and *B. brassicae* was significantly lower on botanical treated plot, synthetic plots than the contol plots in both seasons. The level of predators and parasitoids did not differ significantly on botanical treated plot and control plot. Botanical treated plots recorded high cabbage heads weight and diameter with less damage thereby increasing the number of marketable heads on botanical treated plots than the control plots.

Keywords: *Zanthoxylum zanthoxyloides, Anarcardium occidentale Plutella xylostella, Brevicornye brassicae*

INTRODUCTION

A conscious effort to improve diet has resulted in cabbage becoming one of the popular vegetables which is highly consumed and intensively cultivated by both urban and rural dwellers in Ghana. Cabbage, *Brassicae oleracea var capitata* is an important global leafy vegetable crop belonging to a member of the family Cruciferae. Cabbage contains indole-3-carbinol which improves the DNA repair in cell as well as reduces the growth of cancers tumors (Fan et al., 2006; Wu. et al., 2010).

Nevertheless like other brassicas, cabbage production is confronted with many constraints especially insect pests infestation. Among these insects the diamondback moth *Plutella xylostella* and the cabbage aphids *Brevicoryne brassicae* have been noted for many decades to be the two most important and destructive pests causing severe loss to production of cruciferous crop beyond Africa (Dattu and Dattu 1995; Munthali, 2004; Macharia et al., 2005; Badenes-Perez et al; 2006).

Due to the level of damage, estimated annual cost management for the diamondback moth has increased to US$4 billion (Zalucki et al., 2012). In Ghana, farmers are struggling to reduce the level of diamondback moth and cabbage aphids by frequent application of synthetic insecticide in order to obtain quality produce for their consumers and to make good profit.

Public awareness on the cautiousness of the threat of

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synthetic organic agrochemicals for the production of cabbage has increased drastically. This has necessitated research into finding cost effective and eco-friendly management of insect pest of cabbage as a way to reduce the total dependence on synthetic insecticides. Several pathogens including fungi (Furlong, 2004), bacteria (Braun et al., 2004) and viruses (Cherry et al., 2004) have been used to reduce *P. xylostella* and *B. brassicae* population. Even though massive efforts are made worldwide to develop integrated pest management programs, predominantly based on manipulation of natural enemies to control insect pests in cabbage production, these are often not affordable to African peasant farmers.Trap cropping has proved to be effective in reducing damage caused by *P. xylostella* in crucifers (Srinivasan and Moorthy, 1991; Charleston and Kfir, 2000; Mitchell et al., 2000). However, success has not been consistent (Silva-Krott et al., 1995; Luther et al., 1996; Shelton and Nault, 2004), probably due to a lack of understanding of the mechanisms deployed by the trap crop in influencing oviposition behavior of insect.

In order to sustain vegetable production in Ghana and its marketability, plant extracts with potential bioactive compounds are one of the best alternative choices to minimize the use of synthetic insecticides. Many plants are known to be effective for insect pest management. They have numerous effects on crop pest through their repellency effect by driving insects away due to their odour or taste, antifeedant effect by preventing insects from feeding hence starving them to death, as oviposition deterrents by preventing insects from laying eggs or as inhibitors by interfering with insect life cycle (Kareru et al., 2013). Plant derived products have been given priority recently to fight and reduce losses caused by agricultural pests and diseases ((Devi and Gupta, 2000; Facknath, 2006; Ssekyewa et al., 2008; Tewary et al., 2005). Kétoh et al. (2002) have demonstrated the insecticidal activity of the *Cymbopogon schoenanthus* against *Callosobruchus maculatus* L. (Coleoptera: Pteromalidae). Sanda et al. (2006) reported high toxicity of *C. schoenanthus* L. in controlling *P. xylostella* under field conditions. Others include *Ocimum basilicum Basil* (Labiae) and the physic nut *Jatropha curcas* L. (Euphorbiaceae). The insecticidal activity of *Zanthoxylum zanthoxyloides* L. has also been effective on stored product pests including cowpea beetle *Callosobrunchus maculatus* L., *Prostephanus truncates* Horn., *Tribolium casteneum* Hebst, *Sitophilus oryzea* L. (Udo et al. 2004; Bisseleua et al. 2008, Buxton et al., 2014, 2017).The aqueous extracts of the leaf, bark and nutshell of *A. occidentale* has shown some larvicidal potential against the larvae of *Anopheles gambia* in Nigeria (Nnamani et al., 2011). Previous laboratory findings also showed some larvicidal potential of *Z. zanthoxyloides* on *P. xylostella* (Osabutey et al., 2015). Few studies of these plants have been conducted on field crops especially vegetables. This study seeks to evaluate the potential of aqueous extracts of *Z. zanthoxyloides* and *A. occidentale* against insect pest complexes of cabbage in an open field conditions.

MATERIALS AND METHODS

Field design and plant culture

Field study was conducted at the University of Ghana Experimental Farm, Legon in the Southern part of Ghana during 2013 major and minor seasons. Cabbage seeds (KK cross) 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. While seedlings were in the nursery, beds were raised at 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 (N.P.K 15-15-15) was done two weeks and four weeks after transplanting at a rate of 8 g per plant.

Plant extracts and application

The leaves and stem bark of *Z. zanthoxyloides,* and leaf and nutshell of *Anarcardium occidentale* were collected from University of Ghana botanical garden, Legon in the Greater Accra Region of Ghana. The plant parts were air-dried, and milled into powder for the extraction. The plants powder (200 g) each was placed into separate plastic containers and 2 L of water were added. The solution was kept for 24 hours and later sieved and further diluted with 3L of 0.2% liquid detergent water to make 6.7% w/v. Attack® (Emamectin benzoate) at the rate of 1.5ml/L was used as positive control and water with detergent solution (0.2%) as control. Treatment applications started two weeks after transplanting using the CP-15 Knapsack sprayer.

Field observation and data collection

Data collection started 14 days after transplanting the seedlings. Three plants in the middle of each plot out of 15 were tagged for sampling. Sampling of insects was done weekly in the morning for 10 weeks. Insects and various natural enemies of DBM and aphids from each plot were monitored and sampled directly in the field. The larvae of DBM were collected and reared in the

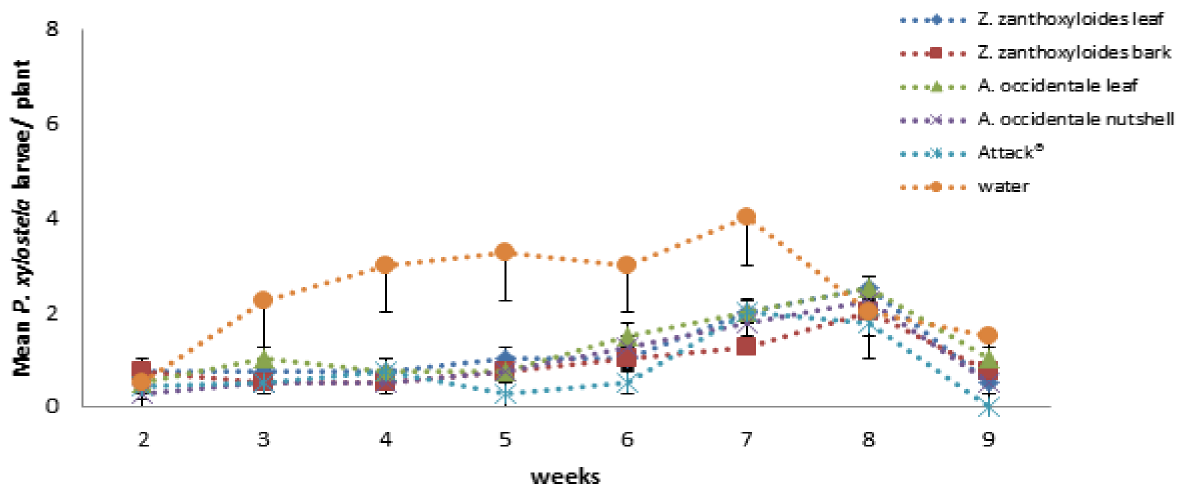

Figure 1. Mean (± SE) level of *P. xylostella* infestation sampled during 2013 the minor rainy season.

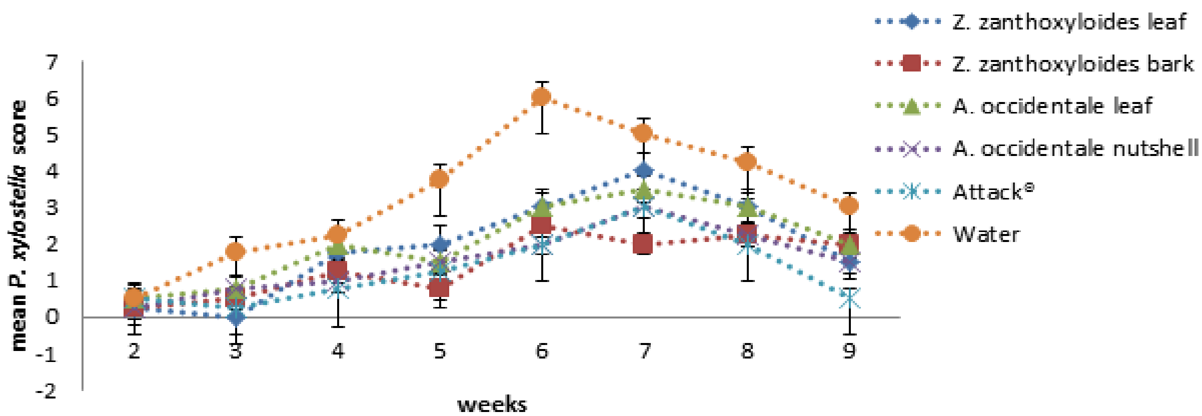

Figure 2. Mean (± SE) level of *P. xylostella* infestation sampled during 2013 major rainy season

laboratory for adult parasitoid emergence. At harvest five cabbage heads were selected at random from each treatments plot for yield assessment. The heads were later grouped into two (2): marketable and unmarketable. Each cabbage head was weighed on EB series digital scale and measured with a measuring tape.

Data analysis

All data collected were subjected to statistical analysis using GenStat Statistical Package 9.2 (9^{th} Edition). The means of weekly count data on insect pest and natural enemies were computed and subjected to Analysis of variance (ANOVA) to determine if there are any differences between the treatments. For yield assessment, mean cabbage head and size were compared and analysed using ANOVA. All means were separated using the Turkey HSD test at alpha level 0.05.Count and percentage data were acrsine square root and log (x +1) transformed before analysis.

RESULTS

Infestation level *of P. xylostella* and *B. brassicae*

The level of *P. xylostella* larvae infestation was lowered on botanical treated plots than on the control plots in both seasons. Infestation started in the 2^{nd} week after transplanting and got to its peak in the 6^{th} and 7^{th} week on control plots and 7^{th} and 8^{th} week on treated plots in the major season than the minor season respectively (Figures 1 and 2). The level of infestation differ significantly between the botanical treated plots and the control plots (ANOVA: Fpr < 0.001) in both seasons. There was significant difference in larvae infestation between the botanicals treatment and the Attack® in the

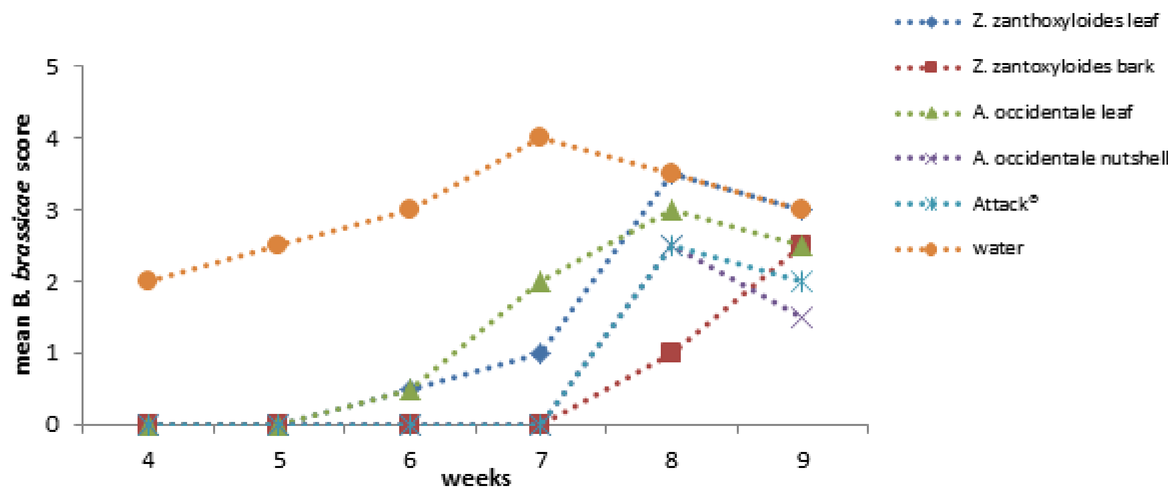

Figure 3. Mean level of infestation of *B. brassicae* sampled during 2013 the minor rainy season

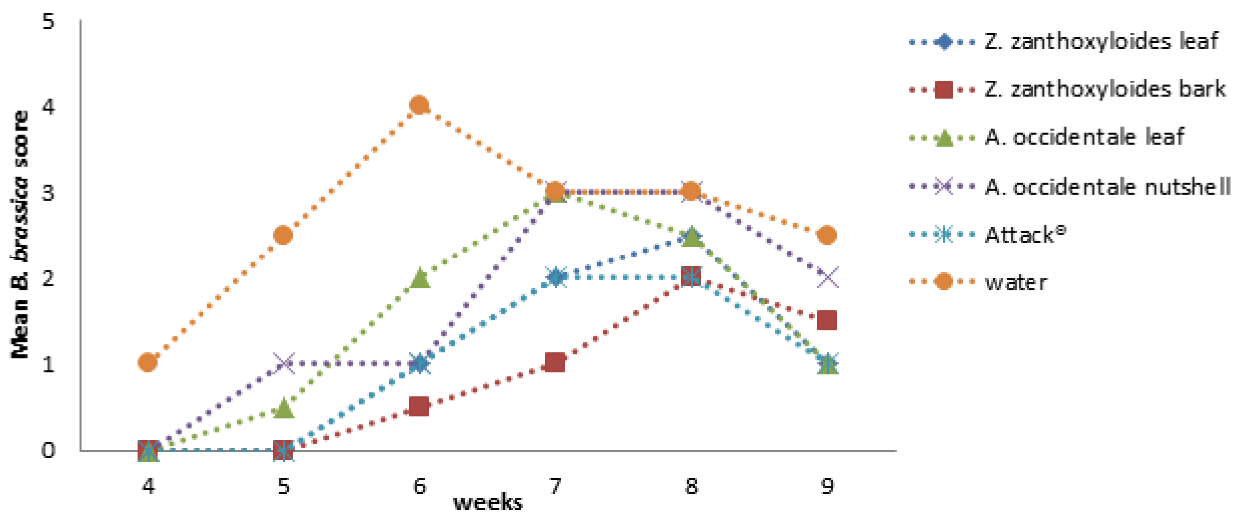

Figure 4. Mean level of infestation of *B. brassicae* sampled during 2013 the major rainy season

minor season (ANOVA: F.pr < 0.001) but insignificant in the major season (ANOVA: F.pr = 0.06)

B. brassicae were the most abundant insect pests in the field in both seasons. However infestation level was high in the major season than the minor season (Figures 3 and 4). Infestation level of *B. brassicae* started in 3^{rd} and 4^{th} week on the control plot during the major and minor seasons respectively. On the treated plots, infestation level started on the 5^{th} week for the major season and 6^{th} week for the minor season. Infestation of aphids got to its peak in the 6^{th} and 7^{th} weeks for the minor season and major season respectively. Botanical treated plots were observed to have reduced *B. brassicae* populations than the control plots. Infestation levels were highly significant in the minor season (ANOVA: F.pr < 0.001) whereas in the major season there were no significant different among the treatments (ANOVA: F.pr = 0.071). Among the plant extracts, *Zanthoxylum* stem bark and *A. occidentale* nutshell recorded the lowest level of infestation.

Infestation levels of other insect pests

Other insect pests found in the field were cabbage flee beetle (*Phyllotreta spp),* cabbage white butterfly (*Pieris rapae*), cabbage webworm *(Hellula undalis*) for major rainy season and (*Spodotera litorallis*), variegated grasshopper (*Zonocerus variegatus*) and cabbage

Table 1. Mean number of other herbivores species during 2013 major and minor rainy season

	Mean ± S.E Insect/plant					
	Major season			Minor season		
Treatments	***Phyllotrata spp***	***Pieris rapae***	***Hellula undalis***	***Spodoptera littoralis***	***Zonocerus variegatus***	***Trichoplusia ni***
Z. zanthoxyloides leaf	2.8 ± 0.25[b]	1.8± 0.48[a]	1.3 ± 0.75[a]	3.8 ± 0.48[a]	1.3 ± 0.25[a]	0.8 ± 0.25[a]
Z. zanthoxyloides bark	1.8 ± 0.48[a]	2.0± 0.41[a]	0.8 ± 0.25[a]	3.5 ± 0.65[a]	1.5 ± 0.65[a]	0.00[c]
A.occidentale leaf	1.8 ± 0.48[a]	2.5± 0.50[a]	1.5 ± 0.65[a]	4.0 ± 0.70[a]	1.5 ± 0.50[a]	1.0 ± 0.41[a]
A.occidentale nutshell	1.5 ± 0.65[a]	1.3± 0.25[a]	1.0 ± 0.58[a]	3.5 ± 0.65[a]	0.5 ± 0.41[a]	0.8 ± 0.48[b]
Attack®	1.0 ± 0.41[ab]	1.0± 0.41[a]	0.5 ± 0.20[a]	2.8 ± 0.25[a]	1.3 ± 0.25[a]	0.8 ± 0.48[a]
Water	2.8 ± 0.25[a]	2.3± 0.25[a]	1.0 ± 0.41[a]	4.0 ± 0.41[a]	1.5 ± 0.29[a]	1.5 ± 0.29[b]

Means within same column with different letters differ significantly (p < 0.05)

Diamondback moth, *Plutella xylostella*

Cabbage aphids, *Brevicornye brassicae*

Cabbage flee beetle, *Phyllotreta spp.*

Cabbage white butterfly, *Pieris rapae*

Cabbage webworm, *Hellula undalis*

Variegated grasshopper, *Zonocerus variegatus*

Spodoptera littoralis

Picture 1. Some insect pest complexes found in the cabbage ecosystem during 2013 minor and major rainy seasons.

looper (*Trichoplusia ni*) for the minor season (Table 1). In the major rainy season, cabbage flee beetle was the most abundant recording 2.8 **±** 0.25 insect per plant whereas *Spodoptera littoralis* was most abundant recording 4.0 insect per plant (Picture 1) in the minor rainy season. However, infestation level of these insects was not significantly different among the treatments and the control in both seasons (ANOVA: F.pr = 0.51).

Effects of botanicals on natural enemies

Predators and parasitoids found on the cabbage ecosystem were from the families; Coccinellidae, Syrphidae and Braconidae (Table 2 and Picture 2). Among these natural enemies, Syrphidae and Braconidae were the most abundant associated with *B. brassicae* and *P. xylostella* respectively. Presence of

Table 2. Mean number of predators and parasitoid sampled in the field during 2013 major and minor seasons.

	Mean ± S.E Insect/plant					
	Major season			Minor season		
Treatments	***Braconid (Braconidae)***	***Ladybirds (Coccinellidae)***	***Hoverflies (Syrphidae)***	***Braconid (Braconidae)***	***Ladybirds (Coccinellidae)***	***Hoverflies (Syrphidae)***
Z. zanthoxyloides leaf	2.0 ± 0.0^{b}	1.5 ± 0.4^{b}	2.0 ± 0.04^{c}	2.0 ± 0.0^{b}	1.5 ± 0.4^{b}	2.0 ± 0.04^{c}
Z. zanthoxyloides bark	3.1 ± 0.1^{a}	1.9 ± 0.05^{b}	3.1 ± 0.05^{b}	3.1 ± 0.1^{a}	1.9 ± 0.05^{b}	3.1 ± 0.05^{b}
A.occidentale leaf	2.2 ± 0.1^{b}	1.8 ± 0.01^{b}	3.9 ± 0.01^{a}	2.2 ± 0.1^{b}	1.8 ± 0.01^{b}	3.9 ± 0.01^{a}
A.occidentale nutshell	3.2 ± 0.01^{a}	1.5 ± 0.03^{b}	1.9 ± 0.5^{c}	3.2 ± 0.01^{a}	1.5 ± 0.03^{b}	1.9 ± 0.5^{c}
Attack®	0.9 ± 0.6^{c}	0.2 ± 0.02^{c}	1.0 ± 0.03^{d}	0.9 ± 0.6^{c}	0.2 ± 0.02^{c}	1.0 ± 0.03^{d}
Water	3.5. ± 0.02^{a}	3.1 ± 0.02^{a}	3.2 ± 0.02^{b}	3.5. ± 0.02^{a}	3.1 ± 0.02^{a}	3.2 ± 0.02^{b}

Means within same column with different letters differ significantly (p < 0.05)

Spider, *Dolomedes numitor*

Ladybird beetle, *Harmonia spp*

Spider, *Dolomedes numitor*

Braconid, *Cotesia plutellae*

Ant, *Oecophylla sp.*

Mason wasp, *Euodynerus spp*

Picture 2. Some natural enemies found in the cabbage ecosystem during the minor and major rainy seasons.

predators and parasitoids on treated plots were significantly different from the control plots (ANOVA: F.pr= 0.001; P<0.05). However, low level of natural enemies was recorded on plots treated with Attack®.

Yield and damage assessment

The weight and size of cabbage heads were significantly higher in treated plots with botanicals and than control plots (ANOVA: F.pr= 0.02; P<0.05). Yield was higher in the minor season than in the major season (Table 3). Apparently, all the treated plots (both botanical and Attack) recorded a higher yield in terms of cabbage head diameter and weight. However, *Z. zanthoxyloides* bark and *A. occidentale* nutshell recorded the highest head weight and head diameter for both seasons. The severity

Table 3. Mean head weight and head diameter recorded for the major and minor rainy season.

	Mean ± S.E yield/cabbage /treatment					
	Major season			**Minor season**		
Treatments	**Weight(g)**	**Size (mm)**	**Marketable head**	**Weight(g)**	**Size (mm)**	**Marketable head**
Z. zanthoxyloides leaf	270.2 ± 68.7[b]	30.2 ± 6.81[b]	1.3 ± 0.1[b]	659.5 ± 97.4[b]	41.6 ± 3.61[b]	2.7 ± 0.3[a]
Z. zanthoxyloides bark	301.0 ± 61.3[a]	33.3 ± 6.77[a]	2 ± 0.4[a]	708.0 ± 74.4[a]	44.1 ± 2.28[a]	3.0 ± 0.2[a]
A.occidentale leaf	226.1 ± 43.8[c]	24.6 ± 8.40[b]	1.3 ± 1.0[a]	703.7 ± 58.4[a]	44.5 ± 2.45[a]	2.3 ± 0.5[b]
A.occidentale nutshell	297.0 ± 54.5[b]	33.5 ± 1.65[a]	1.7 ± 0.2[a]	728.2 ± 79.3[a]	42.2 ± 0.82[a]	2.3 ± 1.0[b]
Attack®	311.9 ± 65.3[a]	31.8 ±3.95[a]	2 ± 0.1[a]	680.1 ± 69.4[b]	42.4 ± 1.60[a]	3.0 ±0.5[a]
Water	9.03 ± 4.9[d]	2.1 ± 0.82[b]	0.3 ± 0.2[c]	256.2 ± 51.8[c]	28.9 ± 3.20[b]	0.7 ± 0.2[c]

Means within same column with different letters differ significantly (p < 0.05)

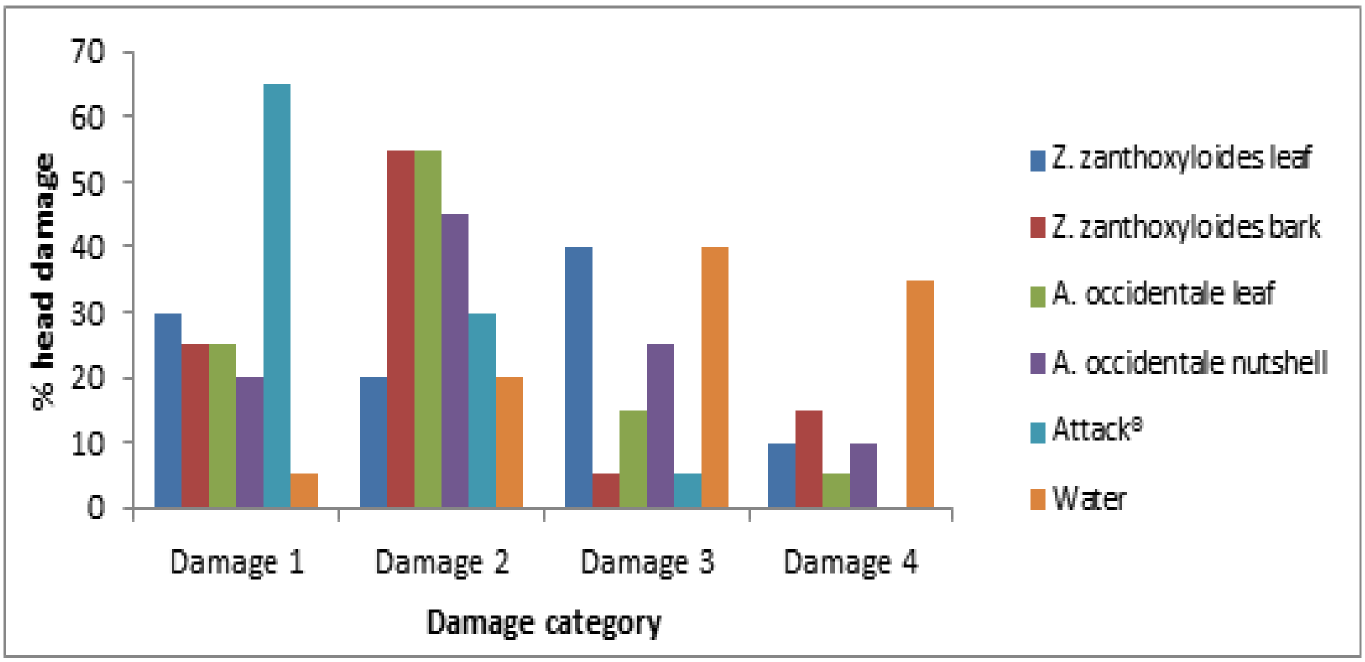

Figure 5. Cumulative percentage damage of cabbage heads within the damage category level: damage 1(0-20%), 2 (20-40%), 3 (40-60%) and damage 4(above 60%) in each treatment for minor rainy season.

of damage on cabbage heads on botanical treated plots was significantly lower than on the control plot for minor rainy season (ANOVA: F.pr= 0.008; P<0.05) and major rainy season (ANOVA: F.pr= 0.05; P<0.05). Most of the cabbage heads on botanical treated plots and Attack® in both season fell within the damage 1 (0-20%) and damage 2 (20-40%) category whereas the damages on the control plot fell within the damage 4 category (above 60%) which was the highest damage category (Figures 5 and 6).

DISCUSSION

Effect of botanicals on insect pests complex of cabbage

The study has shown the potential of *Z. zanthoxyloides,* and *A. occidentale* in controlling the insect pests of cabbage most especially the diamondback moth and cabbage aphids. The various plant parts; leaf and stem bark of *Z. zanthoxyloides*, the leaf and nutshell of *A.*

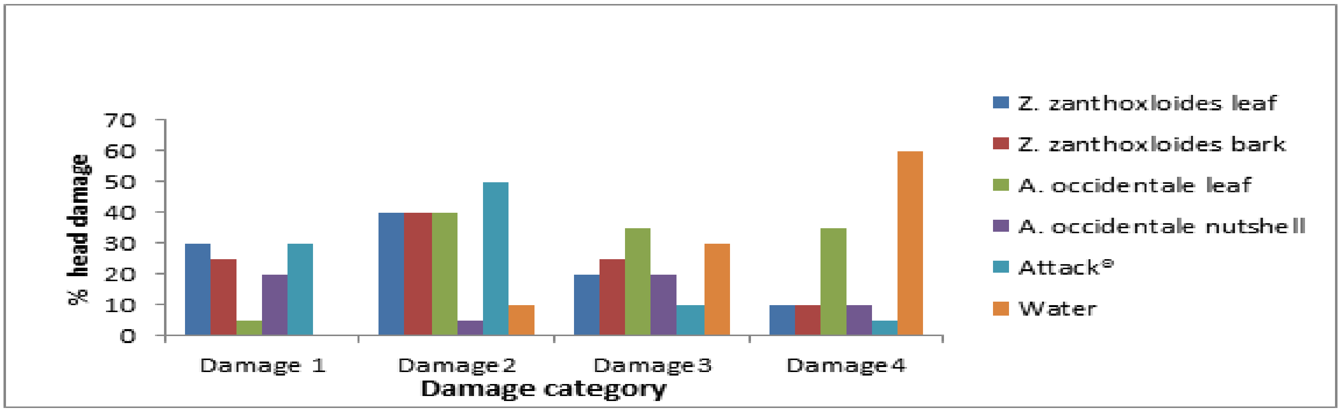

Figure 6. Cumulative percentage damage of cabbage heads within the damage category level: damage 1(0-20%), 2 (20-40%), 3 (40-60%) and damage 4 (above 60%) in each treatment for major rainy season.

occidentale exhibited different levels of insecticidal properties against insect pests of cabbage. Despite similar infestation levels of *P. xylostella* larvae, infestation was significantly lowered on botanical treated plots than the control plot. This reduction may be due to the insecticidal compounds that may be present in the plants. Botanicals and plant based insecticides have been noted for their larvicidal effects (Sanda et al., 2006; Ogendo et al., 2008; Agboka et al., 2009). Similar findings by Sanda et al. (2006) showed that *Cymbopodon schoenanthus* L. significantly reduced the larval population of *P. xylostella* under field conditions. The performance of *Z. zanthoxyloides* in the field confirms the various findings that the plant is an effective pesticide and repellent against stored product pests (Owusu et al., 2007; Eziah et al., 2013; Buxton et al., 2014).

The presence and abundance of other herbivores species found on botanical treated and the control plots did not differ among the plots. Although the infestation levels of these insects were similar, the botanicals treated plots were observed to have reduced population of the insects. These insect species complexes found in the cabbage ecosystem for both minor and major rainy seasons were *Phyllotrata spp*. *H. undalis*, *T. ni*, *P. rapae*, *S. littoralis* and *Z. variegatus*. Similarly, Chalfant et al. (1979), Shelton et al. (1982) and Mochiah et al. (2011) confirmed that the above mentioned insects are found in the cabbage ecosystem. Insect pests that attacked the cabbage field in the major rainy season were different from those that were present in the minor rainy season. This shows that the presence and abundance of an insect in an ecosystem 2013 insect infestation was high in the major season than the minor season. Notwithstanding, the performance of the plant extracts in reducing the population of *P. xylostella* and *B. brassicae* indicates their usefulness in controlling insect pests when incorporated into Integrated Pest Management.

Effects of botanical extracts on parasitoids and predators

Ideally, insecticides used in controlling insect pests should either have less impact on natural enemies or promote their build- up. The number of parasitoids and predators observed on cabbage plants on botanical treated plot was not different from that of the control plot but significantly lower on synthetic treated plots. Notwithstanding, the proportion of *Cotesia plutellae*, a larval parasitoid for *P. xylostella* was found to be significantly higher on botanical treated plots as the control plot than the synthetic treated plots. Similarly, Charleston *et al*. (2006) also reported that the proportion of *C. plutellae* was significantly higher on *P. xylostella* larvae feeding on cabbages treated with botanicals derived extract from *Melia azedarach* and *Azadirachta indica* in the field. This is because botanicals derived extracts have the ability to prolong the developmental stages of *P. xylostella* (Charleston, 2004), hence making them readily available as food source for the parasitoids for a longer period of time thereby promoting a high level of parasitism on cabbage plants treated with botanicals. Among these natural enemies *Allograpta exotica*, a predator for *B. brassicae* were most dominant especially on the control plot and this is possibly due to the high infestation levels of *B. brassicae*. Botanicals have positive effects on the population of natural enemies and therefore the use of botanical and biological control is effective in the management of insect pests in cabbage production.

Effects of botanicals extracts on damage and yield assessment

The severity of insect pest damage on cabbage leaves and heads was significantly reduced on botanical treated plots as well as the synthetic plot than the control plot.

This confirms laboratory findings where most of the leaves treated with botanicals were less infested by the larvae of *P. xylostella* compared to untreated leaves. The repellency and larval damage effects exhibited by the two insects *P xylostella* and *B. brassicae* in the laboratory (Osabutey et al., 2015) confirm the reason for the reduced number of damage on cabbage heads in the field.

Higher yield of cabbage head was recorded on botanical treated plots Most of the cabbage heads harvested on the treated plots were more marketable than those on the control plots. The high rate of damage found on the control plots is an indication that cabbage cannot be cultivated without making an attempt to control insect pests because like other crucifers, they contain mustard oil and glucosides (Gupta and Thorteinson 1960) which make them more susceptible to insect pest attack especially the *P. xylostella* and *B. brassicae.*

CONCLUSION

Cabbage is prone to insect pests attack, and the tendency to produce a healthy and quality cabbage heads with low insecticide residue to meet consumers demand has been a problem yet to be fully solved. Plant parts and their derivatives contain chemical compounds which are responsible for bioactivities such as antifeedent, oviposition deterrent, insecticidal, ovicidal and growth regulators against insect pests. From the study, the plants have the potential to significantly reduce insect pests of cabbage and could serve as effective botanical insecticides when included in Integrated Pest Management for vegetable production.

ACKNOWLEDGEMENT

We are grateful to The Carnegie Corporation through The University of Ghana (UG-CCNY 'Next Generation Project'), Office of Research, Innovation and Development (ORID), for funding the research. We thank Mr Davis for the insect identification. We thank Mr. Agyekum for plant culture and transplanting. Emelia Forson and Edwin Mustapha are thanked for assistance in data collection.

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