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Comparing the Effectiveness of Garlic (*Allium sativum* L.) and Hot Pepper (*Capsicum frutescens* L.) in the Management of the Major Pests of Cabbage *Brassica oleracea* (L.)

P. K. Baidoo[1] & M. B. Mochiah[2]

[1] Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[2] Entomology Section, Crops Research Institute, P. O. Box 3785, Kwadaso, Kumasi, Ghana

Correspondence: P. K. Baidoo, Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. E-mail: pkbaidoo2002@yahoo.com

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Abstract

The use of chemical insecticides in crop production has resulted in increased food production in Africa, but their use has resulted in the destruction of beneficial organisms and development of resistance by some insects to the insecticides. The effectiveness of garlic *Allium sativum* and hot pepper, *Capsicum frutescens* in controlling the pests of cabbage, *Brassica oleracea* was evaluated. These botanicals were compared with a standard chemical insecticide Attack® (Emamectin benzoate). The experiment was conducted in a randomized complete block design, with 3 treatments and a control, each of which was replicated 3 times. *Plutella xylostella, Brevicoryne brassicae, Hellula undalis* and *Trichoplusia ni* were found on cabbage plants. Significantly fewer of them were found on the treated plants than the control plants. The use of the plant extracts resulted in a reduction in mortality ranging from 10.76% to 55.94%. Fewer natural enemies of *B. brassicae* were sampled on the insecticide-sprayed plots than the garlic and pepper-sprayed plots. The cost of protecting cabbage plants from insect infestation using Attack was higher than the botanicals. Garlic-treated plots recorded the highest cost: benefit ratio of 1:16 while Attack®-treated plots recorded the least of 1: 9.2. The control effects of the botanicals compared favourably with that of the chemical insecticides. Thus these botanicals can be used as substitutes to chemical insecticides.

Keywords: *Cheilonemes*, emamectin benzoate, *Hellula undalis*, natural enemies, *Plutella xylostella*

1. Introduction

The problem of feeding the ever-increasing population of Africa is being hampered by a number of constraints to increased food production such as low soil fertility, poor seed quality, low rainfall, diseases and pests which attack crops both on the field and during storage. The combined effects of these factors are responsible for the low agricultural productivity in Ghana and Africa as a whole. In Ghana, the problem of low yields due to poor seed quality has been partially mitigated with the release of improved varieties of some cereal and leguminous crops by the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research, Ghana. Even though many factors are responsible for low yields of most crops, the most important factor is the incidence and resurgence of pests. The cultivation of vegetable crops in Ghana has always been associated with the use of chemical pesticides to control pests due to their quick action.

Due to the incidence of insect pests and diseases, farmers apply chemical insecticides to improve the yields of their crops. The indiscriminate use of insecticides reduce biodiversity by causing the death of useful animals like bees and butterflies which pollinate flower (Angbanyere & Baidoo, 2014) and soil organisms which improve soil structure. In addition, the indiscriminate use of insecticides poses health risks to farmers (Critchley, 1995). In Ghana, the vegetables commonly cultivated are tomatoes, onion, pepper and egg plant; however, in recent years the cultivation of cabbage as part of urban and peri-urban agriculture has increased, with cultivation of the crop taking place along rivers and streams.

Cabbage, *Brassica oleracea* is an important biennial leafy plant grown as an annual mainly for use as a vegetable crop. It is closely related to other cole crops (Gibson, 2012) like broccoli, cauliflower and Brussels sprouts

(Delahaut & Newenhouse, 1997). The plant grows best on well-drained soil, ranging from lighter sand and heavier clay, but all prefer fertile soils (Delahaut & Newenhouse, 1997). The crop is a good source of potassium and manganese (Norman & Shealy, 2007), has antioxidant and anti-inflammatory properties (Steinbrecher & Linseisen, 2009) as well as detoxifying effect due to its high sulphur and vitamin C contents (Kuszneirewicz et al., 2008). The high nutritional content of cabbage makes it attractive to many phytophagous insects which feed on the crop and cause various damages and economic losses to it.

The major pests of cabbage include the diamondback moth, *Plutella xylostella*, the cabbage webworm, *Helula undalis*, cabbage white butterfly, *Pieris brassicae* and the cabbage aphid, *Brevycoryne brassicae*. These pests infest the crop at different stages of growth, causing significant damage to the crop during the different growth stages (Timbilla & Nyarko, 2004). As a result of its usefulness in the diets of humans, demand for cabbage, especially in the urban areas has necessitated the need to apply some insect control measures to increase production. The use of insecticides is believed to be one of the major reasons behind the significant increase in agricultural productivity in the 20th century (Cooper & Hans, 2007). Even though insecticide use has resulted in increased crop production, many are toxic to humans and other animals and may be concentrated in the food chain (Plimmer & Johnson, 1991) which might exceed the maximum residual levels. The negative effects of the use of insecticides have necessitated the search for a more sustainable and environmentally friendly way of managing insect pests.

Certain plants contain chemical compounds with insecticidal properties. These compounds are used by the plants that contain them as defence mechanism against herbivorous insects. Such compounds therefore have chemical properties useful to humans (Wilbraham et al., 2002). Garlic, *Allium sativum* and hot pepper, *Capsicum frutescens* are two examples of botanicals with insecticidal properties. The insecticidal properties of garlic are attributed to sulphur volatiles produced when allicin tissues are degraded (Koch & Lawson, 1996). Hot pepper, commonly called chilli pepper is a spice that is used in preparing food. The active component of chilli pepper is capsaicin which is an irritant when it comes into contact with the skin, giving off a burning sensation. It is also used to ward off pests such as squirrels (Dray, 1992), however, its insecticidal properties have not been fully exploited. The study therefore assessed the effectiveness of garlic and chilli pepper in the management of the major insect pests of cabbage and how they affected other non-target animals, the natural enemies of the pests.

2. Material and Methods

2.1 Study Area

The experiment was conducted on an experimental plot on Kwame Nkrumah University of Science and Technology campus. The soil type is sandy loam and the topsoil is about 0.30 m deep. Twelve plots, each measuring 5 m × 2 m were prepared. The experiment was conducted in a randomised complete block design (RCBD) consisting of four treatments, each of which was replicated 3 times. The treatments were 60 g garlic in 1L water, 100 g chilli pepper, chemical insecticide, Attack® (a.i Emamectin benzoate) and a control.

2.2 Nursing and Transplanting of Seedlings

Seeds of cabbage (*Brassica oleracea* var. *oxyllus*), obtained from an Agrochemical shop were nursed in seed boxes 60 cm × 60 cm in the greenhouse to prevent insect infestation before transplanting. The broadcasting method was used to nurse the seeds. After 3 weeks of nursing, the seedlings were transplanted onto the experimental plots. The planting interval of the seedlings was 45 cm between the columns; intra-column planting interval was 45 cm. There were 3 plants in a row and 10 plants in a column giving a total of 30 cabbage seedlings on each plot.

2.3 Preparation and Application of Plant Extracts

Fresh pepper fruits and garlic were obtained from the open market and 140 g of pepper and 100 g of garlic were weighed using an electronic balance. Each was blended with 500 ml distilled water and filtered into a beaker. Each filtrate was diluted with water to obtain a volume of 2 L and transferred into a hand sprayer. Three drops each of paraffin oil and liquid soap were added as adjuvant to each of the preparations and shaken thoroughly to ensure a uniform mixture to enable the extract stick onto the leaves. Five millilitres of chemical insecticide, Attack® (Emamectin benzoate) was added to 2 L of distilled water and applied on the plants on the insecticide plots. The various parts of the plants were sprayed, paying particular attention to the underside of the leaves. The control plants were left unsprayed. The first spraying of plants was done 2 weeks after transplanting and subsequently weekly for 4 weeks. Before each application of the plant extracts and insecticide, data on pests' numbers were taken.

2.4 Data Collection

Cabbage plants were observed weekly for signs of and presence of insect pests. Counts of insect pest numbers were taken in the morning before spraying was done and then 3 days after spraying. This continued weekly until 12 weeks after transplanting. Assessment of aphid infestation was done by scoring on a scale of 0 to 5 depending on the area of the leaf covered by the aphid colony (Salifu, 1982). Other insect pests were counted by randomly sampling 5 infested plants. *Helula undalis* was counted by carefully removing the wrapper leaves and their numbers counted and recorded. Natural enemies of aphids were also counted at the same time.

2.4.1 Harvesting

At 12 WAT, cabbage heads were harvested and weighed using a top pan balance. The weights were recorded and the mean for each treatment was calculated and recorded. The numbers of damaged and undamaged heads for each treatment were counted and recorded.

2.4.2 Economic Analysis

The numbers of undamaged heads per treatment were multiplied by average head weight per plant to obtain yield per hectare for each treatment. Total income was obtained by adding incomes from undamaged heads and that of damaged heads. Income from undamaged yield was obtained by multiplying the head yield per hectare by the selling price per kilogramme of cabbage head. Income from damaged heads was obtained by multiplying damaged head yield by the selling price per kilogramme of damaged heads. No premium was achieved for the garlic and hot pepper-sprayed produce. Net benefit per hectare for each treatment was derived by subtracting the total cost of plant protection from total income (Shabozoi et al., 2011). Benefit over unsprayed (control) for each sprayed treatment was obtained by subtracting the income of the control treatment from that of each sprayed treatment. The cost: benefit ratio of each treatment was derived by subtracting the income of the control treatment from the net income of each sprayed treatment and the products were divided by total cost of plant protection for each treatment (Shabozoi et al., 2011).

2.5 Data Analysis

Data obtained were subjected to analysis of variance using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc. 2011). Where significant differences existed, means were separated using the Student Neuman Keul's (SNK) test at P< 0.05. Percentage data and aphids score were arcsine square root transformed while insect counts data were log (x+ 1) transformed data were analysed.

3. Results

3.1 Pests' of Cabbage

The major pests of cabbage which infested the plant during the period of study were: the cabbage aphid, *Brevicoryne brassicae*(L.), diamondback moth, *Plutella xylostella*(L.), the cabbage webworm, *Helula undalis* (Fab.) and the cabbage looper, *Trichoplusia ni*(Hub). These pests infested the plants at different growth stages. With the exception of H. *undalis*, which was observed at the head-forming stage, the rest were observed during the early stages of growth.

3.1.1 *Brevicoryne brassicae*

Brevicoryne brassicae infestation was observed 4 weeks after transplanting, remaining on the crop till harvest. Aphids score was least on the insecticide-spayed plots and highest on the control plots. Aphid scores were significantly reduced (P< 0.05) on all the treated plots 3 days after spraying. On the control plots, however, aphids score before and after treatment was not significantly (P> 0.05) different. Spraying cabbage plants with garlic and pepper extracts reduced B. *brevicoryne* infestation by 42.05 % and 26.36 % respectively. On the control plots, however, aphid score increased by 15.29 % (Table 1).

Table 1. Mean *Brevicoryne brassicae* scores on cabbage plants before and after treatment application

Treatment	Before	After	t, P	% Reduction
Garlic	$1.07^{a} \pm 0.09$	$0.62^{a} \pm 0.04$	4.70; 0.0093	42.05
Hot pepper	$1.10^{a} \pm 0.06$	$0.81^{b} \pm 0.03$	4.71; 0.0093	26.36
Emamectin benzoate	$0.72^{b} \pm 0.02$	$0.21^{c} \pm 0.02$	14.94; 0.0001	70.83
Control	$2.68^{c} \pm 0.12$	$3.09^{d} \pm 0.09$	2.75; 0.05	-15.29
P value	0.001	0.001		

Within columns, means with the same letter are not significantly different (P > 0.05).

3.1.2 *Plutella xylostella*

This pest was observed on cabbage plants 3 weeks after transplanting (WAT), remaining on the plants until 12 WAT. They were found mostly on the under surface of the leaves where they were protected from excessive heat from the sun. Significantly larger numbers were recorded on the control plots than the treated plots; however, no significant differences (P > 0.05) in *P. xylostella* numbers existed between the garlic and pepper-sprayed plots, both of which differed from the insecticide-sprayed plots post-treatment (Table 2). Percentage reduction in *P. xylostella* numbers ranged from 31.60 % on the garlic–sprayed plots to 60.95 % on the insecticide-sprayed plots. On the control plots, however, *P. xylostella* numbers increased by 14.90 % post treatment.

Table 2. Mean numbers of *Plutella xylostella* on cabbage plants before and after treatment application

Treatment	Before	After	t, P	% Reduction
Garlic	$80.33^{a} \pm 0.09$	$55.07^{a} \pm 0.67$	22.69; 0.001	31.60
Hot pepper	$83.50^{a} \pm 0.06$	$53.33^{a} \pm 1.40$	14.71; 0.001	33.70
Emamectin benzoate	$83.67^{a} \pm 0.02$	$32.67^{b} \pm 1.45$	20.67; 0.001	60.95
Control	$208.07^{b} \pm 0.12$	$239.09^{c} \pm 10.21$	2.03; 0.001	-14.90
P value	0.001	0.001		

Within columns, means with the same letter are not significantly different (P > 0.05).

3.1.3 *Trichoplusia ni*

Trichoplusia ni was identified on the plants 3 WAT. Relatively larger numbers were sampled on the control plants than the sprayed plants (Table 3). Post-treatment observation indicated that there were significant reductions in numbers 3 days after application of the control measures, ranging from 10.76 % on the garlic-sprayed plants to 31.67 % on the insecticide-sprayed plants; the control plants recorded a 26.65 % increase post treatment.

Table 3. Mean numbers of *Trichoplusia ni* on cabbage plants before and after treatment application

Treatment	Before	After	t, P	% Reduction
Garlic	$52.30^{a} \pm 1.65$	$46.67^{a} \pm 1.88$	4.02; 0.015	10.76
Hot pepper	$55.60^{a} \pm 2.60$	$45.53^{a} \pm 3.20$	4.90; 0.008	18.11
Emamectin benzoate	$46.35^{b} \pm 1.58$	$31.67^{b} \pm 1.20$	9.51; 0.007	31.67
Control	$91.33^{c} \pm 2.40$	$115.67^{c} \pm 1.76$	7.85; 0.001	-26.65
P value	0.001	0.001		

Within columns, means with the same letter are not significantly different (P > 0.05).

3.1.4 *Hellula undalis*

This pest, which prefers matured cabbage plants, was identified on the plants, 6 weeks after transplanting. This pest was found hidden within the wrapper leaves, completely shielded from the sun. As a result of the effects of the chemical insecticides, the least numbers were recorded on the insecticide-sprayed plots. The control plants recorded the largest numbers of this pest (Table 4). Infestation on the plots sprayed with the aqueous plant

Table 4. Mean numbers of *Hellula undalis* on cabbage plants before and after treatment application

Treatment	Before	After	t, P	% Reduction
Garlic	$8.01^{a} \pm 0.58$	$4.67^{a} \pm 0.33$	5.22; 0.001	41.69
Hot pepper	$8.33^{a} \pm 0.88$	$3.67^{b} \pm 0.33$	5.79; 0.004	55.94
Emamectin benzoate	$3.33^{b} \pm 0.33$	$1.33^{c} \pm 0.33$	4.10; 0.014	60.06
Control	$13.01^{c} \pm 0.58$	$18.30^{d} \pm 1.76$	5.97; 0.001	-40.66
P value	0.001	0.001		

Within columns, means with the same letter are not significantly different (P > 0.05).

extracts did not differ significantly; however, both plant extracts differed from the insecticide-sprayed plants. Application of the insecticides and the plant extracts reduced infestation by between 41.69 % on the garlic plants and 60.06 % on the insecticide-sprayed plants.

3.2 Natural Enemies

Two natural enemies of cabbage aphids were found in association with *B. brassicae*. These were the ladybird beetle, *Cheilomenes* sp. (Coleoptera: Coccinellidae) and the ant, *Camponotus* sp. (Hymenoptera: Formicidae). Fewer numbers of these natural enemies were recorded both before and after application of the control measures. After application of the control measures, even smaller numbers were recorded on the insecticide-sprayed plants than on the garlic and pepper-sprayed plants (Table 5).

Table 5. Numbers of natural enemies of *B. brassicae* before and after treatment application

Natural Enemy	*Cheilomenes* sp.		*Camponotus* sp.	
Treatment	Before	After	Before	After
Garlic	20.67^{a}±1.20	11.33^{a} ±0.88	27.33^{a} ±1.45	22.33^{a} ±1.20
Hot pepper	20.01^{a}±0.58	12.05^{a} ±0.65	28.08^{a} ±1.53	23.33^{a} ±0.67
Emamectin benzoate	7.67^{b}±0.88	5.01^{b}±0.55	7.67^{b} ±0.88	3.33^{b} ±0.67
Control	35.20^{c}±1.15	44.33^{c}±2.33	34.67^{c} ±2.03	44.10^{c} ±2.08
P value	0.001	0.001	0.001	0.001

Within columns, means with the same letter are not significantly different (P > 0.05).

3.3 Yield and Income

3.3.1 Yield

The two botanical treatments and the synthetic insecticide in this study were superior financially compared to the control treatment in which cabbages were heavily attacked by the major pests of cabbage. Accordingly, treatments, apart from the control had larger numbers of undamaged head yields which resulted in revenue that exceeded the cost of the plant protection regime (Table 6). The cost of plant protection using Attack® was higher than the botanicals. Yields of plots sprayed with garlic and pepper plant extracts were 21 and 25.3 t/ha respectively which were significantly higher than that of the control (4.7 t/ha). Even though income from damaged heads contributed to the total income for all treatments, the amounts were small and not markedly different among the treatments. The highest benefit over the control treatment of US$ 4,205 was obtained from plots sprayed with Attack®.

Table 6. Evaluation of the cost and benefit of managing cabbage pests with botanical and synthetic insecticides

Treatment	Mean head weight/plant (kg)	Percent damaged heads	Undamaged head yield (t/ha)	Cost of plant protection (US$/ha)	Income from un-damaged heads (US$/ha)	Income from damaged heads (US$/ha)	Total income (US$/ha)	Net benefit (US$/ha)	Benefit over unsprayed treatment (US$/ha)	Cost: benefit
Garlic	0.85± 0.03a	1.25 ± 0.64c	20.99 ± 6.53a	203.02	8655	458	9113	8910	3248	1:16
Hot pepper	0.91± 0.06a	3.70 ± 0.46b	25.43 ± 1.59a	203.02	7985	462	8447	8244	2582	1:12.7
Emamectin Benzoate	0.79 ± 0.03a	2.33 ± 0.63b	18.85 ± 9.65a	456.8	9950	374	10324	9867	4205	1:9.2
Control	0.32 ± 0.07b	8.33 ± 0.00a	4.67 ± 0.88b	0.00	5200	462	5662	5662	0	-

Garlic treatment had an intermediate benefit over control treatment of US$ 3248; with the least being US$ 2,582 from plots sprayed with hot pepper. The difference between the highest and the lowest benefit over control treatment was US$ 1623.

3.3.2 Cost:Benefit

In the study, garlic treatment recorded the largest cost:benefit ratio of 1:16 . It was followed by the hot pepper treatment with a cost:benefit ratio of 1:12.7. Plots sprayed with Attack® had the lowest cost:benefit ratio of 1:9.2.

4. Discussion

4.1 Pest's of Cabbage

Cabbage *Brassica oleracea*, is a green leafy vegetable with very high nutritional value. In Ghana, the crop is cultivated mainly by small-scale urban farmers. Due to its high nutritional value, the crop is infested by many phytophagous insects. It was observed during the study period that the plant extracts were able to significantly reduce the incidence of pests on cabbage plants. Large numbers of the pests were recorded on the plants before the application of the plant extracts; infestation significantly reduced on all the sprayed plants. On the control plants, however, infestation rather increased three days after the application.

Brevycoryne brassicae is a resident pest of cabbage; it is commonly found on the underside of the leaves, either singly or in colonies. This pest appeared during the early stages of the plant. Infestation and feeding by this pest resulted in curled and wrinkled leaves (Brust, 2008). The destructive effects of this pest were most pronounced on the control plots. This was an indication that *Cheilomenes sp.* was not effective in controlling *B. brassicae*. It appears that there is a time lag between pest infestation on a crop and the build up of its natural enemy to be able to bring about an effective reduction of pest numbers. On the insecticide-sprayed plots, the numbers were kept very low because of the persistent nature of the insecticide. The effect of the plant extracts were less pronounced compared with the chemical insecticide because of the possibility of them being washed off the leaves after rainfall, which actually occurred frequently during the study period.

Even though the plant extracts reduced pest numbers, their performance in terms of pest management were not comparable to the chemical insecticide. The active ingredient of garlic, allicin is known to degrade very fast (Koch & Lawson, 1996), while most chemical insecticides persist in the environment for a considerable period of time. Garlic is known to have anti-feedant, insecticidal and repellent properties (Vijayakshmi et al., 1999) which accounted for lower numbers of pests on the garlic-sprayed plants. Apart from allicin, garlic contains sulphur compounds which deter insects from feeding on plants (Vijayakshmi et al., 1999).

In an experiment where onion was intercropped with cabbage (Baidoo et al., 2012a) fewer B. brassicae were observed on the onion-cabbage intercrop compared with the sole cabbage plots. This they attributed to the confusing olfactory cues offered by onion which reduced their ability to disperse. Garlic and onion produce pungent alliaceous compound, allyl-epropyle-disulphide which is responsible for their repellent attribute. Baidoo et al. (2012b) reported very low numbers of *Aphis craccivora* on cowpea after treatment with aqueous extracts of neem, *Azadirachta indica*. The significant reduction of the pests on cabbage after their application was indicative of the potency of garlic and hot pepper in controlling these pests. These plant semiochemicals therefore have the potential to replace chemical insecticides in the control and management of insect pests on crops. However, since these semiochemicals have low persistence on treated crops, scouting for signs of pest infestation must be done so that application would be done when the pests are present on the crop for effective control. Botanical insecticides are known to degrade quickly (Koch & Lawson, 1996) while most chemical insecticides have longer persistence and are able to manage insect pests better.

Studies have been carried out on some plants such as garlic, *Allium sativum* and *Ocimum basilicum* that have semiochemical properties (Senthil-Nathan et al., 2005). These plants are sometimes used as border plants to repel insects from cultivated crop. Work done by Antonious (1995) showed that pepper, *C. annuum* has insecticidal properties. This has been tested on the cabbage looper, *Trichoplusia ni,* recording high mortality of this pest. In the present study *C. annuum* recorded a high mortality, leading to a significant reduction of this pest on cabbage plants. Even though the main chemical component of *C. annuum* is capsaicin, the chemical component with insecticidal property is not capsaicin but pentadecanioc acid methyl esters (Antonious, 1995).

4.2 Natural Enemies

Two species of natural enemies of *B. brassicae* were observed on the cabbage plants. These were the ladybird beetle *Cheilomenes vicinia* (Coleoptera: Coccinellidae) and the carpenter ant *Camponotus* sp. (Hymenoptera: Formicidae). Their numbers were significantly lower on the insecticide-sprayed plots than the garlic and pepper-sprayed plots. The smaller numbers of these natural enemies on the insecticide-sprayed plots was due to the negative effects of the chemical insecticide. Being non-selective it eliminated non-target animals that came into contact with this insecticide. The insecticide caused the mortality of *B. brassicae* which is the food source of *Cheilomenes* sp. thereby causing starvation and ultimately death. Other members of the genus *Cheilomenes* such as *C. lunata* are an important predator of citrus aphid (Holm & Schultz, 1985) and wheat aphid (Picker et al., 2004). *Cheilomenes vicinia* has also been found as biological control agent for the cowpea aphid, *Aphis craccivora* (Ofuya, 1986). Similar results were reported by Baidoo et al. (2012a) in which smaller numbers of *Harmonia axyridis*, which is the natural enemy of the cowpea aphid, *A. craccivora* were recorded on the insecticide-sprayed plots. This they attributed to the negative effects of chemical insecticides on the natural enemy.

Camponotus sp. is omnivorous, feeding on a wide variety of food sources including honeydew, sap, living and dead insects. They were attracted to the cabbage plants as a result of the honeydew produced by *B. brassicae*. They were also negatively affected by the chemical insecticide since fewer of them were encountered on the insecticide-sprayed plots. Thus continuous use of chemical insecticides on crops, even though will lead to increased food production, will also result in reduction in natural enemy population. In situations where insect pests are developing resistance to conventional insecticides, their continuous use will have serious implications for agriculture in many African countries. Consequently, the use of natural plant products for pest management is a promising option that has recently attracted much attention worldwide (Ascher, 1996; Zehnder et al., 1997; Obeng-Ofori & Ankrah, 2002; Antonious et al., 2007; Mochiah et al., 2011). Moving into the future, there is the need to consider effective plant protection products that are readily available, cheap and safe to the environment, wildlife and consumers for adoption by small-scale vegetable growers.

Results from this study showed that Attack® treatment produced higher total income than garlic and hot pepper. Cabbage plants sprayed with the botanicals produced significantly higher undamaged head yield than the control and resulted in higher incomes. The labour cost of preparation, in addition to the cost of garlic and hot pepper accounted for relatively higher cost which was close to that of Attack® in this study. The labour associated with preparation is usually significant which makes the total cost of plant protection with botanicals close to that of purchasing and using the synthetic insecticide option. In a related study to develop simple plant products for farmers in Ambon (Indonesia), Leatemia (2003) indicated that less economic benefit may be gained from the use of botanicals due to the labour cost involved in collection and preparation. Labour cost at the location where botanicals are used will be an important factor of the overall benefit that would be derived from their use. In several parts of the developing world, many resource-limited farmers do not have the financial capacity to purchase synthetic insecticides or commercially formulated botanicals but have free and adequate labour to prepare and use plant products irrespective of the labour requirements. Thus, they will still find the use of locally prepared botanicals more suitable.

4.3 Cost:Benefit Ratio

Cost:benefit ratio is an indicator of the relative economic performance of the treatments. A ratio of more than one indicates the economic viability of the treatment compared with the control treatment. In this study, cost:benefit ratios of between 1:16 and 1:13 indicated that the treatments were biologically effective and resulted in significant returns on investment in plant protection. Garlic and hot pepper were more economically viable than Attack® in the study. Since the two botanicals gave cost:benefit ratios higher than Attack®, cabbage producers have the option of selecting any of two botanicals for pests management on cabbage. While Shabozoi et al. (2011) obtained a cost:benefit ratio of 1:4.1 from application of a neem-based botanical, Patel et al. (1997) obtained a ratio of 1:14.2 and 1:12.6 for botanical (neem extract) and synthetic insecticide (endosulfan) respectively in managing insect pests of pigeon pea. Arivudainambi et al. (2010), however, reported a much lower favourable ratio of 1:1.3 which was lower than that in this study.

The cost:benefit ratio, the total income and the benefit obtained from each treatment option is greatly influenced by the price of the commodity, in this case, cabbage. In the current study, cabbage heads from plots where synthetic insecticide was applied and those from botanical plots were sold for the same price. If cabbage heads from plots protected with botanicals were sold for premium price there would be corresponding increases in economic benefit. In developed countries where human health is of supreme importance, there are premium prices for food commodities that do not have pesticide contamination, and health-conscious consumers eagerly patronise them (Njoroge & Manu, 1999). In Ghana, however, food commodities, including vegetables such as cabbage on the market are not currently recognized as organic and inorganic. Reasons for this include the few or relative lack of sophistication in the market (simple marketing chains lacking quality control measures) and low or lack of any organic certification scheme or residue-monitoring programme for food commodities. Botanicals are generally regarded as safer to users, consumers, animals and the environment due to their non-persistent nature (Buss & Park-Brown, 2002). The current study lends credence to the use of available plant products as efficacious, less expensive and gives financial benefits that are higher or comparable to synthetic insecticides.

5. Conclusion

The present study evaluated the effectiveness of two botanicals, garlic and hot pepper in the management of major pests of cabbage. The two botanicals proved to be cost effective plant protection alternatives to synthetic insecticides. Results from the study showed that the botanicals were able to reduce the incidence of pests on cabbage. The use of botanical insecticides by the average resource-poor African farmer will reduce their reliance on chemical insecticides and their attendant detrimental effects on non-target organisms. The use of botanicals in controlling insect pests will help conserve natural enemies of pests since these botanicals have limited negative effects on non-target organisms. These botanicals could therefore be considered as alternatives to the control of insect pests on crops.

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