Advances in Crop Science and Technology

Ezena et al., Adv Crop Sci Tech 2016, 4:4
DOI: 10.4172/2329-8863.1000230

Research Article Open Access

Exploiting the Insecticidal Potential of the Invasive Siam Weed, *Chromolaena odorata* L. (Asteraceae) in the Management of the Major Pests of Cabbage and their Natural Enemies in Southern Ghana

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Abstract

Cabbage is an important leafy vegetable widely cultivated and consumed in Ghana. It offers a good source of vitamins and minerals to the human body. Despite its importance cabbage production is constrained by insect pests attack. Chemical control has being the main strategy, but without much success, thus the need for alternative options for pest management. Field experiments were conducted in the major and minor rainy seasons of 2014 to evaluate the insecticidal potential of Siam weed, *Chromolaena odorata* L. at three concentrations (10, 20 and 30 g/L w/v) in the management of the key pests of cabbage and its effect on their natural enemies. Neem seed extract (50 g/L) and Lambda cyhalothrin (Sunhalothrin® 2.5 ml/L) were used as reference insecticides with tap water as a control. The key pests recorded during the major season were the cabbage aphid, *Brevicoryne brassicae*, and cabbage webworm, *Hellula undalis*, whiles Diamondback moths (DBM), *Plutella xylostella* and *B. brassicae* were recorded in the minor season. Generally, the three concentrations of *C. odorata* were efficacious in controlling aphids and DBM than the tap water and conventional insecticide, Sunhalothrin® in both the minor and major seasons. However, the 10 and 20 g/L *C. odorata* recorded the highest buildup of natural enemy populations and also had higher yield as compared to 30 g/L *C. odorata*, Sunhalothrin®, and tap water. The cabbage plots sprayed with neem obtained the highest yield and was the most economical to adopt, followed by the *Chromolaena*, and the least being the synthetic insecticide. Crude extracts from neem and *C. odorata* could become an integral part in the Integrated Pest Management of vegetables, especially in smallholder farms.

Keywords: *Plutella xylostella*; *Hellula undalis*; *Brevicoryne brassicae*; Natural enemies; *Chromolaena odorata*; Neem seed extract; Cost benefit analysis

Introduction

Cabbage (*Brassica oleracea var* capitata) is an important crop for many smallholder farmers in Africa and Asia, due to its nutritional and financial benefits Asare-Bediako et al. [1]. It is one of the popular vegetables consumed and cultivated by both the urban and rural dwellers in Ghana Timbilla and Nyarko [2]. The crop has replaced many indigenous green vegetables and its cultivation has provided a good source of employment in Ghana, Timbilla and Fening [3,4]. The cabbage plant has medicinal properties such as its anti- inflammatory property; and can also prevent cancer and a good remedy for ulcer Norman and Shealy [5]. Although there seems to be numerous studies conducted on cabbage pest management, cabbage production in Ghana, is still faced with numerous constraints especially insect pest attack De Lannoy and Mochiah et al. [6,7]. The diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutellidae), the cabbage webworm, *Hellula undalis* (Fab) (Lepidoptera: Crambidae) and the cabbage aphid, *Brevicoryne brassicae* L. (Hemiptera: Aphididae) are the most important pests of cabbage in Ghana Ninsin, (Obeng- Ofori and Ankrah) and (Timbilla and Nyarko) [2,8,9]. The DBM, for instance, has been one of the greatest threats to crucifer production in the tropics causing over 90% crop losses Charleston [10], if not managed. Farmers have limited control options and have therefore resorted to the use of synthetic insecticides which have led to insect pest resistance problems, toxic residues in cabbages posing high risks to humans, animals and the environment Ninsin, Amoako and Fening et al. [8,11,12].

Botanicals, which are derived from plant products are reported to be effective against many insect pests and are considerably cheap and biodegradable when applied Amoabeng et al. [13]. Studies in some African countries suggest that, extracts of locally available plants can be effective as crop protectants Isman [14]. Extracts from marigold have been used effectively against the bruchid beetle from cowpeas in storage in Uganda Kawuki et al. [15]. In Benin, the bushmint, *Hyptis suaveolens* (L.) Poit (Lamiales:Lamiaceae) extract has been used for the control of pink stalk borer, *Sesamia calamistis* H. (Lepidoptera: Noctuidae) on maize in the field. In Ghana, several botanicals such as neem seed extracts, *Azadirachta indica*; hot chilli pepper, *Capsicum frutescens*; garlic extract, *Allium sativum*; tobacco, *Nicotiana tabacum*; cassia plant, *Cassia sophera;* physic nut, *Jatropha curcas*; castor oil plant, *Ricimus communis*; basil, *Ocimum gratissimum*; goat weed, *Ageratum conyzoides*, Siam weed, *Chromolaena odorata* and Cinderella weed, *Synedrella nodiflora*, etc., have been used to protect foodstuffs such as vegetables in the field and stored grains against insect pest infestations Obeng- Ofori, Ankrah, Fening et al. and Amoabeng et al. [9,12,13].

Most plant species with potential insecticidal properties are in the families of Meliaceae, Rutaceae, Asteraceae, Piperaceae, Compositae,

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Received June 29, 2016; **Accepted** July 20, 2016; **Published** July 21, 2016

Citation: Ezena GN, Akotsen-Mensah C, Fening KO (2016) Exploiting the Insecticidal Potential of the Invasive Siam Weed, *Chromolaena odorata* L. (Asteraceae) in the Management of the Major Pests of Cabbage and their Natural Enemies in Southern Ghana. Adv Crop Sci Tech 4: 230. doi:10.4172/2329-8863.1000230

Lamiaceae, Euphorbiaceae, Combretaceae and Annonaceae. They are common weed, shrub and tree species on and around farms (Devanand and Rani) and Amoabeng et al. [13,16]. Pests control using these local materials offer the farmer the opportunity to reduce production cost, as the plants often grows in the wild and around farms and so can be obtained with little effort and zero or minimal cost Amoabeng et al. [13].

However, some botanicals may adversely affect beneficial insects Buss & Park- Brown, Dubey et al. [17,18]. Amoabeng et al. [13] confirmed this in a field experiment using 30 g/L *C. odorata* to control DBM larvae among other botanicals. They showed that although the 30 g/L *C. odorata* extract was effective in reducing pest populations, this concentration was however detrimental to natural enemies and non-targeted organisms in the field. Fening et al. [19] have also cautioned that higher concentrations of botanicals could possibly have some detrimental effects on the natural enemy populations because their numbers reduce with increasing concentrations. Hence, the current research was conducted to optimize the concentrations of crude extract from Siam weed, *C. odorata* for effective control of the key pests of cabbage with minimal or no adverse effect on the natural enemies of these pests and other non- target organisms.

Materials and Methods

Study site

The field experiments were carried out at the University of Ghana's Forest and Horticultural Crops Research Center (FOHCREC), Kade, in the Eastern Region, Ghana. The Centre is located (06º 09' 26N, 000º 55' 00W) in the forest transition ecological zone. It is characterized by humid climate associated with a bimodal rainfall ranging between 1200-1500 mm. This provides the appropriate environmental conditions for many plantain cultivars to do well in this region (wet seasons and a dry spell with average elevation of 150 m). The mean annual temperature range at this location is 24-38°C. Relative humidity is around 70-80% in most part of the year.

Preparation of extracts/treatments

Fresh leaves of Siam weed, *C. odorata* were obtained from around FOHCREC and the leaves were washed with tap water to remove sand, dust and other possible chemical contaminants. The leaves were then dried under shade on concrete platform. A mortar and a pestle were used to ground the leaves into coarse powder which was weighed into the different concentrations (10, 20 and 30 g/L w/v) of *C. odorata* and then soaked in 30 litre plastic buckets. The solutions were then stirred continuously for a few minutes and left to stand overnight. Prior to applications, the extracts were filtered using muslin cloth and three drops of natural vegetable oil (0.15 ml per litre of sunflower oil) and local soap (*alata samina*- is a mixture of roasted cocoa pods, red palm oil, coconut oil, sea salt and shea butter with fragrances added to make it more appealing) were added to enhance the stickiness on the leaf surface of the cabbage.

Neem seed extract (50 g/L w/v) was also prepared and used as a standard botanical treatment. Fresh neem seeds were collected along Winneba to Apam road and dried in the sun for a week. The kernel were removed from the shells and pounded in a mortar to obtain a coarse powder. The recommended concentration was soaked in a plastic container. The solution was left overnight and filtered through a fine linen material before application. A reference conventional insecticide, Sunhalothrin® 2.5 ml/L (a.i. lambda cyhalothrin) and tap water, as control were also prepared for application.

Nursery establishment, land preparation and transplanting of seedlings

Cabbage seeds (cv. *oxylus*) were obtained from AGRIMAT Ltd. in Accra, Ghana. The seeds were nursed in rows in seed trays raised 1 m above the ground. The soil used in the nursery was made of a mixture of sandy loam with carbonated rice husks in the ratio 2:1. Watering was done manually with a watering can, twice daily. The experimental fields were manually cleared and later sprayed with herbicide (Gramoxone) before cabbage seedlings were transplanted on raised beds. The entire field measuring 19 × 11.5 m was pegged, labeled with 3 replications. Cabbage seedlings were transplanted at 4-5 true leaf stage (about 30 days after sowing) in a spacing of 0.5 × 0.5 m. The individual plots measured 1.5 × 2.5 m resulting in 24 plants per plot and a 2 meter wide unplanted alley was left between each plot to avoid spray drift. Standard cultural and agronomic practices such as weed control, watering and earthing-up of soil to improve aeration were employed during the growing periods.

Experimental design, treatment application and data collection

A randomized complete block design was used with three replications in each of the growing seasons. There were six treatments including: three concentrations of *C. odorata* (10, 20 and 30 g/L), neem seed extract (50 g/L of water), Sunhalothrin® (2.5 ml/ L) and tap water. A 15 L capacity Knapsack sprayer (JA- 15 model/ type obtained from AGRIMAT Ltd., Madina- Accra) was used to apply each of the treatments at recommended concentrations. Application of treatments commenced 2 weeks after transplanting of seedlings. Data collections started 2 weeks after transplanting and were done on weekly basis for all the growing seasons. Data on insect population such as DBM, aphid and other pests and natural enemies were counted and recorded from the middle row excluding the border plants. In all, an average of 8 plants per plot was used for yield and insect damage assessment. Data collection was done between 06:00 and 08:00 GMT.

Cost and benefit assessments were also carried out for both seasons, with the production costs and yield (sold at prevailing prices on the local market) were computed into formulae used by Amoabeng et al. [13]. Income was converted to a per hectare basis by extrapolating the plant population of each plot based on plant spacing 0.5 × 0.5 m. A total plant population of 64,000 per ha were assessed, following the procedures used by Amoabeng et al. [13].

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using JMP statistical package (JMP version 10, SAS 2010). The number of insect counts and the percentage yield data were used to determine the effectiveness of the treatments. All the data were tested to ensure that they meet the assumptions of ANOVA. Where the assumptions of ANOVA were found to have been violated the data were transformed using $\sqrt{x+0.5}$ for insect counts and arcsine $\sqrt{x+0.5}$ for percentage yield. Treatment means were separated using Tukey-Kramer Honestly Significant difference (HSD) test. Significant difference was set at $P \leq 0.5$.

Results

Insect fauna encountered on cabbage

Some insect species were recorded during the entire seasons of the cabbage production. These include diamondback moth, *P. xylostella*, cabbage aphid, *B. brassicae*, cabbage webworm, *H. undalis*,

whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae), variegated grasshopper, *Zonocerus variegatus* (Orthoptera: Pyrgomorphidae), cabbage flea beetle, *Phyllotreta* spp. (Coleoptera: Chrysomelidae) and cabbage looper, *Trichoplusiani* (Hübner) (Lepidoptera: Noctuidae). Other pests such as snails (class Gastropoda) and millipedes (class Diplopoda) were also observed attacking the cabbage. Some natural enemies of cabbage pests such as *Diaeretiella rapae* (Stary) (Hymenoptera: Braconidae) *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae), hoverflies (Diptera: Syrphidae), ladybird beetles, *Cheilomenes* spp. (Coleoptera: Coccinellidae) and other beneficial arthropod such as spiders (order Araneae) was identified and observed attacking some insect pests.

Effects of treatments on insect pest population

Infestations of aphid and cabbage webworm were high compared with other pest in the major season (Table 1). The results showed that, there were significant differences among treatments in the aphid infestation (Table 1). The three concentrations of *C. odorata* extracts and neem seed extract had significantly lower number of aphids (0.67 ± 0.22, 1.58 ± 0.29, 1.58 ± 0.22, 1.08 ± 0.28) than the conventional insecticide, Sunhalothrin® (3.33 ± 0.43) (Table 1). Also, 10 g/L *C. odorata* extract (0.67 ± 0.22) had less number of aphids than the plots sprayed with tap water (2.58 ± 0.58) (Table 1). The effect of all the botanicals and the conventional insecticide, Sunhalothrin® were effective in managing the cabbage webworm than tap water treated plots (Table 1). The results also indicated that, the *C. odorata* extracts applied at 10 and 20 g/L (w/v) and sunhalothrin (2.5 ml/ L) were better than tap water plots in managing the infestation of other pests (Table 1). Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$). Other pests: cabbage flea beetle (*Phyllotreta* spp.), cabbage white butterfly (*Pieris rapae*), cabbage looper (*Trichoplusia ni*), and Cotton leafworm (*Spodoptera litorallis*).

The two major pests of cabbage identified and recorded with high infestations during the minor season were the diamondback moth and the cabbage aphid (Table 2). There were significant differences in the infestation of aphids in the minor season (Table 2). The result showed that the botanicals had significantly lower number of aphids than the conventional insecticide, Sunhalothrin® and the tap water plots in the minor growing season (Table 2). However, there were no significant differences among all treatments in the management of *P. xylostella* and the other pests (Table 2).

Effects of treatments on natural enemies

The result showed that 20 g/L (w/v) of *C. odorata* had the highest number of *Diaretiella rapae* as compared to 30 g/L (w/v) of *C. odorata*, neem seed extract and sunhalothrin® (Table 3). The result again exhibited that, 20 g/L *C. odorata*, neem and the tap water (control) had the highest number of other natural enemies as compared to the plots treated with the conventional insecticide, sunhalothrin® (Table 3). Meanwhile, the results revealed that there were no significant differences among all treatments in the number of spiders and hoverflies sampled (Table 3).

The results for the minor rainy season showed that there were no significant differences in the numbers of *D. rapae*, *C. plutellae* and hoverflies when the various treatments were applied (Table 4). However, 20 g/ L of *C. odorata* and neem had significantly high number of spiders compared to the other treatments (Table 4). Also, for other natural enemies sampled, 20 g/L *C. odorata* treated plots had significantly high populations than that of sunhalothrin® (Table 4).

Mean ± SE insect pests/ plant			
Treatments	***B. brassicae***	***H. undalis***	**Other pests[1]**
10 g/L *C. odorata*	0.67 ± 0.22 c	1.38 ± 0.27 b	1.83 ± 0.30 b< 0.00*
20 g/L *C. odorata*	1.58 ± 0.29 bc	1.38 ± 0.28 b	2.46 ± 0.31 b
30 g/L *C. odorata*	1.58 ± 0.22 bc	1.79 ± 0.28 b	2.63 ± 0.39 ab
50 g/ L Neem	1.08 ± 0.28 c	1.13 ± 0.21 b	3.04 ± 0.43 ab
Sunhalothrin®	3.33 ± 0.43 a	1.13 ± 0.23 b	1.83 ± 0.34 b
Tap water	2.58 ± 0.58 ab	4.0 ± 0.56 a	4.08 ± 0.35 a
F	7.44	11.13	5.56
P	< 0.00*	< 0.00*	< 0.00*

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).[1]Other pests: cabbage flea beetle (*Phyllotreta* spp.), cabbage white butterfly (*Pieris rapae*), cabbage looper (*Trichoplusia ni*), and Cotton leafworm (*Spodoptera litorallis*).

Table 1: Mean (± *SE*) populations of insect pests on cabbage sprayed with botanical and conventional insecticides and tap water as control, during 2014 major rainy season.

Mean ± SE insect pests/ plant			
Treatments	***B. brassicae***	***P. xylostella***	**Other pests[1]**
10 g/L *C. odorata*	1.83 ± 0.22 b	4.50 ± 0.73 a	1.67 ± 0.35 a
20 g/L *C. odorata*	1.21 ± 0.25 b	3.13 ± 0.69 a	1.13 ± 0.25 a
30 g/L *C. odorata*	1.58 ± 0.32b	3.79 ± 0.64 a	1.13 ± 0.25 a
50 g/ L Neem	1.46 ± 0.26 b	3.08 ± 0.54 a	1.13 ± 0.31 a
Sunhalothrin®	3.96 ± 0.64 a	4.13 ± 0.09 a	1.46 ± 0.30 a
Tap water	3.75 ± 0.62 a	5.08 ± 1.01 a	1.96 ± 0.32 a
F	7.61	1.02	1.67
P	< 0.00*	0.41	0.15

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).[1]Other pests: cabbage flea beetle (*Phyllotreta* spp.), cabbage white butterfly (*Pieris rapae*), cabbage looper (*Trichoplusia ni*), cabbage webworm (*Hellula undalis*) and Cotton leafworm (*Spodoptera litorallis*).

Table 2: Mean (± *SE*) populations of insect pests on cabbage sprayed with botanical and conventional insecticides and tap water as control during 2014 minor rainy season.

Mean ± SE natural enemies/ plant				
Treatments	***D. rapae***	**Spider**	**Hoverfly**	**Other N.E[1]**
10 g/L *C. odorata*	1.88 ± 0.57 ab	2.13 ± 0.30a	0.63 ± 0.25a	2.29 ± 0.42 ab
20 g/L *C. odorata*	3.75 ± 0.63 a	2.00 ± 0.26a	0.04 ± 0.05a	3.50 ± 0.56 a
30 g/L *C. odorata*	0.83 ± 0.21 b	1.63 ± 0.38a	0.08 ± 0.09a	2.83 ± 0.42 ab
50 g/ L Neem	1.25 ± 0.38 b	2.08 ± 0.28a	0.17 ± 0.09a	3.50 ± 0.51 a
Sunhalothrin®	2.33 ± 0.75 b	1.17 ± 1.22a	0.46 ± 0.24a	1.46 ± 0.26 b
Tap water	2.29 ± 0.57 ab	2.00 ± 0.32a	0.54 ± 0.29a	3.38 ± 0.31 a
F	3.51	1.55	1.68	3.65
P	0.01*	0.18	0.14	0.00*

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).[1]Other natural enemies: ladybird beetle (*Cheilomenes lunata*), earwigs, red ants (*Oecophylla* sp.) and mason wasp.

Table 3: Mean (± *SE*) numbers of natural enemies of pests of cabbage sprayed with botanical and conventional insecticides during 2014 major rainy season.

Effects of treatments on cabbage head damage

Head damage was mainly caused by insects such as DBM, cabbage webworms, the variegated grasshoppers and the millipedes in the growing seasons (Table 5). There were no significant differences in the head damage among the treatments in the major rainy season (Table 5). On the other hand, there was significant difference in the

Mean ± SE natural enemies/ plant					
Treatments	***D. rapae***	***C. plutellae***	**Spider**	**Hoverfly**	**Other N.E1**
10 g/L *C. odorata*	1.67 ± 0.64a	1.58 ± 0.62a	2.33 ± 0.41 ab	1.0 ± 0.35	1.25 ± 0.8 ab
20 g/L *C. odorata*	2.38 ± 0.78a	1.83 ± 0.50a	2.58 ± 0.43 a	1.08 ± 0.22	1.50 ± 0.26 a
30 g/L *C. odorata*	1.0 ± 0.43a	0.83 ± 0.39a	1.92 ± 0.40 ab	0.58 ± 0.25	0.42 ± 0.20 ab
50 g/ L neem	1.13 ± 0.45a	1.25 ± 0.34a	2.67 ± 0.41 a	1.17 ± 0.35	1.13 ± 0.24 abc
Sunhalothrin®	2.29 ± 0.97a	1.88 ± 0.53a	0.83 ± 0.21 b	0.42 ± 0.15	0.29 ± 0.11 c
Tap water	2.5 ± 0.86a	2.21 ± 0.58a	1.96 ± 0.31ab	1.25 ± 0.38	0.67 ± 0.20 abc
F	0.84	0.95	3.22	1.27	4.82
P	0.52	0.45	0.01*	0.28	0.00*

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).[1]Other natural enemies: ladybird beetle (*Cheilomenes lunata*), earwigs, red ants (*Oecophylla* sp.) and mason wasp.

Table 4: Mean (± *SE*) numbers of natural enemies of pests of cabbage sprayed with botanical and conventional insecticides during 2014 minor rainy season.

Mean ± SE head damage/ plant		
Treatment	**Major rainy season**	**Minor rainy season**
10 g/L *C. odorata*	3.17 ± 0.33 a	2.5 ± 0.28 ab
20 g/L *C. odorata*	3.21 ± 0.29 a	2.96 ± 0.30 ab
30 g/L *C. odorata*	3.13 ± 0.37 a	2.79 ± 0.32 ab
50 g/ L Neem	1.96 ± 0.25 a	1.83 ± 0.27 b
Sunhalothrin®	3.04 ± 0.35 a	2.75 ± 0.27 ab
Tap water	3.04 ± 0.31 a	3.38 ± 0.31 a
F	2.20	3.03
P	0.06	0.01*

Means within a column for each treatment under each concentration followed by different letter differ significantly from each other.

Table 5: Mean (± *SE*) scores for head damage during 2014 major and minor seasons.

mean head damage among treatments in the minor rainy season (Table 5). Cabbage heads from tap water treated plots had the highest head damage as compared to neem seed extract which had the lowest damage (Table 5). Means within a column for each treatment under each concentration followed by different letter differ significantly from each other.

Effects of treatments on multiple head formation, weight and yield of cabbage

The results on the percentage number of cabbage with multiple heads for the major season showed that the 30 g/L (w/v) of *C. odorata* and tap water treated plots had the highest number, followed 10, 20 g/L *C. odorata* and Sunhalothrin, with the neem seed extract having the lowest number of multiple heads formed (Table 6). The result also showed that, there were no significant differences among treatments on the weight per cabbage head and yield, with the exception of the neem seed extract plots which had the highest head weight and yield (Table 6).

In the minor season, the result depicted that there were no significant differences in multiple head formation among all treatment plots. The head weight of cabbage had no significant differences among all treatments with the exception of neem seed extracts which had the highest head weight. The yield (t/ha) had significant differences among treatments, with neem seed extract having the highest yield, followed by 10 and 20 g/L (w/v) *C. odorata* and then Sunhalothrin and 30 g/L (w/v) *C. odorata*. The tap water treated plots had the lowest yield (Table 7).

Cost: benefit ratio

The results indicated that, the 10 and 20 g/L (w/v) *C. odorata* had higher cost benefit ratios as compared to 30 g/L *C. odorata* for both seasons (Tables 8 and 9). The neem seed extract had the highest cost: benefit ratio as compared to the conventional insecticide, sunhalothrin® (Tables 8 and 9).

Discussion

Our goal was to evaluate the efficacy of the various Siam weed as a potential botanical insecticide in providing acceptable control of pest of cabbage in southern Ghana. In both seasons, all materials tested resulted in the production of marketable cabbage heads with considerably lower pest pressure and crop damage ratings compared with untreated control plots which never yielded marketable produce. These results indicate that all five botanicals at the different concentrations were effective in controlling the pests, mainly the lepidopterans. The presence and abundance of insect presence differed during both seasons, and this could be attributed to seasonal and climatic differences. Surprisingly, diamondback moth, *P. xylostella* was not found on the treatment plots during the major season. This may be attributed to the occurrences of natural elements such as rainfall, which washes off the eggs, larvae, pupae and the adults from the plant to the soil where they are destroyed and may have led to the disruption of the lifecycle of the pest during the period.

Populations of the aphid, *B. brassicae*, were dominant throughout both seasons and were reduced as a result of the application of the

Treatments	**No. of cabbage with multiple heads (%)**	**Weight per cabbage head (kg)**	**Total yield of cabbage (t/ ha)**
10g/L *C. odorata*	3.13 ± 1.14 ab	0.21 ± 0.05b	8.37 ± 1.83 b
20g/L *C. odorata*	2.08 ± 0.95 ab	0.26 ± 0.05b	10.50 ± 2.19 b
30g/L *C. odorata*	6.25 ± 1.30 a	0.24 ± 0.05b	9.67 ± 1.95 b
50g/L Neem	1.56 ± 0.87 b	0.52 ± 0.06a	20.75 ± 2.39 a
Sunhalothrin®	2.60 ± 1.07 ab	0.24 ± 0.05b	9.43 ± 1.88 b
Tap water	6.25 ± 1.29 a	0.20 ± 0.05b	3.30 ± 0.58 b
F	3.44	4.93	8.96
P	0.01*	0.00*	< 0.00*

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).

Table 6: Mean (± *S.E*) number of multiple heads, weight of cabbage heads and yield of cabbage under different spray treatments during 2014 major rainy season.

Mean ± *SE*			
Treatments	**No. of cabbage with multiple heads (%)**	**Weight per cabbage head (kg)**	**Total yield of cabbage (ton/ ha)**
10g/L *C. odorata*	3.65 ± 1.18 a	0.25 ± 0.03 b	10.04 ± 1.08 b
20g/L *C. odorata*	2.60 ± 1.05 a	0.25 ± 0.04 b	10.13 ± 1.60 b
30g/L *C. odorata*	5.73 ± 1.29 a	0.24 ± 0.03 b	9.56 ± 1.31 bc
50g/ L Neem	3.13 ± 1.14 a	0.47 ± 0.06 a	18.80 ± 2.45 a
Sunhalothrin®	4.69 ± 1.25 a	0.22 ± 0.03 b	8.99 ± 1.17 bc
Tap water	5.73 ±1.30 a	0.17 ± 0.03 b	3.49 ± 0.62 c
F	1.20	7.14	10.82
P	0.31	< 0.00*	< 0.00*

Means within a column for each treatment under each concentration followed by different letters differ significantly from each other ($P \leq 0.05$).

Table 7: Mean (± *S.E*) number of multiple heads, weight of cabbage heads and yield of cabbage under different spray treatments during 2014 minor rainy season.

Treatment	Mean total yield per plant (ton/ha)	Marketable Head Yield (ton/ha)	Unmarketable head yield (ton/ha)	Cost of Treatment (US$/ha)	Income from Mktable head (US$/ha)	Income from Unmktable head (US$/ ha)	Total Income (US$/ ha)	Net benefit (US$/ha)	Benefit Over Ctrl.	Cost: Benefit Ratio
10 g/L *C. odorata*	10.04 ± 1.08	6.01 ± 1.04	4.02 ± 0.42	100.00	3,756	1,005	4,761	4,661	3,159	1:32
20 g/L *C. odorata*	10.13 ± 1.60	8.04 ± 1.02	2.10 ± 0.44	100.00	5,025	525	5,550	5,450	3,948	1:41
30 g/L *C. odorata*	9.56 ± 1.31	6.07 ± 1.12	3.45 ± 0.45	100.00	3,794	864	4,656	4,556	3,053	1:31
50 g/L Neem	18.80 ± 2.45	15.06 ± 1.95	3.20 ± 0.58	128	9,413	800	10,213	10,085	8,583	1:67
Sunhalothrin	8.99 ± 1.17	4.54 ± 1.07	4.02 ± 0.55	113	2,838	1,005	3,843	3,730	2,228	1:20
Tap water	3.49 ± 0.62	1.74 ± 0.42	1.66 ± 0.48	0.0	1,088	415	1,503	1,503	0	-

Table 8: Evaluation of cost and benefit in managing cabbage pests with crude water extracts of Siam weed, neem and conventional insecticide, Sunhalothrin® during 2014 minor rainy season.

Treatment	Mean total yield per plant (ton/ha)	Marketable Head Yield (ton/ha)	Unmarketable head yield (ton/ha)	Cost of Treatment (US$/ha)	Income from Mktable head (US$/ha)	Income from Unmktable head (US$/ha)	Total Income (US$/ ha)	Net benefit (US$/ha)	Benefit Over Ctrl.	Cost: Benefit Ratio
10 g/L *C. odorata*	8.37 ± 1.83	7.05 ± 1.02	1.32 ± 0.60	88	2,644	165	2,809	2,721	1,946	1:22
20 g/L *C. odorata*	10.50 ± 2.19	8.32 ± 1.61	2.15 ± 0.65	88	3,120	269	3,389	3,301	2,526	1:29
30 g/L *C. odorata*	9.67 ± 1.95	6.31 ± 1.19	3.22 ± 0.81	88	2,366	403	2,769	2,681	1,906	1:22
50 g/L Neem	20.75 ± 2.29	16.45 ± 1.25	4.33 ± 1.05	115	6,169	541	6,710	6,595	5,820	1:51
Sunhalothrin	9.43 ± 1.88	7.17 ± 1.05	2.55 ± 0.95	113	2,689	319	3,008	2,895	2,120	1:19
Tap water	3.30 ± 0.58	1.65 ± 0.45	1.25 ± 0.55	0.0	619	156	775	775	0	-

Table 9: Evaluation of cost and benefit of managing cabbage pests with crude water extracts of Siam weed, neem and conventional insecticide, Sunhalothrin® during 2014 major rainy season.

botanical treatment. This was especially observed in the 10 g/L *C. odorata* and neem seed extracts plots in both the minor and major seasons. This reduction was due to the toxic effect of the plants. Botanicals and plant - based insecticides have been noted for their larvicidal effects Sanda et al., Ogendo et al. and Agboka et al. [20-22]. The effectiveness of botanicals in the study was generally better as compared to the conventional insecticide in the control of aphid. This may be due the fact that, *B. brassicae* may gradually be developing resistance to the conventional insecticides Fening et al. [12]. The performance of the plant extracts in reducing the population of *B. brassicae* indicates their usefulness in controlling insect pests when incorporated into Integrated Pest Management (IPM). The efficacy of the botanical treatments against *B. brassicae* is supported by the findings of previous studies on this insect pest. For instance, the extracts of *Azadirachta indica* and *Melia azedarach* have been successfully used to control infestations of cabbage aphids Rando et al. and Kibrom et al. [23,24].

The number of natural enemies of the insect pests observed on the cabbage treated plot was somewhat not different from that of the control. In the minor season, *D. rapae* and *C. plutellae* showed no significant difference due to less toxicity of the treatments on the beneficial insects. For instance, neem products have been proved to be harmless to beneficial insects and environmentally friendly Borror et al. [25]. However, the lower concentrations of *C. odorata* (10 and 20 g/L w/v) were more benign to the natural enemies, ensuring the survival of *D. rapae* as compared to the 30 g/L *C. odorata* treated plots. This may be attributed to the low toxicity of the treatment at low concentrations on the beneficial insects, hence making them available and thereby promoting high level parasitism and predation of pest Charleston [10].

In the study, it was observed that the botanicals and the conventional insecticides, sunhalothrin® were most active against insect pests causing damage to cabbage heads as compared with control plot in the both seasons. Fening et al. [19] however, revealed that the use of plant extracts in IPM provides added advantage over the use of synthetic insecticide; as, they are not persistent in the environment, readily available, affordable and easily made. The findings on high number of multiple head formed on untreated plots as compared to treated plots indicated that, cabbage cannot be cultivated without making an attempt to control insect pests. This is because, like other crucifers, they contain mustard oil and glucosides Gupta and Thorsteinson [26] which make them palatable and more susceptible to insect pest attack.

High yield of cabbage head was recorded on treated plots against that of tap water treated plot, with Neem seed extract treated plots recording the highest mean weight of cabbage heads due its insecticidal ability. This result confirms the findings of Landis et al. [27] that aqueous neem seed extracts (ANSE) applied at 50-70 g/L provided good protection against collard insect pests and increased dry matter content significantly.

The cost: benefit ratio, the total income and the benefit obtained from each treatment is greatly influenced by the price of the commodity. The price of cabbage heads were about 50% higher in the minor season harvest than the major season yield. The study has shown that the 10 g/L and 20 g/L of *C. odorata* extracts were effective in the management of insect pests, less detrimental to natural enemies and also economical to use than the higher rate, 30 g/L *C. odorata* extracts. This finding has therefore offered a remedy to Amoabeng et al. [13] who applied *C. odorata* extract at 30 g/L and was effective in the control of insect pests but was more detrimental to the survival of natural enemies. Thus, *C. odorata* applied at 10-20 g/L (w/v) and also neem at 50 g/L are recommended for use by small scale cabbage farmers (especially those in organic farming systems) to ensure food and environmental safety Fening [4].

Acknowledgements

We are grateful to the Technical staff, of the Entomology Unit of the Forestry and Horticultural Crops and Research Centre (FOHCREC), University of Ghana, Ghana.

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Citation: Ezena GN, Akotsen-Mensah C, Fening KO (2016) Exploiting the Insecticidal Potential of the Invasive Siam Weed, *Chromolaena odorata* L. (Asteraceae) in the Management of the Major Pests of Cabbage and their Natural Enemies in Southern Ghana. Adv Crop Sci Tech 4: 230. doi:10.4172/2329-8863.1000230