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Botanicals for the management of insect pests in organic vegetable production

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This study was conducted to evaluate the efficacies of some botanical products on insect populations associated with two vegetables; Eggplant and Okra. Two field experiments were conducted on-station at the CSIR-Crops Research Institute, Kwadaso, Kumasi, and on-farm at Eatwell farm at Agona-Mampong all in the Ashanti region of Ghana from December 2009 to March 2010 and September to December 2010, respectively. Seven botanical treatments were applied viz; Ecogold (10 ml/l of water); Alata soap (5 g/l of water); Garlic (30 g/litre of water); Neem oil (3 ml/l of water); Papaya leaves (92 g/l of water); Wood ash (10 g/plant stand) and control (no botanical). The experimental set up was a Randomized Complete Block design (RCBD) with three replications. Parameters studied included insect pest numbers and their natural enemies, number of days to 50% flowering, plants height at flowering (cm), number of fruits per plant, fruit damage, and mean weight of fruits (g). Major insect pest recorded on the two vegetables included aphids (*Aphis gossypii*), flea beetles (*Podagrica* spp), white flies (*Bemisia tabaci*), fruit borers (*Earias* sp), cotton strainers (*Dysdercus superstitiosus* (F.)), variegated grasshoppers (*Zonocerus variegatus* L.), *Urentius hysterricellus* (Richter) and shoot and fruit borers *(Leucinodes orbonalis* Gn). The natural enemies of pests of the two vegetables identified were the ladybird beetles, (*Cheilomenes* sp) and predatory spiders (*Araneae*). There were significant percentage reductions in pests for all the botanicals applied (P< 0.05) on both the eggplant and okra plants compared to the control. Generally, plants to which the botanicals were applied produced the highest mean weight of fruits, translating into mean percentage increases in fruit weight ranging between 21 and 59% on both the eggplant and okra plants compared to the control in both growing periods. It is concluded that botanicals such as Ecogold, Alata soap, exotic garlic, neem oil, papaya leaves and wood ash could be effectively considered as pest management options to reduce insect pest populations and increase eggplant and okra productivity.

Key words: Organic vegetables, botanicals, insect pests, beneficial insects.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) and eggplant (*Solanum intergrifolium* L.) are vegetables, which are consumed nearly on a daily basis in many households in Sub-Saharan Africa and therefore are considered important components of the diet (El-Shafie, 2001; Timbilla and Nyarko, 2004; Bennette-Lartey and Oteng-Yeboah, 2008; FAO, 2008; Obopile et al., 2008) even though they are exotic to Africa (FAO, 2000; 2003).

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The fruit of *Solanum intergrifolium* L. (Solanaceae) is a good source of vitamins A and C, potassium, phosphorus, calcium and, dietary fibre (USDA Nutrient database, 2008) and is known to possess medicinal properties as well. The fruit of the eggplant can be eaten raw or served as a baked, grilled, fried or boiled vegetable and can be used in stews or as a garnish (FAO, 2003).

In Ghana, the fruits of eggplant and okra are produced and marketed primarily by small-scale farmers who are distributed throughout the country. A broad range of market participants are involved in trading these vegetables.

They are particularly a source of cash for rural households in the southern and central parts of Ghana (Obeng-Ofori et al., 2002). In spite of its usage throughout the year, the country can meet the domestic demand only during the rainy season. In the dry season, the lack of irrigation facilities together with the higher incidence of pests relative to the rainy season drastically reduces total production of these vegetables. These vegetables are usually attacked by insect pests, mostly caterpillars that cause extensive damage to parts of the plants affecting their yield and marketability (Zehnder et al., 1997; Sibanda et al., 2000; FAO, 2000, 2003). For okra, the most significant pest damage is caused by the flea beetle (*Podagrica* spp) while for eggplant white flies (*Bemisia tabaci* [Genn.]), transmitter of viral diseases, and thrips (*Thrips tabaci* Lind.) represent the most economic important pests (Owusu-Ansah et al., 2001). Over time, chemical control has been practiced by farmers for higher gains (Gerken et al., 2001), but these pests can become resistant to chemical insecticides very quickly. Moreover, the misuse of chemical insecticides in terms of quantity applied or in dangerous combinations (Obeng-Ofori et al., 2002) have created a myriad of problems which include pest resistance, resurgence of pests, pesticide residues, destruction of beneficial fauna and environmental pollution (Sibanda et al., 2000; AVRDC, 2003b). Under such debilitating circumstances, interest in organic farming has been growing and therefore exploring alternative options to control pests of okra and eggplant is a fundamental means of supporting the smallholder farmer to diversify into organic production and be able to tap into the high profits associated with organic products. Furthermore, the export market continues to impose tight restrictions (including zero tolerance) on many widely used pesticides. Large-scale growers, who produce for the export market, are looking for alternatives to synthetic pesticides. One viable alternative is the use of botanical insecticides which is also considered eco-friendly. Hence this study aims at evaluating different botanicals and their efficacies in the management of insect pests in organic vegetable production.

MATERIALS AND METHODS

Study sites

Studies were conducted in the dry season and minor rainy season. In the dry season the study was conducted on-station at the Crops Research Institute, Kwadaso, Kumasi from December 2009 to March 2010 while in the minor rainy season, the study was conducted on-farm at Eatwell Farms located at Agona-Mampong from September to December 2010. Both sites have ferric acrisols as the dominant soil type.

Land preparation and transplanting

The land was cleared and root stumps removed after weeding prior to sowing of seeds. Ploughing and harrowing were performed onthe land before beds were made. The vegetables sown were Okra (*A. esculentus* (L.) Moench) and egg plant (*S. intergrifolium* L.).

Eggplant seedlings from the nursery were transplanted to the main experimental plot on 11th January, 2010 and 2nd September, 2010 in the dry and minor rainy seasons, respectively, while the okra seed were directly sown on 12th January, 2010 and 2nd September 2010 in the dry and minor rainy seasons, respectively. Uniform seedlings of height 15 cm with 3 to 5 leaves were transplanted. The planting distances were 70 cm × 30 cm for okra on plots that measured 4.2 m × 4.0 m whereas for eggplant, the plant spacing was 80 cm × 80 cm on plots that measured 4.8 m × 4.0 m. Watering was done twice a day (morning and evening) especially in the dry season.

Experiment design

There were two experiments, one each for okra and eggplant. In each experiment, the design was a Randomized Complete Block (RCBD) consisting of seven treatments replicated three times. The treatments were Ecogold (10 ml/l of water); Alata soap (5 g/l of water (Alata soap at 0.5%W/V); exotic garlic (30 g/l of water); neem oil (3 ml/l of water); papaya leaves (92 g/l of water); wood ash (10 g/plant stand) and control (no botanical but sprayed with only water). Both Eco-gold and neem oil are commercial products manufactured by PAKS Agro Division.

Preparation and application of garlic bulb extract, papaya leaves extract and wood ash

Garlic bulb extract

The outer layers of the matured garlic were peeled off. 200 g of garlic were mixed with 1 L of water and ground with a blender to obtain garlic juice. This juice was thoroughly mixed with additional 1 L of water. The mixture was then sieved to obtain a uniform extract.

Papaya leaves extract

92 g of papaya leaves were collected and ground using local mortar and pestle. 1 L of water was then added and left to stay for 20 to 24 h. 1 L of water was later added to the mixture/extract which was sieved to obtain a uniform extract. 10 ml of fish oil and liquid soap were added to the garlic and papaya leaves extracts to improve their delivery and to allow them to stick unto the surface of the leaves of the plants.

Wood ash

Wood ashes were collected and sieved using a fine wire mesh such that sieved materials were just like powder which was sprinkled uniformly and moderately on both the lower and upper surfaces of the vegetable leaves.

Spraying of botanical extracts as well as the wood ash commenced 14 days after transplanting and 21 days after planting of the eggplants and okra, respectively, using a knapsack sprayer. 2 L of the extracts to 3 L of water was put in the knapsack to form the spraying mixture before application. Both garlic and papaya extracts were applied bi-weekly but application was repeated within the week whenever there were heavy rains a day or two after application in the minor growing season. The bi-weekly spraying schedule continued until about 14 days to harvesting. Since some of these botanicals do have some systemic effect in plants, spraying was done as other contact insecticides, ensuring thorough

spray coverage and targeting the undersides of the leaves where pests tend to cluster and hide.

Application of nutrients

In each season (dry and minor rainy season), poultry manure was applied two times each at a rate of 50 g per plant in a ring. The first application was done ten days after transplanting and the second application was 25 days later.

Data collected

Data collection started 21 days after transplanting. Data on numbers of insects pests, natural enemies, days to 50% flowering, plant height at flowering (cm), number of fruits per plant, fruit damage and yield (mean fruit weight, g) were recorded from the two central rows of each plot which had 24 and 14 plants for okra and eggplant, respectively. The assessment of the numbers of various insect pest species and natural enemies were done by carefully examining each vegetable plant; leaf by leaf to collect any insects from the under-surface of the leaves. The insect pests collected from each plot were identified and counted. The insects' population data were collected every 7 days until harvest, between 06:30 and 09:00 h. Mean % increase in fruit weight was calculated using the formula thus:

$$\text{Mean \% increase in fruit weight} = \frac{(X_2 - X_1)}{(X_2)} \times 100$$

Where, X_2 = protected yield and X_1= unprotected yield

Statistical analysis

Data were analysed by analysis of variance (ANOVA), using the general linear model (GLM) procedure of SAS Version 9 (SAS, 2005). Number of insects were log (x+1) transformed. Treatment means separation was carried out with the Student Newman Keul's (SNK) test and the probability of treatment means being significantly different was set at $P < 0.05$.

RESULTS

Insect pests of okra and eggplant

Insects from five major orders (Homoptera, Lepidoptera, Heteroptera, Orthoptera and Coleoptera) were found associated with the okra and eggplant.

Okra (*A. esculentus* (L.) Moench): Insect pests recorded on the okra included aphids (*A. gossypii*), Flea beetles (*P. uniformis*) (Figure 1), White flies (*B. tabaci*), cotton strainers (*D. superstitiosus* (F.) (Figure 2), variegated grasshoppers (*Zonocerus variegatus* L.) (Figure 3) and fruit borer (*Earias* spp) (Figure 4).

Eggplant (*S. intergrifolium* L.): Insect pests recorded on the eggplant included aphids (*A. gossypii* Glover) (Figure 5), whiteflies (*B. tabaci*), *Urentius hysterricellus* (Richter) (Figure 6), shoot and fruit borers (*Leucinodes orbonalis* Guenée) (Figure 7), cotton strainers (*D. superstitiosus*) and variegated grasshoppers (*Z. variegatus* L.).

Effect of botanicals on insect pest populations

Generally, insect pest populations were lower and ranged between 12 and 16% in the minor rainy growing season of 2010 between September and December compared to the dry season of (December 2009 to March 2010 for the two crops (Tables 1, 2, 3 and 4). Botanical treated plots were observed to have reduced insect pest populations compared to the control plots. For Okra, the percentage reduction in pests as a result of botanical applications ranged between 49.2 and 62.3%, 68.1 and 76.8%, 52.9 and 66.8%, 54.9 and 76.9%, 42.8 and 63.3% as well as 52.9 and 63.3% for *A. gossypii*, *P. uniformis, D. superstitiosus B. tabaci, Z. variegatus* and *Erias* sp respectively. Similarly for eggplant, the percentage reduction in pests as a result of the same botanical applications ranged between 52.4 and 68.9%, 33.1 and 66.9%, 48.3 and 73.5%, 49.2 and 67.4%, 46.1 and 68.4% as well as 54.9 and 66.0 for *A. gossypii*, *U. hysterricellus, D. superstitiosus B. tabaci, Z. variegatus* and *L. orbonalis* sp respectively. Among the botanicals, there were significant differences in the number of *P. uniformis, D. superstitiosus* and *Z. variegatus*. Plots sprayed with botanicals such as EcoGold 999 Plus, neem oil and exotic garlic significantly reduced the populations of *P. uniformis* (by 76.8, 75.8 and 72.7%), *D. superstitiosus* (66.8, 66.1 and 59.5%) and *Z. variegatus* (63.3, 61.3 and 55.9%) than plots that were sprayed with Alata soap (68.1, 57.5 and 48.6%), papaya leaf extracts (68.1, 56.8 and 50.3%) and wood ash (68.1, 52.8 and 42.8%) respectively, for the same pest populations (Tables 1 and 2).

Natural enemies of okra and eggplant insect pests

The natural enemies of pests of both okra and eggplant are the ladybird beetles, (*Cheilomenes* sp) (Coleoptera: Coccinellidae) (Figure 8) and predatory spiders (Araneae) (Figure 9). The mean numbers of the various natural enemies are presented in Tables 3 and 4. Generally for the two seasons and the two crops, *Cheilomenes* sp and predatory spiders' populations were highest on the control plots, even though the differences compared to the botanical treatments were not significant (Tables 3 and 4).

Crop growth, fruit yield and crop damage assessment

In both dry and minor rainy seasons for the two vegetable crops, there were significant differences in plant height at flowering (cm), number of fruits per plant, mean fruit weight and fruit damage, among the botanical treatments

Figure 1. *Podagrica* sp on okra.

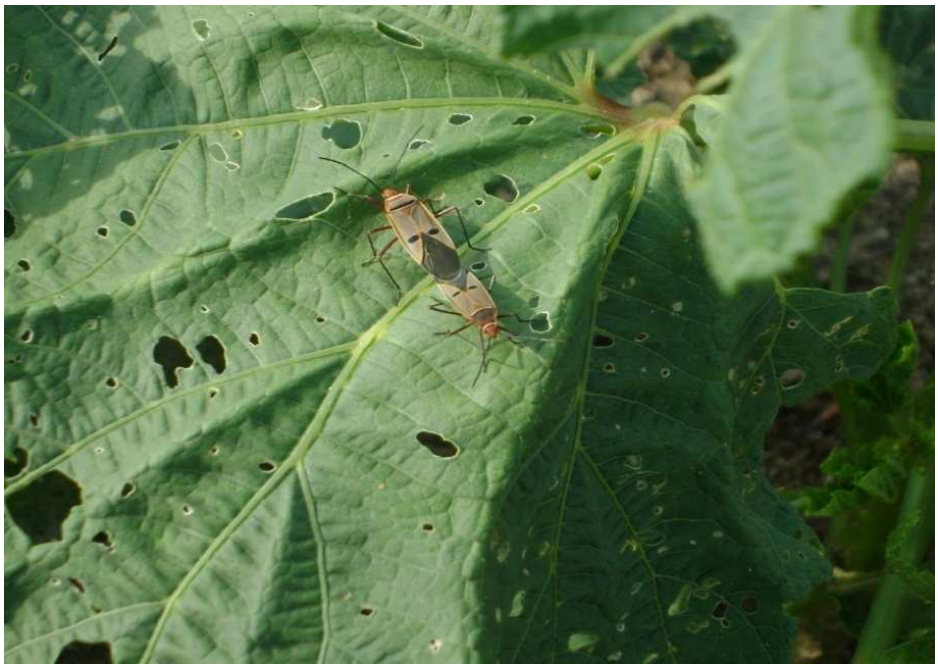

Figure 2. *Dysdercus* sp. mating on Okra.

(P<0.05). On Okra, Ecogold, Alata soap, neem oil and garlic were observed to have performed better in terms of plant height compared with the wood ash and the Control. In terms of number of fruits, all the botanicals performed better than the control. Ecogold performed best in terms of fruit weight compared to the Control which gave the poorest in both the dry and rainy seasons.

Similarly for the eggplant, all the botanical treated plants performed better in terms of plant height compared with the Control in both the dry and rainy seasons. However, Ecogold-treated plants gave the highest number

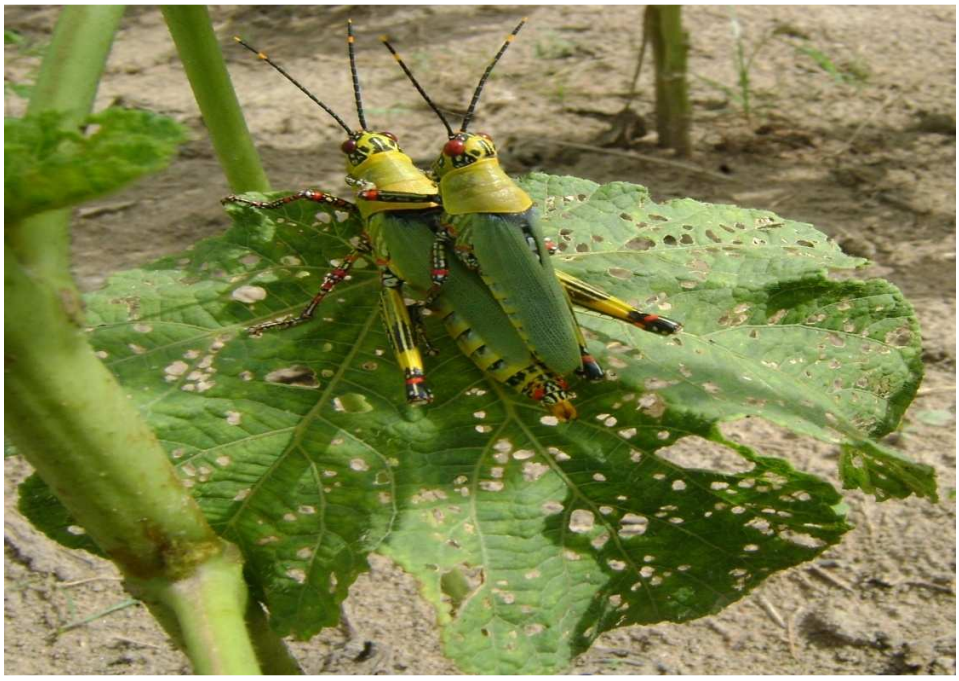

Figure 3. *Z. variegatus* mating on okra.

Figure 4. *Earias* sp (larva) on okra.

nof fruits while the Control recorded the least in the minor rainy season of 2010. Ecogold-treated plants produced the heaviest okra fruits for both dry (336 g) and minor rainy (341 g) seasons. On the other hand, garlic extract-treated plants produced the heaviest fruits of eggplant for both dry (267 g) and minor rainy (287 g) seasons. For both okra and eggplant, the control plants yielded the least fruits for both dry and minor rainy sea-sons, (Tables 5 and 6). Ecogold, garlic extract and neem extract - treated plots recorded the least mean number of fruit damage, whilst the control plots recorded the largest number of fruit damage (Tables 5 and 6). The highest

Figure 5. Aphids attack on egg plant.

Figure 6. *U. hysterricellus* attack on eggplant.

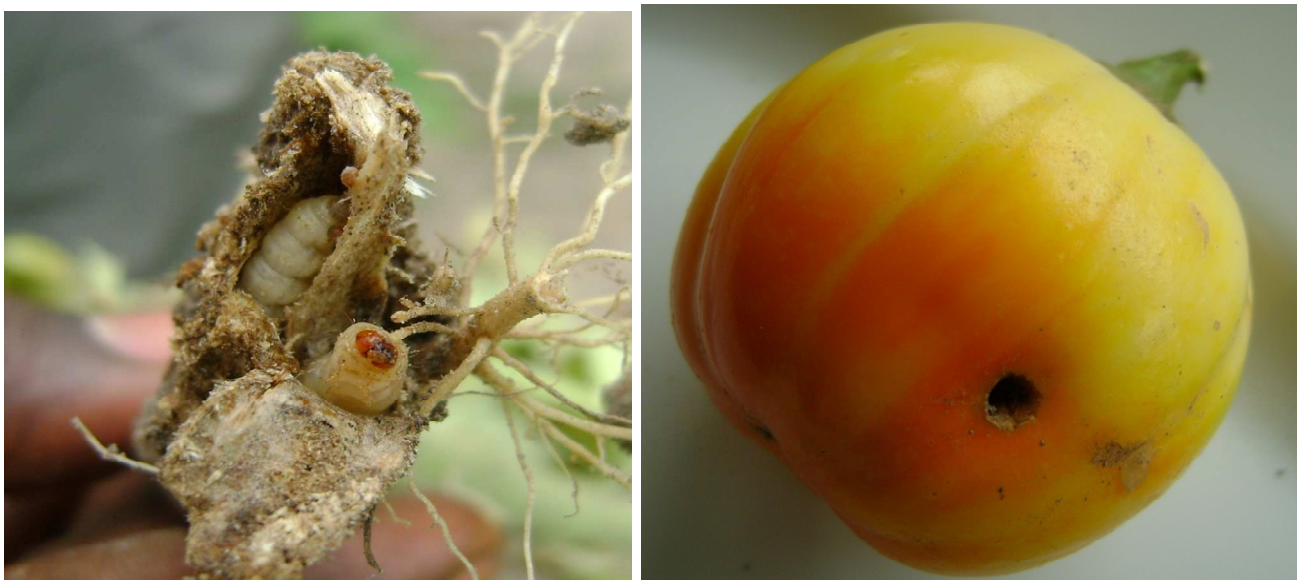

Figure 7. Stem and fruit borer (*L. orbonalis*) (a) inside stem (b) borer hole on fruit of eggplant.

Table 1. Effect of botanical treatments on numbers of major insect pests of okra: (a) minor season, 2009 and (b) major season, 2010 at Kwadaso.

Botanical	Minor season, 2009					
	Mean ± (SE) number of insects/plant					
	A. gossypii	***P. uniformis***	***D. superstitiosus***	***B. tabaci***	***Z. variegatus***	***Earias* spp**
EcoGold 999 Plus	7.01 ± 0.23^{a}	6.05 ± 0.11^{a}	5.02 ± 0.23^{a}	2.50 ± 0.38^{a}	5.14 ± 0.33^{a}	4.12 ± 0.38^{a}
Alata soap	8.23 ± 0.15^{a}	8.32 ± 0.12^{b}	6.42 ± 0.10^{b}	2.62 ± 0.21^{a}	7.21 ± 0.21^{b}	4.82 ± 0.21^{a}
Papaya leaves	9.06 ± 0.23^{a}	8.32 ± 0.21^{b}	6.52 ± 0.12^{b}	5.01 ± 0.04^{a}	7.15 ± 0.13^{b}	5.32 ± 0.04^{a}
Neem oil	7.68 ± 0.59^{a}	6.32 ± 0.55^{a}	5.12 ± 0.42^{a}	4.61 ± 0.23^{a}	5.42 ± 0.02^{a}	4.18 ± 0.23^{a}
Exotic garlic	8.14 ± 0.01^{a}	7.12 ± 0.23^{a}	6.12 ± 0.26^{a}	4.62 ± 0.18^{a}	6.17 ± 0.21^{a}	4.32 ± 0.08^{a}
Wood ash	8.19 ± 0.75^{a}	8.32 ± 0.16^{b}	7.12 ± 0.15^{b}	4.72 ± 0.03^{a}	8.02 ± 0.23^{b}	5.12 ± 0.07^{a}
Control	18.56 ± 0.41^{b}	26.12 ± 0.12^{c}	15.10 ± 0.03^{c}	11.1 ± 0.34^{b}	14.0 ± 0.58^{c}	11.2 ± 0.31^{b}
P	0.0012	0.0013	0.0001	0.0001	0.0001	0.0001
	Major season, 2010					
EcoGold 999 Plus	5.42 ± 0.28^{a}	5.02 ± 0.21^{a}	3.02 ± 0.23^{a}	2.50 ± 0.38^{a}	4.12 ± 0.33^{a}	3.12 ± 0.38^{a}
Alata soap	6.22 ± 0.18^{a}	7.42 ± 0.13^{b}	5.42 ± 0.11^{b}	2.62 ± 0.21^{a}	6.11 ± 0.28^{b}	3.62 ± 0.21^{a}
Papaya leaves	7.16 ± 0.18^{a}	7.52 ± 0.22^{b}	5.52 ± 0.02^{b}	3.52 ± 0.04^{a}	6.15 ± 0.12^{b}	4.52 ± 0.04^{a}
Neem oil	5.68 ± 0.48^{a}	5.12 ± 0.45^{a}	3.12 ± 0.42^{a}	2.51 ± 0.23^{a}	4.42 ± 0.08^{a}	3.12 ± 0.23^{a}
Exotic garlic	7.12 ± 0.01^{a}	6.12 ± 0.28^{a}	4.12 ± 0.28^{a}	2.52 ± 0.18^{a}	5.17 ± 0.28^{a}	3.32 ± 0.18^{a}
Wood ash	7.18 ± 0.83^{a}	8.12 ± 0.18^{b}	6.12 ± 0.13^{b}	3.12 ± 0.08^{a}	7.02 ± 0.28^{b}	4.12 ± 0.08^{a}
Control	13.56 ± 0.81^{b}	23.1 ± 0.05^{c}	12.12 ± 0.07^{c}	7.12 ± 0.36^{b}	13.02 ± 0.58^{c}	9.12 ± 0.36^{b}
P	0.0014	0.0023	0.0001	0.0001	0.0001	0.0001

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

mean percentage increase in okra fruit weight was recorded from plants spayed with Ecogold (51%) while Alata soap gave the lowest (22%). Similarly, the highest mean percentage increase in eggplant fruit weight was recorded

Table 2. Effect of botanical treatments on numbers of major insect pests of egg plant (a) Minor season, 2009 at Kwadaso and (b) Major season, 2010 at Agona-Mampong.

(a) Minor season, 2009						
	Mean ± (SE) number of insects/plant					
Botanical	***A. gossypii***	***U. hysterricellus***	***D. superstitiosus***	***B. tabaci***	***Z. variegatus***	***L. orbonalis***
EcoGold 999 Plus	3.40±0.23[a]	3.02 ± 0.21[a]	3.42 ± 0.53[a]	2.32±0.34[a]	4.12±0.33[a]	3.12± 0.38[a]
Alata soap	4.23±0.11[a]	5.32 ± 0.18[b]	5.52 ± 0.31[b]	2.72±0.21[a]	6.11± 0.28[b]	3.62± 0.21[a]
Papaya leaves	5.19±0.13[a]	5.52 ± 0.25[b]	5.78 ± 0.12[b]	3.62±0.14[a]	6.15± 0.12[b]	4.52± 0.04[a]
Neem oil	3.68±0.31[a]	3.42 ± 0.45[a]	3.89 ± 0.42[a]	2.71±0.21[a]	4.42± 0.08[a]	3.12± 0.23[a]
Exotic garlic	5.21±0.01[a]	4.32 ± 0.28[a]	4.45 ± 0.38[a]	2.82±0.12[a]	5.17± 0.28[a]	3.32± 0.18[a]
Wood ash	5.04±0.33[a]	6.10 ± 0.17[b]	6.67 ± 0.23[b]	2.92±0.01[a]	7.02± 0.28[b]	4.12± 0.08[a]
Control	10.94±.51[b]	9.12 ± 0.18[c]	12.89 ± 0.17[c]	7.12±0.36[b]	13.02±0.58[c]	9.12± 0.36[b]
P	0.0012	0.0011	0.0001	0.0001	0.0001	0.0001
(b) Major season, 2010						
EcoGold 999 Plus	4.41 ± 0.26[a]	3.92 ± 0.21[a]	3.23 ± 0.41[a]	2.13 ± 0.01[a]	3.98 ± 0.33[a]	1.52 ± 0.38[a]
Alata soap	5.23 ± 0.18[a]	4.32 ± 0.16[b]	5.22 ± 0.21[b]	2.11 ± 0.02[a]	6.01 ± 0.28[b]	1.62 ± 0.21[a]
Papaya leaves	6.17 ± 0.19[a]	4.52 ± 0.15[b]	5.13 ± 0.12[b]	3.10 ± 0.11[a]	6.12 ± 0.10[b]	2.22 ± 0.04[a]
Neem oil	4.68 ± 0.51[a]	3.42 ± 0.35[a]	4.79 ± 0.42[a]	2.24 ± 0.01[a]	4.42 ± 0.08[a]	1.12 ± 0.23[a]
Exotic garlic	6.22 ± 0.11[a]	3.32 ± 0.18[a]	4.12 ± 0.38[a]	2.23 ± 0.10[a]	4.17 ± 0.28[a]	1.32 ± 0.18[a]
Wood ash	6.08 ± 0.13[a]	7.10 ± 0.19[b]	6.01 ± 0.23[b]	2.21 ± 0.11[a]	6.02 ± 0.28[b]	2.12 ± 0.08[a]
Control	10.44 ± 0.51[b]	8.12 ± 0.15[c]	9.89 ± 0.17[c]	5.12 ± 0.08[b]	10.02 ± 0.58[c]	6.12 ± 0.36[b]
P	0.0010	0.0013	0.0001	0.0001	0.0001	0.0001

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

from plants sprayed with exotic garlic (59%) while Alata soap produced the lowest (21%). However, in terms of the number of days to 50% flowering, the plants treated with botanicals were similar compared with the Control. .

DISCUSSION

Populations of flea beetles (*Podagrica* spp.) and whiteflies (*B. tabaci*) in this present study were suppressed with the use of garlic bulb extract, a finding supported by Purseglove (1969) and Prasterink (2000) that garlic and onion acts as a repellent for insects. Garlic produces a pungent alliaceous compound, allyl-epropyl-disulphide, which probably is responsible for its pest repellent attribute. Population of the shoot and fruit borer (*L. orbonalis*) in the present study was significantly reduced by the application of the botanicals and therefore very few fruits were observed to be hollow and filled with frass, the indicative damage by the fruit borer. Among the botanicals, fruit borer populations were consistently lower with the application of Ecogold, garlic extract and neem extract. Similar results from studies in Asia and parts of Africa lend support to these findings (Fiscian, 1999; AVRDC, 2003a; FAO 2003).

The use of botanicals such as neem and other bio-pesticides to control insect pests of vegetables is gaining attention (Obeng-Ofori and Ankrah, 2002; Coulibaly et al., 2007). The botanicals provide alternative means of insect pest management which conserves the ecosystem (Zehnder et al., 1997; 2011; Obeng-Ofori and Ankrah, 2002; Dively et al., 2003). Worldwide, the non-pesticide management (NPM) of crops is becoming popular among vegetable growers since it endeavours to keep management of insect pests and crop cultivation costs to a minimum and avoid dependency on manufactured inputs by utilizing materials that are readily available to farmers, in this case, the adoption and use of botanicals. In the present study, the populations of natural enemies mainly ladybird and huntsman spider were similar on both the botanically treated plants and the control, suggesting that the botanicals did not have any adverse effect on the natural enemies. This finding is significant against the background that several studies on biopesticides (Sibanda et al., 2000; Navon, 2000; Owusu-Ansah et al., 2001; Obeng-Ofori and Ankrah, 2002), do not clearly indicate the effect biopesticides on natural enemies of insect pests. In light of this, the present study is the first report of the non-harmful attributes of EcoGold 999 Plus, neem oil and garlic bulb extract as botanicals on ladybird and huntsman spider as natural enemies of white flies and aphids. The presence of the ladybird beetle on both the Control and Botanicals-treated plants in the present study, was indicative that the white flies were still present

Table 3. Effect of botanical treatments on numbers of natural enemies on okra minor season (a) 2009 at Kwadaso and (b) 2010 at Agona-Mampong.

Botanical	Minor season, 2009 at Kwadaso		Minor season, 2010 at Agona-Mampong	
	Mean ± (SE) number of beneficial insects		Mean ± (SE) number of beneficial insects	
	Lady bird beetles (*Cheilomenes* sp)	Predatory spiders (Araneae)	Lady bird beetles (*Cheilomenes* sp)	Predatory spiders (Araneae)
EcoGold 999 Plus	9.42 ± 0.28	8.01 ± 0.21	8.42 ± 0.38	7.01 ± 0.11
Alata soap	8.22 ± 0.18	7.42 ± 0.13	8.22 ± 0.10	6.82 ± 0.10
Papaya leaves	8.16 ± 0.11	7.42 ± 0.22	8.16 ± 0.11	6.92 ± 0.12
Neem oil	7.68 ± 0.48	6.82 ± 0.45	7.68 ± 0.21	6.82 ± 0.35
Exotic garlic	7.82 ± 0.01	7.12 ± 0.28	8.82 ± 0.01	7.12 ± 0.17
Wood ash	6.88 ± 0.83	7.22 ± 0.18	6.88 ± 0.03	6.52 ± 0.10
Control	10.16 ± 0.61	9.12 ± 0.45	8.96 ± 0.31	8.12 ± 0.45
P	0.6061	0.7043	0.4521	0.5610

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

Table 4. Effect of botanical treatments on numbers of natural enemies on egg plant (a) Major season, 2010 at Kwadaso and (b) Minor season, 2009 at Agona-Mampong.

Botanical	Major season, 2010 at Kwadaso		Minor season, 2009 at Agona-Mampong	
	Mean ± (SE) number of beneficial insects		Mean ± (SE) number of beneficial insects	
	Lady bird beetles (*Cheilomenes* sp)	Predatory spiders (Araneae)	Lady bird beetles (*Cheilomenes* sp)	Predatory spiders (Araneae)
EcoGold 999 Plus	7.12 ± 0.28	6.71 ± 0.01	6.14 ± 0.18	6.01 ± 0.02
Alata soap	6.67 ± 0.18	7.11 ± 0.12	5.63 ± 0.16	5.49 ± 0.11
Papaya leaves	6.56 ± 0.11	7.22 ± 0.01	5.61 ± 0.11	5.64 ± 0.02
Neem oil	5.68 ± 0.48	6.82 ± 0.45	4.89 ± 0.21	5.82 ± 0.05
Exotic garlic	5.82 ± 0.01	7.12 ± 0.28	4.82 ± 0.01	5.62 ± 0.25
Wood ash	6.58 ± 0.03	7.22 ± 0.20	5.87 ± 0.03	5.52 ± 0.21
Control	7.16 ± 0.61	8.01 ± 0.65	7.16 ± 0.52	6.41 ± 0.45
P	0.6132	0.7147	0.7132	0.6578

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

on the treated plants albeit not at the economic threshold.

Fruit yields from okra and eggplant were higher on Botanically-treated plants than the Control plants, probably due to the reduced fruit damage on the treated plants. Furthermore, for both okra

Figure 8. *Cheilomenes* sp on okra plant.

Figure 9. Predatory spider on okra plant.

Table 5. Effect of insecticide treatments on growth and yield per plant of Okra. (a) Minor season, 2009 at Kwadaso and (b) Major season, 2010 at Agona-Mampong.

Botanical	Mean no. of days to 50% flowering	Mean plant height at flowering (cm)	Mean no. of fruits	Mean no. of fruits damaged	Mean weight of fruits (g)	Mean % increases in fruit weight
(a) Minor season, 2009 at Kwadaso						
EcoGold 999 Plus	33.5 ± 0.1^{a}	62.1 ± 2.6^{b}	9.8 ± 2.8^{b}	1.1 ± 0.3^{a}	336.1±1.8^{c}	50.5± 1.8^{c}
Alata Soap	34.1 ± 0.2^{a}	61.9 ± 3.1^{b}	7.6 ± 0.2^{b}	1.3 ± 0.2^{a}	215.7±4.0^{b}	22.9± 2.1^{b}
Papaya leaves	33.5 ± 0.6^{a}	54.5 ± 2.2^{ab}	6.2 ± 1.4^{b}	1.5 ± 0.1^{a}	219.3±5.8^{b}	24.2± 3.4^{b}
Neem oil	33.7 ± 0.7^{a}	60.1 ± 2.5^{b}	8.3 ± 1.4^{b}	1.1 ± 0.2^{a}	318. ± 5.2^{c}	47.8±2.2^{c}
Exotic garlic	34.1 ± 0.6^{a}	60.7 ± 3.1^{b}	7.7± 1.9^{b}	1.3 ± 0.1^{a}	234. ± 7.1^{b}	29.1±3.1^{b}
Wood ash	33.6 ± 0.1^{a}	49.2 ± 2.6^{a}	7.4 ± 1.8^{b}	1.1 ± 0.1^{a}	224. ± 3.8^{b}	25.8± 2.4^{b}
Control	34.1 ± 0.2^{a}	49.5 ± 3.3^{a}	4.5 ± 0.6^{a}	3.2 ± 0.2^{b}	166.3±7.8^{a}	0.0
P	0.9987	0.0010	0.0001	0.0001	0.0001	0.0001
(b) Major season, 2010 at Agona-Mampong						
EcoGold 999 Plus	33.6 ± 0.2^{a}	63.1 ± 2.5^{b}	10.2 ± 2.8^{b}	1.3 ± 0.1^{a}	341.3 ± 1.6^{c}	49.9 ± 1.2^{c}
Alata Soap	34.3 ± 0.3^{a}	62.9 ± 3.0^{b}	8.7 ± 0.2^{b}	1.5 ± 0.2^{a}	219.8 ± 3.9^{b}	22.2 ± 2.5^{b}
Papaya leaves	33.6 ± 0.6^{a}	53.7 ± 2.3^{ab}	7.5 ± 1.4^{b}	1.6 ± 0.2^{a}	224.7 ± 3.8^{b}	23.9 ± 2.4^{b}
Neem oil	33.8 ± 0.8^{a}	57.8 ± 2.4^{b}	9.1 ± 1.2^{b}	1.4 ± 0.2^{a}	324.3 ± 4.1^{c}	47.3 ± 3.1^{c}
Exotic garlic	34.3 ± 0.5^{a}	58.8 ± 3.3^{b}	8.7 ± 1.7^{b}	1.3 ± 0.2^{a}	238.2 ± 5.0^{b}	28.2 ± 3.0^{b}
Wood ash	33.5 ± 0.2^{a}	49.1 ± 2.5^{a}	8.6 ± 1.5^{b}	1.3 ± 0.1^{a}	229.2 ± 2.2^{b}	25.4 ± 2.1^{b}
Control	34.2 ± 0.1^{a}	49.4 ± 3.2^{a}	5.2 ± 0.4^{a}	3.4 ± 0.3^{b}	171.0 ± 5.3^{a}	0.0^{a}
P	0.9481	0.0031	0.0001	0.0001	0.0001	0.0001

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

and eggplant, the reduction in population of the foliage defoliators (*P. uniformis* and *Z. variegatus* L.) implied the availability of more undamaged foliage which through photosynthesis resulted in increased dry matter accumulation in the fruits. Zehnder et al. (1996; 1997) also reported increased marketable yields of vegetables treated with garlic and red pepper.

Conclusion

The current study presents an array of botanicals that could significantly reduce pest populations and conveniently maintain ecological balance with their natural enemies on okra and eggplants. However, for expected result as observed in this study we agree with Zehnder et al. (1997) and Ahmed et al. (2009) and caution users that the application frequency of these botanical materials should be based on climatic variations in particular regions in order to achieve the desired results. These botanicals when applied in the right dosages and frequencies could offer large-scale growers, who produce for both the local and export markets and are looking for alternatives to synthetic pesticides to manage insect pest of vegetables at relatively less cost and at no harm to the consumer and environment. This will eventually make vegetable cultivation a profitable business and improve the livelihood of growers.

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Table 6. Effect of insecticide treatments on growth and yield per plant of egg plant. (a) Minor season, 2009 at Kwadaso and (b) Major season, 2010 at Agona-Mampong.

Botanical	Mean no. of days to 50% flowering	Mean plant height at flowering (cm)	Mean no. of fruits	Mean no. of fruits damaged	Mean weight of fruits (g)	Mean % increases in fruit weight
(a) Minor season, 2009 at Kwadaso						
EcoGold 999 Plus	64.8 ± 0.1^{a}	64.1 ± 2.2^{b}	10.4 ± 2.3^{a}	1.2 ± 0.3^{a}	215.7 ± 4.0^{bc}	49.4± 2.1^{c}
Alata soap	64.8 ± 0.2^{a}	64.2 ± 2.1^{b}	8.3 ± 0.2^{a}	1.5 ± 0.2^{a}	166. ± 2.9^{b}	34.6± 2.3^{b}
Papaya leaves	64.5 ± 0.1^{a}	64.1 ± 2.2^{b}	7.4 ± 1.4^{a}	1.3 ± 0.1^{a}	143. ± 2.8^{b}	24.1± 2.1^{b}
Neem oil	65.0 ± 0.4^{a}	64.5 ± 2.0^{b}	7.2 ± 1.5^{a}	1.3 ± 0.2^{a}	216. ± 3.0^{b}	49.5± 2.3^{c}
Exotic garlic	65.1 ± 0.3^{a}	64.7 ± 3.1^{b}	6.7 ± 1.9^{a}	1.4 ± 0.1^{a}	266. ± 4.0^{d}	59.0± 2.4^{d}
Wood ash	64.9 ± 0.1^{a}	62.7 ± 2.6^{a}	6.2 ± 0.6^{a}	1.5 ± 0.1^{a}	138. ± 2.7^{b}	21.4± 2.2^{b}
Control	65.4 ± 0.2^{a}	62.5 ± 3.3^{a}	4.7 ± 0.3^{b}	2.7 ± 0.4^{b}	109.2 ± 1.6^{a}	0.0a
P	0.7869	0.0019	0.0001	0.0001	0.0001	0.0001
(b) Major season, 2010 at Agona-Mampong						
EcoGold 999 Plus	64.6 ± 0.2^{a}	64.2 ± 2.0^{a}	11.4 ± 2.7^{c}	0.7 ± 0.1^{a}	236.5 ± 4.0^{c}	49.8 ± 2.6^{c}
Alata soap	64.6 ± 0.1^{a}	64.3 ± 1.9^{a}	8.7 ± 0.2^{ab}	0.8 ± 0.2^{a}	178.2 ± 2.9^{b}	33.4 ± 2.2^{b}
Papaya leaves	64.3 ± 0.1^{a}	64.3 ± 2.1^{b}	9.1 ± 1.4^{b}	0.6 ± 0.1^{a}	166.9 ± 2.8^{b}	28.9 ± 2.3^{b}
Neem oil	65.1 ± 0.1^{a}	64.5 ± 1.8^{b}	9.3 ± 1.4^{b}	0.7 ± 0.2^{a}	228.4 ± 3.0^{b}	48.0 ± 2.7^{c}
Exotic garlic	65.2 ± 0.2^{a}	64.7 ± 2.1^{b}	9.8 ± 1.9^{c}	0.7 ± 0.1^{a}	287.3 ± 3.9^{c}	58.7 ± 3.1^{d}
Wood ash	64.7 ± 0.1^{a}	62.4 ± 2.2^{a}	8.6 ± 1.8^{ab}	0.8 ± 0.1^{a}	159.8 ± 2.6^{b}	25.7 ± 2.1^{b}
Control	65.2 ± 0.1^{a}	62.5 ± 2.1^{a}	5.8 ± 0.6^{a}	2.3 ± 0.4^{b}	118.7 ± 1.8^{a}	0.0a
P	0.8694	0.0012	0.0001	0.0001	0.0001	0.0001

Means within a column followed by the same letter do not differ significantly from each other (P > 0.05; SAS, PROC GLM, SNK).

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