Efficacy of promising insecticides and lures for the management of insect pests of quarantine importance on ridged gourd (*Luffa acutangula* L.)

K. Amouzou[1], K.O. Fening[1, 2*], W. Hevi[3], E. E. Forchibe[1] and M.K. Billah[4]

[1] *ARPPIS Sub-regional Centre for West Africa, University of Ghana, Legon, Accra, Ghana.*

[2] *Soil and Irrigation Research Centre, SIREC, University of Ghana.*

[3] *CABI West Africa Centre, 6 Agostino Neto Road, CSIR Campus, Accra, Ghana.*

[4] *Department of Animal Biology and Conservation Science, University of Ghana, Legon, Accra, Ghana*

*Corresponding Author: *kfening@ug.edu.gh*

Abstract

Insecticides play an important role in the management of insect pests on ridged gourd (*Luffa acutangula* L.) or turia. The sweet potato whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae), thrips, *Thrips* spp. Karny (Thysanoptera:Thripidae), and fruit flies, *Zeugodacus cucurbitae* (Coquillett) and *Bactrocera dorsalis* (Hendel) (Diptera:Tephritidae) are the commonly found insect pests on turia in Ghana. These insect pests have been intercepted in some vegetables including turia exported into the European Union. The current study evaluated the efficacy of promising insecticides and lures for the management of these pests of quarantine importance on turia. The study was undertaken at a vegetable production site at Torgorme in the Volta region of Ghana during the dry and rainy seasons of 2017 and 2018, respectively. The experiment was laid out in a Randomized Complete Block Design with five treatments replicated four times. The treatments included use of Eradicoat T GH® (Maltodextrin 282g/L) at 150 ml per 15L of water, Ecopel® (*Bacillus thuringiensis* 32000 IU/mg at 25g/15L of water, Aqueous Neem Kernel Extract (ANKE) (Azadirachtin) at 50g/L of water, and Viper® (Acetamiprid 16g/l + Indoxacarb 30g/l) at 40ml /15L of water, and untreated control plot. Fruit fly traps with different pheromones or lures (i.e., Methyl Eugenol, Cuelure, Terpinyl Acetate and Trimedlure) were set at the four corners of the field to monitor the different species of fruit flies. Yellow sticky traps were also set within treatment plots to monitor pest populations. Whitefly population was significantly different among the treatments for both cropping seasons, while fruit fly population was not significant for both seasons. There was a significant difference in thrips population for the rainy season, however, it was not significant in the dry season. In a descending order, Acetamiprid 16g/l + Indoxacarb 30g/l and Azadirachtin were the most effective insecticides in controlling these pests on turia. There is, therefore, the need to alternate these two insecticides for effective management of pests on turia.

Key words: Ridged gourd, turia, whiteflies, thrips , fruit flies, biopesticides, insect traps.

Introduction

Luffa acutangula L., generally known as ridged gourd or turia is a vegetable consumed widely in Asian countries. It belongs to the family Cucurbitaceae and has varied names depending on the community (Rathore et al., 2017) . In the tropics, vegetable production is severely constrained by many insect and mite pests. The sweet potato whitefly, *Bemisia tabaci* Gennadius, (Hemiptera: Aleyrodidae), the melon thrips, *Thrips palmi* Karny (Thysanoptera:Thripidae) and fruit flies (belonging to the genera *Zeugodacus*, *Dacus*, *Ceratitis*, and *Bactrocera*) are among the major insect pests of vegetables which are of quarantine importance (Fening et al., 2017). Growers rely heavily on synthetic insecticides to protect their vegetable crops . However, the misuse of these pesticides has adverse effect on the environment and human health (Srinivasan, 2009; Fening et al., 2013, 2014, 2017; Amoabeng et al., 2017; Forchibe et al., 2017). Farmers mostly use these synthetic pesticides in anticipation for higher gains (Gerken et al., 2001), but pests quickly develop resistance, rendering them ineffective. Ghana was struck by a ban on some vegetable crops (chillies, gourds and eggplants) in October 2015 because of the detection of high incidence of harmful organisms, mainly insect pests of quarantine importance on exported vegetables into the European Union (EU) (Fening and Billah 2016; Yeray et al., 2016; 2017a,b; Fening et al., 2017).

The most common insect pests found to attack ridged gourd are the sweet potato whitefly, *Bemisia tabaci* Gennadius, (Hemiptera: Aleyrodidae), *Thrips* spp. (Thysanoptera; Thripidae) and the fruit flies, *Zeugodacus cucurbitae* (Coquillett) and *Bactrocera dorsalis* (Hendel) (Diptera:Tephritidae) (Yeray et al., 2016; Fening et al., 2016, 2017). To combat these pests, a comprehensive action plan was devised by the Plant Protection and Regulatory Services Directorate (PPRSD) of the Ministry of Food and Agriculture (MoFA) and its Export Taskforce set by the Ministry of Agriculture (Yeray et al., 2016 ; Fening et al., 2017). Entomologists from the University of Ghana African Regional Postgraduate Programme in Insect Science (ARPPIS) have been at the forefront in the development of these interventions and have developed protocols and roadmap for the management of these pests of quarantine importance for exporters and their out-growers (Fening et al., 2016; 2017; Fening and Billah, 2017a, b). Hence, this study was carried out as a further validation of these protocols to evaluate the efficacy of promising biological and synthetic pesticides and some lures in the management of whiteflies, thrips and fruit flies attacking ridged gourd in the field. This will offer growers information on the most effective insecticides and lures to be considered as an integral part of an IPM strategy to ensure the production of pest free turia for export.

Materials and Methods

Study site

The study was conducted from December 2017 to May 2018 at Torgorme (6˚12'17.8994"N, 0˚5'9.312'E), in the Volta region in Ghana for two consecutive seasons (dry and major rainy seasons). Torgorme is part of the Coastal Savanna agro-ecological zone of Ghana with black clay soils known as the vertisols or Akuse series. Temperatures in this region are high and range between 26 ºC-30 ºC. The relative humidity which is high throughout the year varies between 70%-80% (Fening et al., 2020a). The dry season in this study extends from the first week of December 2017 to the last week of February 2018, while the major rainy season extends from the third week of March 2018 and ends at the last week of May 2018 as per the data collection period. Torgorme was selected due to the availability of the Volta River dam and an irrigation facility that allows all year-round irrigation and crop production. This place is one of the sites where the Asian vegetables, mostly the gourds (ridged gourd and bottle gourds) are grown by Joekopan Enterprise for export.

Experimental design and treatments

The experimental design was a Randomized Complete Block (RCBD), consisting of five treatments with four replications. The treatments were Eradicoat T GH® (Maltodextrin 282 g/L) @ 150 ml/15L of water, Aqueous Neem Kernel Extract (ANKE) (Azadirachtin) @ 50 g/L of water, Viper 46 EC® (Acetamiprid 16 g/l + Indoxacarb 30 g/l) @ 40ml/15L of water, Ecopel® (*Bacillus thuringiensis kurstaki* (Btk) (32000 IU /mg) @ 20g/15L of water and untreated control.

Land preparation and planting of turia

The land was cleared of weeds, ploughed, harrowed, and ridged. Certified healthy hybrid seeds of turia were obtained from Tikola seeds in Tema and were sown on raised beds in the field, two seeds per hole. Planting of turia was done during the dry season on first week of December 2017 and data collection started three weeks later until the last week of February 2018. During the major season, planting was done on the last week of March 2018, three weeks later data collection started until first week of July. The planting distance was 150 cm x 150 cm, with a total of 9 plants per plot. The area per plot was 5m x 5m. Inter-plot distance was 1.5 m and inter-block distance was 2.0 m. Staking was undertaken using sticks and robes when the turia was

TABLE 1
Name of pheromones (lures) used and targeted fruit fly species

Name of the pheromone	Target species
Methyl Eugenol (ME)	*Bactrocera dorsalis*
Cuelure (CUE)	*Zeugodacus cucurbitae*
Terpinyl Acetate (TA)	*Ceratitis cosyra*
Trimedlure (TML)	*Ceratitis capitata*

three weeks old in the field.

Appropriate agronomic and cultural practices such as weed control, staking and supplementary irrigation (especially during the dry season) were employed regularly throughout the growing period to promote healthy growth of plant. NPK 15-15-15 (5 g/plant) and Sulphate of Ammonia (3 g/plant) were applied in a ring form around each plant two weeks and six weeks after planting.

Preparation of aqueous neem kernel extract

The *ANKE* was prepared following the methods of Forchibe et al. (2017). The required amounts of dry neem seeds (e.g., 750g) was weighed and pounded in a wooden mortar using a wooden pestle. The homogenate was mixed with 2L of water. The resultant mixture was left overnight, and later sieved through a fine linen material. The resultant 2L suspension was topped up with 13L of water to give a mixture/formulation of 750g/15L of water and about 5ml of liquid soap (Madar Renzo®) and vegetable oil added to enhance its delivery and stickiness onto the leaf surfaces of the turia plant.

Application of treatments

All treatments were applied using a CP15 knapsack sprayer at the recommended application rate, as indicated above, during late afternoon (4-6 pm). Treatments were applied weekly for 7 and 10 weeks during the dry and major rainy seasons of 2017 and 2018, respectively.

Sampling of insect pests

Within crop sampling involving the collection of plant parts (mainly leaves, flowers and fruits, as applicable to whiteflies, thrips, and fruit flies, respectively) and pest counts in the vicinity of the crop involving catches on sticky traps and fruit fly traps with their specific lures were undertaken. The composition of the lures used, and the target fruit fly species is indicated in Table 1.

Set up of yellow sticky traps

One yellow sticky trap (40 cm length/20 cm width) was placed in the middle row of each treatment plot of turia at the height of the staked plants 2 weeks after planting in the field. The sticky traps were collected from the field weekly and brought to the laboratory for counting and recording of the number of catches of the different insects. The yellow sticky traps were set in each experimental plot to monitor whiteflies, thrips, and fruit fly population dynamics weekly. The sticky traps were replaced with a fresh one each week.

Five topmost expanded leaves were examined carefully to count the number of whiteflies present during early morning 6-7 am, where they were inactive (Fening et al., 2016). Ten flowers were sampled per plot into a vial containing 70% alcohol for counting of thrips. The number of thrips was counted and recorded, facilitated by a hand lens at the African Regional Postgraduate Programme in Insect Science (ARPPIS) Entomology laboratory at the University of Ghana.

Set up of fruit fly traps with 4 lures

In addition, fruit fly traps with different pheromones or lures (Table 1) were set up at the four corners of the field to monitor the different species of fruit flies. The traps were emptied every week for subsequent identification and recording. The trap positions were rotated weekly. To assess fruit fly infestation, ten turia fruits were randomly picked from each plot for incubation in the laboratory at ARPPIS, University of Ghana. This was done two weeks after the beginning of fruiting and one month afterwards. At the laboratory, these fruits were incubated in a plastic box (20 cm x 30 cm) containing sterilized semi wet sand closed with a lid with a net.

Identification of insects

Collected specimens of fruit flies and whiteflies were sent to ARPPIS Laboratory for morphological identification. Pictorial keys of Prabhakar et al. (2012), and Billah et al. (2007) were used for fruit fly identification, while identification key by EPPO (2004) was used for whitefly identification. Fruit fly species identification were confirmed by Dr. Maxwell Kelvin Billah, a fruit fly taxonomist. Thrips specimens were sent to CABI Plantwise Diagnostic and Advisory Service laboratory, UK for molecular analysis and identification.

Data analysis

After log-transformation of count data, GenStat was used to perform all analysis of variance (ANOVA), for the treatments. The efficacy of different pesticides in controlling pests of ridged gourd was done by comparing control plots with the treatments and mean separation test done using LSD ($P < 0.05$) when ANOVA was significant.

Results

Whiteflies and thrips abundance on turia

Whiteflies and thrips abundance on turia were low during both seasons. However, during the dry season, the highest number of whiteflies (3), was recorded on the Viper, Neem and Control plots on weeks 4, 2, 7, respectively. In the major rainy season also, only a total of 4 whiteflies were recorded on each of the Ecopel, Eradicoat and Neem plots during week 6, 3, 7, respectively. Few numbers of thrips were also recorded from the flowers. A total of 5 and 3 thrips were observed in all the plots during the dry and major rainy seasons, respectively. Whiteflies species identified on turia leaves and sticky traps was *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), while thrips species identified on flowers and sticky traps was *Thrips parvispinus* Karny (Thysanoptera: Thripidae). The samples or specimens sent for identification at CABI showed 100% similarity to each other, marching with *T. parvispinus* in the GenBank, Accession number KF 144125.1 from Indonesia (Chang & Ramasamy 2013).

Whiteflies population based on trap catches

The lowest and the highest mean population of 20 and 230 *B. tabaci*, were recorded during the dry season in 2017 on Viper 46 EC® (Acetamiprid 16g/l + Indoxacarb 30g/l) and the control treatment plots, respectively, (Fig. 1). For both seasons, the number of *B. tabaci* recorded during the first week for each

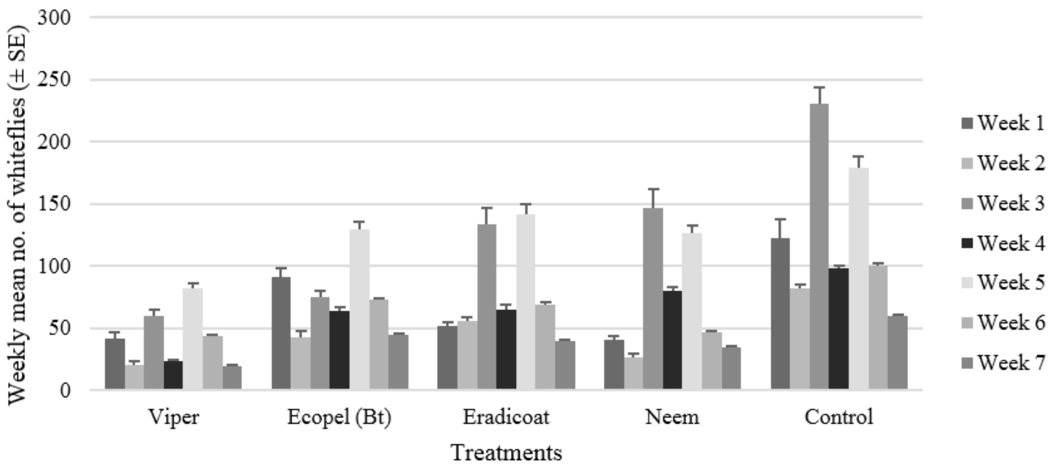

Fig. 1 Effects of treatments on mean (± SE) weekly counts of *B. tabaci* on sticky trap during the dry season

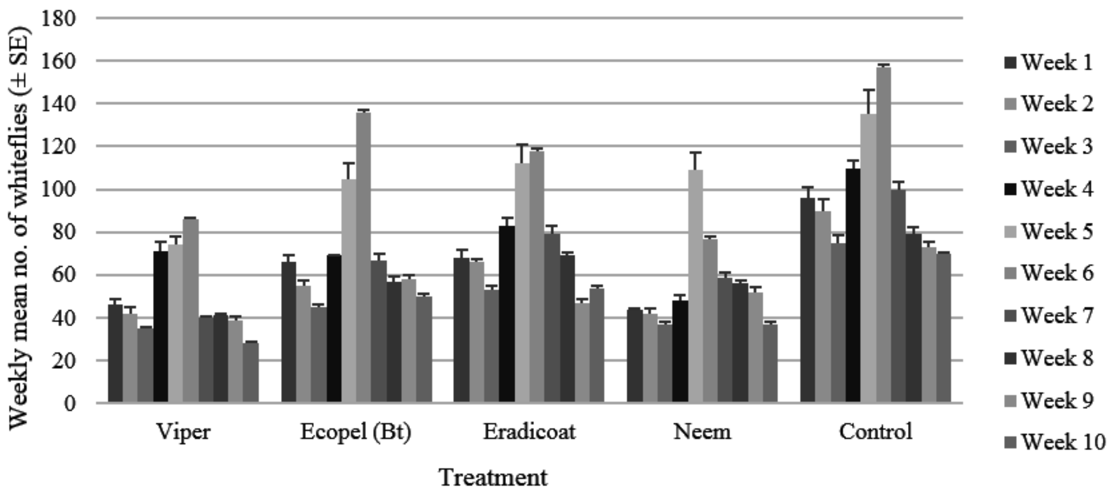

Fig. 2 Effects of treatments on mean (± SE) weekly counts of *B. tabaci* on sticky trap during the major rainy season

treatment was always higher than the number recorded at the last week of data collection. During the dry season in 2017, the peak *B. tabaci* population was recorded on the fifth week for Viper 46 EC®(Acetamiprid +Indoxacarb), Ecopel®(Btk) and Eradicoat T GH® (maltodextrin) treatments, while the peak population on neem (azadirachtin) and control (water only) treatments was on the third week. The trend of the data collected during the major rainy season in 2018 (Fig. 2) showed a peak of *B. tabaci* population at the sixth week for all treatments, apart from the Neem whose peak was on the fifth week. Subsequently there was a drop of *B. tabaci* population for the four remaining weeks. There was a significant difference in the effect of the different treatments on whiteflies population for the dry and major rainy seasons, respectively ($F_{4,19}$ = 15.09; P < 0.001, and $F_{4,19}$ = 80.39; P < 0.001). The mean separation test revealed that Viper 46 EC® performed better than the other treatments and the second most efficacious was neem seed extract for both cropping seasons.

There was also a significant difference in the effect of each treatment on the population of *B. tabaci* among the weeks of sampling for both seasons ($F_{6,139}$ = 28.76; P < 0.001 and $F_{9,199}$ = 12.77; P = < 0.001). However, the interaction between the treatments and weeks of sampling of *B. tabaci* was not significant for both seasons ($F_{24,139}$ = 0.93; P = 0.507 and $F_{36,199}$ = 0.42; P = 0.962).

Thrips population based on sticky trap catches

The weekly trap catches showed variations through the two sampling seasons. The occurrence of thrips was recorded from the first week to the end of the dry season for all treatments (Fig. 3). During the same period, thrips infestation was not recorded on the plot

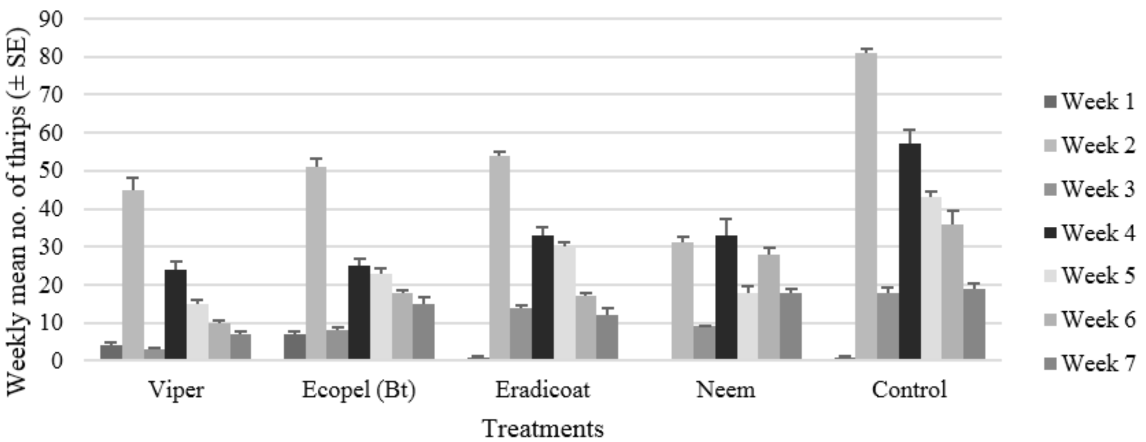

Fig. 3 Effects of treatments on mean (± SE) weekly count of thrips, *T. parvispinus* on sticky trap during the dry season

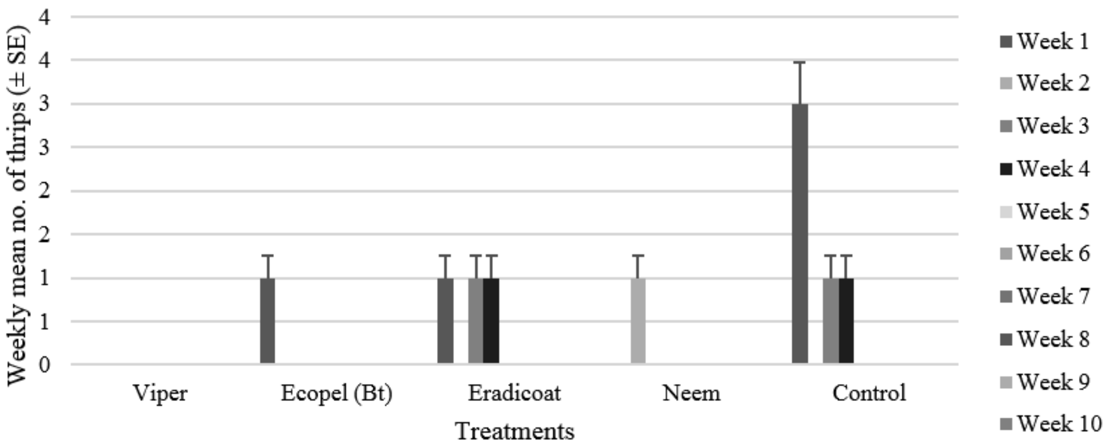

Fig. 4 Effects of treatments on mean (± SE) weekly counts of *T. parvispinus* on sticky trap during the major rainy season

treated with Viper 46 EC®(Acetamiprid + Indoxacarb). However, it was recorded only at the first and second week for plots treated with Ecopel®(Btk) and Neem (azadirachtin), respectively during the major rainy season (Fig. 4). For the rest of the treatments during the same rainy season, there were no thrips infestation after the fourth week. There was a drop in thrips population between the peak on the untreated plot for the dry season (81) and the major rainy season (3) as shown in Figs. 3 and 4, respectively. There was a significant difference in the effect of the different treatments on thrips for the dry season ($F_{4,19}$ = 11.43; P < 0.001), while it was not significant for the major rainy season ($F_{4,19}$ = 1.15; P = 0.378). Plots treated with Viper 46 EC® (Acetamiprid + Indoxacarb) recorded the lowest number of thrips among all the treatments during the dry season. There was a significant difference in the effect of each treatment on the population dynamics of thrips among the weeks of sampling for the dry season ($F_{6,139}$ = 28.76; P < 0.001) and no significant difference for the major rainy season ($F_{9,199}$ = 2.69; P = 0.075). The interaction between the treatments and sampling time was not significant for both seasons ($F_{24,139}$ = 1.26; P = 0.275 and $F_{36,199}$ = 1.06; P = 0.414).

Fruit fly infestation in incubated Turia fruits

Turia fruits incubated to check for fruit flies' infestation showed a very low level of infestation. Only fruits incubated during the dry season were infested. A total of 6 fruit flies emerged, with 2 from neem (Azaditachtin) treated plot and 4 from the control (water only) plot. The fruit flies were all identified as the melon fruit fly, *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae).

Fruit fly population based on catches from sticky traps and pheromone traps

Sticky traps

Fruit fly species, mainly *Z. cucurbitae* was recorded only in the dry season (Fig. 5). The highest mean number of 15 fruit flies was recorded on Eradicoat (maltodextrin) plot, and the lowest of 0 fruit flies was on Ecopel (Btk) plot. The ANOVA was not significant for the effect of the different treatments on fruit flies ($F_{4,19}$ = 0.78; P = 0.56), but the repeated measures of ANOVA on the effect of each treatment on the population of fruit flies among the weeks of sampling was significant ($F_{6,139}$ = 4.75; P = 0.003). However, the interaction between the treatments and weeks of sampling of fruit flies was not significant ($F_{24,139}$ = 1.25; P = 0.264).

Pheromone traps

The incidence of fruit flies was highest from the first week of sampling and drastically declined as the weeks progressed during the dry season (Fig. 6.). Fruit fly, mainly *Z. cucurbitae* was recorded during the dry season

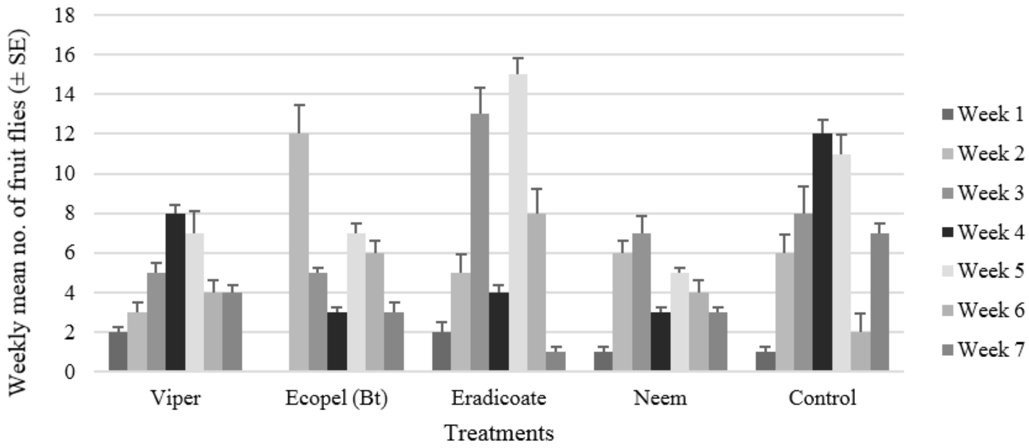

Fig. 5 Effects of treatments on mean (± SE) weekly counts of fruit flies (*Z. cucurbitae*) on sticky traps during the dry season

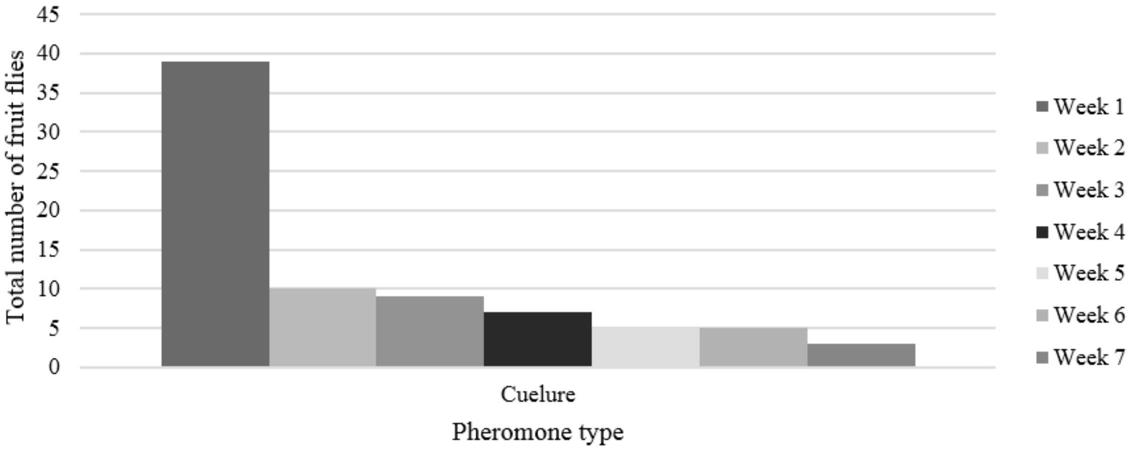

Fig. 6 Total number of catches of fruit flies, *Z. cucurbitae*, using the pheromone trap with Cuelure attractant during the dry season

on Cuelure baited pheromone trap, with the other lures recording no other fruit fly species. The major rainy season recorded no fruit fly species for all the four lures.

Yield of Turia

The yield obtained for the different treatments were not significantly different during the two seasons ($F_{4,19}$ = 0.54; P = 0.72; $F_{4,19}$ = 0.19; P = 0.94) (Table 2).

TABLE 2

Mean yield of turia (t/ha) (± SE) during the dry season of 2017 and major rainy season of 2018

	Mean yield t/ha (±SE)	
Treatments	Major rainy season	Dry season
Viper 46 EC® (Acetamiprid + Indoxacarb)	5.85 ± 1.53	6.36 ± 1.51
Ecopel® (*Bacillus thuringiensis kurstaki*) (Btk)	4.57 ±1.31	6.03 ± 1.31
Eradicoat T GH® (Maltodextrin)	5.09 ± 1.12	6.52 ± 1.12
Control (Water only)	3.91± 0.34	5.98 ± 0.34
Neem (Azadirachtin)	4.44 ± 0.40	6.00 ± 0.43
df	4, 19	4, 19
F	0.54	0.19
P	0.720	0.940

Discussion

The current study has demonstrated that Viper 46 EC® (Acetamiprid 16g/l + Indoxacarb 30g/l) was very effective in controlling whiteflies for both cropping seasons, and effective in controlling thrips during the dry season as revealed by trap catches within the crop. These results are in line with the studies of Horowitz et al. (1998) who also demonstrated the efficacy of Acetamiprid against whiteflies on cotton. Zabel et al. (2001) also reported the efficacy of Acetamiprid against whiteflies on tomato. Studies undertaken by Rudramuni et al. (2011) proved the efficacy of indoxacarb against whiteflies and thrips on cotton. The efficacy of Viper 46 EC® (Acetamiprid 16 g/l + Indoxacarb 30 g/l) was confirmed again during the major rainy season where the population of thrips was much close to zero. Also, during that same season, thrips were recorded on treatment plots with neem (azadirachtin) only in the second week.

The thrips species encountered in the current study was the tobacco thrips, *Thrips parvispinus* Karny which is considered as a highly polyphagous species. The current study is the first report of *T. parvispinus* in Ghana. It is reported as a major pest of *Capsicum* (Vos and Frinking 1998) in Java, and of vegetable crops in Thailand (Bansiddhi and Poonchaisri 1991). In Malaysia, it is a pest of papaya on which damage caused by its feeding is associated with secondary attacks by the saprophytic fungus *Cladosporium oxysporum* (causing bunchy and malformed tops of papaya) (Lim 1989). Extensive leaf damage by *T. parvispinus* was observed on *Gardenia* plants in Greece (Mounds and Collins 2000). It is also recorded as a vector of tobacco streak ilarvirus in transmission studies (Klose et al., 1996). This pest was removed from the EPPO alert list in 2001 as doubts were expressed about the severity of damage in the EPPO region (EPPO 2001b).

The efficacy of neem (azadirachtin) in controlling insect pests on various crops has been proven (Owusu-Ansah et al., 2001; Obeng-Ofori and Sackey 2003; Sheikh 2011; Forchibe et al., 2017; Fening et al., 2017; 2020b) Chen et al. (1996) and Ranganath et al. (1997) also reported the efficacy of neem based bio-pesticides against fruit fly in terms of reduction in fruit infestation and anti-oviposition effect. This was also observed for Ecopel (Btk) plots only during the first week. The present finding is supported by the findings of Aliakbarpour et al. (2011) who reported neem oil being effective against thrips on mango panicles and its compatibility with mango pollinators. Findings by Pandey et al. (2013) also concurs the effectiveness of neem against thrips on onion.

Very low number of thrips and whiteflies recorded on the turia for both seasons is an indicator of the efficacy of the treatments in this study. It was also evident that the incidence of pests was higher during the dry season (Dec 2017- Feb 2018) and lower during the major rainy season of 2018 (March-May). Several studies have supported higher pests (whiteflies, fruit flies and thrips) infestation during dry seasons where there is very limited and/or erratic rainfall and varying temperature and relative humidity (Leite 2005; Appiah et al., 2009; Gebretsadkan, 2017).

The use of sex pheromones has been very efficient as demonstrated by the drastic reduction in fruit fly populations during the major rainy season which followed the dry season. No fruit flies were recorded during the major rainy season probably due to the combination of insecticides, sticky traps and sex pheromones used during the dry season, which offered an effective population suppression of the fruit flies. Hardy (1979) reported that 90% of fruit fly species were strongly attracted to the sex pheromones (Cuelure and Baculure). The current results is in line with the findings of Verghese et al. (2005) who used three indigenous attractants with three established attractants and observed maximum number of different flies trapped in Methyl Eugenol and Cuelure traps than indigenous traps. However, the action of these lures could be augmented with the use of protein food baits applied as spot application within the foliage in the ridged gourd field which will attract all species and sexes of fruit flies, making it a more holistic and sustainable approach to fruit fly management in turia (Billah et al., 2007; Fening et al., 2016, 2017; Fening and Billah, 2017b). The current study has shown that the melon fruit fly, *Z. cucurbitae* is the commonest and most important species of fruit fly attacking turia in the study area and Cuelure which is the lure for attracting this species should be a priority for farmers. The generally low level of pest population suggests the management interventions (roadmap) proposed for these pests of quarantine importance should be strictly enforced to ensure commodities for export are ultimately free from pests . The yields (fresh weight) of turia were not significantly different for the various treatments. This could be partly due to the mass trapping of fruit fly males around the four corners of the field and both sexes on sticky traps within the field, including other pests like whiteflies and thrips, thus reducing their numbers significantly. So, no significant damages were caused that could result in quantitative or qualitative yield losses. However, the effectiveness of the treatments (plant protection products, lures and sticky traps) in eliminating the target pests of quarantine importance (*Thrips* sp. and fruit flies, mostly *Z. cucurbitae*), which are normally intercepted in exported produce offers some hope for the farmers and the exporters to produce pest-free produce for the local market and export.

Conclusion

This study is part of the studies that have been carried out to further develop more crop and pest specific management interventions and to ascertain if the farmers are conforming to the guidelines given in the protocols and roadmap for pest reduction in exported commodities from Ghana. Therefore, among the ridged gourd insect pest management options that was studied here, Viper 46 EC® (Acetamiprid 16g/l + Indoxacarb 30g/l) reduced drastically the pest population during both cropping seasons, followed by Aqueous Neem Kernel Extract (ANKE) (Azadirachtin). Since vegetable crops are consumed fresh and have to be free of pesticide residues, Viper 46 EC®(Acetamiprid 16g/l + Indoxacarb 30g/l) being a binary synthetic insecticide could be used during the early stages of the crop until flowering, then followed by an environmentally friendly and less persistent natural insecticide such as Neem (Azadirachtin), Eradicoat T GH® (Maltodextrin 282 g/L) or Bypel® (Bkt) when the plant starts fruiting to ensure food and environmental safety. Trapping (involving both sticky and pheromone traps) can be used for monitoring and as a population suppression tool (mass trapping) by increasing the trap density, for the sustainable management of these key pests of quarantine importance on turia and other vegetables which share similar pests' spectrum to ensure harvested commodities are free from pests to enhance their export into the international markets.

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