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Managing Eggplant Fruit And Shoot Borer (Leucinodes Orbonalis (Guenée)) In Ghana:

Effect And Profitability Of Insecticides And Plastic Mulch

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Abstract

Leucinodes orbonalis is a key insect pest of garden eggs (Solanum aethiopicum) in Ghana that is generally managed by the use of harmful pesticides, necessitating the development of strategies which are more environmentally benign. This study compared the effectiveness and profitability of using black plastic mulch (PM) to manage L. orbonalis incidence with chlorpyrifos-ethyl (C-ethyl) and emamectin benzoate (EB). The PM was laid before transplanting while C-ethyl and EB were applied fortnightly up to the fruiting stage. The incidence of L. orbonalis on shoots and fruits, the percentage of infested fruits, yield, and gross margins of the treatments were determined. The incidence of plants with newly infested shoots between treatments across all treatment dates were not significant ($P > 0.05$). Between 30.41% (PM + EB) and 94.49% (PM + C-ethyl) of fruits harvested showed signs of L. orbonalis infestation. Significant differences in the percentage of infested fruits between treatments were respectively observed 12 ($P = 0.021$) and 16 ($P = 0.035$) weeks after transplanting. Plants from plots with EB as mixed (PM + EB) or sole (EB) treatment produced the highest yield over the Control of 33.6% and 30.3%, respectively. Gross margin analysis indicated that the treatment of plants with EB was most profitable at peak price. At the least price obtainable, the use of all treatments particularly, PM was not profitable. Due to the possibility that movement of larvae between fields reduced the ability of PM to effectively suppress L. orbonalis populations, future work should evaluate the effect of PM using whole fields.

Keywords: Plastic mulch, insecticides, damage, gross margin analysis, Leucinodes orbonalis

Introduction

The Eggplant Fruit and Shoot borer (EFSB) (Leucinodes orbonalis) (Lepidoptera: Crambidae) is a major insect pest of garden eggs (Solanum aethiopicum) (Solanaceae) in Ghana (Youdeowei 2002; MoFA 2011). Severe infestation by this pest can reduce garden eggs yield by up to 70% (Srinivasan 2009). Recommended non-pesticide management strategies for L. orbonalis include use of resistant cultivars or varieties, avoiding cultivation of garden eggs on the same field for more than two consecutive seasons, conservation of natural enemies, and frequent removal and destruction of infested shoots and fruits (Srinivasan 2009; MoFA 2011). The implementation of these non-chemical management practices however poses challenges to farmers. For instance, frequent removal and destruction of garden egg shoots and fruits is labour intensive and may increase cost of production. Farmers' ability to practice crop rotation and fallowing in Ghana is constrained by limited availability of suitable land in the peri-urban areas where the crop is cultivated. Moreover, in Ghana, there is no garden egg variety or cultivar resistant to L. orbonalis.

In other major production areas, notably Southern Asia, conventional breeding efforts spanning a period of over 40 years did not result in the development of any commercial variety with appreciable levels of resistance to the pest (Alam et al., 2003; Hanur 2008; Srinivasan 2008; IIVR 2013). Due to lack of success in breeding L. orbonalis resistant varieties, the focus has shifted to genetically modified (GM) insect resistant varieties (Hautea et al., 2016: Prodhan et al., 2018). In view of the limited availability of effective alternate management strategies, farmers continue to perceive chemical pesticides as the most effective means of controlling pests (Hardy 1995; Gerken et al., 2001; Yeboah 2013), relying almost exclusively on these pesticides for the management of L. orbonalis on garden eggs. A study in Ghana indicated that garden eggs farmers in the Volta Region sprayed insecticides on their crop between 16–20 times per growing season to control L. orbonalis (Boamah et al., 2017). In areas of Asia where eggplants are intensively cultivated, between 20–140 insecticide applications per growing season have been reported (BARI 1994; Alam et al., 2003; Hautea et al., 2016). The repeated use of insecticides pose several challenges such as development of resistance by the targeted pests to insecticide active ingredients, contamination of pesticide applicators, the produce, as well as the environment. These adverse effects necessitate the development of strategies that are less damaging in outcome and have more benign effects on the environment.

Ghimire & Khattiwada (2001) have suggested that manipulating the crop environment to make it unfavourable to insect pests may present an opportunity to reduce pest incidence. Newly hatched larvae of L. orbonalis are reported to use plant parts or debris deposited on the soil beneath the plant canopy as breeding/maturation media (Srinivasan 2009). The mature larva of the pest typically requires plant debris on soil surface to pupate and complete its life cycle. Therefore, manipulating the below plant environment to deny pupation may present an opportunity for mitigating intensive insecticide use on plant foliage and fruits. This study compared the effect and profitability of using black plastic mulch to manage L. orbonalis by limiting contact between larval stages and soil surface with application of chlorpyrifos- ethyl the most commonly used insecticide on garden eggs in Ghana (Asiedu 2013; Donkor et al., 2016), and emamectin benzoate, a biorational insecticide which is reported to be effective against L. orbonalis and increase yield in the native range of the pest (Anil & Sharma 2010; Anwar et al., 2015; Kumar & Devappa 2006).

Materials and Methods

The experiment was conducted at the CSIR–Plant Genetic Resources Research Institute (PGRRI), Bunso, Ghana in 2019. The set-up was under rain-fed conditions and watering was undertaken when necessary. Three 23 m × 10 m blocks were marked and cleared after which six 2 m × 10 m plots were demarcated in each block. One set of three plots in each block were randomly selected and covered with 2 m × 10 m black plastic mulch. The other set of three plots were left uncovered. Seedlings of a farmer-preferred garden egg cultivar, Dwomo were transplanted onto the prepared plots (covered and uncovered) at five weeks after germination. Transplanting on plastic mulch covered plots was done by first using pegs to mark points for planting holes in each of the three rows. A sharp blade was used to cut a 5 cm diameter ring around each peg after which a sharp cutlass with pointed edge was used to create a hole for the transplanting of seedlings. There were three rows of 10 plants per each treatment plot. A 1 m planting distance was maintained between and within rows of plants, and 1.5 m alley between adjacent plots. The experimental design was randomised complete block with three replications.

Two weeks after transplanting, all the set of black plastic mulch covered plots in the three blocks were assigned numbers. Using the numbers, one plastic-mulched plot in each block was randomly selected and left unsprayed while the other two were either sprayed with a biorational insecticide (emamectin benzoate at the rate of 250 ml/ha) or a synthetic insecticide (chlorpyrifos-ethyl at the rate of 1.4 l/ha). The same procedure was used to select bare ground plots (plots without plastic mulch) for insecticide application using the same regime. The experimental treatments were thus: Control, Plastic mulch (PM) only, Emamectin benzoate (EB), Chlorpyrifos-ethyl (C-ethyl), PM + EB, PM + C-ethyl. Each plot was well labelled and treatments (spraying) were repeated every fortnight from two weeks after transplanting until 12 weeks after transplanting. All other recommended agronomic practices for garden egg production were adhered to. Data on the incidence of ***L. orbonalis*** on 10 plants in the middle rows of each plot commenced two weeks after transplanting. The incidence of new infestation on shoots was collected before the first insecticide application, and thereafter, the incidence was recorded a week after each insecticide application. After each data collection, all infested shoots were excised with secateurs and destroyed by burying them deep in the soil. On weekly basis, the total number of fruits harvested per treatment was counted and weighed. The number and weight of damaged fruits was also recorded and expressed as a percentage of the total number and weight of the fruits assessed. Yield (tonnes/hectare) was estimated using the total weight of fruits harvested per treatment plot.

Data analysis

Data on the incidence and damage of ***L. orbonalis*** on garden egg fruits and shoots were transformed (count data = square root, percentage data arcsine, weight data = log) to normalise variances (Gomez & Gomez 1984) before being subjected to analysis of variance (ANOVA) using SPSS (version 24) statistics software (IBM Corporation, U.S.A.). Un-transformed means are however presented in Tables and in Figures. Treatment means that were significant were compared and separated using Tukey's multiple comparison test ($P = 0.05$).

Gross margin analysis

The gross margin for a crop is the difference between the revenue obtained from selling the crop and the direct costs incurred in producing the crop (Buckett 1988). Gross margins can be a quick means through which farmers can determine which technology among several alternatives they should adopt (Karen 2006). The gross margins for each treatment evaluated were calculated under two scenarios reflecting the marketing of garden egg fruits in the southern part of Ghana. The first is the sale of fruits at peak price (GH¢ 0.5 per fruit), and the second being sale of fruits at the least price (GH¢ 0.07 per fruit). The cost of the treatments was computed on a per hectare basis: emamectin benzoate GH¢ 140.00, chlorpyrifos-ethyl (mid-dose) GH¢ 100.00, plastic mulch GH¢ 140.00.

Results

With the exception of the control treatment, the incidence of new plants with infested shoots decreased after the first insecticide application. The incidence of plants with newly infested shoots recorded between the third and fifth insecticide applications were all higher than those recorded before and after the first insecticide applications. Differences in the incidence of plants with newly infested shoots between treatments across all treatment dates were not significant ($P > 0.05$) (Table 1).

Table 1. Incidence of fresh garden egg shoots infested by *Leucinodes orbonalis* larvae at Bunso

Treatment	Percentage of garden egg shoots with new infestation on different spray days (Mean±s.e)					
	Before Spray	Spray 1	Spray 2	Spray 3	Spray 4	Spray 5
Control	26.67 ± 4.02	28.33 ± 5.20	58.33 ± 3.21	70.00 ± 3.94	58.33 ± 2.81	75.00 ± 5.34
PM	33.33 ± 6.36	10.00 ± 8.22	40.00 ± 5.08	65.00 ± 6.22	56.67 ± 4.45	63.33 ± 8.45
C-Ethyl	26.67 ± 3.67	21.67 ± 4.74	51.67 ± 2.93	63.33 ± 3.60	50.00 ± 2.57	70.00 ± 4.88
EB	20.00 ± 4.50	11.67 ± 5.81	46.67 ± 3.59	66.67 ± 4.40	61.67 ± 3.15	66.67 ± 5.97
PM+EB	23.33 ± 9.00	8.34 ± 11.62	45.00 ± 7.18	50.00 ± 8.80	55.00 ± 6.29	60.00 ±11.94
PM+C-ethyl	20.00 ± 5.19	13.33 ± 6.71	46.67 ± 4.14	76.67 ± 5.08	65.00 ± 3.63	68.33 ± 6.90
F	0.389	1.123	0.929	0.643	1.032	0.203
P	0.847	0.399	0.496	0.672	0.442	0.955

Garden egg fruits were ready for harvesting nine weeks after transplanting (WAT). Due to the low number of fruits available, the fruits harvested between nine (9) and 11 WAT were pooled together. This also enabled the fruits harvested between insecticide applications to be separated from those harvested after the last insecticide application was made at 11 WAT. More fruits were harvested from EB only, PM + EB, and PM + C-ethyl treated plots than from Control plots on all harvest dates (weeks) (Figure 1). Differences in the number of fruits harvested between treatments on all harvest dates were not significant ($P > 0.05$).

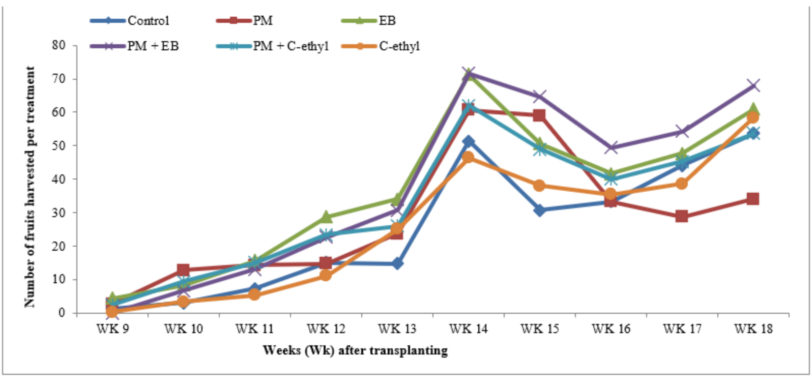

Figure 1: Number of garden egg fruits harvested from plots with different pest/crop management treatments at Bunso

Between 30.41% (PM+EB) and 94.49% (PM+C-ethyl) of fruits harvested showed signs of ***L. orbonalis*** infestation. The least proportion of infested fruits was harvested in between insecticide applications, while the highest proportion of infested fruits was harvested five weeks after the last insecticide application was made at 11 WAT (Table 2). Significant differences in the percentage of fruits infested between treatments were observed 12 WAT ($F_{(5,12)}$ = 4.115; P = 0.021) and 16 WAT ($F_{(5,12)}$ = 3.55; P = 0.035). Differences on all other dates, including 17 and 18 WAT (data not shown) were not significant (P >0.05).

Table 2. **Weekly incidence of Leucinodes orbonalis damage on garden egg fruits at Bunso**

Treatment	Mean (± SEM) garden egg fruit infestation (%) on different dates					
	11 WAT*	12 WAT	13 WAT	14 WAT	15 WAT	16 WAT
Control	72.96 ± 8.54	41.71 ± 3.04ab	52.08 ± 4.60	86.64 ± 5.91	82.72 ± 4.65	79.65 ± 2.05b
PM	41.48 ±13.50	74.58 ± 4.81a	44.59 ± 7.28	81.63 ± 9.35	86.58 ± 7.35	88.75 ± 3.24a
C-Ethyl	65.87 ± 7.79	38.83 ± 2.78b	51.23 ± 4.20	72.69 ± 5.40	91.28 ± 4.24	86.86 ± 1.87b
EB	55.00 ± 9.54	58.44 ± 3.40ab	69.89 ± 5.15	76.02 ± 6.61	80.31 ± 5.20	82.45 ± 2.29b
PM+EB	30.41 ±19.09	49.11 ± 6.80ab	56.69 ± 10.29	75.69 ± 13.22	76.84 ± 10.39	86.40 ± 4.58a
PM+C-ethyl	50.83 ±11.02	56.63 ± 3.93ab	56.21 ± 5.94	77.08 ± 7.63	84.22 ± 6.00	94.49 ± 2.65a
F	0.866	4.115	0.834	0.835	0.948	3.55
P	0.531	0.021	0.550	0.550	0.485	0.034

*** Harvest made during insecticide application**

The mean number of exit holes per infested fruit ranged from 1.3 (Control) to 2.32 (C-ethyl). Differences in the number of exit holes per fruit between treatments was not significant ($F_{(5,12)}$ =1.664; P =0.218) (Table 3). There was weak negative correlation (r= –0.40) between weight per fruit and number of exit holes per fruit.

Table 3. Some garden egg fruit and *Leucinodes orbonalis* damage characteristics

Treatment	Mean number of exit holes per fruit	Percentage by weight of infested fruits	Weight per fruit (g)
Control	1.32 ± 0.04	66.52 ± 6.11	40.00 ± 0.02a
PM	1.93 ± 0.06	67.51 ± 9.67	40.00 ± 0.04a
C-Ethyl	2.32 ± 0.04	66.72 ± 5.58	30.00 ± 0.02b
EB	1.87 ± 0.05	64.29 ± 6.84	40.00 ± 0.03a
PM+EB	1.83 ± 0.09	53.78 ± 13.67	36.96 ± 0.05ab
PM+C-ethyl	1.95 ± 0.05	66.64 ± 7.89	37.00 ± 0.03ab
F	1.664	0.181	4.713
P	0.218	0.965	0.013

Yield obtained from treatment plots ranged from 1.52 t/ha to 2.29 t/ha. The yield obtained from plots treated with EB only, PM + EB and PM + C-ethyl were higher than that obtained from Control plots and plots treated with PM only or C-ethyl only (Figure 2).

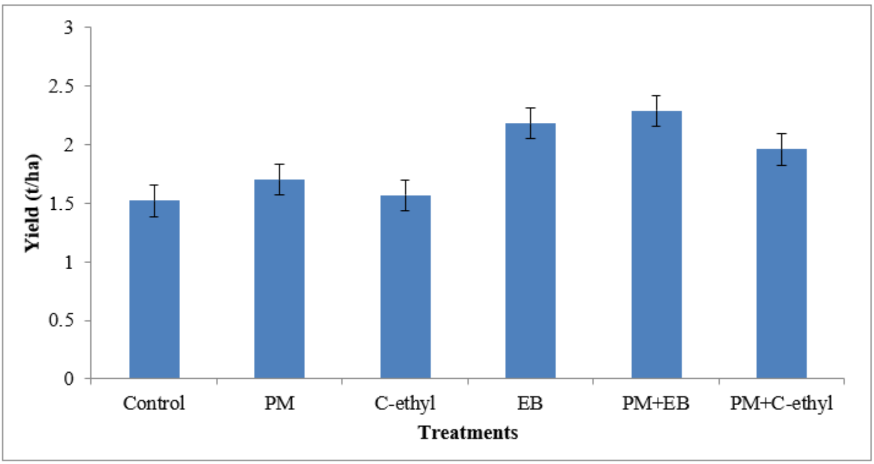

Figure 2: Yield of garden egg plants cultivated under different pest/crop management treatments at Bunso Table 4 indicates the gross margins associated with the cultivation of garden eggs using the different treatments evaluated in this study. The gross margins consider

two marketing scenarios, the first being sale of fruits at peak price (Scenario A), and the second being sale of fruits at the least price obtainable (Scenario B). Using scenario A, cultivation using all treatments was profitable although the highest yield was obtained from PM + EB plots, with the highest benefit cost ratio (BCR) of 2.48 obtained for control plots on bare ground. The least BCR of 1.54 was obtained in PM + C-ethyl treated plots (Table 4). Under scenario B, cultivation using all treatments was associated with negative returns. The highest negative returns were obtained from plots with plastic mulch, either as sole or as co-treatment (Table 4).

Table 4. **Gross margins associated with the cultivation of garden eggs under different pest/crop management treatments at Bunso**

Activity/item	Cost (GH¢) per hectare of treatment					
	Control (Bare ground)	Plastic mulch (PM)	Chlorpyrifos-ethyl (C-ethyl)	Emamectin Benzoate (EB)	PM + C-ethyl	PM + EB
Yield (t/ha)	1.52	1.70	1.57	2.18	1.96	2.29
Gross income A[1]	21,708.90	24,279.69	22,423.01	31,135.13	27,993.05	32,706.17
Gross income B [2]	3,040.00	3,400.00	3,140.00	4,360.00	3,290.00	4,580.00
Variable costs						
Land preparation[3]	260.38	3,655.20	260.38	260.38	3,655.20	3,655.20
Field establishment[4]	251.43	251.43	251.43	251.43	251.43	251.43
Insecticide costs[5]	0.00	0.00	968.57	1,008.57	968.57	1,008.57
Fertilizer costs[6]	2,916.52	2,916.52	2,916.52	2,916.52	2,916.52	2,916.52
Weeding (4x)	1,215.24	0	1,215.24	1,215.24	0.00	0.00
Harvesting (8x)	1,453.33	1,620.95	1,495.24	2,076.19	1,862.86	2,177.14
Total variable costs (TVC)	6,096.95	8,444.10	7,107.38	7,728.33	9,654.58	10,008.86
Gross margin A	15,611.95	15,835.54	15,315.59	23,406.75	18,338.42	22,697.26
Gross margin B	-3,056.95	-5,044.15	-3967.43	-3,368.33	-6,364.63	-5,428.91
Fixed costs						
Cutlass	45.00	45.00	45.00	45.00	45.00	45.00
Knapsack sprayer	0.00	0.00	1200.00	1200.00	1200.00	1200.00
Wellington boot	50.00	50.00	50.00	50.00	50.00	50.00
Harvesting sacks	50.00	50.00	50.00	50.00	50.00	50.00
Total fixed costs	145.00	145.00	1345.00	1345.00	1345.00	1345.00
Total cost	6,241.95	8,589.10	8,452.38	9,073.33	10,999.58	11,353.86
Net Return A	15,466.95	15,690.54	13,970.59	22,061.75	16,993.42	21,352.26
Net Return B	-3,201.95	-5,189.15	-5,312.43	-4,713.33	-7,709.63	-6,773.91
Benefit Cost Ratio (BCR) A	2.48	1.83	1.65	2.43	1.54	1.88

[1]Based on an estimate of the value of harvest at peak price of GH¢ 14,282.17 x yield obtained
[2]Based on an estimate of the value of harvest at least price of GH¢ 2,000.00 x yield obtained
[3] Land clearing + leveling + cost of plastic mulch + cost of laying mulch [4]Cost of seeds + transplanting
[5]Insecticide product + cost of application (applied 5x); [6]NPK+ foliar fertilizer + application costs (applied 5x)

Discussion

The infestation by ***Leucinodes orbonalis*** in this study did not reflect any clear pattern. A similar observation was made by Shukla & Khatri (2010) who reported that the population of ***L. orbonalis*** fluctuated to a very high degree from one month to the other. None of the treatments evaluated was effective in significantly reducing ***L. orbonalis*** damage in all the sampling weeks. Relative to fruits harvested during insecticide application, the percentage of infested fruits harvested two weeks after cessation of insecticide application in all treatments was markedly higher, exceeding 75% of harvested fruits. Duodu (1986) reported that infestation of fruits by ***L. orbonalis*** is comparatively higher in local cultivars of eggplant than improved varieties. Chakraborti & Sarkar (2011) have observed that the application of effective pest management strategies at the initiation of ***L. orbonalis*** infestation prevents a build-up of heavy populations of the pest. In the current study, it appears that the high susceptibility of the local cultivar coupled with the treatment application at two-week intervals, was ineffective, and may have resulted in a build-up of the population which carried over to the fruiting stage. Results of previous studies suggest that extending insecticide application beyond the fruiting period is critical for achieving significant reduction in damage by ***L. orbonalis*** (Latif ***et al***., 2009; Mochiah ***et al***., 2011; Owusu 2011).

Compared to the estimated 8.0 t/ha and 15.0 t/ha average yield and achievable yield, respectively of garden eggs in Ghana, the yields obtained in this experiment were significantly lower. This could be as a result of the farmer-saved seeds (recycled) used in the experiment. According to Schippers (2000), the yield of garden egg plants raised from certified or improved seeds is between 100–150% higher than that obtained from using farmer-saved seeds. Additionally, the low yield obtained could be due to the short harvesting period (9–18 WAT), as harvesting of marketable fruits has been reported to extend beyond 30 WAT (Obodji ***et al***., 2015). In contrast to the results of shoot and fruit damage, all the treatments evaluated in the study had a yield advantage over the Control. Plants from plots with emamectin benzoate treatment either as a mixed (PM+EB) or sole (EB) treatment produced the highest yield of 33.6% and 30.3%, respectively over the Control. The observed yield advantage obtained from EB treated plots is consistent with the results of previous studies (Sharma & Srivastava 2010; Shah ***et al***., 2012; Dey 2019). The efficacy of EB as a co-treatment with Neem Seed Kernel Extract (NSKE) and Cartap hydrochloride has been reported by Chakraborti & Sarkar (2011) and Dey (2019). With respect to plastic mulch, AVRDC (2012) reported that the use of plastic mulch following seedbed preparation with organic manure resulted in more fruit production. This may account for the yield advantage of PM over the Control and the C-ethyl treatments.

One of the main determinants of the prices of garden egg fruits in Ghana is the season (GIDA ***et al***., 2004). In the study area, personal interaction with farmers revealed that the peak price was attainable in December. The highest gross income in the current study was obtained through the application of EB to plants in plastic mulch plots during periods of peak market value. Due to high production costs associated with the use of the plastic mulch and application of insecticides, the BCR of cultivating garden eggs on bare ground (Control) was higher than that obtained from all other treatment plots. The use of plastic mulch as a co-treatment significantly increased production costs. Thus, treatments with plastic mulch were the most unprofitable at low price. This reflects the findings of Horna ***et al***. (2007) which indicated that while gross margins for garden egg production in Ghana indicate that the cultivation of the crop can be a profitable activity, there is also the potential for negative returns. The use of plastic mulch has been shown to facilitate plant growth and lead to early flowering and fruiting (Kotey ***et al.,*** 2018). This may be due to better soil moisture conservation during dry conditions as those that prevail during most of the minor or dry seasons in most parts of Ghana. It is therefore possible that in areas of high water stress, the laying of plastic mulch may result in good plant growth and an increased yield. This together with higher savings on labour for frequent irrigation may increase incomes associated with plastic mulch use.

The most important damage by ***L. orbonalis*** on garden eggs is the feeding activity of the larvae in fruits which renders them unmarketable and unfit for human consumption (Hautea ***et al.,*** 2016; Srinivasan 2009). In this study, the application of C-ethyl up to the beginning of fruiting did not confer any significant advantage over the Control treatment in terms of yield or reducing the incidence and damage of ***L. orbonalis***. Similarly, the use of C-ethyl was less profitable under all scenarios compared to the Control, EB and plastic mulch treatments. Similar results of the lack of efficacy of C-ethyl have been previously reported (Latif ***et al***., 2010; Anwar ***et al***., 2015; Niranjana ***et al***., 2017). Srinivasan (2009) reported that the best approach for the effective management of ***L. orbonalis*** is through the combination of several tactics in an IPM programme. In Ghana, C-ethyl is sprayed as many as 16 to 20 on eggplant from transplanting up to the fruiting stage (Donkor ***et al***., 2016; Boamah ***et al***., 2017). Chropyrifos is highly persistent (AVRDC 1999). While the residues of biorational insecticides such as emamectin benzoate can degrade quickly, those of synthetic insecticide active ingredients such as chlorpyrifos can persist over a number of days. Angioni ***et al.*** (2011) reported that repeated application of chlorpyrifos can result in accumulation, leading to residue levels above Maximum Residue Levels (MRLs) even after the pre-harvest interval (PHI). The PHI of the chlorpyrifos product used in this study is 15 days, farmers in Ghana however harvest garden egg fruits twice a week (Horna ***et al***., 2007), which is more than 11 days before the recommended PHI. Due to the fact that garden egg fruits may be eaten fresh or with little processing, the risks of exposure of consumers to toxic residues is very high. Persistence of an insecticide in the environment also facilitates resistance development in target pests. ***Leucinodes orbonalis*** is reported to have a remarkable ability to develop resistance to many synthetic insecticides including chlorpyrifos (Dittrich ***et al***., 1985; Prabhaker ***et al***., 1995; Shirale ***et al***., 2017). While there is no report of ***L. orbonalis*** resistance to chlorpyrifos in Ghana, previous studies have reported resistant populations of the diamond back moth (***Plutella xylostellai***), a lepidopteran pest of cabbage which is frequently targeted with chlorpyrifos in Ghana (Kaiwa 2000; Odhiambo 2005). According to Thompson (2004), when an insecticide loses its efficacy against an insect pest, farmers try to compensate for the loss of efficacy by increasing the application frequency and dosage, thus setting up a positive feed-back loop in which intensive pesticide use brings about increased resistance development, more pest situations, and environmental contamination.

Conclusion

The application of chlorpyrifos ethyl and emamectin benzoate every two weeks did not result in any significant reduction to Leucinodes orbonalis damage to fruits and shoots of garden eggs. The use of emamectin benzoate or plastic mulch as sole or co-treatments resulted in a yield advantage over Control and chlorpyrifos only treated plots. While treatments with plastic mulch were among the most profitable at peak price of garden eggs, high production costs associated with the use of plastic mulch made them the least profitable at low prices. Given the results obtained with plastic mulch, future work should evaluate the effect of plastic mulch using whole fields. This will reduce the possibility for the movement of L. orbonalis larvae and adults between plots. The use of insecticide products with chlorpyrifos as an active ingredient is a common feature in all garden egg production areas of Ghana. Results of this study and that of others indicate that while the continued use of chlorpyrifos confers no advantage over control plots, it poses significant risks to consumers and the environment. Increasing farmer and consumer awareness as well as research and policy formulation to promote more benign alternatives will improve the economic and environmental sustainability of garden egg production.

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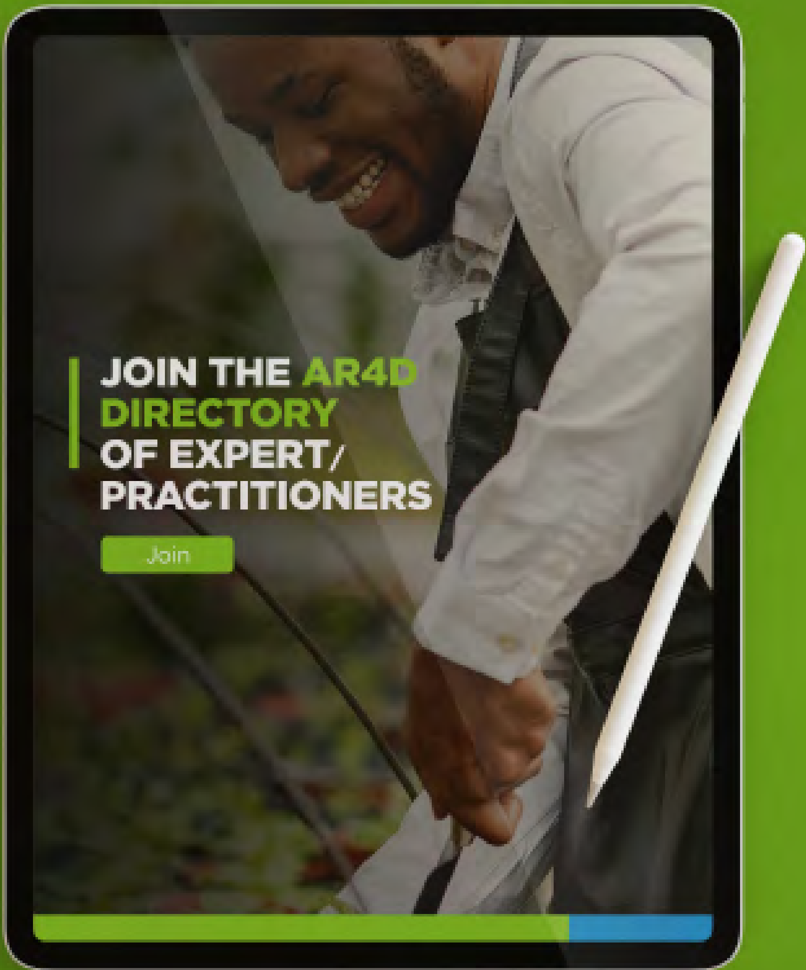

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