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EFFICACY OF SOME SYNTHETIC INSECTICIDES FOR CONTROL OF COTTON BOLLWORMS IN NORTHERN GHANA

K.B. BADII and S.K. ASANTE[1]
Department of Agronomy, University for Development Studies, P. O. Box TL 1882, Tamale, N/R, Ghana
[1]CSIR-Savanna Agricultural Research Institute, P. O. Box TL 52, Tamale, N/R, Ghana
Corresponding author's email address: benbadii@yahoo.com

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ABSTRACT

Lepidopteran bollworms are a major constraint to increased and sustainable production of cotton in the savanna ecology. Studies were conducted at the Experimental Farms of the University for Development Studies, Nyankpala in northern Ghana, during the 2009 cropping season to evaluate the effects of three commonly used insecticide formulations, namely, Betsulfan and Endosulfan (each at 3.2, 3.5 and 3.9 l ha^{-1}), and Thionex (at 2.3, 2.5 and 2.8 l ha^{-1}), on the population density and damage incidence of the bollworm complex, and their effects on the yield of cotton. The incidence and abundance of bollworms were significantly ($P < 0.05$) affected by the different insecticide treatments. Bollworm infestation in all treated plots was significantly reduced. Among the insecticide treatments, Thionex at 2.8 l ha^{-1} was the most effective. This was followed by that of Betsulfan at 3.9 l ha^{-1}, Betsulfan or Endosulfan (each at 3.2 l ha^{-1}) recorded the highest infestation. Lint seed yield of cotton also increased significantly with increased concentrations of the insecticides, Thionex at 2.8 l ha^{-1} and Betsulfan at 3.2 l ha^{-1} recorded the highest and lowest yields, respectively. For effective control of cotton bollworms for maximum yield in the ecology, Thionex applied at 2.8 l ha^{-1} is recommended.

Key Words: Diparopsis watersi, Helicoverpa armigera, Gossypium

RÉSUMÉ

Les chenilles constituent une contrainte majeur à l'augmentation et à la production durable du coton dans l'écologie de la savane du Ghana. Des études étaient menées en Fermes Expérimentales de l'Université pour Etudes Développementales, Nyankpala au Nord du Ghana, durant la saison pluvieuse 2009, pour évaluer les effets de trois formulations d' insecticides communément utilisées, à savoir, Betsulfan et Endosulfan (chacun à 3.2, 3.5 et 3.9 l ha^{-1}), ainsi que Thionex (à 2.3, 2.5 et 2.8 l ha^{-1}) sur la densité de populationon et l'incidence de dommage du complexe de chenille, et leurs effets sur le rendement du coton. L'incidence et l'abondance des chenilles étaient significativement ($P<0.05$) affectées par les différents traitements d'insécticides. L'infestation de la chenille dans toutes les parcelles traitées avec insecticides était significativement réduite. Parmi les traitements d'insecticides, Thionex à 2.8 l ha^{-1} était le plus efficace. suivi par les traitements de Betsulfan (3.9 l ha^{-1}), Betsulfan ou Endosulfan (chacun à 3.2 l ha^{-1}) avec une infestation la plus élevée. Le rendement en fibre du coton a aussi augmenté significativement avec l'augmentation des concentrations des insecticides. Le Thionex (2.8 l ha^{-1}) avait induit des rendements les plus élevés pendant que les parcelles avec Betsulfan (3.2 l ha^{-1}) avient produit des rendements les plus basses. Afin de mieux contrôler les chenilles du coton pour un rendement maximum dans lécologie, le Thionex appliqué à 2.8l ha^{-1} est le plus recommendé.

Mots Clés: Diparopsis watersi, Helicoverpa armigera, Gossypium

INTRODUCTION

Cotton, *Gossypium* spp (Malvaceae) is an important industrial fibre crop widely cultivated along the Guinea savanna and derived savanna zones of West Africa (Hill and Waller, 1988; Matthews, 1989; Langer and Hill 1991). In the savanna ecology of Ghana, lepidopteran bollworms are a major constraint to the increased and sustainable production of cotton (Kumar, 1983; Obeng-Ofori, 2007). Among the most serious species of bollworms infesting cotton are the red bollworm, *Diparopsis watersi* Roths (Lepidoptera: Noctuidae), the African bollworm, *Helicoverpa armigera* Hu¨bner (Lepidoptera: Noctuidae), the pink bollworm, *Pectinoptera gossypiella* Saund (Lepidoptera: Gelechiidae), the spiny bollworm, *Earias insulana* Boisd. (Lepidoptera: Noctuidae) and the false codling moth, *Cryptophlebia leucotreta* Meyr. (Lepidoptera: Tortricidae) (Obeng-Ofori, 2007; Brevault *et al*., 2009). These species generally constitute the bollworm complex of cotton in sub-saharan Africa (Renou and Deguine, 1992). Losses caused by these pests are as high as 60% in unprotected fields (Hill, 1987; Salifu, 1996).

Most cotton growers in Ghana and neighbouring countries rely on the use of synthetic chemical insecticides such as Endosulfan, Betsulfan and Thionex, which are usually provided by their contracted companies, for the control of bollworms and other pests in cotton farms. These insecticides are known to be biorational, with no crossresistance with other compounds; and also, complement integrated pest management strategies (Fitt *et al*., 2004; Horowitz and Ishaaya, 2004). Recent studies have, however, shown that these insecticides do not usually provide satisfactory results in field efficacy (Abdulai *et al*, 2006). Average seed and lint yields are as low as 800 kg ha^{-1} compared to the world's average of 1,200 kg ha^{-1} (FAO, 1998; Salifu, 1996; Abdulai *et al*., 2006).

Since cotton yields in Ghana are greatly influenced by successful control of bollworms using these insecticides (Obeng-Ofori, 2007; Abdulai *et al*., 2006), the inherent low yield of cotton in the savanna ecology could be attributed to inappropriate choice and dosage of the insecticide formulations applied. Vaissayre *et al*. (2006) observed that proper selection and rate of applications are critical to achieving efficacy and optimising the cost and effectiveness of synthetic insecticides. While field efficacy of some insecticides in controlling bollworms has been achieved (Brickle *et al*., 2001), reports from IPM Farmers' Field Schools in northern Ghana have shown that recommended rates of the commonly used insecticides, supplied in the manufacturers' labels, do not usually provide the expected economic returns for cotton (Akaste *et al*., 1999, Abdulai *et al*, 2006). This has called for the need to evaluate the formulations and application rates of these insecticides so as to provide more comprehensive chemical control interventions for the major field pests of cotton. This study sought to determine the most effective formulation and application rate of three commonly used insecticides in control of the bollworm complex of cotton in the savanna ecology of Ghana.

MATERIALS AND METHODS

The study was conducted during the 2009 cropping season at the Experimental Farms of the University for Development Studies, Nyankpala in the northern guinea savanna agro-ecological zone of Ghana. The farm is located at183 metres above sea level, 9º252 413 N and 0º582 423 W. It receives 500-900 mm rainfall.

Treatments included the different insecticide formulations laid out as follows: (i) Endosulfan at 3.2 l ha^{-1} (10% below the recommended rate); (ii) Endosulfan at 3.5 l ha^{-1} (the recommended rate); (iii) Endosulfan at 3.9 l ha^{-1} (10% above the recommended rate); (iv) Betsulfan at 3.2 l ha^{-1} (10 % below the recommended rate); (v) Betsulfan at 3.5 l ha^{-1} (the recommended rate); (vi) Betsulfan at 3.9 l ha^{-1} (10% above the recommended rate); (vii) Thionex at 2.3 l ha^{-1} (10% below the recommended rate); (viii) Thionex applied at 2.5 l ha^{-1} (the recommended rate); (ix) Thionex applied at 2.8 l ha^{-1} (10% the above recommended rate); and (x) Control (check, sprayed with water).

The field was laid out in the randomised complete block design. Plots measured 20 m x 15 m with inter- and intra- row spacing of 80 cm x 30 cm, respectively. A one metre border was allowed between the plots so as to avoid spray drifts to adjacent plots. The treatments were applied at 10 days intervals beginning from 52 days (i.e. 7 weeks) after planting using the battery-operated electrodyn sprayer. Spraying was done at 52, 62, 72 and 82 days after planting. On each spraying occasion, all plants under each treatment were sprayed until complete coverage or wetting was achieved.

The improved, early maturing and high yielding cotton variety (Sarcot 1) obtained from the Plant Breeding Unit of the Savanna Agricultural Research Institute (SARI) was used for planting. Sowing was done on the 3rd week of July, 2009, a time of the season generally considered most appropriate for covering the peak incidence of the bollworm complex of the cotton crop in the ecology (Tanzubil, 1991; Abdulai *et al*., 2006). A maximum of 4-5 seeds were sown per hill and later thinned to two plants per stand at one week after germination.

Sampling for the infestations of the different bollworm species was done using the diagonal method to take record of the incidence (proportion of squares and bolls infested) and the abundance (population density of bollworm species observed on the plants) (Wilson *et al*., 1989; Beyo *et al*., 2004). The target pests included the larval forms of *D. watersi*, *H. armigera*, *P. gossypiella*, *C. leucotreta* and *E. insulana* which were the most prevalent bollworm species in the field. Each plot was sampled two days after each spray application, beginning from flowering to boll maturity or opening. For each plot, a set of 50 plants evenly spaced along the two diagonals of the plot was evaluated. Only bollworm larvae were recorded and this was done separately on each plant.

Between 120 and 150 days after planting, all mature open bolls were harvested by hand-picking of the seed lint from the plants. Cotton yield (seed lint) per plot was then weighed, and the results obtained extrapolated to kilogrammes per hectare for each treatment. The data obtained were subjected to the Analysis of Variance (ANOVA) using the GENSTAT Discovery Edition 3 software (http://www.discovery. genstat.co.uk). Where there were significant differences among treatments, the Least Significant Difference (LSD) test was used to separate the means at 5% level of significance.

RESULTS

Incidence of bollworms on cotton squares. There were significant differences among treatment means ($P < 0.05$) in bollworm damages on cotton squares (Table 1). A higher number of squares was infested in the control plot than in the insecticide-treated plots. Among the insecticide treatments, Thionex recorded the lowest infestation; followed by those of Betsulfan. In contrast, Endosulfan recorded the highest infestation. Also, bollworm infestation decreased with increasing concentration of the insecticides.

TABLE 1. Effects of insecticide formulations on the incidence of bollworms on cotton squares in Northern Ghana

Treatments (l ha^{-1})	Squares per sample n = 7	Infested squares	Proportion (%) of squares infested
Control	56	22	39.5
Endosulfan at 3.2	80.5	11	13.8
Endosulfan at 3.5	78.3	9.3	12.2
Endosulfan at 3.9	84.7	8.7	10
Betsulfan at 3.2	79.2	9.2	11.7
Betsulfan at 3.5	84.7	7.8	9.3
Betsulfan at 3.9	89.2	7.3	8
Thionex at 2.3	88.3	7.7	9
Thionex at 2.5	84.8	6.7	7.7
Thionex at 2.8	89	6	6.9
LSD (0.05)	8.58	1.62	2.97

n = number of plants sampled

Differences between Betsulfan at 3.2 l ha^{-1} and Thionex at 2.3 l ha^{-1} were not statistically significant ($P > 0.05$). Overall, Thionex applied at the rate of 2.8 l ha^{-1} gave the best control of bollworms in squares (~ 90% control).

Abundance of bollworm species on cotton squares. The abundance of the different bollworm species on cotton squares under the different insecticide applications is presented in Table 2. There was a significant difference in population of *D. watersi* on the squares due to insecticide treatment ($P < 0.001$). However, no differences were observed among the insecticide treatments. The exception in this case was with *H. Armigera* themselves ($P < 0.05$). Generally, *H. armigera* numbers were higher in plots treated with Endosulfan at 3.2 l ha^{-1}, Betsulfan at 3.2 and 3.5 l ha^{-1} as well as Thionex at 2.3 l ha^{-1}, than in Thionex at 2.8 l ha^{-1} which recorded the lowest infestation.

Also, the population of *P. gossypiella* recorded on the control plot was significantly higher than for any of the insecticide treatments ($P < 0.001$). Moreover, significant differences existed among the insecticide treatments, with plots treated with Thionex at 2.5, and 2.8 l ha^{-1} recording the lowest number of *P. Gossypiella*, while higher numbers were recorded on plots treated with Betsulfan at 3.2 , 3.5 and Endosulfan at 3.2 l ha^{-1}. In the case of *E. insulana*, there were no significant differences among the insecticide-treated plots, even though Betsulfan at 3.5 l ha^{-1} and Thionex at 2.3 or 2.8 l ha^{-1} recorded the highest and lowest infestations, respectively. Overall, among the insecticide-treated plots, *E. insulana* was the most dominant bollworm species, followed by *P. gossypiella* and *H. armigera*, with *D. watersi* being the least abundant.

Incidence of bollworms on cotton bolls. The effects of the test insecticides on the incidence of the bollworm species on the developing bolls of cotton is presented in Table 3. Pesticide treatment had a significant effect on bollworm incidence ($P < 0.001$). Endosulfan applied at 3.5 and 3.2 l ha^{-1} had the highest and lowest number of infested bolls, respectively. Although there were no significant differences observed in the proportion of infested bolls among the insecticide-treated plots, Thionex applied at 2.5 or 2.8 l ha^{-1} tended to provided the best protection from boll infestation.

Abundance of bollworm species on cotton bolls. The number of *D. watersi* on the cotton bolls was significantly affected by the insecticide treatments ($P < 0.05$). Cotton plants sprayed with Endosulfan at 3.5 l ha^{-1} recorded significantly higher number of bollworms than those sprayed with Thionex at 2.8 l ha^{-1}; whereas the rest of the insecticide treatments did not show significant differences. *Helicoverpa armigera* population was highest on the control plots followed by plots treated with Endosulfan at 3.2 l ha^{-1}. Plots treated

TABLE 2. Effect of insecticide formulations on the abundance of bollworms on cotton squares in Northern Ghana

Treatments (l ha^{-1})	Squares per sample	Number of *D. watersi*	Number of *H. armigera*	Number of *P. gossypiella*	Number of *E. insulana*	Total number of boll worms
Control	56	3	4.5	5.2	6.8	19.5
Endosulfan at 3.2	80.5	1.1	1.8	2.3	2.3	7.7
Endosulfan at 3.5	78.3	1.5	1.7	1.7	2.3	7.2
Endosulfan at 3.9	84.7	0.6	1.3	1.5	2	5.5
Betsulfan at 3.2	79.2	1.7	1.8	2.5	2.7	8.6
Betsulfan at 3.5	84.7	0.8	1.8	2.3	3	8.3
Betsulfan at 3.9	89.2	0.6	1.2	1.7	2.2	5.5
Thionex at 2.3	88.3	0.5	1.8	1.8	2	6.2
Thionex at 2.5	84.8	0.3	1.5	0.8	2.2	5
Thionex at 2.8	89	0	0.5	0.7	2	2.8
LSD (0.05)	8.58	2.01	0.01	0.85	1.15	2.39

with Thionex at 3.2 l ha^{-1} and 2.8 l ha^{-1} recorded the lowest population. There was no strong insecticide effect on *P. gossypiella* ($P > 0.05$). However, all the insecticide treatments showed some levels of efficacy, with Thionex at 2.8 l ha^{-1} being superior and Endosulfan at 3.2 l ha^{-1} performing the least.

Also, the mean number of *E. insulana* was significantly affected by the treatments. Endosulfan at 3.2 l ha^{-1} and 3.5 l ha^{-1} recorded the highest mean number of *E. insulana* among the insecticide treatments, whereas plots treated Thionex had the lowest. *E. insulana*, again appeared to be the most dominant bollworm species infesting the cotton bolls. Among the test insecticides, the highest and lowest population of bollworms was recorded in plots treated with Endosulfan at 3.2 l ha^{-1}, and Thionex at 2.8 l ha^{-1}, respectively (Table 4).

Effect of the insecticides on the yield. Figure 1 shows the effects of the different insecticide treatments on the seed lint yield of cotton. Cotton yield was significantly different among the insecticide treatments ($P < 0.001$). Cotton plots treated with Betsulfan or Endosulfan at 3.2 l ha^{-1} recorded relatively low yield. On the other hand, plots treated with Thionex at 2.3 l ha^{-1}, 2.5 l ha^{-1} and 2.8 l ha^{-1} produced the maximum seed yields of cotton. Overall, all insecticide treatments above the recommended rates recorded higher yields than those treated at or below the recommended

TABLE 3. Effect of insecticide formulations on the incidence of bollworms on cotton bolls in Northern Ghana.

Treatment (l ha^{-1})	Number of plants per sample	Number of bolls per sample	Number of infested bolls	Proportion (%) of bolls infested
Control	7.7	64.3	13.8	39.7
Endosulfan at 3.2	7	69	1.2	5.7
Endosulfan at 3.5	7.5	74.2	3.5	5
Endosulfan at 3.9	7.7	77.3	2.7	3.7
Betsulfan at 3.2	7.7	79.3	2.7	3.8
Betsulfan at 3.5	7.3	80.8	2.3	3.3
Betsulfan at 3.9	7.7	89	1.5	2.3
Thionex at 2.3	7.7	91	2.2	2.3
Thionex at 2.5	7.7	54.5	1.7	1.8
Thionex at 2.8	7.3	65.3	1.3	1.7
LSD (0.05)	0.81	16.88	1.77	4.53

TABLE 4. Effect of insecticide formulations on the abundance of bollworms on cotton bolls in Northern Ghana

Treatments (l ha^{-1})	Plants per sample	Bolls per sample	Number of *D. watersi*	Number of *H. armigera*	Number of *P. gossypiella*	Number of *E. Insulana*	Total number of bollworms
Control	7.7	64.3	3	3.8	6	6.7	19.5
Endosulfan at 3.2	7	69	1.3	2.3	2.7	2.7	9
Endosulfan at 3.5	7.5	74.2	0.8	1.3	2.2	2.3	6.7
Endosulfan at 3.9	7.7	77.3	0.3	0.8	1.5	1.8	4.5
Betsulfan at 3.2	7.7	79.3	1.3	1.3	2.2	2	6.8
Betsulfan at 3.5	7.3	80.8	0.5	0.7	1.7	2	4.8
Betsulfan at 3.9	7.7	89	0.2	0.7	1.2	1.5	3.7
Thionex at 2.3	7.7	91	0.5	1.2	1.3	0.5	4.7
Thionex at 2.5	7.7	54.5	0.2	0.5	0.5	1	2.3
Thionex at 2.8	7.3	65.3	0	0.3	0.3	0.2	1
LSD (0.05)	0.81	16.88	0.72	0.8	0.77	0.96	2.25

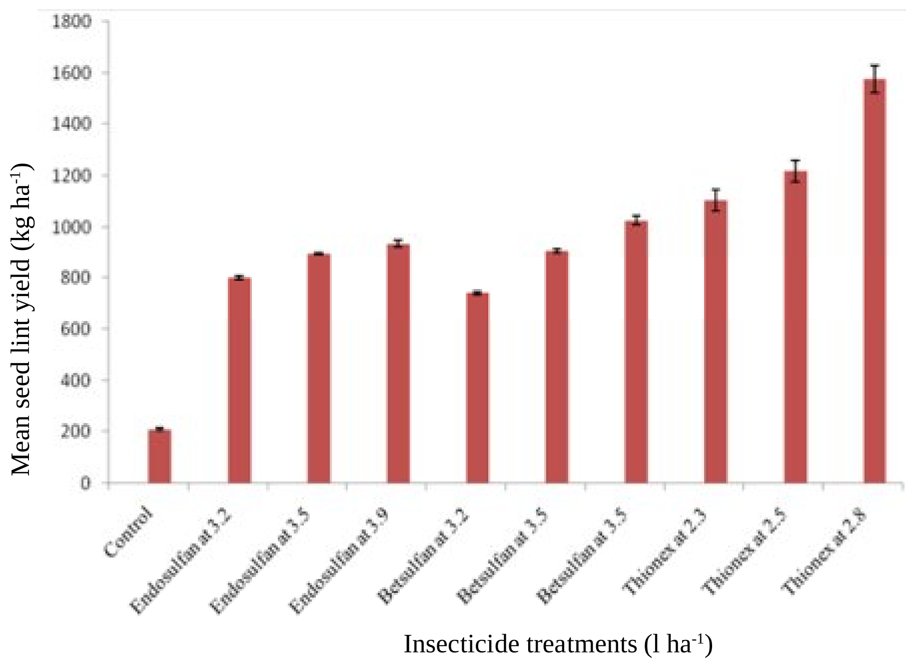

Figure 1: The effects of insecticide formulations on the seed lint yield of cotton in Northern Ghana.

rates. However, the variations in yield among the different rates within each insecticide, in most cases, did not differ significantly.

DISCUSSION

The results of this study have shown that the insecticide formulations applied have a dose-dependent effect on bollworm incidence and abundance, and on cotton yield. Thionex and to a lesser extent, Betsulfan and Endosulfan showed good efficacy against the bollworm complex. However, Thionex was more effective against bollworm larvae than Betsulfan and Endosulfan. Several factors affect insecticide efficacy on leaf surface, the most important being insecticide persistence, foliage growth and the prevailing weather conditions during and after application (Mulrooney and Elmore, 2000). Long persistence could be explained by systemic properties that protect the active ingredient against environmental constraints. Thionex is a systemic poison which is translocated through the plant sap and this possibly delayed its degradation under field conditions. Endosulfan and Betsulfan, on the other hand, are contact and stomach poisons with lower adhesive properties (Brevault *et al*., 2009). They penetrate leaf tissues by translaminar movement (Tomlin, 2003). Hence, active ingredients such as endosulfan and betsulfan probably showed low persistence and thus, low efficacy as compared with thionex.

Additionally, foliage growth not only dilutes non-systemic insecticide deposits on the leaf surface (Wilson *et al*., 1983) but also results in new leaves as insecticide-free refuges to insects which could decrease the mean efficacy of the insecticides. Rainfall, temperature and sunlight intensity could also be responsible for insecticide degradation under field conditions, but our experiment could not be conducted in controlled environment to check this effect.

The results also showed that insecticide dosages above the recommended rates, in most cases, registered significantly higher efficacy than those at or below the recommended rates (Tables 1 and 3). This could be attributed to the varying active ingredients in the formulations. Apart from the poor control, applying sublethal doses of an insecticide can result in the development of resistance in late season larval instars. Already, pyrethroid resistance in field populations of *H. armigera* has been reported on cotton in Cote d'voire (Vassal *et al*., 1997; Martin *et al*., 2000, 2002). Therefore, more effective control of bollworms may be achieved by applying these insecticides at dosages above the recommended rates provided in the manufacturers' labels.

The results further indicated that *E. insulana*, which was the most dominant bollworm species in the field seemed to exhibit higher reproductive potential than *D. watersi*, which may result in relatively more generations per season (Tables, 2 and 4). Alternatively, the feeding habits of the two insect species have been reported to vary greatly, especially at the reproductive stage of the cotton plants. When the larvae of *D. watersi* enter a boll, they disappear completely into the boll and rarely emerge to enter new bolls, but that of *E. insulana* wander about as they probe from one boll to another (Mathews, 1989). *Pectinophora gossypiella* also dominated *H. armigera* probably due to their feeding habit. During feeding, the larvae of *H. armigera* bore into the boll with the hind part of the body exposed outside the boll. This could have exposed the larvae to the direct effect of the insecticides than that of *P. gossypiella* which tunnels into its boll and remains entirely inside (Hill and Waller, 1988; Mathews, 1989). In our study, larval mortality in the field may have been overestimated due to the quality of spraying and to the selection of bolls or squares from the upper part of plants where the greatest numbers of insecticide droplets are collected.

CONCLUSION

This experiment has shown that the insecticides tested have a dose-dependent effect on the incidence and abundance of the bollworm species infesting the cotton plants in the savanna ecology of Ghana. The lowest bollworm infestation and highest cotton yield is recorded with sprays with Thionex. This is followed by Betsulfan. Overall, Endosulfan records the highest infestation and the lowest seed cotton yield. Dosages above the recommended rates are more effective than those at or below the recommended rates. Therefore, for effective control of cotton bollworms for maximum yield in the ecology, Thionex applied at 2.8 l ha^{-1} is most recommended. Farmers who choose to use Endosulfan or Betsulfan for economic reasons (as these are less expensive than Thionex) may do so but these should be applied at 3.5 l ha^{-1} for comparable control and yield.

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