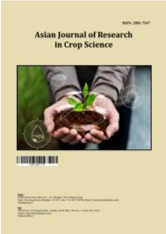

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Efficacy of Spinosad 48SC on the Management of Cotton Bollworms *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) in Zimbabwe

F. Jimu [a*], R. Mapuranga [b], W. Mubvekeri [a] and D. Kutywayo [c]

[a] Cotton Research Institute, P. Bag 765, Kadoma, Zimbabwe.
[b] Gwanda State University, Epoch Mine Campus, P.O. Box 30, Filabusi, Zimbabwe.
[c] Department of Research and Specialist Services, P.O. Box CY594, Causeway, Harare, Zimbabwe.

Authors' contributions

This work was carried out in collaboration among all authors. Author FJ designed the study, did data analyses and prepared first draft. Author RM coordinated the data collection. Author WM supervised the study. Author DK edited the first draft of manuscript and perfected it before sending it to the journal. All authors revised the manuscript.

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ABSTRACT

Bollworms management remains one of the major constraints to higher cotton productivity in Zimbabwe. Field trials to investigate the efficacy of Spinosad 48 SC on *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) were carried out for three seasons 2010/11 to 2013/14 at Cotton Research Institute, Kuwirirana, Umguza, and Chizvirizvi in Zimbabwe. A Randomised Complete Block Design with five treatments and four replications was used in this

**Corresponding author: E-mail: fjimu@yahoo.co.uk, ftjimu@gmail.com;*

experiment. Three doses of Spinosad 48 SC 40ml/ha, 60ml/ha and 80ml/ha, were evaluated, along with Lambda cyhalothrin 5 EC at 200ml/ha as the standard treatment and the untreated control. Observations on bollworms eggs, larval counts and predator counts. The square root transformation of (x + 3/8) was used for data not following normal distribution. Data were analysed using Genstat 14th Edition. All the three doses of Spinosad 48 SC (40ml/ha, 60ml/ha and 80ml/ha) controlled *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) at CRI, Kuwirirana, Umguza and Chizvirizvi. The highest dose of Spinosad 48 SC of 80ml/ha resulted in the highest yield of seed cotton at CRI and Kuwirirana. All the three doses of Spinosad 48 SC killed predators in the same way as the standard insecticide. Spinosad 48 SC was recommended for registration on control of the two bollworms in Zimbabwe at 80ml/ha dose.

Keywords: Cotton; bollworms; spinosad 48 SC; karate 5 EC; predators.

1. INTRODUCTION

The cotton bollworm is a major pest limiting cotton productivity worldwide. It is the most damaging pest of cotton because it attacks the fruiting parts of the plant, [1]. The damage caused by bollworms as they feed on cotton buds, flowers and bolls results in 20-60% yield and quality loss, [2]. Three bollworm species cause main damage on cotton in India: the pink bollworm (*Pectinophora gossypiella*), the spotted bollworm (*Earias* vitella), and the American bollworm (*Helicoverpa* armigera), [3]. *H. armigera* Hb. (Lepidoptera: Noctuidae) feeds on cotton leaves and shoots in the absence of fruiting parts or during movement from one boll to the other, [4]. This bollworm migrate from bud to bud and can therefore easily destroy half a dozen squares or more during its lifetime, [5]. Damage caused by bollworms in cotton is the monetary value lost to the commodity resulting from injury by the pest in form of spoilage of cotton bolls, hence reduction in yield and loss of quality of the crop, [6]. Researchers are now advocating for an integrated pest management approach because it enables intelligent selection and use of pest management techniques thus resulting in favourable ecological, social and environmental benefits. In an experiment to determine the resistance levels of *Helicoverpa amigera* (Hampson) on *Spinosad* (a fungal derivative) in India, China and Pakistan, the bollworm was found to be susceptible to the insecticide, [7]. *Spinosad* is an insecticide from the new class of insect control products, called naturalytes. It was derived from the metabolites of naturally occurring actinomycete bacterium, *Saccharopolyspora spinosa* via fermentation, [8]. Today Spinosad is produced in state-of –art, fermentation facility in Harbor Beach, Michigan. *S. spinosa* colonies are grown in natural products such as soyabean and cottonseed meal. *Spinosad* is primarily composed of two active components, spinosyn A which is the major component and spinosyn D (the minor component), in approximately 17:3 ratio, [8]. It has a wide spectrum of activity and contact activity on all life stages of a pest: the egg, larva, pupa and adult, laboratory tests have shown exceptional activity on pests belonging to the order Lepidoptera, Diptera and Thysanoptera, some species of Coleoptera consuming large amounts of foliage like the Colorado potato beetle (*Leptinotarsa decemlineata*), Orthopteran grasshoppers in cotton and western yellow striped armyworm (*Spodoptera praefica*). This insecticide has low toxicity and is safe to predaceous insects like Ladybird beetles (*Coccinellidae*), lacewings (*Sryphid* larva), and big eyed bugs (Geocoris spp) and Hymenoptera parasitoids [9]. Evaluation of new bollworm insecticides to complement those already in use is an important part of bollworms control strategy. The objective (s) of this research work was to evaluate the efficacy of new bollworm insecticide Spinosad 48 SC compared to Lambda cyhalothrin 5EC and the control treatment. The effect of the new insecticide on predators was also assessed.

2. MATERIALS AND METHODS

Investigation on the effectiveness of Spinosad 48SC in controlling bollworms in Zimbabwean cotton was carried out in field trials from the 2010-11 to 2013-14 season at Cotton Research Institute (CRI) in Kadoma, Kuwirirana in Gokwe North and Umguza in Matebeland North, and Chizvirizvi in Masvingo Province. At Umguza in Matabeleland North only two seasons' trials were carried out from 2010-11 and 2011-12, while the last season of this trial 2013-14 was done at Chizvirizvi in Chiredzi, Masvingo province. The trials were laid in a randomized complete block design with five treatments and four replications.

Table 1. Details of knapsack used at all sites

Knapsack Type	Nozzle Type	Operating Pressure	Pumping frequency	Walking speed	Spray Volume litres/ha
Taurus	Rex 15	3	6	72	100

Cotton was grown using the basic agronomic practices as outlined in the Cotton Handbook of 1998, partial revised edition standards, [10]. Other practices done not listed in the cotton handbook were: the experiment was hand planted at all sites using a commercial cotton variety CRI MS2. The measurements were bollworm eggs and larval counts as well as predator counts and counts of other pests. The treatments were: the control treatment, chemical control of *Diparopsis castanea* (Hubner) (red bollworm) and *Herlicoverpa amigera* (Hampson) (*Heliothis* bollworm) with Lambda Cyhalothrin 5 EC, the new insecticide Spinosad 48 SC was evaluated at three doses: 40ml, 60ml and 80ml per hectare. The observations bollworm eggs, predator as well as counts of other pests were done during the first scouting day in the week. Bollworms scouting was done through examining all parts of the plant paying particular attention to fruiting points. Whenever bollworm eggs reached or exceeded economic threshold levels of 6 or more for *Diparopsis castanea*, (Hubner) 12 or more for *H. amigera* (Hampson) eggs, and 6 or more larva for *Erias spp* on 24 scouted plants treatment sprays were applied using a Taurus knapsack, Table 1. Scouting for sucking pests was done once a week in all treatments by checking and counting the numbers present on the middle leaf, top two fully expanded leaves and the growing point of the plants. A second scouting for bollworms larva and predators focussed on fruiting parts of the plant was also done in the same week whenever a chemical spray for bollworm control was applied in any one of the treatments. Chemical sprays for control of other pests were applied over the whole trial area.

3. RESULTS AND DISCUSSION

3.1 Cotton Research Institute (CRI)

3.1.1 Bollworms

At CRI, results over the three seasons show significant differences ($p<0.05$) among treatments on *Herlicoverpa amigera* (Hampson) larval populations and seed cotton yield per hectare (Table 2). The control treatment had the highest *Herlicoverpa amigera* (Hampson) bollworm larval populations while the Spinosad 48SC at the three doses and the standard Karate (Lambda cyhalothrin 5EC) had comparably the least larval populations of the bollworm. The least yield of seed cotton per hectare was recorded in the control treatment while the highest yield of seed cotton was recorded in Spinosad 48SC the dose of 40ml and 80ml per hectare, (Table 2). The decrease in yield observed in the control treatment was due to the damage by the *Herlicoverpa amigera* (Hampson) bollworm larva since in this treatment no bollworm insecticide was applied.

Table 2. Bollworm larval counts on treatments over three seasons at CRI from 2010-11 to 2013-14

Treatments	*Diparopsis castanea* (Hubner) larva	*Herlicoverpa amigera* (Hampson) larva	Yield of seed cotton kg/ha
1. No control of bollworms	0.42	1.0b	644a
2. Lambda-cyhalothrin 5 EC at 200 ml	0.37	0.54a	997bc
3. Spinosad 48SC at 40ml/ha	0.34	0.60a	1095c
4. Spinosad 48SC at 60ml/ha	0.23	0.45a	903b
5. Spinosad 48SC at 80ml/ha	0.28	0.53a	1036c
Mean	0.33	0.64	935
p-value	0.516	<0.001	<0.001
LSD	-	0.2532	207.3
CV, (%)	19.2	7.6	15.5

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test). A represents the least pest population while c show the highest pest population

3.1.2 Predators

Significant differences (p<0.05) were observed on populations of predator ladybird adults and spiders over the three seasons while there were no significant differences among treatments on *Chrysopa* eggs and ladybird larval populations, Table 3. The populations of lady bird adult populations in the control treatment, Spinosad at 80ml/ha and Karate 5 EC were comparable. This scenario could be explained by predator populations' response to prey. Predators only respond to increase in prey populations as observed by Studies by Sarina and Zalucki [11], but when prey populations diminish due to predation, predator populations begin to decrease. Bollworms eggs and small larvae are among pests Ladybird adults feed on, a decrease in the two could have led to decrease in ladybird adult populations to numbers comparable to Karate 5 EC and Spinosad at 80ml/ha. The control treatment where no bollworm insecticide was applied had the highest spider populations while the three rates of Spinosad 48 SC and Lambda-cyhalothrin 5 EC had comparably the least spider populations, (Table 3). This is explained by the toxicity of the applied insecticides to spider populations thus killing the predator. No significant differences among treatments on *Crysopa* egg counts were observed.

3.2 Kuwirirana

3.2.1 Bollworms

At Kuwirirana, results over the three seasons show significant differences (p<0.05) among treatments on *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) bollworm larval populations and yield of seed cotton per hectare (Table 4). The standard Lambda cyhalothrin 5EC and Spinosad at 40ml/ha had the least *Diparopsis castanea* (Hubner) larval populations while the control treatment where no bollworm insecticide had the highest larval populations of the bollworm. All the three rates of Spinosad 48 SC and Lambda cyhalothrin 5EC gave good control of *Herlicoverpa amigera* (Hampson) while the control treatment had the highest populations of the bollworm because no bollworm insecticide was applied in this treatment. The higher populations of *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) in the control treatment translated to low seed cotton yield due to the damage caused by the two bollworms. Seed cotton yields in the three doses of Spinosad 48 SC were comparably higher due to good control of the two bollworms offered by the insecticide, (Table 4).

3.2.2 Predators

Significant differences (p<0.05) were observed on populations of predator ladybird beetle larva. The highest population of the lady bird larva were recorded in the control treatment due to reasons eelier mentioned, while Lambda cyhalothrin 5EC and the three rates of Spinosad 48 SC killed the predator in the same manner thus had comparably the least predator populations, (Table 4). There were no significant differences among Crysopa egg counts, ladybird adults and spider populations, (Table 5).

Table 3. Predator populations at CRI from 2010-11 to 2013-14 season

Treatments	*Chrysopa* eggs	Labybird larva	Ladybird adult	spiders
1. No control of bollworms	0.51	0.37	0.47b	0.33b
2. Lambda-cyhalothrin 5 EC at 200 ml	0.55	0.30	0.41ab	0.18ab
3. Spinosad 48SC at 40ml/ha	0.44	0.51	0.30a	0.20ab
4. Spinosad 48SC at 60ml/ha	0.58	0.36	0.14a	0.11a
5. Spinosad 48SC at 80ml/ha	0.41	0.33	0.44b	0.13a
Mean	0.50	0.37	0.35	0.19
p-value	0.484	0.829	0.043	0.049
LSD	-	-	0.3954	0.2654
CV, (%)	52.9	27.6	19.1	15.8

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test).

A show the least pest population while b show the highest pest population

Table 4. Bollworm larval counts on treatments and over three seasons at Kuwirirana from 2010-11 to 2013-14

Treatments	*Diparopsis castanea* larva	*Herlicoverpa amigera* (Hampson) larva	Yield of seed cotton kg/ha
1. No control of bollworms	1.2c	1.6b	588a
2. Lambda-cyhalothrin 5 EC at 200 ml	0.9a	1.2a	904b
3. Spinosad 48SC at 40ml/ha	1.0ab	1.2a	990bc
4. Spinosad 48SC at 60ml/ha	1.1bc	1.2a	1056bc
5. Spinosad 48SC at 80ml/ha	1.1bc	1.4a	1147c
Mean	1.054	1.321	937
p-value	<0.001	<0.001	<0.001
LSD	0.1935	0.2470	300.5
CV, (%)	12.9	13.1	22.5

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test). a represents the least pest population while c show the highest pest population

Table 5. Predator populations at Kuwirirana from 2010-11 to 2013-14 season

Treatments	Crysopa eggs	Labybird larva	Ladybird adult	spiders
1. No control of bollworms	0.7	0.8b	0.7	0.9
2. Lambda-cyhalothrin 5 EC at 200 ml	0.3	0.7a	0.7	0.7
3. Spinosad 48SC at 40ml/ha	0.8	0.7a	0.7	0.9
4. Spinosad 48SC at 60ml/ha	0.3	0.7a	0.6	0.8
5. Spinosad 48SC at 80ml/ha	0.5	0.7a	0.8	0.9
Mean	0.498	0.712	0.696	0.829
p-value	0.064	0.028	0.069	0.012
LSD	-	0.1734	-	-
CV, (%)	83	17.1	14.3	23.9

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test).
A show the least pest population while b show the highest pest population

3.3 Umguza

3.3.1 Bollworms

At Umguza, results over the two seasons show significant differences (p<0.05) among treatments on *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) bollworms larval populations, (Table 6). The control treatment had the highest *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) bollworm larval populations due to reasons cited earlier. The standard treatment and Spinosad 48SC at the three doses had comparably the least bollworms larval populations due to good control of the two bollworms offered by the two insecticides, (Table 6). There were no significant differences among treatments on seed cotton yield, this could be attributed to predation done on bollworms eggs and small larvae by high ladybird larval populations in this treatment as shown in Table 7.

3.3.2 Predators

Significant differences (p<0.05) were observed on populations of predator ladybird larva. The highest ladybird larva were observed in the control treatment where no toxic bollworm insecticide was applied. The standard treatment and the three rates of Spinosad 48SC had comparably the least populations of the predator because these insecticides had toxic effects on the predators, (Table 7). There were no significant differences on populations of *Chrysopa* eggs, ladybird larva and spiders, Table 7.

Table 6. Bollworm larval counts on treatments and over three seasons at Umguza from 2010-11 to 2011-12

Treatments	***Diparopsis castanea* (Hubner) larva**	***Herlicoverpa amigera* (Hampson) larva**	**Yield of seed cotton kg/ha**
1. No control of bollworms	1.0b	1.0b	836
2. Lambda-cyhalothrin 5 EC at 200 ml	0.8a	0.7a	1001
3. Spinosad 48SC at 40ml/ha	0.8a	0.7a	936
4. Spinosad 48SC at 60ml/ha	0.7a	0.8a	967
5. Spinosad 48SC at 80ml/ha	0.8a	0.8a	965
Mean	0.789	0.789	941
p-value	<0.001	<0.001	0.641
LSD	0.1518	0.1536	323.4
CV, (%)	13.3	13.4	23.7

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test). A represents the least pest population while c show the highest pest population.

Table 7. Predator populations at Umguza from 2010-11 to 2011-12 season

Treatments	***Chrysopa* eggs**	**Labybird larva**	**Ladybird adult**	**spiders**
1.No control of bollworms	0.8	1.2b	0.4	0.9
2. Lambda-cyhalothrin 5 EC at 200 ml	0.8	0.9a	0.2	0.8
3.Spinosad 48SC at 40ml/ha	0.8	0.9a	0.3	0.8
4. Spinosad 48SC at 60ml/ha	0.7	0.8a	0.3	0.7
5. Spinosad 48SC at 80ml/ha	0.7	0.8a	0.2	0.8
Mean	0.777	0.895	0.263	0.779
p-value	0.239	<0.001	0.511	0.047
LSD	-	0.1816	-	-
CV, (%)	14.2	14	75	14.6

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test).
A show the least pest population while b show the highest pest population.

Table 8. Bollworm larval counts on treatments over one season at Chizvirizvi for 2013-14 season

Treatments	***Diparopsis castanea* (Hubner) larva**	***Herlicoverpa amigera* (Hampson) larva**	**Yield of seed cotton kg/ha**
1. No control of bollworms	0.0	0.8b	1434
2. Lambda-cyhalothrin 5 EC at 200 ml	0.1	0.1a	1615
3. Spinosad 48SC at 40ml/ha	0.1	0.3a	1733
4. Spinosad 48SC at 60ml/ha	0.0	0.3a	1729
5. Spinosad 48SC at 80ml/ha	0.0	0.1a	1622
Mean	0.050	0.300	1626
p-value	0.611	0.003	0.744
LSD	-	0.2899	535.1
CV, (%)	329	14.5	21.4

N.B. Values followed by the same letter are not significantly different at the 5% level (Duncan `s Multiple Range Test). A represents the least pest population while b show the highest pest population.

Table 9. Predator populations at Chizvirizvi in 2013-14 season

Treatment	*Chrysopa* eggs	Lady bird larva	Lady bird adults	Spiders
1.No control of bollworms	0.1	0.0	0.0	0.0
2. Lambda-cyhalothrin 5 EC at 200 ml	0.0	0.1	0.1	0.0
3.Spinosad 48SC at 40ml/ha	0.0	0.0	0.0	0.1
4. Spinosad 48SC at 60ml/ha	0.0	0.0	0.0	0.0
5. Spinosad 48SC at 80ml/ha	0.0	0.0	0.0	0.0
Mean	0.03	0.03	0.03	0.03
p-value	0.445	0.45	0.445	0.45
LSD	-	-	-	-
CV, (%)	447	446	447	446

3.4 Chizvirizvi

3.4.1 Bollworms

Significance differences among treatments ($p<0.05$) were observed on *Herlicoverpa amigera* (Hampson) bollworm larva. The trend exhibited at other sites was repeated at Chizvirizvi whereby the control treatment had the highest *Herlicoverpa amigera* (Hampson) bollworm larval populations due to reasons cited earlier. The three rates of Spinosad 48SC had comparably the least larval populations of the bollworm due to good control of the bollworm offered by the insecticides, (Table 8).

3.4.2 Predators

There were no significant differences ($p<0.05$) among treatments on predator populations due to very low predator populations at Chizvirizvi in the season, Table 9.

4. CONCLUSION

The doses rates 40ml, 60ml and 80ml/ha of Spinosad 48SC controlled *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) at CRI, Kuwirarana, Umguza and Chizvirizvi in the same manner as the standard insecticide Lambda cyhalothrin 5EC. Spinosad 48 SC killed predators in the same manner as Lambda cyhalothrin 5EC. Good control of *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) by Spinosad 48 SC resulted in higher seed cotton yield even better than Lambda cyhalothrin 5EC. The 80ml/ha dose of Spinosad 48 SC resulted in the highest seed cotton yield per hectare at CRI and Kuwirirana. Spinosad 48 SC was recommended for registration on control of *Diparopsis castanea* (Hubner) and *Herlicoverpa amigera* (Hampson) in Zimbabwe at the dose of 80ml/ha.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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