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EFFICACY OF *BACILLUS THURINGIENSIS*-CHEMICAL INSECTICIDE MIXTURES FOR COTTON BOLLWORM, *HELICOVERPA ARMIGERA* (HUBN.) CONTROL

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Abstract

The efficacy of commercially prepared *Bacillus thuringiensis* (BT) mixed separately with different chemical insecticides at sublethal dosages was determined for controlling cotton bollworm, *Helicoverpa armigera* (Hubn.) at field conditions, at the CRDI Central Experiment Station, Batac, Ilocos Norte.

At three days after spraying, BT + 1/2 Recommended Rate (RR) of thiodicarb or metamidophos or cypermethrin-cyfluthrin-cypermethrin sequence or carbaryl was comparably effective with deltamethrin, the check insecticide against *H. armigera*. On the other hand, BT+ 1/2 RR thiodicarb or carbaryl was comparable with deltamethrin at five days after spraying.

The number of bolls produced was significantly higher from cotton sprayed with deltamethrin or BT + 1/2 RR chemical insecticide mixtures than BT alone or untreated check. The seedcotton yield was comparable for all treatments except BT alone which yielded lowest like the untreated check. Boll weight and plant height were not affected by the treatments.

The highest net benefit was derived from cotton sprayed with deltamethrin, followed by that from Bt + 1/2 RR thiodicarb, then by Bt + 1/2 RR cypermethrin-cyfluthrin-cypermethrin sequence and finally Bt + 1/2 RR carbaryl.

The reduced rate of chemical insecticides mixed with *B. thuringiensis* gave an efffective bollworm control relative to Bt alone. The full application of deltamethrin gave the superior control of the pest.

Key Words: *Bacillus thuringiensis*, chemical insecticides, efficacy, bollworm, seedcotton yield, boll number synergist

INTRODUCTION

In the Philippines, farmers' control of cotton bollworm, *Helicoverpa armigera* (Hubn.) primarily depends on chemical insecticides (Cruz, et al. 1992). However, some cotton famers have claimed that a number of chemical insecticides were no longer effective, hence requiring frequent spraying. This situation causes an increase in the cost of production and also leads to accumulation of toxic residues in the agroecosystem. Further, intensive use of chemicals causes risks to human health through occupational or indirect exposure from food and water residues (Beaumont and Dinham, 1993).

Cognizance of this situation necessitates a reduction in the application of chemical insecticides yet warranting effectiveness in terms of an increase in seedcotton yield. This would require the use of low contact toxicity yet highly safe

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control agents in combination with chemical insecticides at reduced rates. An innovative method developed in Australia (Anonymous, 1991) was mixing a microbial insecticide, such as *B. thuringiensis* with a chemical, that is, BT + endosulfan or BT + synthetic pyrethroids which effectively controlled lepidopterous insects. Further, Bullen et al. (1991) obtained better control of resistant *Heliothis* spp. with Dipel ES (a commercially prepared BT) in combination with reduced rates of synthetic pyrethroids than full pyrethroid alone. Dipel ES acted as a stomach poison and complemented the chemical mode of action of the synthetic pyrethroid as a synergist, thus making the remaining population more susceptible.

B. thuringiensis is a bacterium and a crystalliferous sporeformer (Falcon, 1971). In addition to forming endospores, this bacterium produces a proteinaceous parasporal crystal in the sporangium at the time of sporulation. The crystal contains an endotoxin called delta-endotoxin capable of paralyzing the gut of most lepidopterous larvae. During its infection, susceptible insects are either killed by the toxic crystals or so weakened that the bacteria can readily invade the hemocoel from the gut and produce a lethal septicemia (Heimpel and Angus, 1963). However, the effect takes about three to four days, making its use as a microbial insecticide unpopular among farmers.

Fortunately, *B. thuringiensis* is compatible with a wide range of chemical pesticides and supplements (Falcon, 1971). Twenty-six out of 36 pesticide agents made up of fungicides, insecticides, herbicides and acaricides and 35 out of 40 supplements including wetting agents, emulsifiers and adhesives were found compatible with *B. thuringiensis* (Benz, 1971). Such property makes *B. thuringiensis* preparations valuable as a component in integrated control programs.

Taking advantage of this compatibility with chemicals, the present study was conducted to determine if the field efficacy of the commercially prepared *B. thuringiensis* will be improved when mixed with chemical insecticides at sublethal dosages.

MATERIALS AND METHODS

The chemical insecticides used and their recommended application rates were as follows:

INSECTICIDE	CHEMICAL GROUP	TRADENAME	RECOMMENDED RATE ml/ha
Metamidophos	Organophosphate	Tamaron 60 EC	1200
Cypermethrin	Synthetic Pyrethroid	Ripcord 2.5 EC	1400
Cyfluthrin	Synthetic Pyrethroid	Baythroid	750
Cypermethrin	Synthetic Pyrethroid	Cymbush 5 EC	1000
Thiodicarb	Carbamate	Larvin 375 F	1330
Carbaryl	Carbamate	Sevn XLR	2950
Deltamethrin	Synthetic pyrethroid	Decis 2.5 EC	500

The rates of the chemical insecticides were reduced into half and each was mixed with *B. thuringiensis* at its recommended rate (240 g/ha). The treatments were as follows: BT + 1/2 RR metamidophos, BT + 1/2 RR cypermethrin-cyfluthrin-cypermethrin sequence, BT + 1/2 RR thiodicarb, BT + 1/2 RR carbaryl, *B. thuringiensis* alone, deltamethrin as check insecticide and untreated check. The experiment was laid in a Randomized Complete Block design (RCBD) with three replications. Each plot was composed of 8 rows x 6 m. long. Rows were 75 cm. apart and plants were spaced at 25 cm. between hills. Two plants were maintained per hill.

Bollworm survey was made one day before and three and five days after spraying. Spraying started at 49 days after planting (DAP) when the critical productivity level, that is, 4 terminals with bollworm, was reached. Flush spraying with profenofos (Selecron 500 EC) was done at 35 and 66 DAP to control leafhoppers, aphids and mites. Other cultural management practices were done according to recommended cotton production technologies (RCPT, 1994).

Percent efficacy was computed based on the Sun-Shepard formula as follows:

$$\%\ \text{EFFICACY} = \frac{Pt \pm Pck}{100 \pm Pck} \times 100$$

where :

$$Pt = \frac{Tb - Ta}{Cb} \times 100$$

$$Pck = \frac{Ca - Cb}{Cb} \times 100$$

Tb, Ta = insect population on the treated plots before and after spraying, respectively

Ca, Cb = insect population on the untreated plots before and after spraying, respectively

Pt = change in population of the treated plot

Pck = change in the population of the untreated check plot

Other parameters to assess the effects of the treatments were the seedcotton yield and agronomic characters such as boll number and weight, plant height, which were obtained from the four inner rows of each plot.

RESULTS AND DISCUSSION

The efficacy of *B. thuringiensis* mixed with chemical insecticides at sublethal dosages at three and five days after spraying is shown in Table 1. From the average % efficacy, the mixtures controlled bollworm as effectively as deltamethrin at three days after spraying, indicating compatibility of *B. thuringiensis* with the chemical insecticides. This corroborates Benz's (1971) report that 17 insecticides, including organophosphates were compatible when mixed with Bt and only technical HCH

Table 1. Mean percent efficacy of the different BT + insecticide mixtures.

TREATMENT	PERCENT EFFICACY	
	3 DAS	5 DAS
BT[1] + 1/2 RR Metamidophos	73.97a[2]	63.76bc[3]
BT + 1/2 RR Synthetic Pyrethroid Sequence	77.10a	65.23bc
BT + 1/2 RR Carbaryl	68.28ab	76.03ab
BT + 1/2 RR Thiodicarb	85.94a	91.53a
B. thuringiensis	52.48b	53.10c
Deltamethrin	87.71a	81.37ab
cv, %	15.00	15.00

[1] BT - *B. thuringiensis* commercially marketed as Dipel WP.
[2] Pyrethroid sequence is cypermethrin-cyfluthrin-cypermethrin.
[3] DAS - days after spraying.

(but not the gamma isomer lindane), malathion and tepp were antagonists.

The lowest efficacy was obtained with *B. thuringiensis* alone, thus an inferior control due to low toxicity to cotton bollworm. Damo (1992) likewise noted the effectiveness of *B. thuringiensis* only at the early stage of the crop, that is, infested with early-instar bollworm larvae. Horn (1988) likewise noted that the lethal effect of BT occurs faster and at lower dosage in early-instar larvae.

At five days after spraying, all the insecticide mixtures had reduced efficacy except for that sprayed with BT + 1/2 RR thiodicarb, which had an improved control. The improved control could be due to the larvicidal and ovicidal action of thiodicarb as noted when Dipel ES was combined with Larvin 175 F (Anonymous, 1991).

Deltamethrin provided the best cotton protection, while organophosphate (metamidophos) and carbamate (carbaryl and thiodicarb) were more effective synergists of BT than synthetic pyrethroids. The synergistic action between *B. thuringiensis* and the organophosphate or carbamate at sublethal doses could be due to the latter imposing physiological stress on the insects. Chemical insecticides might act as stressors and thus promote contraction or activation of infectious diseae or make insects more suscptible to the action of the microbial toxins (Benz, 1971).

Seedcotton yield was comparable for all BT + insecticide mixtures and was significantly higher than that of BT alone but lower than that of deltamethrin. Cotton sprayed with BT alone had comparable yield with the untreated check. The yield indicated an improved bollworm control for BT mixed with chemical insecticides relative to BT alone. The full pyrethroid (deltamethrin) treatment still was the

Table 2. Seedcotton yield and other agronomic characters as affected by the different BT+ chemical insecticides and deltamethrin or *B. thuringiensis* sprayed alone.

TREATMENT	BOLL PER PLANT (g)	BOLL WEIGHT	PLANT HEIGHT (cm)	SEEDCOTTON YIELD (kg/ha)
BT[1] + 1/2 RR Metamidophos	10.77ab[2]	4.80	96.23	1914.54b[2]
BT + 1/2 RR Synthetic Pyrethroid Sequence [3]	10.40b	4.82	91.30	1983.33b
BT + 1/2 RR Carbaryl	10.70ab	4.72	92.73	1946.78b
BT + 1/2 RR Thiodicarb	10.43b	4.85	89.33	2092.91b
B. thuringiensis	7.87c	4.95	92.53	1295.00c
Deltamethrin	11.63a	4.85	94.37	2525.13a
Untreated check	6.27d	4.70	84.53	1153.33c
cv (%)	5.00	4.00	6.00	11.00

[1] BT - *B. thuringiensis* commercially marketed as Dipel WP.
[2] Means marked with the same letter(s) in a column are not significantly different from each other at 5% level using DMRT.
[3] Pyrethroid sequence was cypermethrin, cyfluthrin and cypermethrin.

Table 3. Benefit-cost analysis of the different insecticide treatments relative to untreated check.

TREATMENT	ADDED INCOME[3] (P)	ADDED COST[4] (P)	NET BENEFIT[5] (P)
BT[1] + 1/2 RR Metamidophos	13,701.78	4,586.95	9,114.83
BT + 1/2 RR Synthetic Pyrethroid Sequence[2]	14,940.00	4,813.19	10,126.81
BT + 1/2 RR Carbaryl	14,282.10	4,203.37	10,078.73
BT + 1/2 RR Thiodicarb	16,912.44	4,338.97	12,573.47
B. thuringiensis	2,550.06	1,526.50	1,023.56
Deltamethrin	24,592.40	5,927.70	18,764.70

[1] BT - *B. thuringiensis* commercially marketed as Dipel WP.
[2] Pyrethroid sequence was cypermethrin-cyfluthrin-cypermethrin.
[3] Added income based on the current seedcotton cost of P18/ki.
[4] Added cost accounts the amount of chemical insecticide.
[5] Net benefit is the difference between added income and added cost.

most effective, likely due to its high knockdown effect.

The number of bolls per plant represents the actual total count of damaged and undamaged bolls produced by cotton. As affected by the treament, the rate of boll production per plant was as follows (Table 2) : Deltamethrin (check insecticide) = BT + 1/2 RR metamidophos = BT + 1/2 RR carbaryl > BT + 1/2 RR thiodicarb = BT + 1/2 RR cypermethrin - cyfluthrin-cypermethrin sequence > BT alone > untreated check.

The boll weight and plant height were not affected by any of the treatments including the untreated check indicating that none of the mixtures or chemicals was adversely affecting the morphological growth of the plants.

Table 3 shows the benefit-cost analysis based on the seedcotton yield as affected by the different treatments. The rank in the derived benefit based on cost of seedcotton yield and chemical was as follows: Deltamethrin > BT + 1/2 RR thiodicarb > BT + 1/2 RR cypermethrin-cyfluthrin-cypermethrin sequence = BT + 1/2 RR carbaryl > BT + 1/2 RR metamidophos > BT alone. Cotton sprayed with BT alone had more than 10x lower net benefit than the rest.

Although the net benefit was highest from the full application of deltamethrin, the use of different BT + insecticide mixtures can still be commendable considering the long-term positive effect on the agroecosystem, particularly on natural enemies of insect pests. However, exposure to sublethal dosages of chemical insecticides may develop resistant insects, yet the rate of resistance development from BT + chemical insecticides is presumed to be much slower than those exposed to full insecticide application rates. The insects would have limited ability to counteract the toxic effects since there are two different sites of action of the mixture, that is, central nervous system for the chemical insecticides and gut hemocoel for the bacteria.

SUMMARY AND CONCLUSION

The field efficacy of different insecticide mixtures at sublethal rates mixed with *B. thuringiensis* was compared with deltamethrin or *B. thuringiensis* sprayed alone throughout the growing season against cotton bollworm, *H. armigera*, at the CRDI Central Experiment Station, Batac, Ilocos Norte.

The different BT + insecticide mixtures except BT + 1/2 RR thiodicarb had efficacies that were comparable to deltamethrin at three days after spraying. BT + 1/2 RR thiodicarb became as effective as deltamethrin later at five days after spraying. Seedcotton yield was comparable for all BT + insecticide mixtures but lower than that of deltamethrin, the check insecticide and higher than BT alone.

The highest net benefit was derived from cotton sprayed with deltamethrin, followed by that from BT + 1/2 RR thiodicarb, then BT + 1/2 RR synthetic pyrethroid sequence, BT + 1/2 RR carbaryl and finally BT + 1/2 RR metamidophos.

The use of BT + chemical insecticides was commendable considering reduction of toxicant in the environment and conservation of natural enemies in the agroecosystem. Also, although the development of insecticide resistance may occur, it is expected to be much slower due to two different sites of action for the chemicals and the bacteria.

LITERATURE CITED

Anonymous. 1991. Dipel ES. The cotton insecticide for the 90's. Abbot Autralia Pty., Ltd. Handout material. 19p.

Beaumont, P. and M. Dinham. 1993. Toward pesticide reduction policies. ILEA Newsletter for Low external Input and Sustainable Agriculture. 2/93. pp. 24-25.

Benz, G. 1971. Synergism of microorganism and chemical insecticides. pp. 327-355. In : H. D. Burgess and N. W. Hussey, Eds."Microbial Control of Insects and Mites". Academic Press, NewYork.

Bullen, K., E. Wattson, K. R. Litzon, and A. J. Farquhar. 1991. Dipel ES, Biological insecticide. 1990/ 1991 Australian cotton trials. Abbot Australia Pty. Ltd.

Cruz, L. T., F. P. Julian and El. V. Santiago. 1992. Farmers' adoption of cotton production technologies. Extension Research Annual Accomplishment Report CY 1991-92. Cotton Research and Development Institute, Batac, Ilocos Norte. pp 35 - 50.

Damo, M. C. 1992. Field evaluation of *Bacillus thuringiensis var. kurstaki* (Dipel) against cotton bollworm. Crop Protection Annual Accomplishment Report. CY 1991-92. Cotton Research and Development Institute, Batac, Ilocos Norte. pp. 29 - 59.

Falcon, L. A. 1971. Use of bacteria for microbial control of insect. pp. 67-90. In : H. D. Burgess and N. W. Hussey, Eds.," Microbial Control of Insects and Mites". Academic Press, New York.

Heimpel, A. M. and T. A. Angus. 1963. As cited by Falcon, L. A. 1971. Use of bacteria for microbial control of insect. pp. 67-95. In : H. D. Burgess and N. W. Hussey, Eds., "Microbial Control of Insects and Mites". New York, Academic Press.

Horn, D. J. 1988. Ecological Approach to Pest Management. Guilford Press, New York. 285p.

Recommended Cotton production Technology. 1994. Cotton Research and Development Institute, Batac, Ilocos Norte. 30p.