Microplitis croceipes (Hymenoptera: Braconidae) Development in Tobacco Budworm (Lepidoptera: Noctuidae) Larvae Treated with *Bacillus thuringiensis* and Thiodicarb[1]

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Abstract *Bacillus thuringiensis* Berliner var. *kurstaki* and thiodicarb were evaluated in laboratory and field assays to determine the effect on tobacco budworm larvae, *Heliothis virescens* (F.), and the parasitoid *Microplitis croceipes* Cresson. Laboratory trials were conducted using *B. thuringiensis* concentrations of 0, 10, 50 and 250 ppm and thiodicarb concentrations of 0, 12.5, 25, 50, 100, and 200 ppm in the diet. The test using field-treated cotton squares was conducted using *B. thuringiensis* and thiodicarb, independently and in combination, at rates recommended for resistance management in Arkansas. Laboratory tests indicated that tobacco budworm mortality was directly related to *B. thuringiensis* and thiodicarb concentrations, although *B. thuringiensis* only significantly increased tobacco budworm mortality at the highest concentration of exposure in the absence of parasitization. Parasitization increased host mortality at all *B. thuringiensis* experimental rates after 6 and 14 days. Although host mortality increased linearly with increasing thiodicarb concentration, parasitization did not significantly increase host mortality over thiodicarb alone until day 14. Emergence of *M. croceipes* was inversely related to *B. thuringiensis* and thiodicarb concentration. In assays using squares from field-sprayed cotton, thiodicarb and thiodicarb/*B. thuringiensis* mixtures provided significantly greater tobacco budworm mortality than did *B. thuringiensis* application alone. In addition, no significant advantage was determined for tank mixtures with *B. thuringiensis* as compared to thiodicarb application alone. However, neither *B. thuringiensis* nor thiodicarb, alone or in combination, caused a high mortality of early third instar tobacco budworm in the absence of parasitization by *M. croceipes.*

Key Words *Microplitis croceipes, Heliothis virescens, Bacillus thuringiensis*, thiodicarb, parasitization, insecticide.

Bacillus thuringiensis Berliner and thiodicarb (Larvin® 3.2 E., Rhone-Poulenc Ag. Company, Research Triangle Park, NC), a carbamate, can be effective insecticides against early-instar *Heliothis virescens* (F.), the tobacco budworm (Johnson et al. 1994). With the development of pyrethroid-resistant tobacco budworm populations (Luttrell et al. 1987, Plapp et al. 1990, Mullins et al. 1991, Elzen 1992), these insecticides are important components of early-season control programs. While there are numerous non-insecticidal means of preventing or delaying resistance development (e.g., early crop maturity and adequate field scouting), insecticides are and will continue to be important components of any pest management strategy. However, in order to fully exploit all means of tobacco budworm control, it is essential to evaluate

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the impact of natural enemies and to assess the impact of insecticide use on these populations.

Microplitis croceipes (Cresson) (Hymenoptera: Braconidae) is one of the most common parasitoids encountered in Arkansas cotton fields. Field collections during 1993 and 1994 suggest that it is second in abundance to *Cotesia marginiventris* (Cresson) in the Red River and Mississippi delta regions of Arkansas (unpub. data). In laboratory tests, mortality of tobacco budworm exposed as second instars and *C. marginiventris* emergence are significantly reduced by both *B. thuringiensis* and thiodicarb at higher rates in the diet. Results suggested that use of thiodicarb and *B. thuringiensis* would preclude maintainence of natural field populations of *C. marginiventris.* However, results differed somewhat when larvae were fed squares from field-treated cotton. (Atwood et al. 1997). Neither *B. thuringiensis* nor thiodicarb, alone or in combination, resulted in mortality of over 33% in third-instar tobacco budworm. In addition, no significant impact was noted on the emergence of *C. marginiventris* in this test (Atwood et al. 1998). Similar studies have not been conducted for *M. croceipes.* Therefore, laboratory diet trials and assays with field-treated cotton were conducted during 1995 and 1996 to evaluate the impact of *B. thuringiensis* and thiodicarb on *M. croceipes.*

Materials and Methods

Laboratory colonies of *H. virescens* and *M. croceipes* were established from tobacco budworm larvae collected from cotton in Little River and Jefferson Co., AR, during the summer of 1994. Additional *M. croceipes* pupae were obtained from the USDA Cotton Research Facility at Stoneville, MS, and added to the colony. Tobacco budworm larvae, reared on a semisynthetic diet (Burton 1969), served as hosts for *M. croceipes.* Colonies were maintained at 25°C, 14:10 L:D in environmental chambers. Insecticides used in these investigations were *B. thuringiensis* (Javelin® WG, Sandoz Crop Protection, Des Plaines, IL) and thiodicarb (Larvin®).

Laboratory tests. Tests were conducted using insecticide concentrations in the diet to induce a wide range of mortality responses in *H. virescens* larvae. These concentrations were established from preliminary dosage mortality tests. Concentrations for *B. thuringiensis* and thiodicarb were 0, 10, 50, and 250 ppm and 0, 12.5, 25, 50, 100 and 200 ppm, respectively. Each insecticide was evaluated alone and in combination with parasitization. There was a total of 8 treatments using *B. thuringiensis* alone and with parasitoids, and 12 treatments with thiodicarb alone and with parasitoids. *Bacillus thuringiensis* and thiodicarb tests were replicated 4 and 7 times, respectively. Both tests were conducted in an incubator at 27 ± 1°C and a photoperiod of 14:10 (L:D) h.

Bacillus thuringiensis and thiodicarb were mixed with buffer (Dulmage et al. 1978) and incorporated directly into the diet. Diet was allowed to cool to 50°C before addition of either insecticide mixture to prevent any inactivation of the insecticidal material. Each experimental diet was thoroughly blended after addition of insecticide to insure consistent concentration throughout the diet.

For each test, 10 late second-instar tobacco budworm larvae were placed in wax-lined 266-ml paper cups (16 cups for *B. thuringiensis* replicates and 24 cups for thiodicarb replicates) containing 20 ml of semisynthetic diet. One female *M. croceipes* was introduced into half of the parasitization cups for a period of 14 h. The larvae in the remaining cups were not parasitized to evaluate insecticide effect alone.

Individual larvae from each treatment (parasitized and nonparasitized) were transferred to 30-ml plastic cups containing larval diet of the desired insecticide concentration. Each cup was then capped and labeled. Larvae were held on each diet continually until death, pupation, or parasitoid emergence. Tobacco budworm mortality was recorded 2, 6 and 14 d after insecticide exposure. *Microplitis croceipes* emergence, as defined by larval emergence from tobacco budworm, was assessed 14 d after insecticide exposure. Data analysis was conducted using analysis of variance (ANOVA) (PROC GLM, $P = 0.05$) with comparisons made using the Student's t-test and LSD (SAS Institute 1988) when appropriate.

Field-treated cotton square tests. The test was conducted using cotton planted at the Arkansas Agricultural Research and Extension Center in Fayetteville, AR (Washington Co.). The test was a randomized complete block design with six replicates. Plots consisted of a single row, 9.1 m in length, with 2-row buffers between adjacent plots and 3.05 m buffers between replicates. Spray dates for replicates were July 16, 17, 18, 19, 23 and 24.

Insecticide concentrations used in this test were those commonly recommended for tobacco budworm control in Arkansas (Johnson and Jones 1995). *Bacillus thuringiensis* rates were 0.56 and 1.12 kg product/ha (0.5 and 1 lb product/acre) and thiodicarb rate was 0.14 kg AI/ha (0.125 lb AI/acre). Each insecticide-rate was tested individually and in combination. A sixth treatment consisted of an untreated control. In addition, each treatment was evaluated alone and in combination with parasitization by *M. croceipes* (described below) for a total of 12 experimental treatments. The test was replicated 4 times. Insecticide application was made using a CO_2 powered backpack sprayer at a pressure of 2.8 kg/cm^2. Treatments were applied in a volume of 94.6 liters/ha using 2 nozzles (TX-6) per row. All applications were made in the late afternoon to minimize sunlight inactivation of *B. thuringiensis* (Ali and Young 1993).

One hour after application, 60 squares in upper terminals were picked from each treatment and placed in a labeled plastic bag for transportation to the laboratory. Squares were placed individually in 30-ml plastic cups to which had been added a moistened filter paper disk. A single tobacco budworm larva, parasitized as in the previous test, or non-parasitized, was then placed in each cup. Larvae were parasitized for this test by placing 15 late second-instar tobacco budworms on semisynthetic diet in 36 wax-lined paper cups (266 ml) for 24 h (540 larvae total). Six cups were used for each treatment with half (3 cups) being provided with two female *M. croceipes* for parasitization and the other 3 cups not parasitized. A total of 30 parasitized and 30 non-parasitized larvae were used for each treatment.

Tobacco budworm larvae (parasitized and non-parasitized) were allowed to feed on the squares from each treatment for 48 h, after which time mortality readings were obtained and each surviving larva was transferred to an individual 30-ml plastic cup containing semisynthetic diet. Additional tobacco budworm mortality was assessed 7 and 14 d after initial exposure to the treated squares. *Microplitis croceipes* emergence was recorded on day 16 after exposure. Data were analyzed using the GLM procedure (SAS 1988) with mean separation by LSD.

Results

Laboratory tests—tobacco budworm mortality. *Bacillus thuringiensis* concentration, parasitization and their interaction significantly influenced tobacco budworm

on day 2 ($F = 4.8$, df = 3, $P \leq 0.05$), and 14 ($F = 22.7$, df = 31, $P \leq 0.05$) following insecticide exposure. No significant interaction was indicated on day 6.

Mortality for tobacco budworm larvae exposed to *B. thuringiensis* was observed to range from 1.7 to 5.0% for non-parasitized larvae and from 3.3 to 26.7% for parasitized larvae 2 days following insecticidal exposure (Table 1). The greatest larval mortality was noted for parasitized larvae at the highest *B. thuringiensis* concentration. No other significant difference in tobacco budworm mortality on day 2 was noted regardless of parasitization state or *B. thuringiensis* concentration.

Six days after exposure to *B. thuringiensis,* tobacco budworm mortality ranged from 1.7 to 55.0% for non-parasitized larvae and from 8.3 to 80.0% for parasitized larvae (Table 1). Both *B. thuringiensis* concentration and parasitization significantly affected host mortality. Significantly greater larval mortality was noted for parasitized larvae at *B. thuringiensis* concentration of 50 and 250 ppm *B. thuringiensis* concentration and for non-parasitized larvae at the highest *B. thuringiensis* concentration.

Fourteen days after initial *B. thuringiensis* exposure, tobacco budworm mortality ranged from 6.7 to 90.0% for non-parasitized larvae and from 66.7 to 91.7% for parasitized larvae (Table 1). The greatest mortality was determined for parasitized larvae at *B. thuringiensis* concentration of 0, 10 and 250 ppm and for non-parasitized

Table 1. Mean (±SEM) percentage tobacco budworm mortality at different *B. thuringiensis* rates on days 2, 6 and 14 after exposure in laboratory tests (4 replicates)

Concentration *B. thuringiensis,* ppm	% Mortality ± SEM	
	Nonparasitized	Parasitized
	Day 2	
0	1.7 ± 1.7b	3.3 ± 1.9b
10	5.0 ± 1.7b	5.0 ± 1.7b
50	5.0 ± 1.7b	5.0 ± 3.2b
250	5.0 ± 3.2b	26.7 ± 7.7a
	Day 6	
0	1.7 ± 1.7d	8.3 ± 5.0d
10	5.0 ± 1.7d	11.7 ± 3.2cd
50	6.7 ± 2.7d	21.7 ± 5.7c
250	55.0 ± 5.7b	80.0 ± 2.7a
	Day 14	
0	6.7 ± 3.8c	81.7 ± 3.2a
10	18.3 ± 7.4c	85.0 ± 6.9a
50	15.0 ± 5.0c	66.7 ± 4.7b
250	90.0 ± 4.3a	91.7 ± 3.2a

Means within day followed by the same letter are not significantly different ($P < 0.05$).

larvae at the highest *B. thuringiensis* concentration. In addition, larval mortality for parasitized larvae at a *B. thuringiensis* concentration of 50 ppm was significantly greater than for non-parasitized larvae at a *B. thuringiensis* concentration of 50 ppm or less. Regardless, results indicate that parasitization accounts for most mortality on day 14 at *B. thuringiensis* concentration below 250 ppm.

A significant two-way interaction ($P < 0.05$) of thiodicarb and parasitization was only determined after larval exposure to the insecticide for 14 days ($F = 29.9$; df = 5, 66; $P \leq 0.05$). Mortality on days 2 and 6 after insecticide exposure were both significant in relation to thiodicarb concentration ($F = 36.8$ and 103.4, respectively; df = 5, 66; $P \leq 0.05$). In addition, parasitization also significantly affected mortality on day 2 ($F = 8.5$; df = 5, 66; $P \leq 0.05$).

Mortality for larvae exposed to thiodicarb ranged from 1.0 to 37.1% for non-parasitized larvae and from 3.8 to 55.2% for parasitized larvae after 2 days (Table 2). Significantly greater larval mortality was noted at thiodicarb concentrations of 50, 100, and 200 ppm for both parasitized and non-parasitized larvae. The greatest larval mortality was observed for parasitized larvae at the highest thiodicarb concentration. Thiodicarb concentration and parasitization significantly increased host mortality individually but no interaction was detected.

Mortality for thiodicarb-exposed larvae on day 6 ranged from 6.7 to 93.3% for non-parasitized larvae and from 9.5 to 94.3% for parasitized larvae (Table 2). Significantly greater mortality was noted for both parasitized and non-parasitized larvae as thiodicarb concentrations exceeded 25 ppm. In addition, mortality for non-parasitized larvae at thiodicarb concentrations above 25 ppm significantly increased with increasing thiodicarb concentrations. Mortality for parasitized larvae was significantly greater at thiodicarb concentrations of 100 and 200 ppm as compared to a thiodicarb concentration of 50 ppm.

Mortality for thiodicarb-exposed larvae on day 14 ranged from 10.5 to 97.1% for non-parasitized larvae and from 84.8 to 100.0% for parasitized larvae (Table 2). The greatest mortality was noted for parasitized larvae at all thiodicarb concentrations and non-parasitized larvae exposed to thiodicarb concentrations of 100 and 200 ppm. Mortality for non-parasitized larvae increased in relation to increasing thiodicarb concentration. In contrast, increasing thiodicarb concentration had no impact on parasitized larval mortality again indicating that mortality attributable to parasitization overwhelms thiodicarb-induced mortality at the lowest concentrations by day 14.

Laboratory tests—*M. croceipes* emergence. Both *B. thuringiensis* ($F = 12.$; df = 3, 15; $P \leq 0.05$) and thiodicarb concentration ($F = 40.8$; df = 5, 41; $P \leq 0.05$) significantly reduced emergence of *M. croceipes.* Emergence of *M. croceipes* ranged from 1.6 to 70.0% and from 32.4 to 83.8%, respectively, for *B. thuringiensis* and thiodicarb exposure (Fig. 1). Increasing *B. thuringiensis* concentration significantly reduced parasitoid emergence. However, emergence from larvae treated with *B. thuringiensis* at 10 ppm did not statistically differ from the control. Parasitoid emergence after host exposure to thiodicarb significantly decreased as thiodicarb concentration increased. However, no statistical difference in mortality was determined for the thiodicarb concentration of 12.5 ppm and the experimental control. Parasitoid emergence did not statistically differ between thiodicarb rates of 100 and 200 ppm.

Field-treated cotton squares—tobacco budworm mortality. Mortality for tobacco budworm larvae on squares from field-treated cotton ranged from 0.0 to 30.0% for non-parasitized larvae and from 0.0 to 40.6% for parasitized larvae two days after insecticidal exposure (Table 3). Parasitization and thiodicarb both significantly in-

Table 2. Mean (±SEM) percentage tobacco budworm mortality at different thiodicarb rates on days 2, 6 and 14 after exposure in laboratory tests (4 replicates)

Concentration thiodicarb, ppm	% Mortality ± SEM	
	Nonparasitized	Parasitized
	Day 2	
0	1.0 ± 1.0d	4.8 ± 3.2d
12.5	0.0 ± 0.0d	3.8 ± 2.0d
25	3.8 ± 2.0d	8.6 ± 2.4d
50	22.9 ± 5.0c	24.8 ± 4.5c
100	21.9 ± 5.9c	30.5 ± 5.2bc
200	37.1 ± 7.7b	55.2 ± 5.4a
	Day 6	
0	7.6 ± 4.7e	9.5 ± 5.4de
12.5	6.7 ± 2.5e	9.5 ± 2.0de
25	20.0 ± 5.0de	22.9 ± 3.8d
50	50.5 ± 7.1c	55.2 ± 9.6c
100	74.3 ± 6.9b	81.9 ± 5.0ab
200	93.3 ± 6.7a	94.3 ± 3.7a
	Day 14	
0	11.4 ± 4.5e	97.1 ± 2.0a
12.5	10.5 ± 3.2e	98.1 ± 1.9a
25	26.7 ± 6.0d	84.8 ± 6.1b
50	59.7 ± 6.8c	93.3 ± 2.5ab
100	81.9 ± 7.1b	98.1 ± 1.2a
200	97.1 ± 2.9a	100.0 ± 0.0a

Means within day followed by the same letter are not significantly different ($P < 0.05$).

creased early tobacco budworm mortality. Significantly greater tobacco budworm mortality was observed in both non-parasitized and parasitized larvae exposed to squares from treatments which included thiodicarb as compared to experimental controls and treatments containing only *B. thuringiensis.* Tobacco budworm mortality was low in all *B. thuringiensis* alone treatments, and did not differ significantly between treatments. Furthermore, mortality in *B. thuringiensis* treatments 2 days after exposure did not significantly differ from the control treatments.

Seven days after exposure to insecticide, significantly greater mortality was observed for non-parasitized and parasitized tobacco budworm larvae exposed to

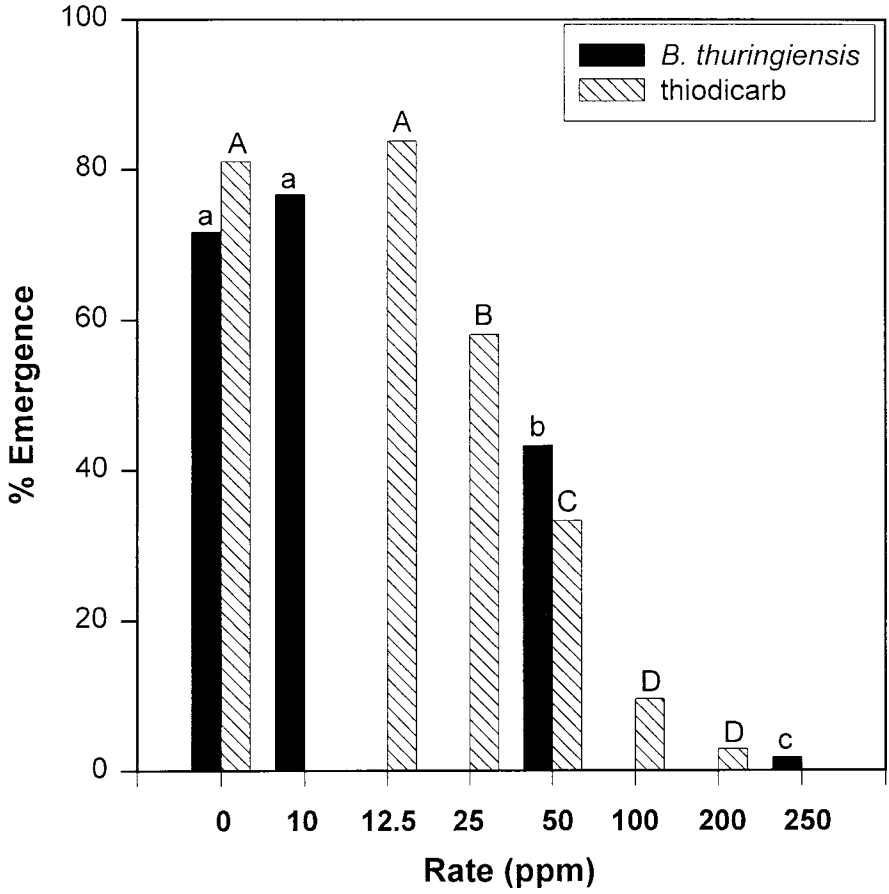

Fig. 1. Percentage emergence of *M. croceipes* from hosts exposed to different *B. thuringiensis* concentrations in diet (0, 12.5, 25, 50, 100 and 200 ppm) and thiodicarb concentrations in diet (0, 10, 50, 250 ppm) in laboratory tests. Bars with the same letter of the same case are not significantly different (LSD, $P < 0.05$).

thiodicarb or thiodicarb/*B. thuringiensis* combinations (42.2 to 50.0% and 50.8 to 57.8%, respectively). Mortality in *B. thuringiensis* and control treatments ranged from 0.0 to 25.6%.

Tobacco budworm mortality 14 days after insecticide exposure illustrates the impact of parasitization (Table 3). Mortality for parasitized larvae ranged from 92.1 to 97.7% with mortality from insecticide exposure not differing significantly from the experimental control. In contrast, mortality for non-parasitized larvae was significantly less than that for parasitized larvae, ranging from 16.1 to 55.0%. Again, significantly lower tobacco budworm mortality was noted for non-parasitized larvae exposed to *B. thuringiensis* alone as compared to larvae exposed to thiodicarb and thiodicarb/*B.*

Table 3. Percentage mean mortality (±SEM) of parasitized and non-parasitized tobacco budworm exposed to *B. thuringiensis* and thiodicarb (alone and in combination) on field-treated squares

	Treatment	Rate (kg/ha)	% Mortality ± SEM		
			Days after application		
			2	7	14
Non-parasitized	Control	—	0.0 ± 0.4c	3.3 ± 1.7e	16.1 ± 2.2d
	B.t.	0.56	3.3 ± 1.2c	14.0 ± 2.3de	22.2 ± 2.9cd
	B.t.	1.12	2.8 ± 1.0c	17.8 ± 3.8cd	27.8 ± 5.13c
	thiodicarb	0.14	25.0 ± 4.8b	50.0 ± 3.9ab	55.0 ± 4.8b
	B.t. + thiodicarb	0.56 ± 0.14	26.7 ± 4.6b	42.2 ± 4.4b	46.0 ± 4.8b
	B.t. + thiodicarb	1.12 ± 0.14	30.0 ± 3.8b	48.9 ± 4.7ab	54.0 ± 5.5b
Parasitized	Control	—	0.0 ± 0.0c	9.5 ± 2.8de	97.7 ± 1.7a
	B.t.	0.56	2.2 ± 1.1c	14.4 ± 2.8d	92.2 ± 3.3a
	B.t.	1.12	4.5 ± 1.4c	25.6 ± 5.5c	92.1 ± 4.2a
	thiodicarb	0.14	40.6 ± 4.2a	57.8 ± 4.8d	95.6 ± 2.4a
	B.t. + thiodicarb	0.56 ± 0.14	31.3 ± 3.1b	50.7 ± 5.4a	95.0 ± 2.2a
	B.t. + thiodicarb	1.12 + 0.14	30.6 ± 2.6b	53.3 ± 2.1a	95.6 ± 1.4a

Means within a column followed by the same letter are not significantly different ($P < 0.05$).

thuringiensis mixtures. Insecticide mixtures were not significantly more effective than thiodicarb alone. In addition, mortality in treatments containing only *B. thuringiensis* did not significantly differ from the experimental control.

Field-treated cotton squares—*Microplitis croceipes* emergence. Parasitoid emergence from tobacco budworm larvae exposed to squares from field-treated cotton ranged from 36.1 to 87.6% (Fig. 2). Significantly lower *M. croceipes* emergence was noted from hosts exposed to thiodicarb or thiodicarb/*B. thuringiensis* mixtures (36.1 to 42.0%) as compared to control and *B. thuringiensis* treatments (64.2 to 87.6%). No significant difference in parasitoid emergence was observed within thiodicarb and thiodicarb/*B. thuringiensis* treatments or between the two *B. thuringiensis* alone treatments. Emergence of *M. croceipes* from larvae in the *B. thuringiensis* alone treatments did not significantly differ from the experimental control.

Discussion

Emergence of *M. croceipes* from *B. thuringiensis* and thiodicarb-exposed tobacco budworm larvae was dependent upon insecticide concentration in laboratory trials. Similar findings were noted for *C. marginiventris* (Atwood et al. 1997). Results of laboratory investigations suggest that *B. thuringiensis* or thiodicarb application may reduce natural parasitoid populations.

One consideration is that the laboratory tests were conducted with continuous insecticide exposure. As shown by Dulmage (1978), Ali and Watson (1982) and Fast

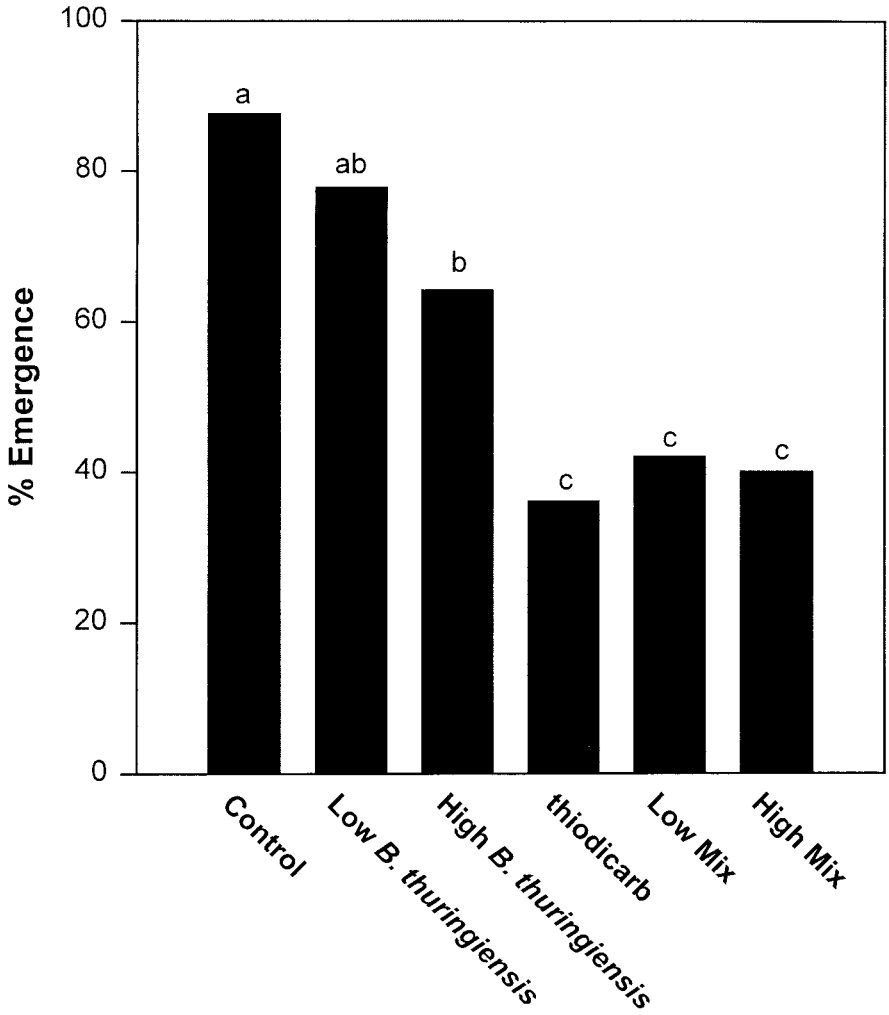

Fig. 2. Percentage emergence of *M. croceipes* from hosts exposed to *B. thuringiensis* and thiodicarb (alone and in combination) in assay on field-treated squares. Low and high *B. thuringiensis* rates were 0.56 and 1.12 kg/ha, respectively. Bars with the same letter are not significantly different (LSD, $P < 0.05$).

and Regniere (1984), lepidopterous larvae may recover from initial doses of *B. thuringiensis*. Results from our field trial with larvae fed on field-treated squares, appear to confirm these findings with *B. thuringiensis* having negligible impact on *M. croceipes* emergence at the suggested rates of application. The lack of *B. thuringiensis* impact on *M. croceipes* emergence also has been observed for *C. marginiventris* (Atwood et al. 1998). However, it also must be considered that the recommended rates for *B. thuringiensis* application used during field trials are targeted at first and

second instar. As shown by laboratory tests, increased *B. thuringiensis* concentration in field application above recommended rates may potentially prevent successful emergence of *M. croceipes,* if exposure to *B. thuringiensis* is not limited. Greater mortality may also have occurred in the current test with longer insecticide exposure. However, Ali and Young (1993) observed a rapid decrease in *B. thuringiensis* activity against first-instar tobacco budworm at these application rates in field tests, with less than 31% of the initial activity remaining after 3 days. Therefore, it is doubtful if longer exposure to *B. thuringiensis*-treated squares would have significantly increased larval mortality. In contrast to findings for *C. marginiventris* (Atwood et al. 1998), these studies, feeding squares from field-treated cotton, indicate a negative impact of thiodicarb on *M. croceipes* emergence at the recommended rate for field application.

Tobacco budworm mortality was directly related to *B. thuringiensis* and thiodicarb concentration in laboratory tests. Furthermore, these findings agree with the observations of Fusco (1980) and Weseloh and Andreadis (1982) which suggest a synergism between *B. thuringiensis* and parasitoids. Laboratory studies indicated that mortality in *M. croceipes* parasitized tobacco budworm larvae on day 6 approximates or exceeds that observed in non-parasitized larvae on day 14 for both *B. thuringiensis* and thiodicarb. Similar results were noted for *C. marginiventris* on day 7 and 14 (Atwood et al. 1997). Overall, these tests appear to indicate that thiodicarb has a greater impact on *M. croceipes* than does *B. thuringiensis.*

Five conclusions can be drawn from this investigation. These are: (1) third-instar tobacco budworm were susceptible to a *B. thuringiensis* rate of 250 ppm and thiodicarb rate of 200 ppm in the diet, (2) *B. thuringiensis* rates above 10 ppm and thiodicarb rates above 12.5 ppm in the diet significantly reduced emergence of *M. croceipes,* (3) mortality of early third-instar tobacco budworm on squares from cotton in field plots treated with *B. thuringiensis* or thiodicarb at current recommended field rates in Arkansas did not exceed 55%, and would not suggest adequate control in the field, (4) thiodicarb and thiodicarb/*B. thuringiensis* combinations provided significantly greater mortality as opposed to *B. thuringiensis* applied alone, although mixes are no more effective than thiodicarb alone and (5) parasitoids within tobacco budworm larvae prior to insecticide application may have the ability to survive and thereby maintain field populations.

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