BEET ARMYWORM (LEPIDOPTERA: NOCTUIDAE) CONTROL ON COTTON IN LOUISIANA

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ABSTRACT

Efficacy of selected labeled and experimental insecticides against beet armyworm, *Spodoptera exigua* (Hübner), populations from Louisiana were determined in both a laboratory diet bioassay and in replicated field plots. Significantly higher LC_{50}'s for chlorpyrifos and thiodicarb were observed for one of two field-collected strains relative to a laboratory-reference strain in the laboratory diet bioassays. No significant differences in susceptibility between the reference strain and field-collected strains were observed for chlorfenapyr (proposed common name), spinosad or tebufenozide. For the reference strain, LC_{50}'s (ppm) for tebufenozide, spinosad, chlorfenapyr, chlorpyrifos, and thiodicarb were 2.6, 2.8, 4.8, 4.9, and 319.8, respectively. In two field tests, all three experimental insecticides (chlorfenapyr, spinosad, and tebufenozide) as well as chlorpyrifos significantly reduced the numbers of beet armyworm larvae relative to the untreated control at all sampling periods (3, 5, 7, and 10 days after treatment), except for Test 2 at 3 days after treatment. Thiodicarb provided satisfactory control of larvae in Test 1; however, in Test 2 thiodicarb did not significantly reduce the numbers of beet armyworm compared with the untreated control. The microbial insecticide Spod-X provided inadequate larval control in both tests.

Key Words: Beet armyworm, insecticides, insecticide efficacy, insecticide bioassay

RESUMEN

Fue determinada la eficacia de insecticidas registrados y experimentales contra poblaciones del gusano de la remolacha, *Spodoptera exigua* (Hübner). Los ensayos se realizaron en el laboratorio, con dietas, y en parcelas replicadas en el campo. En los ensayos de laboratorio fueron observadas CL_{50} significativamente más altas para chlorpyrifos y thiodicarb en una de las dos cepas colectadas en el campo en relación con una cepa de referencia de laboratorio. No fueron halladas diferencias significativas entre la cepa de referencia y las colectadas en el campo, en cuanto a la susceptibilidad a chlorfenapyr (nombre común propuesto), spinosad o tebufenozide. Para la cepa de referencia, las CL_{50} para tebufenozide, spinosad, chlorfenapyr, chlorpyrifos y thiodicarb fueron 2.6, 2.8, 4.8, 4.9 y 319.8 ppm, respectivamente. En dos ensayos de campo, los tres insecticidas experimentales (chlorfenapyr, spinosad, y tebufenozide), así como chlorpyrifos, redujeron significativamente los números de larvas del gusano de la remolacha en relación con el testigo sin tratar en todos los muestreos (3, 5, 7 y 10 días después del tratamiento), excepto en el ensayo 2 a los tres días después del tratamiento. Thiodicarb produjo un control satisfactorio de las larvas en el ensayo 1; sin embargo, en el ensayo 2 thiodicarb no redujo significativamente los números del gusano de la remolacha comparados con los del testigo no tratado. El insecticida microbiano Spod-X produjo un control larval inadecuado en ambas pruebas.

The beet armyworm, *Spodoptera exigua* (Hübner), has historically been viewed as a secondary pest of cotton in most of the southeastern United States. However, population outbreaks experienced in the 1980's and early 1990's in Alabama, Georgia, Louisiana, Mississippi (Douce & McPherson 1991, Burris et al. 1994, Layton 1994, Smith 1994), and more recently in Texas (Arrillago 1995) have demonstrated the potential damage associated with this pest and the ineffective control provided by most currently labeled insecticides. During the outbreak of 1993, beet armyworms infested 60% of the total cotton acreage in the mid-south and southeastern states, with approximately 35% of this acreage having infestations above an economic level (Smith 1994).

The economic impact of beet armyworm infestations varies from region to region and includes both the direct yield loss caused by insect injury and the high production costs associated with frequent and costly insecticide usage. In some regions of the southeast, such as Alabama and Mississippi, where the beet armyworm outbreak of 1993 was particularly devastating, large cotton acreages were abandoned after the control costs exceeded $250-370 per ha (Layton 1994, Smith 1994).

The studies reported here were designed to evaluate the susceptibility of field populations of beet armyworm to standard and experimental insecticides in laboratory and field experiments.

MATERIALS AND METHODS

Laboratory and field experiments were conducted to evaluate the efficacy of standard and experimental insecticides against the beet armyworm. Insecticides tested included commercial formulations of two currently recommended insecticides, thiodicarb [Larvin® 3.2F (flowable powder), Rhone-Poulenc Ag. Co., Research Triangle Park, North Carolina] and chlorpyrifos [Lorsban® 4EC (emulsifiable concentrate), DowElanco, Indianapolis, Indiana], as well as three experimental compounds, tebufenozide (Confirm® 2F, Rohm & Haas Co., Philadelphia, Pennsylvania), chlorfenapyr (Pirate® 3F, American Cyanamid Co., Wayne, New Jersey) and spinosad (Tracer® 4F, DowElanco, Indianapolis, Indiana). Spod-X® (Crop Genetics International, Wilmington, Delaware), a NPV (nuclear polyhedrosis virus) product which is labeled for beet armyworm control in cotton, was included in the field tests.

Diet Bioassay

Susceptibility of a laboratory-reference and two field-collected strains of beet armyworms was evaluated using a surface-treated diet bioassay similar to that described by Joyce et al. (1986) and Chandler & Ruberson (1994). Both field strains were collected from northeast Louisiana, one near Newellton and the other near St. Joseph. These strains were bioassayed using individuals from the F_2-F_4 laboratory-reared generations. Three ml of an artificial wheat germ/pinto bean diet were pipetted into individual 30 ml diet cups (Schneider Paper Product Inc., New Orleans, Louisiana) and allowed to cool. Serial dilutions were prepared for each insecticide tested, and 100 µl of each concentration (four concentrations and a water control) were individually pipetted onto the surface of the diet and allowed to air dry at room temperature for approximately 1 h. Diet cups were shaken to evenly distribute the insecticide solution over the diet's surface.

One first instar (approximately 3-d old) beet armyworm larva was placed on the treated diet and cups were then capped. A minimum of 50 larvae per dose were bioassayed for each insecticide and mortality was observed at 48, 72, 96, and 120 h. Larvae were considered dead if they did not respond to prodding with a paint brush. Bioassays were conducted under constant light at 22±1°C and 40±5% RH. Data from the diet bioassay were analysed by probit analysis using POLO-PC (LeOra Software 1987). LC_{50}'s of field-collected strains were considered to be significantly different than that of the reference strain if the 95% confidence limits did not overlap. Toxicity ratios (TR) were calculated by dividing the LC_{50} of a field strain by that of the reference strain. Field strains bioassayed were collected from the same region where field studies were conducted. The reference strain of beet armyworms was obtained from the USDA-ARS, Southern Insect Management Laboratory (SIML) at Stoneville, Mississippi.

Field Experiments

Field tests were conducted at the Northeast Research Station (Test 1) near St. Joseph, Louisiana and at the Macon Ridge location of the Northeast Research Station (Test 2) near Winnsboro, Louisiana during the summer of 1995. Both tests were arranged in a randomized complete block design with 4 replications. Plots measured four rows (approximately 1 m centers) by 15.25 m. Test 1 was planted to 'Stoneville LA 887' cotton on 16 May and Test 2 was planted to 'DPL 5690' cotton on 20 June.

Larval densities in each block were estimated before insecticide application by taking 6-10 drop cloth (approximately 1 row meter each) samples. Treatments for Test 1 and 2 were applied on 15 and 30 August, respectively, with a high clearance sprayer. In Test 1, the sprayer was calibrated to deliver 93.5 liters total spray volume per ha through Teejet X-12 hollow cone nozzles (2 per row) at 3.6 kg/cm^2. In Test 2, the sprayer was calibrated to deliver 105.5 liters total spray volume per ha through Teejet X-8 hollow cone nozzles (2 per row) at 3.1 kg/cm^2.

Treatment effect was measured by taking 2 drop cloth samples in each plot and counting the number of live larvae. Sampling was done in areas within a row where evidence of a 'hit' (recently hatched egg mass) and/or larval feeding was observed. This sampling procedure was adopted because randomly sampling for a clump-distributed pest population would not appropriately reflect larval densities in field plots. At each sampling period [2, 5, 7, and 10 days after treatment (DAT)], one row of each plot was sampled, so that rows 1, 2, 3, and 4 were sampled at 3, 5, 7, and 10 DAT, respectively. This sampling pattern was used to avoid sampling an individual 'hit', which may have been disturbed during an earlier sampling period. Recently deposited egg masses were avoided during the last two sampling dates, because these 'hits' represented infestations which would not have received the full treatment effect**.** With this sampling approach, neonates through second instar larvae were not included in samples taken at 7 and 10 DAT. Total number of live larvae per 0.3 m of row was used in the data analysis. Data were analyzed by ANOVA and means were separated according to Fischer's protected LSD (SAS Institute 1988).

RESULTS

Diet Bioassay

In the thiodicarb bioassays, LC_{50}'s ranged from 320 to 641 ppm (parts per million) and a significantly higher LC_{50} was obtained with larvae of the Newellton strain compared with the SIML reference strain (Table 1). In the chlorpyrifos bioassays, Newellton strain larvae had a significantly higher LC_{50} than both the St. Joseph and the reference strain. Furthermore, the toxicity ratio for Newellton strain (TR = 7.1) was much higher for chlorpyrifos than for all other insecticides. There were no significant differences in the LC_{50}'s between either of the field-collected strains and the SIML strain for all three experimental insecticides. For the tebufenozide bioassays, LC_{50}'s for all strains evaluated ranged from 2.6 to 5.5 ppm. A similar range in LC_{50}'s was observed for spinosad (2.1-4.8 ppm). Slightly higher LC_{50}'s, which ranged from 4.0 to 6.1 ppm, were obtained in the chlorfenapyr bioassays. Slopes of dosage-mortality lines for chlorfenapyr were steeper compared with slopes for the other chemicals.

Field Experiments

The average number of beet armyworm larvae per 0.3 m of row in Test 1 and 2 prior to application of the various treatments was 5.1 and 12.5, respectively. In Test 1, numbers of beet armyworm larvae were significantly lower than that of the untreated control for all treatments at 3 and 5 DAT, except for Spod-X (Table 2). Similar results were observed at 7 DAT when all treated plots, except for Spod-X and thiodicarb, had fewer live larvae than the untreated control. At the final observation (10 DAT), all treatments had significantly reduced the number of beet armyworm larvae relative to the untreated control.

In Test 2, no significant differences among treatments were observed at 3 DAT (Table 3). At 5 DAT, only the chlorfenapyr and spinosad treatments significantly reduced the number of beet armyworm larvae compared with the untreated control. All treated plots, except for thiodicarb and Spod-X, had significantly fewer larvae than the untreated control at 7 DAT. By 10 DAT, all treatments, except for thiodicarb, had significantly fewer larvae relative to the untreated control (Table 3).

TABLE 1. SUSCEPTIBILITY OF TWO FIELD-COLLECTED AND A LABORATORY-REFERENCE STRAIN OF BEET ARMYWORM TO SELECTED INSECTICIDES AFTER FIVE DAYS OF EXPOSURE TO TREATED DIET.

					95% Conf. Limits		
Strain	Insecticide	N[1]	LC_{50} (ppm)	Slope(SE)	Low	High	TR[2]
SIML, MS[3]	chlorfenapyr	400	4.9	3.94(0.50)	2.8	6.7	
Newellton, LA		250	4.0	3.96(0.68)	3.2	6.7	0.8
St. Joseph, LA		250	6.1	2.97(0.40)	2.6	9.6	1.2
SIML, MS	chlorpyrifos	180	4.8	1.85(0.48)	1.8	8.6	
Newellton, LA		250	34.2*	2.56(0.39)	26.6	42.3	7.1
St. Joseph, LA		250	14.5	3.44(0.40)	7.7	24.0	3.0
SIML, MS	spinosad	250	2.8	1.78(0.39)	1.3	4.5	
Newellton, LA		275	4.8	1.28(0.22)	2.7	7.9	1.7
St. Joseph, LA		250	2.1	1.77(0.23)	1.5	3.1	0.7
SIML, MS	tebufenozide	250	2.6	2.26(0.40)	1.5	4.0	
Newellton, LA		250	3.5	1.82(0.32)	1.2[4]	5.4	1.3
St. Joseph, LA		400	4.4	2.69(0.29)	2.6	6.2	1.7
SIML, MS	thiodicarb	250	319.8	1.74(0.34)	238.0	479.9	
Newellton, LA		275	614.3*	2.78(0.34)	510.2	728.4	1.9
St. Joseph, LA		250	641.4	3.28(0.33)	406.4	926.0	2.0

[1] N - Indicates number of individual larvae tested.
[2] TR - Toxicity ratio = LC_{50} field strain/LC_{50} SIML.
[3] SIML - Southern Insect Management Laboratory, USDA-ARS, Stoneville, Mississippi.
[4] 90% Confidence Limits reported.
*Indicates significantly different LC_{50} values compared with the SIML strain.

TABLE 2. EFFICACY OF SELECTED INSECTICIDES AGAINST BEET ARMYWORM AT 3, 5, 7, AND 10 DAYS AFTER TREATMENT IN TEST 1 AT THE NORTHEAST RESEARCH STATION, ST. JOSEPH, LOUISIANA.

	Numbers of Beet Armyworm Larvae per 30.5 cm				
Treatment	Rate (kg AI/ha)	3 DAT[1]	5 DAT	7 DAT	10 DAT
Chlorfenapyr	0.22	0.5 b	0.3 c	0.6 b	0.3 b
Chlorpyrifos	1.12	0.9 b	0.5 c	1.2 b	0.5 b
Spinosad	0.08	0.7 b	0.2 c	0.4 b	0.2 b
Spod-X	185.5[2]	6.1 a	3.7 ab	4.0 a	1.1 b
Tebufenozide	0.14	2.1 b	0.6 c	1.1 b	0.5 b
Thiodicarb	0.67	1.7 b	2.7 b	1.9 ab	0.9 b
Untreated		5.1 a	5.1 a	3.9 a	2.4 a
$P > F$		0.01	0.01	0.01	0.01

[1]Means within a column not followed by a common letter are significantly different ($P = 0.05$; LSD).
[2]Milliliters formulated material per ha.

DISCUSSION

Variation in susceptibility of field-collected strains of beet armyworm to chlorpyrifos have been reported by Chandler & Ruberson (1994); three (Bartow Co., Georgia, Macon Co., Alabama and Yazoo Co., Mississippi) of seven field strains had significantly higher LC_{50}'s than the SIML reference strain. LC_{50}'s of field strains reported by Chandler & Ruberson were 2- to 29-fold higher than the highest LC_{50} (Newellton, Louisiana) observed in the bioassays reported herein. As with chlorpyrifos, ranges of LC_{50}'s reported for thiodicarb by Chandler & Ruberson (1994) were larger than those observed in bioassays of Louisiana strains. LC_{50}'s observed for all three experimental compounds generally were much lower than those observed with the standard insecticides tested (Table 1). Significantly higher LC_{50}'s observed with the Newellton field strain in both the chlorpyrifos and thiodicarb bioassays likely are due to the fact that this strain was collected from an area which typically receives high insecticide inputs. Although the St. Joseph strain also was collected from a high-input cotton producing region, the actual collection was made from a field within the Northeast Research Station, which typically does not receive intensive insecticide applications.

Susceptibility of the beet armyworms on the Northeast Research Station (both the St. Joseph and Macon Ridge locations) to standard insecticides was also observed in the field tests in which chlorpyrifos (Tables 2 and 3) and thiodicarb (Table 2) significantly reduced the numbers of beet armyworm larvae relative to the untreated control. Considerable variation in control of beet armyworms with chlorpyrifos and thiodicarb is reported in the literature. Smith (1985) reported 65 and 76% control at 3 DAT in Texas with chlorpyrifos and thiodicarb, respectively. In South Carolina, Sullivan et al. (1991) reported 90% control with thiodicarb, while in Mississippi Reed et al. (1994) reported less than 50% larval control with either insecticide. In both field tests, chlorfenapyr and spinosad provided excellent and rapid beet armyworm control and performed as well as, or better than, the standard, chlorpyrifos. Efficacy of chlorfenapyr against beet armyworm also has been documented in numerous EUP trials

TABLE 3. EFFICACY OF SELECTED INSECTICIDES AGAINST BEET ARMYWORM AT 3, 5, 7, AND 10 DAT IN TEST 2 AT THE MACON RIDGE RESEARCH STATION, WINNSBORO, LOUISIANA.

	Numbers of Beet Armyworm Larvae per 30.5 cm[1]				
Treatment	Rate (kg AI/ha)	3 DAT[1]	5 DAT	7 DAT	10 DAT
Chlorfenapyr	0.22	2.8 a	0.6 c	1.1 b	0.4 c
Chlorpyrifos	1.12	4.7 a	3.6 bc	1.2 b	0.3 c
Spinosad	0.08	5.8 a	0.7 c	1.3 b	0.4 c
Spod-X	185.5	10.7 a	7.9 a	3.4 ab	0.7 bc
Tebufenozide	0.14	14.5 a	1.4 bc	0.4 b	0.7 bc
Thiodicarb	0.67	12.6 a	4.4 ab	5.2 a	1.4 ab
Untreated	—	9.2 a	4.4 ab	5.4 a	1.8 a
$P > F$		0.41	0.02	0.04	0.05

[1]Means within a column not followed by a common letter are significantly different ($P = 0.05$; LSD).
[2]Milliliter formulated material per ha.

throughout the southeast (Wiley et al. 1995) where 90-98% control was reported. Tebufenozide, an insect growth regulator, provided satisfactory control of beet armyworm. However, this compound generally had a slower mode of action that required 5 days or more to obtain maximum control. Similar findings were reported by Furr & Harris (1995) where maximum control (83%) was achieved with tebufenozide at 9 DAT. Although this product has a slightly slower mode of action than chlorfenapyr and spinosad, it appears to be well suited for integration into an overall pest management program. Commercialization of these new compounds for beet armyworm control in cotton may lower the insecticide inputs (kg AI/ha) required to maintain this pest under an economic threshold level.

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