

Baseline Susceptibility of Cabbage Looper to Insecticides

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Abstract

Populations of cabbage looper were collected during 1998 from 12 geographical locations in the United States, and were assessed for susceptibility to six new insecticides: Alert, Avaunt, Confirm, Intrepid, Proclaim, and Success, and to a standard insecticide, Pounce. There was no detectable evidence indicating insecticide resistance to any of the new insecticides. However, variability in response to Confirm, Proclaim, and Success warrants close resistance monitoring. Cabbage looper response to Pounce was extremely variable, and there was strong evidence for the occurrence of resistance. Populations from Jackson, MS, Sunderland, MA, and Whately, MA all exhibited high levels of resistance to Pounce with resistance ratios of 90.60, 93.50, and 76.30-fold respectively.

Introduction

The cabbage looper, *Trichoplusia ni* Hübner, is a serious key pest of leafy vegetables in most of the vegetable growing areas of the United States. Because of heavy reliance of insecticides to control this pest in many portions of the U.S., there is concern that insecticide resistance may develop. Cabbage looper resistance to organophosphates, carbamates, and organochlorines have been reported. Although insecticide resistance has not been documented in the desert southwest, in recent years some pest control advisors have reported that cabbage loopers are becoming increasingly more difficult to control with pyrethroids in leafy greens and cole crops. Fortunately, several new insecticides with activity towards cabbage looper have received registrations in these crops, which seems to have mediated much of the control problems previously encountered. However, it is important that good resistance management practices be adopted to subvert the potential for developing resistance to the new insecticide chemistries. Establishing baseline susceptibility levels in cabbage looper is the first step in developing an insecticide resistance management program for this pest. Baseline susceptibility data collected before or early in an insecticide's introduction, provides a reference for tracking shifts in susceptibility over time. Additionally, collecting baseline susceptibility data over a broad geographical range of populations provides information regarding natural variation in insecticide concentration-mortality, and may aid in identifying those insecticides where resistance is more likely to develop.

In this study we report the results of laboratory bioassays to determine the baseline susceptibility of cabbage looper to six new insecticide chemistries, Alert (chlorfenapyr), Avaunt (indoxacarb), Confirm (tebufenozide), Intrepid, Proclaim (emamectin benzoate), and Success (spinosad). We also report susceptibility/tolerance data to a standard insecticide widely utilized for cabbage looper control, Pounce (permethrin).

Materials and Methods

Populations. During 1998-1999, with the aid of collaborators, cabbage looper populations were collected from 12 geographically distinct vegetable production areas throughout the United States. These sites included populations from:

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Arlington, WI, Brighton, CO, Geneva, NY, Holtville, CA, Jackson, MS, King City, CA, Lakeview, CA, Las Cruces, NM, Sanford, FL, Sunderland MA, Whately, MA, and Yuma, AZ. Notable exceptions not evaluated include populations from south Texas and New Jersey. Populations from these areas were collected, but due to high incidences of disease and parasitism, test populations could not be established. Field populations of 28-200 larvae were sent to the University of Arizona Yuma Agricultural Center, Yuma, AZ, where they were reared separately on cabbage looper artificial diet (Southland Products Inc., Lake Village, AR). Field populations were allowed to increase to the F₂ or F₃ generation before testing. The F₂ generation was preferentially used, however due to disease, parasitism, or low vigor, some populations required an additional generation to produce enough progeny to conduct the tests. In addition to field populations, larvae from a laboratory population obtained from the Western Cotton Research Laboratory (WCRL), USDA-ARS, Phoenix, AZ, was evaluated as a susceptible standard.

Bioassays. Baseline susceptibility data were collected from six new insecticide chemistries: chlorfenapyr (Alert 2SC), indoxiacarb (Avaunt), tebufenozide (Confirm), methoxyfenozide (Intrepid), emamectin benzoate (Proclaim 5SG), and spinosad (Success 2SC). Of these insecticides, only Confirm and Success have seen extensive use in commercial crops. In addition to the new insecticides, permethrin (Pounce) was tested to provide relative information from a commonly used standard insecticide.

Insecticide solutions were prepared by diluting the insecticides in distilled water. Concentrations used for the bioassays were: Alert (0, 1, 2, 10, 20, and 100 ppm), Avaunt (0, 0.2, 1, 2, 10, and 20 ppm), Confirm (0, 0.02, 0.2, 2, 20, and 200 ppm), Intrepid (0, 0.002, 0.02, 0.2, 2, 20, and 200 ppm), Proclaim (0, 0.002, 0.02, 0.2, 2, and 20 ppm), Success (0, 0.02, 0.2, 2, 20, and 200 ppm), and Pounce (0, 0.2, 2, 20, 200, 2,000 ppm). Each concentration of Confirm and Intrepid also include Latron CS-7 at 0.125% v/v.

Baseline susceptibility data for each cabbage looper population was determined using a leaf-dip bioassay. Young, fully-expanded cotton leaves, 'DPL 5461', were dipped and gently agitated in the insecticide solutions for five seconds. These leaves were then placed upside down on paper towels and allowed to air dry for 30 minutes. The leaves were then placed upside down on moistened filter paper in petri dishes, and infested with 10 second instar cabbage loopers. This procedure was repeated 4 times for each insecticide concentration.

The infested leaves were held in a temperature controlled room at $24 \pm 2^\circ\text{C}$, with a 12:12 hour L:D photoperiod. Mortality was assessed after 48 hours for Alert, Avaunt, Proclaim, Success, and Pounce, and after 96 hours for Confirm and Intrepid. Those larvae not able to actively move about upon prodding with a pencil were considered dead.

Statistical Analysis. Dosage-mortality curves for all bioassays were estimated using Probit's analysis (SAS Institute 1989). Dosages required to kill 50% (LD₅₀) and 95% (LD₉₅) of the populations were estimated using the Probit regression, 95% confidence limits (CL) were used to separate differences. Resistance ratios were calculated comparing field populations to the insecticide-susceptible strain (RR-L) by dividing the LD₅₀ of the field strain by the LD₅₀ of WCRL insecticide-susceptible strain. Because the WCRL population was not always the most susceptible population tested, or in some cases may represent an extremely sensitive population, resistance ratios among field strains (RR-F) were calculated by dividing the LD₅₀ of field populations by the LD₅₀ of most susceptible field populations. Mean \pm SEM, of the slopes, LC₅₀s, and LC₉₅s were calculated for each insecticide. Additionally, coefficient of variability, and median statistic for LC₅₀s across all populations were calculated for each insecticide.

Results and Discussion

The LC₅₀ values for Alert ranged from 1.71 to 6.23 ppm, and had a mean baseline susceptibility value of 3.52 ppm (Table 1). The coefficient of variability (CV) was low, 42.87, suggesting a lack of extremely susceptible or tolerant populations in the sample. The susceptible laboratory strains (WCRL) did not statistically differ from four of the field collected populations, and only slightly from the others. None of the resistance ratios produced with Alert suggest development of resistance.

Avaunt appeared to be highly toxic to cabbage looper with LC₅₀s, ranging from 0.68 to 4.20 ppm (Table 2). Unlike Alert, based on resistance ratios (RR-L), the WCRL population appeared to be highly sensitive to this insecticide relative to the field populations. Thus, future resistance studies utilizing the WCRL population may result in slightly

skewed higher resistance ratio values that may be misleading. The low CV and RR-F values indicate a fairly uniform response to Avaunt and no immediate evidence of resistance.

Cabbage looper response to Confirm was variable with LC₅₀s ranging from 0.35 to 8.14 ppm, and a CV of 82.69 (Table 3). The Las Cruces, NM population was the most susceptible population evaluated, but did not significantly differ from the WCRL population. Most of the populations evaluated exhibited acceptably low resistance ratios. However, when using the Las Cruces, NM population as a susceptible reference, the Yuma, AZ population exhibited a resistance ratio of 23.26-fold. Although this value is not excessive, it is of concern. Confirm has been used extensively in leafy vegetable and cole crops in Yuma, AZ for several years, and the elevated RR-F value suggests a shift in susceptibility worthy of close monitoring. Additionally, the median LC₅₀ was 28.3% lower than the mean LC₅₀ for Confirm, again suggesting a skewness toward higher insecticide tolerance among some populations. Although, Intrepid is similar to Confirm in chemistry and mode of action, it did not exhibit the variability and elevated resistance ratios observed with Confirm (Table 4). Intrepid was extremely active towards cabbage looper with LC₅₀s ranging from 0.04 and 0.14 ppm.

Proclaim exhibited the highest toxicity of any of the insecticides evaluated with LC₅₀s ranging for 0.05 to 0.31 ppm (Table 5). The most susceptible field population was from Yuma, AZ, whose LC₅₀ was the same as the WCRL population. Although resistance ratios were low, variability based on a CV value of 63.36, and a median LC₅₀ 30.77% lower than the mean LC₅₀ suggests a tendency towards higher insecticide tolerance in several field populations, i.e. Geneva, NY, Jackson, MS, King City, CA, and Sunderland, MA. This does not necessarily indicate a immediate threat of insecticide resistance, but is noteworthy and justifies close resistance monitoring.

Similarly to Proclaim, cabbage looper response to Success was somewhat variable with LC₅₀s ranging from 0.18 to 2.78 ppm, and a CV of 67.33 (Table 6). However, unlike Proclaim the median LC₅₀ was similar to the mean LC₅₀, indicating a more even distribution in response among the populations, and demonstrating the presence of highly susceptible populations such as Brighton, CO, relative to more tolerant populations like Jackson, MS. This wide range in LC₅₀ values also resulted in several slightly elevated resistance ratios, i.e. Jackson, MS had a RR-F of 15.28-fold. Whether or not this indicates a shift towards higher tolerances is not certain, but may simply be indicative of a high level of susceptibility in a few populations. However, if the Brighton, CO population's response to Success is indicative to what would have been noted had the study been conducted prior to commercial introduction of Spinosad several years ago, then this may indicate an initial shift toward higher tolerances. Future monitoring will be necessary to determine the case.

Pounce was included in this study for comparison purposes of cabbage looper response to an older standard insecticide relative to the newer insecticides. In 1983, cabbage looper populations collected throughout portions of the United States indicated a very uniform, highly susceptible response to permethrin. In our study, we found a great deal of variability among populations, with LC₅₀s ranging from 0.30 to 28.05 ppm, and a CV of 92.56 (Table 6). With the exception of the Las Cruces, NM population, all of the field populations evaluated had significantly higher LC₅₀s than the susceptible laboratory population, WCRL. Using the WCRL population as a susceptible reference, the Jackson, MS, Sunderland, MA, and Whately, MA populations were 90.60, 93.50, and 76.30-fold more resistant to permethrin respectively. Whether or not these differences would translate into field control failures is not certain. The high level of resistance found the Jackson, MS population may be the result of extensive pyrethroid use in this area, particularly in cotton. The populations we evaluated from Massachusetts originated from small sample sizes, following pyrethroid applications. Thus, these samples may represent field selections for pyrethroid resistance. In Massachusetts, growers have been using pyrethroids, particularly Warrior (lambda-cyhalothrin), in rotation with *B.t.s* and other classes of insecticide for cabbage looper with little control difficulty. Thus, although there may be evidence of high levels of resistance to Pounce in the Massachusetts populations, a good resistance management program appears to have alleviated control problems. In another case, before widespread use of Success and Confirm in Yuma, AZ pest control advisors there reported inconsistent control of cabbage loopers with pyrethroids. Since the incorporation of these new insecticides into insecticide rotation and tank mix schemes, control difficulties appear to be much less frequent.

Table 1. Susceptibility of cabbage looper to Alert in ppm, 48 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	2.41 ± 0.27	4.13 (3.21-5.29)	19.87 (13.88-33.46)	2.42*	2.19*	2.69	3
Brighton, CO	240	1.83 ± 0.23	3.23 (2.37-4.30)	25.35 (16.19-50.26)	1.89*	1.71	4.83	3
Geneva, NY	240	2.16 ± 0.24	5.14 (3.95-6.69)	29.79 (20.78-52.93)	3.01*	2.74*	0.28	3
Holtville, CA	240	2.69 ± 0.31	5.40 (4.24-6.82)	22.07 (15.92-35.28)	6.16*	2.86*	2.47	3
Jackson, MS	240	1.89 ± 0.23	3.08 (2.28-2.28)	22.75 (14.61-44.66)	1.80*	1.63	1.47	3
King City, CA	240	2.32 ± 0.31	2.24 (1.71-2.89)	11.42 (7.76-20.93)	1.31	1.19	4.47	3
Lakeview, CA	240	2.68 ± 0.29	4.57 (3.60-5.80)	18.81 (13.52-30.04)	2.67*	2.42*	3.07	3
Las Cruces, NM	240	2.87 ± 0.46	1.94 (1.54-2.46)	7.23 (4.96-14.13)	1.14	1.03	0.14	3
Sanford, FL	240	2.12 ± 0.24	6.23 (4.23-8.14)	37.23 (24.85-67.11)	3.64*	3.30*	4.68	3
Sunderland, MA	240	3.11 ± 0.55	1.71 (1.37-2.14)	5.75 (3.99-11.70)	1.00	0.91	3.48	3
Whately, MA	240	3.06 ± 1.34	2.19 (1.76-2.75)	7.52 (5.36-13.07)	1.28	1.16	28.7 ^d	3
Yuma, AZ	240	2.25 ± 0.39	4.04 (3.12-5.23)	21.82 (14.83-38.60)	3.64*	2.14*	6.51	3
WCRL	240	2.50 ± 0.36	1.89 (1.45-2.41)	8.58 (5.85-16.22)	1.10	1.00	7.65	3
Mean ± SEM		2.45 ± 0.12	3.52 ± 0.42	18.32 ± 2.69				
Median			3.23					
CV			42.87					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Sunderland, MA); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 2. Susceptibility of cabbage looper to Avaunt in ppm, 48 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	1.95 ± 0.23	2.81 (2.12-3.70)	19.63 (12.68-37.57)	1.76*	4.13*	5.77	3
Brighton, CO	240	1.54 ± 0.18	1.94 (1.39-2.66)	22.54 (13.32-49.80)	1.21	2.85*	5.73	3
Geneva, NY	240	2.10 ± 0.24	3.45 (2.65-4.53)	20.97 (13.78-38.31)	2.16*	5.07*	7.16	3
Holtville, CA	240	1.93 ± 0.22	4.20 (3.18-5.61)	29.82 (18.91-58.54)	2.63*	3.87*	11.24 ^d	3
Jackson, MS	240	2.07 ± 0.23	3.65 (2.80-4.80)	22.71 (14.94-41.89)	2.28*	5.37*	7.96 ^d	3
King City, CA	240	2.34 ± 0.27	2.68 (2.09-3.47)	13.50 (9.17-23.89)	1.68	3.94*	7.25	3
Lakeview, CA	240	2.01 ± 0.23	2.14 (1.63-2.82)	14.15 (9.27-26.47)	1.34	3.15*	1.74	3
Las Cruces, NM	240	1.71 ± 0.20	2.00 (1.47-2.70)	18.29 (11.34-37.10)	1.25	2.94*	7.05	3
Sanford, FL	240	2.22 ± 0.27	1.60 (1.23-2.09)	8.82 (5.88-16.26)	1.00	2.35*	11.86 ^d	3
Sunderland, MA	240	2.05 ± 0.23	2.28 (1.74-3.01)	14.47 (9.46-26.98)	1.43	3.35*	14.98 ^d	3
Whately, MA	240	2.11 ± 0.26	1.80 (1.37-2.34)	10.83 (7.21-20.03)	1.13	2.65*	3.34	3
Yuma, AZ	240	2.07 ± 0.23	2.60 (1.99-3.42)	16.22 (10.67-29.96)	1.63	3.82*	9.36 ^d	3
WCRL	240	2.98 ± 0.42	0.68 (0.52-0.85)	2.42 (1.79-3.85)	0.41* *	1.00	0.45	3
Mean ± SEM		2.08 ± 0.09	2.45 ± 0.26	16.49 ± 1.95				
Median			2.28					
CV			38.34					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Sanford, FL); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 3. Susceptibility of cabbage looper to Confirm in ppm, 96 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	238	0.84 ± 0.10	1.72 (0.94-3.22)	156.94 (56.87-712.14)	4.91*	1.64	14.50 ^d	3
Brighton, CO	240	0.72 ± 0.09	1.71 (0.88-3.39)	326.90 (100.13-2006)	4.89*	1.63	10.00 ^d	3
Geneva, NY	240	0.56 ± 0.08	3.47 (1.54-8.36)	707.59 (170.73-7240)	9.91*	3.31	8.99 ^d	3
Holtville, CA	239	1.45 ± 0.19	1.25 (0.79-1.96)	17.01 (8.92-45.51)	3.57*	1.19	2.83	3
Jackson, MS	239	1.12 ± 0.13	1.58 (0.94-2.65)	46.76 (21.59-145.06)	4.51*	1.51	7.96 ^d	3
King City, CA	239	0.66 ± 0.08	1.35 (0.64-2.75)	423.73 (119.16-3093)	3.86	1.29	17.30 ^d	3
Lakeview, CA	240	1.48 ± 0.19	2.08 (1.31-3.23)	26.90 (14.34-70.70)	5.94*	1.98	11.95 ^d	3
Las Cruces, NM	237	0.66 ± 0.09	0.35 (0.15-0.72)	110.26 (32.98-757.57)	1.00	0.33	2.28	3
Sanford, FL	240	1.96 ± 0.30	2.11 (1.43-3.17)	14.56 (8.19-38.23)	6.03*	2.01	3.59	3
Sunderland, MA	240	2.05 ± 0.23	2.28 (1.74-3.01)	14.47 (9.46-26.98)	6.51*	2.17	13.55 ^d	3
Whately, MA	240	1.79 ± 0.26	4.06 (2.67-6.11)	33.60 (18.80-86.46)	11.60*	3.87*	0.79	3
Yuma, AZ	237	0.91 ± 0.11	8.14 (4.56-15.36)	515.73 (186.69-2395)	23.26*	7.75*	19.74 ^d	3
WCRL	240	0.80 ± 0.09	1.05 (0.56-1.98)	123.57 (43.26-599.66)	2.91	1.00	11.48 ^d	3
Mean ± SEM		1.15 ± 0.15	2.40 ± 0.55	193.63 ± 63.15				
Median			1.72					
CV			82.69					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Las Cruces, NM); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 4. Susceptibility of cabbage looper to Intrepid in ppm, 96 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	0.94 ± 0.11	0.04 (0.02-0.06)	2.03 (0.82-7.94)	1.00	0.36*	24.70 ^d	3
Brighton, CO	240	0.83 ± 0.10	0.04 (0.02-0.08)	4.10 (1.54-18.15)	1.00	0.36	3.78	3
Holtville, CA	240	0.76 ± 0.09	0.14 (0.07-0.27)	20.42 (6.78-108.78)	3.50*	1.27	4.38	3
Jackson, MS	240	0.99 ± 0.11	0.12 (0.07-0.21)	5.57 (2.34-20.13)	3.00*	1.09	9.64 ^d	3
Lakeview, CA	240	0.93 ± 0.10	0.13 (0.08-0.24)	7.83 (3.25-27.97)	3.25*	1.18	2.22	3
Las Cruces, NM	240	0.75 ± 0.08	0.14 (0.07-0.26)	21.52 (7.65-95.63)	3.50*	1.27	15.56 ^d	3
Sanford, FL	240	0.92 ± 0.11	0.07 (0.04-0.12)	3.98 (1.59-15.80)	1.75	0.64	7.30	3
Sunderland, MA	240	0.91 ± 0.10	0.16 (0.09-0.29)	10.53 (4.14-42.11)	4.00*	1.46	2.92	3
Whately, MA	240	0.84 ± 0.10	0.10 (0.05-0.18)	8.91 (3.31-39.78)	2.50	0.91	11.18 ^d	3
WCRL	240	1.04 ± 0.12	0.11 (0.07-0.20)	4.31 (1.85-15.21)	1.10	1.00	15.54 ^d	3
Mean ± SEM		0.89 ± 0.03	0.11 ± 0.01	8.92 ± 2.17				
Median			0.12					
CV			40.23					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Arlington, WI); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 5. Susceptibility of cabbage looper to Proclaim in ppm, 48 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	2.24 ± 0.34	0.07 (0.05-0.11)	0.41 (0.25-0.93)	1.40	1.40	0.04	3
Brighton, CO	240	1.27 ± 0.16	0.15 (0.09-0.24)	2.94 (1.41-9.03)	3.00*	3.00*	9.25 ^d	3
Geneva, NY	240	1.01 ± 0.11	0.31 (0.18-0.54)	13.02 (5.46-46.79)	6.20*	6.20*	9.29 ^d	3
Holtville, CA	240	1.70 ± 0.23	0.15 (0.10-0.23)	1.39 (0.76-3.63)	3.00*	3.00*	0.09	3
Jackson, MS	240	1.97 ± 0.30	0.22 (0.15-0.33)	1.52 (0.87-3.85)	4.40*	4.40*	0.13	3
King City, CA	240	1.35 ± 0.16	0.22 (0.17-0.45)	3.67 (1.84-10.32)	4.40*	4.40*	8.35 ^d	3
Lakeview, CA	240	1.74 ± 0.10	0.08 (0.05-0.13)	0.72 (0.41-1.81)	1.60	1.60	2.24	3
Las Cruces, NM	240	1.92 ± 0.29	0.09 (0.06-0.13)	0.60 (0.34-1.52)	1.80	1.80	0.29	3
Sanford, FL	240	1.62 ± 0.22	0.06 (0.04-0.10)	0.64 (0.34-1.71)	1.20	1.20	2.08	3
Sunderland, MA	240	1.78 ± 0.25	0.22 (0.15-0.34)	1.83 (1.00-4.92)	4.40*	4.40*	6.60	3
Whately, MA	240	2.59 ± 0.39	0.07 (0.05-0.10)	0.31 (0.20-0.62)	1.40	1.40	0.01	3
Yuma, AZ	240	1.36 ± 0.17	0.05 (0.03-0.08)	0.84 (0.43-2.23)	1.00	1.00	15.05 ^d	3
WCRL	240	1.84 ± 0.27	0.05 (0.03-0.08)	0.40 (0.22-1.02)	1.00	1.00	0.42	3
Mean ± SEM		1.72 ± 0.12	0.13 ± 0.02	2.18 ± 0.95				
Median			0.09					
CV			63.36					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Yuma, AZ); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 6. Susceptibility of cabbage looper to Success in ppm, 48 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	1.42 ± 0.18	1.00 (0.64-1.60)	14.35 (7.25-41.06)	5.56*	4.76	3.68	3
Brighton, CO	240	1.02 ± 0.13	0.18 (0.10-0.31)	7.44 (3.21-27.66)	1.00	0.86	0.32	3
Geneva, NY	240	0.96 ± 0.12	0.41 (0.22-0.71)	21.24 (8.93-77.93)	2.28	1.95	1.97	3
Holtville, CA	240	1.23 ± 0.15	1.39 (0.85-2.27)	29.86 (14.38-88.69)	7.72*	6.62*	0.98	3
Jackson, MS	240	1.37 ± 0.17	2.78 (1.75-4.45)	44.27 (22.22-126.64)	15.28*	13.24*	0.57	3
King City, CA	239	1.13 ± 0.13	1.35 (0.81-2.27)	39.07 (17.83-125.48)	7.50*	6.43*	1.71	3
Lakeview, CA	240	1.30 ± 0.16	0.67 (0.41-1.07)	12.24 (5.94-36.37)	3.72*	3.19*	7.55	3
Las Cruces, NM	240	1.06 ± 0.13	0.44 (0.26-0.75)	15.45 (6.77-53.93)	2.44	2.10	4.35	3
Sanford, FL	240	1.31 ± 0.16	1.65 (1.02-2.69)	29.78 (14.49-88.33)	9.17*	7.86*	6.47	3
Sunderland, MA	240	1.18 ± 0.14	1.51 (0.92-2.51)	37.01 (17.18-117.71)	8.39*	7.19*	8.84 ^d	3
Whately, MA	240	1.75 ± 0.24	0.97 (0.64-1.47)	8.48 (4.74-21.35)	5.39*	4.62*	1.24	3
Yuma, AZ	240	1.27 ± 0.16	1.45 (0.90-2.37)	28.60 (13.81-86.27)	8.05*	6.91*	3.66	3
WCRL	239	1.26 ± 0.17	0.21 (0.12-0.34)	4.14 (2.02-12.77)	1.67	1.00	6.13	3
Mean ± SEM		1.25 ± 0.06	1.08 ± 0.20	22.46 ± 3.66				
Median			1.00					
CV			67.33					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Brighton, CO); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits..

^dChi-square significant (P ≥ 0.05).

Table 7. Susceptibility of cabbage looper to Pounce in ppm, 48 hr after treatment using a cotton leaf dip bioassay.

Population ^a	<i>n</i>	Slope ± SE	LC ₅₀ (95% CL)	LC ₉₅ (95% CL)	RR-F ^b	RR-L ^c	χ ²	df
Arlington, WI	240	1.65 ± 0.23	8.78 (5.74-13.51)	87.85 (47.07-239.65)	12.54*	29.27*	1.38	3
Brighton, CO	240	1.14 ± 0.14	5.43 (3.25-9.14)	151.07 (68.65-493.12)	7.76*	18.10*	9.58 ^d	3
Geneva, NY	240	1.08 ± 0.14	2.05 (1.16-3.48)	97.53 (30.11-239.40)	2.93	6.83*	2.29	3
Holtville, CA	240	1.66 ± 0.23	7.46 (4.88-11.44)	73.07 (39.39-197.65)	10.66*	24.87*	1.07	3
Jackson, MS	240	2.01 ± 0.31	27.18 (18.42-40.53)	178.97 (102.56-453.99)	38.83*	90.60*	1.25	3
King City, CA	240	0.88 ± 0.11	3.65 (1.94-6.57)	261.69 (103.33-1075)	5.21*	12.17*	1.69	3
Lakeview, CA	240	1.40 ± 0.19	2.53 (1.59-4.04)	37.87 (18.93-111.94)	3.61*	8.43*	2.96	3
Las Cruces, NM	240	0.81 ± 0.12	0.70 (0.28-1.38)	75.44 (27.83-402.06)	1.00	2.33	2.32	3
Sanford, FL	240	1.80 ± 0.25	10.27 (6.70-15.44)	84.60 (48.58-200.36)	14.67*	34.23*	10.43 ^d	3
Sunderland, MA	240	2.38 ± 0.42	28.05 (19.55-40.62)	137.56 (82.18-359.16)	40.07*	93.50*	0.18	3
Whately, MA	240	2.27 ± 0.40	22.89 (15.69-33.15)	121.16 (72.11-312.93)	32.70*	76.30*	0.65	3
Yuma, AZ	280	1.11 ± 0.12	9.82 (5.87-16.65)	294.75 (135.57-896.84)	14.03*	32.73*	22.69 ^d	3
WCRL	240	1.83 ± 0.26	0.30 (0.20-0.45)	2.33 (1.30-6.07)	0.43	1.00	5.70	3
Mean ± SEM		1.54 ± 0.14	9.93 ± 2.72	123.38 ± 23.04				
Median			7.46					
CV			92.56					

^aWCRL = Western Cotton Laboratory USDA-ARS, Phoenix, AZ (susceptible laboratory strain), remaining entries are field collected populations.

^bRR-F, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the most susceptible field population (Las Cruces, NM); * indicates a significant difference based on non-overlapping 95% confidence limits.

^cRR-L, resistance ratio calculated by dividing the LC₅₀ of the strain tested by the LC₅₀ of the susceptible laboratory strain (WCRL); * indicates a significant differences based on non-overlapping 95% confidence limits.

^dChi-square significant (P ≥ 0.05).