Insecticide Tests for Control of the Western Bean Cutworm

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ABSTRACT

Little has been published on insecticidal control of the western bean cutworm on beans and corn. This report summarizes results of tests in southern Idaho from 1950 to 1980. Of 53 chemicals tested in the laboratory, 24 showed effectiveness approximately equal to or better than DDT or carbaryl, which were used as standards. Of 26 materials applied as sprays to beans with ground equipment, 7 that were tested most extensively indicate effectiveness equal to or better than carbaryl, and 9 tested less extensively indicate a high degree of effectiveness. Of those materials applied by air to sweet corn, permethrin provided almost perfect control. Three formulations of carbaryl did not differ significantly in performance in individual tests, but the newer formulations appear to be an improvement. The efficacy of insecticides decreased with delay in time of application in relation to peak moth flight due to a combination of increased size of larvae and increased foliage density.

KEYWORDS: Western bean cutworm, *Loxagrotis albicosta*, beans, *Phaseolus vulgaris*, sweet corn, *Zea mays*, insecticides.

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In recent years, our research has been supported by grants to the University of Idaho from Union Carbide Corp., ICI Americas Inc., Chevron Chemical Co., Stauffer Chemical Co., Shell Chemical Co., and FMC Corporation.

Many growers have cooperated by providing field plot space for applications to beans, and Green Giant Corp. cooperated closely in making aerial applications to sweet corn.

Bob Winterfeld, pilot, (USDA Laboratory, Yakima, Wash.) made most of the aerial applications. Bruce Mackey, statistician, (USDA, SEA-AR, Western Regional Research Center, Albany, Calif.) analyzed the laboratory data for 1980.

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INSECTICIDE TESTS FOR CONTROL OF THE WESTERN BEAN CUTWORM

By C. C. Blickenstaff and R. E. Peckenpaugh[1]

INTRODUCTION

In southern Idaho, the western bean cutworm, *Loxagrotis albicosta* (Smith), was first noticed damaging beans (*Phaseolus vulgaris* L.) in 1942 (Hoerner *1948*)[2] and corn (*Zea mays* L.) in 1954 (Douglass et al. *1957*). The history and biology of the western bean cutworm (WBC) in southern Idaho were discussed in detail by Blickenstaff (*1979*).

The first report of efforts to control the WBC was that of McCampbell (*1941*) in Colorado, who used bran-sawdust bait mixed with sodium arsenite in heavily infested fields and obtained up to 90-percent control. He suggested that sprays of zinc arsenite be applied until bean foliage closed the rows and that bait should be spread at time of cutting or placed under bean shocks to prevent further damage during the curing.

Hoerner (*1948*) summarized tests conducted on beans in Colorado in 1942, 1943, 1944, and 1945. Of various baits, dusts, and sprays tested, DDT dust at 0.9 pounds active ingredient per acre (lb AI/A) and DDT sprays gave the best control.

Hagen reported results of tests on dent corn (*1962*) and on beans (*1963*) in Nebraska. Increases in yield of corn at dosages tested (lb AI/A) were 32 percent for endrin (0.2), 24 percent for endosulfan (1.5), 18 and 12 percent for DDT (1), 9 percent for carbaryl (1.7), and 2 percent for diazinon (0.25). On beans, total yield per acre over 3 years of testing was not increased significantly by any treatment, but culls were reduced significantly by aldrin spray (2.5 lb AI/A), aldrin granular (0.4 lb AI/A), endosulfan granular and spray (0.5 lb AI/A), DDT dust (1.5 lb AI/A), and carbaryl wettable powder and dust (1 lb AI/A).

Surprisingly, no further research results have been published. Testing has continued, however, and the results are reflected in more recently published

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[2]The author's name followed by the year in italic, refers to Literature Cited, p. 11.

guidelines for control: Hantsbarger (*1969*) for Colorado; Munson et al. (*1969*), Hagen and Roselle (*1970*), and Hagen (*1973*, *1976*) for Nebraska; Blickenstaff et al. (*1975*) and Capizzi et al. (*1980*) for Idaho; and Neal (*1979*) for the United States.

These guidelines list insecticides for control of WBC on crops as follows:

Dry beans: carbaryl, trichlorfon, and endosulfan

Field corn: endrin, trichlorfon, and carbaryl

Sweet corn: carbaryl

This report summarizes data for laboratory and field tests conducted in southern Idaho from 1950 to 1980, none of which has been previously published.

Names of materials used are listed in the appendix.

LABORATORY TESTS

Laboratory tests involving 53 materials plus the standards, DDT or carbaryl, were conducted in 1950, 1962, 1971, 1972, 1976 and 1980. In nearly all these tests, the foliage of bean plants was treated and fed to larvae of various ages. Methods by year and test were as follows:

1950

Potted bean plants were dusted with different rates of the test materials. Then, 10 WBC larvae were placed on each plant and covered with a wire screen cage. Each treatment was replicated five times. The chemicals, rates (grams per plant), and percent mortality after 48 hours were: DDT (3.4) 98 percent, parathion (3.9) 100 percent, toxaphene (4) 82 percent, and chlordane (3.7) 70 percent. Mortality counts taken one day later showed 100-percent mortality for all but chlordane, which was 90 percent.

1962, Test 1

Individual bean plants were sprayed, at the rate of 35 gallons per acre (gpa), while they were rotating on a turntable. Two replications of 10 plants per treatment were sprayed. One day after spraying, each plant was infested with two third and fourth instar larvae and covered with a cage. Chemicals, rates, mortality at 48 hours, and estimated LD_{90} are given in table 1.[3]

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[3]Tables follow the text, beginning on p. 16.

1962, Test 2

Bean seed was treated with the systemic insecticides dimethoate, menazon, schradan, or mexacarbate at 4 or 8 oz/100 lb seed as either a slurry (insecticide plus methyl cellulose seedcoat) or a seed soak (3 hours) and planted the following day. Seven days later, 10 plants of each treatment were transplanted to individual pots. Four days later, each plant was infested with five WBC larvae (6 to 7 days old). Plants were then covered with a cage. Cages were removed after 3 more days, and larval mortality was recorded. None of these treatments were effective against WBC larvae.

1971

Bean foliage was sprayed in the field with nine materials each applied at a rate of 1.5 lb AI/A. Five, 13, and 19 days after spraying, 10 leaves per treatment were picked and placed in a petri dish containing 10 second instar larvae. Mortality data and materials used are given in table 2.

1972

Bean foliage was sprayed in the field with 16 materials, each applied at a rate of 1.5 lb AI/A. Five leaves per treatment were placed in each petri dish along with 5 or 10 third to fourth instar WBC larvae at intervals of 1, 8, 15, and 22 days after spraying. Materials used and mortality data gathered 48 hours after treatment are given in table 3.

1976

Bean leaf disks were dipped in insecticide-water mixtures ranging from 0.0123 to 1 percent (weight of active ingredient). Treated disks were air dried and fed to second to fourth instar larvae. Three leaf disks and five larvae per petri dish were replicated four times for each dilution. Because L-588 and L-794 are antimolting insecticides, larvae were held for 12 days before mortality was recorded. For the other two materials (carbaryl and Mobil 9087), mortality data are given for 48 hours after treatment. The data are given in table 4.

1980

Bean leaf disks were dipped in serial dilutions of insecticide-water mixtures, air dried, and fed to either third or fifth instar larvae. Depending on their availability, from 4 to 10 larvae per petri dish were used per replicate, and the number of replicates varied from two to four. Mortality was determined 24 and 48 hours after exposure. The pyrethroids, permethrin (Ambush) and fenvalerate, and carbaryl (XLR) were compared by probit analysis in terms of lethal dosages (LD) to give 50- and 95-percent mortality. The results are summarized in table 5.

Summary of Leaf Feeding Tests

In table 1, materials tested are listed in descending order of overall effectiveness in terms of estimated LD_{90}. Twelve of these resulted in 90-percent mortality or better within 48 hours at dosages ranging from 0.25 to 2 lb AI/A. Mexacarbate, trichlorfon, carbaryl, endosulfan, Q-137, and endrin all resulted in 90- to 100-percent mortality at the low dosage of 0.25 lb AI/A. In this test, DDT at 1.5 lb gave 98-percent control.

As shown in table 2, four materials gave 100-percent mortality within 48 hours when exposed to treated leaves 5 days after spraying at dosages of 1.5 lb AI/A, and dicrotophos continued to give 100-percent mortality when larvae were exposed 19 days after spraying. In this test (table 2), DDT gave only 70-percent control at 5 days and no control at 19 days.

As shown in table 3, 10 materials gave 100-percent mortality when exposed one day after spraying, but mortality declined rapidly with time. Methamidophos, phosfolan, EI 47,470, mexacarbate, and chlorpyrifos were approximately equal to or better than DDT (all at 1.5 lb AI/A) over the time of testing. Regressions fitted by eye indicated these five materials still gave 50 percent or better mortality when larvae were exposed 10 to 21 after treatment.

As shown in table 4, Mobil 9087 performed better than carbaryl at the same dosages. No dosage response was shown for the two antimolting compounds.

The purpose of the test summarized in table 5 was to compare the effectiveness of three insecticides on larvae of different sizes. The data did not fit well for permethrin on fifth instar larvae at 24- and 48-hour exposures as indicated by high chi-square values. All other sets had relatively low chi-square values (0.22 to 2.5), indicating relatively good fit of mortality data to increasing dosages. An average of 10 times (4 to 15) more fenvalerate, 44 times (15 to 100) more permethrin, and 3.5 times (0.9 to 5.9) more carbaryl were required to achieve the same mortality of fifth instar larvae as compared with third instar larvae. All mortality occured within 24 hours with fenvalerate, but larval mortality continued to increase from 24 to 48 hours with permethrin and carbaryl. Fenvalerate was more effective than permethrin and carbaryl. Potency ratios for permethrin averaged 0.309 (0.0132 to 0.7242). These results indicate that on the average it took 3.24 times more permethrin to achieve the same mortality as with fenvalerate. For carbaryl, the average potency ratio was 0.0023 (0.0010 to 0.0039); or, it took 435 times more carbaryl to achieve the same results as with fenvalerate.

Thus, in laboratory tests, a large number of materials (24 of 53) were found approximately equal to or better than the standards--DDT or carbaryl.

FIELD TESTS

Chlorinated Hydrocarbons

Field tests on beans, primarily with chlorinated hydrocarbons, were conducted in south-central Idaho between 1950 and 1960. The results demonstrated that insecticides applied to seed or to soil surface and worked in prior to planting were not effective. When materials were applied after egg hatch as sprays or dusts with either ground or aerial equipment, DDT gave consistently superior control; dieldrin, aldrin, heptachlor, toxaphene, and endrin were also quite effective. Since these materals are no longer included in control guidelines, test details are omitted.

Granular Formulations

In 1968, granular formulations of 15 carbamate or phosphorous derivative insecticides were applied at rates of 1 and 2 lb AI/A either in the seed furrow at planting or dribbled over bean plants during moth flight. All applications gave poor or ineffective control.

In 1974, 1975, 1976, and 1977, systemic insecticides, at rates of 2 lb AI/A, were applied by injection on the water furrow side after plant emergence. Plots were 50 to 60 feet long and three or six rows wide. In 1974, no WBC were present, and no data were obtained. The results of the other tests based on damaged beans at harvest were as follows:

	Percent control		
Material	1975	1976	1977
Carbofuran	76	51	
Disulfoton	50		
Phorate	58	42	
Acephate		12	
Aldicarb	0		24, 28
Untreated [percent damage]	[0.84]	[4.2]	[6.84]
No. replications	4	5	8
Date of application	7/25	8/9	6/8, 6/30

Although some control was indicated, treatments did not differ significantly from untreated checks in any of these three tests.

Foliar Spray Applications with Ground Equipment on Beans

Nine tests involving 26 materials were conducted from 1971 through 1980. In 1971, plots were 12- to 24-row strips through the field; in 1972, plots were six- or eight-row strips through the field; and from 1976 to 1980, plots were four or six rows wide and 50 feet long. Sprays were applied at the rate of 20 gpa with tractor-mounted equipment, using two nozzles per row from a single drop tube between each row. Applications were made between mid-July and the first week of August, depending on when peak moth flight occurred as determined by blacklight trap catches. Efficacy was determined by randomly picking pods at harvest and examining them in the laboratory for holes in the pods or eaten and damaged seeds. The results are summarized in table 6.

Damaged beans in untreated check plots were very low in all tests, ranging from approximately 0.1 percent in 1971 (estimated from 0.4 holes per 100 pods, one bean damaged per hole, and four beans per pod) to 2 percent in 1980. These were nearly all subeconomic infestations if 2 percent is considered an economic level lowering quality and requiring additional effort in the cleaning process to separate out damaged beans (Blickenstaff *1979*). The data also indicated a high degree of spotty damage with many samples showing no damage. The data were, therefore, analyzed as $\sqrt{x + 0.5}$ to reduce the variation. Even so, there was often little significant difference among insecticide treatments within tests; however, the data often indicated dosage responses both in individual tests and averaged over tests. Materials averaging 90-percent control or better in two or more tests and their dosage (AI/A) were: AC 222,705 (0.04), acephate (1), chlordane (2), DDT (1), EPN (1), fenvalerate (0.1), and permethrin (0.1). Those indicating 90-percent control or better but applied in only one test were: carbofuran (1.5), carbophenothion (3.5), cryolite (10), diazinon (1.5), endosulfan (1), methoxychlor (2), methyl parathion (1), profenofos (0.5 to 1), and sulprofos (1). Of the three materials currently registered for WBC control on beans (carbaryl, endosulfan, and trichlorfon), only endosulfan was in the above category in these tests.

Comparison of Laboratory and Foliar Field Tests on Beans

Comparisons among laboratory results (table 1, 2, 3, and 5) and field results with ground sprays on beans (table 6) are shown in table 7. Of the six materials from table 1 with relatively low LD_{90}'s, field control varied from 40 percent for carbophenothion to 100 percent for endosulfan, but none of those with higher LD_{90}'s were field tested. Of the three materials listed in table 2 and field tested at comparable rates, each averaged 91-percent control or better. Again, none of the three poorer materials in table 2 were field tested. DDT performed rather poorly in this laboratory test but provided excellent control in the field. Four of the materials listed in table 3 were in the field but at rates varying considerably from those used in the laboratory; however, with the exception of methamidophos, field performance did correlate well with laboratory results. Permethrin and fenvalerate (table 5) were much more toxic than carbaryl in the laboratory and also gave better control in the field at one-twentieth the carbaryl rate.

Of the 14 materials listed in table 7, 13 ranked relatively high in laboratory tests and 8 of the 13 indicated 90-percent control or better in field tests. The one material, diflubenzuron, that performed very poorly in laboratory tests also performed very poorly in the field at a low rate of application. We conclude that laboratory testing can be of considerable value for initial screening.

Timing of Insecticide Application in Relation to Peak Moth Flight

Based on a generalized life history chart, Blickenstaff (*1979*) suggested that insecticide applications made between 7 and 18 days after peak moth flight would be most effective. During that period, most eggs would have hatched, and most larvae would still be less than half grown (third instar). In general, small larvae are easier to kill than large larvae.

A test in 1978 with carbaryl (Sevimol formulation) compared rates of 1 and 2 lb AI/A applied on days 6, 18, and 32 after peak moth flight with six replicates of each treatment. Results were as follows:

	Percent control at rates of:	
Day	*1 lb*	*2 lb*
6	60	65
18	28	60
32	29	7

Combining the two rates, the correlation was -0.85*, and the line or regression values were, a = 73.52, and b = -1.72.

The results of a second test, where applications were made 15, 22, and 29 days after peak moth flight, are given in table 8. The pyrethroids, permethrin (Pounce and Ambush) and fenvalerate (Pydrin), did not differ significantly when applied on the same dates at the same rates. They were, thus, combined for correlation and linear regression. Although the data sets were small, the correlation for permethrin at 0.05 lb AI/A was nearly perfect (r = 0.9998*, n = 3), and the correlations were very nearly significant at the 5-percent level for the pyrethroids at 0.1 lb AI/A (r = 0.69, n = 8) and carbaryl at 2 lb AI/A (r = 0.96, n = 3). The pyrethroids at the higher (0.2 lb AI/A) rate gave nearly perfect control when applied as late as 29 days after peak moth flight.

The data from both tests were combined, except for the high pyrethroid dosage, and shown in figure 1. The data for all sets but permethrin at 0.05 lb AI/A showed a slight tendency for control to be less than that predicted by the regression line for applications made 29 and 32 days after peak moth flight and also slightly less than the regression line for applications made 6 and 15 days after peak moth flight, whereas the 22- and 18-day applications showed control greater than the regression line. The lower control obtained with applications made 29 to 32 days after moth flight was attributed partly to the fact that larger larvae were present at that time, and these were more difficult to kill than smaller larvae as was determined in the 1980 laboratory test (table 5). Also, bean plants increase rapidly in size during July and August, and thorough spray coverage becomes increasingly difficult with the passage of time. The pyrethroids at the 0.2-lb rate were highly effective when applied 29 days after peak moth flight, the pyrethroids at the 0.1-lb rate were highly effective when applied 22 days after the peak, and carbaryl was most effective with 6- and 15-day postpeak applications.

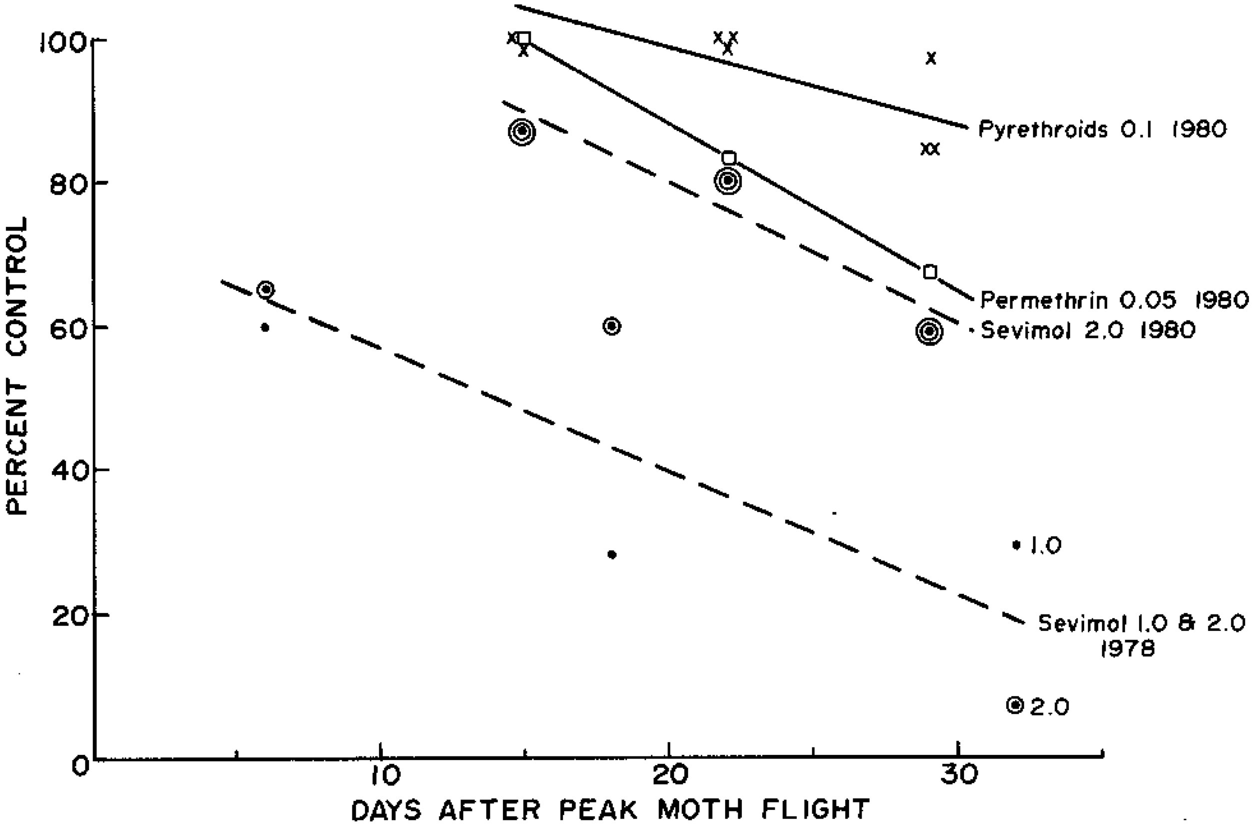

Figure 1.--Percent control of western bean cutworm on beans in relation to time of application and insecticide rates, in pounds active ingredient per acre.

Aerial Sprays on Sweet Corn

Six materials were applied by helicopter in 5 to 10 gpa of spray to sweet corn in five tests in 1976 through 1980. Plots were 100 or 150 feet wide (two or three swaths) and 300 feet long or longer. In 1979 and 1980, plots were not replicated; five subsamples per plot were used for analysis of variance.

The data are summarized by test in tables 9 through 13. Differences among insecticide treatments were seldom significant, but trends are indicated. Multiple applications tended to increase control in two tests (tables 9 and 10), but not in a third test (table 11). Permethrin provided excellent control at the rate of 0.1 lb AI/A with either single or double applications (tables 10 and 11) and at 0.2 lb AI/A in single applications (tables 11, 12, and 13). In table 10, acephate and thiodicarb are indicated as being effective; for some unknown reason, methomyl was ineffective in field 2, and chlorpyrifos showed no promise.

In the 1978, 1979, and 1980 tests (tables 11, 12, and 13), the corn earworm, *Heliothis zea* (Boddie), was a complicating factor. Since the corn earworm (CEW) lays its eggs on silks and damages the ear almost exclusively at the tip end, whereas the WBC enters and damages the ear at all points about equally, it was possible (with the addition of larval identification) to attribute most of the damage recorded in 1978 and 1979 to the respective species. Since sprays were applied for WBC when none or few silks had appeared, they could be expected to have little, if any, effect on the CEW. Permethrin at 0.2 lb AI/A, however, reduced tip damage attributed to CEW by 34 percent (table 11) and 41.6 percent (table 12) by actual count of larvae. In 1980 (table 13), no control of CEW was indicated, and there were more larvae (but not significantly more) in treated than in untreated plots.

Carbaryl Rates and Formulations

Carbaryl formulated as Sevimol (in molasses) was compared at 1- and 2-lb AI/A rates in 1975, 1976, 1978, and 1979. Rates did not differ significantly in any test, but the 2-lb rate averaged slightly better control (about 2 percent) than the 1-lb rate as follows:

Year	Application timing (days + peak moth flight)	Percent control at rates of:	
		1 lb AI/A	2 lb AI/A
1975	- 4	74	77
1976	+19	79	89
1978	+ 6	60	65
1978	+18	28	60
1979	+19	98	57
Average		68	70

Comparisons of carbaryl formulations at the same rates were made in four tests (tables 6, 10, and 12) and results are summarized in table 14. Differences within each test were not significant; however, in comparison to Sevimol, the SL-2 formulation indicated increased control in each of four comparisons with an average of 18.2 percent. The XRL formulation in two direct comparisons, averaged 9.9-percent increase in control over Sevimol. Since the rates for Sevimol and XLR formulations in table 13 were not the same, due to an error in application, those data are not included in the comparison.

SUMMARY AND CONCLUSIONS

Little has been published on insecticide testing for control of the WBC, and nothing since 1963. This report summarizes results of tests conducted in the laboratory and field in southern Idaho from 1950 to 1980.

Approaches to control that were found to be ineffective were (1) treating bean seed prior to planting in soaks or slurries of systemic insecticides, (2) applying insecticides (primarily hydrocarbons) to seed or to the soil surface and worked in prior to planting, (3) applying granular formulations of carbamate- or phosphorous-derivative insecticides to the seed furrow or dribbled over bean plants during moth flight, and (4) injecting systemic insecticides into the soil on the water furrow side of the row after plant emergence.

Of 53 chemicals tested in the laboratory by exposing larvae to treated bean levels, 24 showed effectiveness approximately equal to or better than DDT or carbaryl, which were used as standards. DDT, parathion, toxaphene, and chlordane at rates of 3.4 to 4 lb AI/A gave 90- to 100-percent mortality in 72 hours. Mexacarbate, trichlorfon, carbaryl, endosulfan, and Q-137 gave estimated LD_{90}'s of less than 0.25 lb AI/A; azinphosethyl plus azinphosmethyl, carbophenothion, EPN, endrin, fensulfothion, and diazinon gave estimated LD_{90}'s ranging from 0.3 to 0.9 lb AI/A. Dicrotophos, monocrotophos, acephate, and carbofuran at 1.5 lb AI/A gave 100-percent mortality to larvae exposed 5 days after spray applications, and dichrotophos continued to give 100-percent mortality when larvae were exposed 19 days after application. In a similar test designed to determine length of chemical effectiveness, the number of days after spray application at 1.5 lb AI/A in relation to larval exposure resulting in 50-percent mortality was: methamidophos, 21; phospholan, 16; DDT 14; EI 47,470, 14; mexacarbate, 11; and chlorpyrifos, 10. In another test, the approximate insecticide concentration to give 90-percent mortality was 0.72 percent for carbaryl and 0.04 percent for Mobil 9087. Fenvalerate and permethrin were approximately 435 and 134 times more effective, respectively, than carbaryl in another test.

In field tests on beans between 1950 and 1960, when materials were applied as dusts or sprays after egg hatch, DDT was consistently superior; however, other chlorinated hydrocarbons (dieldrin, aldrin, heptachlor, toxaphene, and endrin) were also effective.

Spray application to foilage during moth flight, generally mid-July to early August, is presently the only effective means of control. Nine tests involving 26 materials were conducted from 1971 through 1980 on beans with tractor-mounted sprayers. The seven materials in two or more tests, averaging 90-percent control or better based on damaged beans, and their dosages (AI/A) were: AC 222,705 (0.04), acephate (1), chlordane (2), DDT (1), EPN (1), fenvalerate (0.1), and permethrin (0.1). Nine additional materials gave 90-percent control or better, but were tested only once. They and their dosages (AI/A) were: carbofuran (1.5), carbophenothion (3.5), cryolite (10), diazinon (1.5), endosulfan (1), methoxychlor (2), methyl parathion (1), profenofos (0.5 to 1), and sulprofos (1). Of the three materials currently registered for WBC control, only endosulfan is in the above groups.

Fourteen materials tested under laboratory conditions were also field tested on beans. All but one gave good to excellent performance under laboratory conditions. Of the 13, 8 gave 91- to 100-percent control in the field, and 5 gave 40- to 84-percent control. The material that performed poorly in the laboratory also performed very poorly in the field at a low rate of application. Although correlation between laboratory and field results was not possible, we feel that laboratory screening would eliminate the less effective materials.

Aerial applications to sweet corn involved six materials in one or more of five tests. Although there was little significant difference among insecticide treatments, permethrin at 0.1 and 0.2 lb AI/A consistently showed better control than carbaryl at 2 lb AI/A in the three tests where they were compared. A fourth test, but at higher rates than intended, also indicated the greater effectiveness of permethrin. Acephate and thiodicarb (1 lb AI/A) were equal to carbaryl (2 lb AI/A) in one test.

A large number of insecticides, thus, show promise for improved control of WBC on beans and corn.

Carbaryl formulations were compared in four tests. The SL-2 formulation gave increased control over Sevimol in each of four comparisons with an average increase of 18.3 percent. The XLR formulation in two direct comparisons averaged 9.9-percent increase in control over Sevimol. Carbaryl at 2-lb-AI/A rates did not differ significantly from 1-lb rates in four tests, but gave slightly better control on the average.

The time of application to beans in relation to peak moth flight and dosage rates was found to have a large effect on degree of control. The pyrethroids, fenvalerate and permethrin, at 0.2 lb AI/A continued to give nearly perfect control when applied 29 days after peak moth flight; the pyrethroids at 0.1 lb AI/A were highly effective when applied 22 days after the peak; and permethrin at 0.05 lb AI/A was highly effective applied 15 days after the peak. Carbaryl at 1 and 2 lb AI/A declined in effectiveness in a near linear fashion with increasing time of application after peak moth flight. This decline in effectiveness of carbaryl and of the pyrethroids at lower dosages is due partly to the increase in larval size, as was determined in a laboratory test, and partly (we think) to increasing plant size, which increases the difficulty of obtaining thorough spray coverage.

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APPENDIX

Common Names, Trade Names, and Chemical Names of Materials Mentioned in Text or Tables

Common name	*Trade name*	*Other*
Aldicarb	Temik	
Aldrin	Octalene	
Acephate	Orthene	
Aldoxycarb	Standak	Aldicarb sulfone.
Aminocarb	Metacil	
Azinphosethyl	Ethyl Guthion	
Azinphosmethyl	Guthion	
Bacillus thuringiensis	Biotrol, Dipel	
Bufencarb	Bux	
Carbaryl	Sevin, Sevimol, SL-2 Sevin XLR	
Carbofuran	Furadan	
Carbophenothion	Trithion	
Chlordane	Ortho-Klor, Octachlor	
Chlordimeform	Galecron, Fundal	
Chlorfenvinphos	Birlane, Supona	
Chlorpyrifos	Dursban, Lorsban	
Chlorpyrifos-methyl	Reldan	
Cryolite (Na_3AlF_6)	Kryocide	
DDT		
Demeton	Systox	
Diazinon	Diazinon, Spectracide	

Common name	*Trade name*	*Other*
Dicrotophos	Bidrin	
Dieldrin		
Diflubenzuron	Dimilin, TH 6040	
Dimethoate	Cygon	
Disulfoton	Di-Syston	
Endosulfan	Thiodan	
Endrin		
EPN		
Fensulfothion	Dasanit	
Fenvalerate	Pydrin	
Fonofos	Dyfonate	
Heptachlor		
Leptophos	Phosvel	
Malathion	Cythion	
Menazon	Saphicol, Sayfos	
Methamidophos	Monitor	
Methiocarb	Mesurol	
Methomyl	Nudrin, Lannate	
Methoxychlor	Marlate	
Methyl parathion	Metacide, Penncap-M	
Mevinphos	Phosdrin	
Mexacarbate	Zectran	
Monocrotophos	Azodrin	
Oxydemeton-methyl	Metasystox-R	
Oxythioquinox	Forstan, Morestan	

Common name	Trade name	Other
Parathion		Ethyl parathion.
Permethrin	Ambush, Pounce	
Phenthoate	Cidial	
Phorate	Thimet	
Phosalone	Zolone	
Phosfolan	Cyolane	
Phosphamidon	Dimecron	
Phoxim	Baythion, Volaton	
Pirimiphos-ethyl	Primicid	
Pirimiphos-methyl	Actellic	
Profenofos	Curacron	
Propoxur	Baygon	
Schradan	OMPA	
Stirofos	Gardona, tetrachlorvinphos	
Sulprofos	Bolstar	
Thiodicarb	Larvin	UC 51762.
Toxaphene	Toxaphene	
Trichlorfon	Dipterex, Dylox	

Numbered compounds	Chemical name	Other
AC 222,705	(±)-cyano(3-phenoxyphenyl)methyl (+)-4-(difluoromethoxy)-α-(1-methylethyl)benzeneacetate.	
Bay Hox 1901	2-[ethyl(thio)methyl]phenyl methylcarbamate.	Ethiofencarb, Crometon.
E.I. 47,470	[probably mephosfolan]	
L-588	2,6-dichloro-*N*-[[[5-(4-chlorophenyl)-2-pyrazinyl]amino]carbonyl]benzamide.	

Numbered compounds	*Chemical name*	*Other*
L-794	*N*-[[[5-(4-bromophenyl)-6-methyl-2-pyrazinyl]amino]carbonyl]-2,6-dichlorobenzamide.	
Mobil 9087	1-(1,1-dimethylethyl)-4-[1-(4-ethoxyphenyl)-2-nitrobutyl]benzene.	
N-2596	S-(p-chlorophenyl)O-ethyl ethanephosphonodithioate.	
PP-484	*O*-[2-(acetylethylamino)-6-methyl-4-pyrimidinyl]*O*,*O*-diethyl phosphorothioate.	
Q-137	1,1'-(2,2-dichloroethylidene)bis[4-ethylbenzene].	Perthane.
TL 1258	*S*,*S*'-[2-(dimethylamino)-1,3-propanediyl]carbamothioate.	Cartap, Padan.

Tables

Table 1.--*Mortality of western bean cutworm in 48 hours on bean plants treated*[1] *at different dosage rates in greenhouse tests, 1962*

Insecticide	Mortality at the following dosage rates (pounds active ingredient per acre): 0.25	0.5	1.0	2.0	Estimated LD_{90}
	Percent				*Lb AI/A*
Mexacarbate	100	100	100	100	<0.3
Trichlorfon	93	100	100	100	< .3
Carbaryl	98	95	98	98	< .3
Endosulfan	93	95	100	100	< .3
Q-137	90	93	100	100	< .3
Azinphosethyl + azinphosmethyl.	70	100	100	100	.3
Carbophenothion	83	90	100	100	.4
EPN	73	93	100	100	.4
Endrin	90	88	93	88	.6
Fensulfothion	70	80	93	100	.8

Table 1.--*Mortality of western bean cutworm in 48 hours on bean plants treated*[1] *at different dosage rates in greenhouse tests, 1962*--Continued

Insecticide	Mortality at the following dosage rates (pounds active ingredient per acre): 0.25	0.5	1.0	2.0	Estimated LD_{90}
	Percent	*Percent*	*Percent*	*Percent*	*Lb AI/A*
Diazinon	55	83	83	98	.9
Malathion	33	58	85	98	1.2
Methoxychlor	63	65	85	78	3.5
Chlorfenvinphos	70	53	68	88	4
Propoxur	8	40	58	63	5.5
Dimethoate	63	73	78	83	6
Demeton	43	28	48	80	6
Phosphamidon	20	53	63	70	6
Mevinphos	65	78	75	78	>10
Methiocarb	53	60	60	75	>10
Aminocarb	53	55	58	73	>10
Phorate	45	35	43	73	>10
Oxydemeton-methyl	13	15	10	15	>10
Oxythioquinox	5	18	5	15	>10
Schradan	8	10	5	5	>10
Menazon	3	8	0	8	>10
DDT standard[2]				98	

[1] 2 3d or 4th instar larvae per plant times 10 plants per treatment. Plants infested day following treatment.

[2] 1.5 lb AI/A.

Table 2.--*Mortality of western bean cutworm larvae 48 hours after exposure to treated*[1] *bean leaves at intervals after spraying, 1971*

Insecticide (1.5 lb AI/A)	Mortality[2] when exposed at days after spray: 5 days	13 days	19 days
	Percent	*Percent*	*Percent*
Dicrotophos	100	100	100
Monocrotophos	100	50	30
Acephate	100	30	40
Carbofuran	100	40	10
N-2596	80	0	0

Table 2.--*Mortality of western bean cutworm larvae 48 hours after exposure to treated*[1] *bean leaves at intervals after spraying, 1971*--Continued

Insecticide (1.5 lb AI/A)	Mortality[2] when exposed at days after spray		
	5 days	13 days	19 days
	Percent		
DDT	70	10	0
TL 1258	40	0	0
Stirofos	20	0	0
Fonofos	0	0	0
Untreated	0	10	0

[1]Sprayed at 1.5 lb AI/A in the field.
[2]10 2d instar larvae exposed to leaves in petri dishes per treatment and time interval.

Table 3.--*Mortality of western bean cutworm larvae 48 hours after exposure to treated*[1] *bean leaves at intervals after spraying, 1972*

Insecticide (1.5 lb AI/A)	Mortality[2] when exposed at days after spraying				Approximate days after treatment when exposure gave 50-percent mortality
	1	8	15	22	
	---------------	------*Percent*------	---------------	---------------	*Number*
Methamidophos	100	100	60	60	21
Phosfolan	100	90	60	10	16
DDT	100	70	40	30	14
EI 47,470	100	40	60	20	14
Mexacarbate	100	62(8)	0	30	11
Chlorpyrifos	100	60	10	10	10
Chlordimeform	60	40	0	50(8)	4.5
PP-484	100	30	0	20	6
Phoxim	100	0	20	20	4-8
Chlorpyrifos-methyl	100	20	10	10	5-7
Phenthoate	100	22(9)	0	0	5.5
Pirimiphos-methyl	80	10	0	20	4-6
Bufencarb	60	0	0	10	2
Diflubenzuron	0	10	0	30	0
Bay Hox 1901	0	10	0	25(8)	0
Pirimiphos-ethyl	0	20	0	0	0
Untreated	0	0(9)	20	0(8)	0

[1]Sprayed in the field at 1.5 lb AI/A.

[2]5 3d and 4th instar larvae exposed to treated leaves in petri dishes per treatment at 1 day. 10 larvae per dish on days 8, 15, and 22, except as noted by numbers in parentheses.

Table 4.--*Mortality of western bean cutworm larvae exposed to bean leaf disks dipped in varying concentrations of chemicals, 1976*

Treatment	Mortality[1] for the following concentrations of: 0.0123	0.037	0.111	0.333	1.0	Approximate concentration to give LD_{90}
	Percent					
Carbaryl	5	10	35	65	95	0.72
Mobil 9087	65	90	95	95	100	.04
L-588	65	55	60	60	75	([2])
L-794	85	95	100	50	70	([2])

[1] Exposure time was 48 hours. Mortality was at 48 hours for carbaryl and Mobil 9087, and over a 12-day period for L-588 and L-794. Each value based on 20 2d to 4th instar larvae.

[2] Values could not be calculated from the data.

Table 5.--*Dosages*[1] *calculated to give 50- and 95-percent mortality of 3d and 5th instar larvae of the western bean cutworm after 24 and 48 hours of exposure to leaf disks dipped in serial dilutions of 3 insecticides, 1980*

Material	LD_{50}	95-percent confidence limits	LD_{95}	95-percent confidence limits	Chi-square	Potency ratios
			3d instar larvae, 24 hours			
Fenvalerate	0.00003	<0.00001 - 0.00031	0.00131	0.00039 - 0.00438	0.683	1
Permethrin[2]	.00019	.00011 - .00034	.00244	.00094 - .00633	1.592	.3606
Carbaryl[3]	.04943	.03243 - .07536	.53378	.20583 - 1.38426	2.494	.0013
			3d instar larvae, 48 hours			
Fenvalerate	.00003	< .00001 - .00031	.00131	.00039 - .00438	.683	1
Permethrin	.00010	.00004 - .00024	.00125	.00049 - .00318	1.257	.7242
Carbaryl	.03500	.02401 - .05103	.32457	.14397 - .73171	1.177	.0029
			5th instar larvae, 24 hours			
Fenvalerate	.00042	.00019 - .00090	.00522	.00145 - .01875	1.045	1
Permethrin	.00283	.00125 - .00638	.07892	.00547 - 1.13836	5.851	.1378
Carbaryl	.10073	.05372 - .18585	2.62350	.37838 - 18.19055	.220	.0039
			5th instar larvae, 48 hours			
Fenvalerate	< .00001		.01490		.927	1
Permethrin	.00214	.00004 - .12182	.13615		7.994	.0132
Carbaryl	.03071	.01185 - .07957	1.90953	.17416 - 20.93643	.419	.0010

[1]Percent dilution of active ingredient. Analyses used a potency-logit computer program.
[2]Ambush.
[3]XLR formulation.

Table 6.--*Percent control*[1] *of western bean cutworm damage to beans following ground spray applications in 9 tests, 1971-80*

Material	Rate	1971 a	1971 b	1971 c	1972	1976	1977	1978	1979	1980	Average and (No. tests)
	Lb AI/A					-Percent-					
AC 222,705	0.04								90ab	99a	94(2)
	.08									93a	93(1)
Acephate	.5					84abc	32 ghi	100a			72(3)
	1					100a	72 bcd	100a			91(3)
Aldoxycarb	1					43abcd					43(1)
	2					0 cd					0(1)
Azinphosmethyl	1	92a	73a	0 b							55(3)
Bacillus thuringiensis.	1				71a						71(1)
Carbaryl[2]	1						S-37 ghi		S-98a XLR-98a	XLR-82ab	79(4)
	1.5				S-99a						99(1)
	2		S-100a	S-95a				S-75a SL2-100a	XLR-76ab S-57ab	XLR-78ab	83(7)
Carbofuran	1.5				100a						100(1)
Carbophenothion	.5					54abcd	22 i				38(2)
	1					56abcd	25 hi				40(2)
	3.5			93a							93(1)
Chlordane	2	100a	100a	100a	89a						97(4)
Chlorpyrifos	.5					74abc	82 bcd				78(2)
	1					93a	69 cd				81(2)
Cryolite	6							49a			49(1)
	10							100a			100(1)
DDT	1	97a	100a	93a							97(3)
	1.5				99a			100a			100(2)
Diazinon	1.5				96a						96(1)
Diflubenzuron	0.6					0 d					0(1)
	.12					0 bcd					0(1)
	.25					6 cd					6(1)
Endosulfan	1							100a			100(1)
	1.5				100a						100(1)
EPN	1	100a		98a							99(2)
Fenvalerate	.05							75a			75(1)
	.1							100a		100a	100(2)
	.2								49 bc	90a	70(2)
	.5						86ab				86(1)
	1						77 bc				77(1)

Table 6.--*Percent control*[1] *of western bean cutworm damage to beans following ground spray applications in 9 tests, 1971-80*--Continued

Material	Rate	1971 a	1971 b	1971 c	1972	1976	1977	1978	1979	1980	Average and (No. tests)
	Lb AI/A					Percent					
Methamidophos	0.5						70 bcd				70(1)
	1						48 fgh				48(1)
Methomyl	1							75a			75(1)
Methoxychlor	2		100a				80 bc				100(1)
Methylparathion	.5					98a					89(2)
(encapsulated)	1							100a			100(1)
Permethrin:											
Ambush	.05						69 cde			83a	76(2)
	.1						75 bcd	100a	98a	100a	93(4)
	.2						93a	100a	100a		98(3)
Pounce	.1									99a	99(1)
	.2								100a	99a	100(2)
Profenofos	.5					93a					93(1)
	1					85abc					85(1)
Sulprofos	1									100a	100(1)
Thiodicarb	.25					72abc	50 efg				61(2)
	.5					40abcd	40 gh		97a	90a	67(4)
	.67								97a	50 b	74(2)
	1					78ab	62 ef				70(2)
Trichlorfon	1.5	53 b	82a	60a	93a			75a			73(5)
		Conditions for individual tests									
Percent damage in untreated plots.		[3]1.8 c	[3].4 b	[3]2.3 b	[3]1.13 b	[4]1.2 bcd	[4].8 i	[4].4 b	[4]1.2 c	[4]2.0 c	
Date sprayed		7/19	7/28	7/19	7/11-12	8/9	8/8-9	8/8	8/3	8/6	
No. replicates		4	3	4	8	6	8	7	6	6	
Sample size (No. of pods) per plot.		1,000	1,000	1,000	1,000	200	200	200	250	200	

[1]Values in columns followed by the same letter do not differ significantly at the 5-percent level. Means separated by Duncan's multiple range test.
[2]Formulations varied: S = Sevimol (carbaryl in molasses); XLR and SL-2 were experimental formulations without molasses.
[3]Damage based on number of holes per 100 pods.
[4]Damage based on percent of beans.

Table 7.--*Comparison of performance of insecticides tested in both laboratory and field tests on beans for efficacy against the western bean cutworm*

Material	Laboratory	Field: Dosage	Field: Control: Average	Field: Control: Range	Field: Control: No. tests
	LD_{90}[1]	*Lb AI/A*	*Percent*		
Endosulfan	< .25	1	100		1
Carbaryl	< .25	2	83	57-100	7
Trichlorfon	< .25	1.5	73	53-93	5
EPN	.40	1	99	98-100	2
Carbophenothion	.40	1	40	25-56	2
Diazinon	.90	1.5	96		1
	Percent mortality[2]				
Carbofuran	100	1.5	100		1
Acephate	100	1	91	72-100	3
DDT	70	1-1.5	98	93-100	5
	Days (50-percent mortality)[3]				
Methamidophos	21	0.5-1	59	48-70	2
DDT	14	1-1.5	98	93-100	5
Chlorpyrifos	10	1	81	69-93	2
Diflubenzuron	0	.25	6		1
	LD_{95}[4]				
Fenvalerate	.0013	0.1	100		2
Permethrin	.0024	0.1	94	75-100	5
Carbaryl	.5338	2	83	57-100	7

[1]Table 1, estimated LD_{90}, in pounds active ingredient per acre.

[2]Table 2, percent mortality of larvae exposed 5 days after treatment with laboratory dosages of 1.5 lb AI/A.

[3]Table 3, days after treatment when exposure gave 50-percent mortality. Laboratory dosages at 1.5 lb AI/A.

[4]Table 5, based on 24-hour exposure of 3d instar larvae, percent concentration to give 95-percent mortality.

Table 8.--*Control of western bean cutworm on beans with materials applied at 3 time intervals following peak moth flight, 1980*

Material	Rate	Control[1] when applied[2] on day following peak moth flight			Correlation	Linear regression		
		15 (July 30)	22 (August 6)	29 (August 13)	r	a	b	n
	Lb AI/A	---Percent---						
Permethrin (Pounce)	0.2	86a	99a	99a	0.45	86.07	0.43	6
Fenvalerate (Pydrin)	.2	100a	90a	99a				
Permethrin (Pounce)	.1	100a	99a	97ab				
Fenvalerate (Pydrin)	.1		100a	84abc	.69	114.19	- .83	8
Permethrin (Ambush)	.1	98a	100a	84abc				
	.05	100a	83a	67 bc	.999*	135.19	-2.36	3
Carbaryl (Sevimol)	2	87a	80a	59 c	.96	119.33	-2	3
Untreated[3]		0 b	0 b	0 d				

[1]Values in columns followed by the same letter do not differ significantly at the 5-percent level. Means separated by Duncan's multiple range test.
[2]Peak moth flight July 15.
[3]There was 1.7-percent damaged seed.

Table 9.--*Control of western bean cutworm on sweet corn by aerial application of carbaryl,*[1] *1976*

Field	Application dates (August)	Infested ears in untreated sample	Control[2] for the following number of applications 1	2	3
		Percent			
1	20	36	81		
1	20, 27	36		92	
2	9, 20	76		97	
2	9, 20, 27	76			99
3	9, 20	39		80	
3	9, 20, 27	39			97
Averages			81	90	98

[1] 2 lb AI/A (Sevimol formulation) applied in 10 gal of water per application by commercial applicator for Green Giant Corp. There was no replication within fields.

[2] Based on examination of from 583 to 1,541 ears per treatment and untreated check strip.

Table 10.--*Control of western bean cutworm on sweet corn by aerial application,*[1] *1977*

Insecticide	Rate	Control[2] following: 1 application (Aug. 8) Field 1	Field 2	Average	2 applications (Aug. 8 and 18) Field 1	Field 2	Average
	Lb AI/A	*Percent*					
Permethrin (Ambush)	0.1				94	72	[3]83a
Acephate	1	64	51	[3]57a	94	64	79a
Carbaryl (SL-2)	2	68	36	52a	79	80	79a
Carbaryl (Sevimol)	2	73	30	52a	61	76	68a
Thiodicarb	1	73	40	56a	67	75	71a
Methomyl	.22	79	0	39ab	68	0	34ab
Chlorpyrifos	1	15	0	8 b			
Untreated				b			b

[1]Applied by helicopter at 10 gpa; plots 100 ft (2 swaths) by 300 ft. No replication within fields.

[2]Based on 200 ears per plot. The percentage of ears damaged in untreated plots was 16.5 in field 1 and 12.5 in field 2.

[3]Values both vertically and horizontally followed by the same letter do not differ significantly at the 5-percent level of probability. Means separated by Duncan's multiple range test.

Table 11.—*Control of western bean cutworm (WBC) and corn earworm (CEW) on sweet corn by aerial applications,*[1] *1978*

	Application		Extent of control based on damaged--		Reduction of damage on:		
					Tip		Side and butt
Insecticide	Rates	Dates (August)	Ears machine husked[2]	Kernels hand husked[3]	CEW	WBC	WBC
	Lb AI/A		--------Percent--------				
Permethrin	0.2	8	[4]69a	68a	34	100	100
(Ambush).	.1	8	49ab	56ab	10	100	100
	.1	8, 15	50ab	46 b	0	100	100
Carbaryl (SL-2)	2	8	37 b	41 b	13	34	85
Untreated			c	c			

[1]Applied by helicopter at 5 gpa spray; plots 100 ft (2 swaths) by 300 ft; 2 replicates.

[2]200 ears per plot, machine husked by Green Giant Corp. personnel; 22 percent of ears damaged in untreated check plots.

[3]100 ears per plot, hand husked by SEA personnel; 86 cm of kernel damage per 100 ears in untreated check plots.

[4]Values in columns followed by the same letter do not differ significantly at the 5-percent level of probability. Means separated by Duncan's multiple range test.

Table 12.--*Control of western bean cutworm (WBC) and corn earworm (CEW) on sweet corn by aerial applications,*[1] *1979*

Insecticide	Application rate	Control[2] based on:					
			Tips			Larvae in ears	
		No. ears damaged	Infested	Damaged	Side and butt damaged (WBC)	CEW	WBC
	Lb AI/A	----------	----------	*Percent*	----------	----------	----------
Permethrin (Ambush)	0.2	88a	85a	82a	100a	42	100
Carbaryl (SL-2)	2	57 b	59a	42ab	90ab	0	84
Carbaryl (Sevimol)	2	42 bc	28 b	42ab	54 bc	12	56
Carbaryl (SL-2)	1	30 cd	27 b	12 bc	51 bc	0	56
Untreated		e	b	bc	cd		
Untreated check (actual values).		[3]45	[4]44.6	[5]30.6	[6]25.2	[7]5.5	[7]9.9

[1]Applied by helicopter August 14 at 5 gpa; plots 150 feet (3 swaths) wide by 1,800 feet long. No replication, but treatments alternating with untreated checks.

[2]250 ears examined in the field per plot (5 subsamples of 50 each). Values followed by the same letter do not differ significantly at the 5-percent level of probability. Means separated by Duncan's multiple range test.

[3]Percent ears with kernel damage.

[4]Percent tips with any infestation.

[5]Percent tips with kernel damage.

[6]Percent ears with damage.

[7]Number of larvae per 100 ears.

Table 13.--*Control of western bean cutworm on sweet corn by aerial application,*[1] *1980*

Insecticide	Rate[3]	Control[2] based on: Tip — Infested ears	Tip — Kernel damage	Tip — Larvae — CEW	Tip — Larvae — WBC	Side and butt — Infested ears	Side and butt — Kernel damage
	Lb AI/A	Percent					
Permethrin (Ambush)	0.174	72a	67	0	100a	94a	98a
	.2	65a	69	0	92a	100a	100a
Carbaryl (XLR)	1.74	57a	47	0	75a	89a	76a
	3.48	64a	63	0	75a	83a	83a
Carbaryl (Sevimol)	4	60a	60	0	83a	89a	89a
Untreated (actual values per 100 ears).		[4]32 b	[5]37	[6]3.2	[6]5 b	[4]7.2 b	[5]20 b

[1]Applied by helicopter on August 12 at 8.75 to 10 gpa spray. No replication.

[2]250 ears examined in the field per plot (5 subsamples of 50 each). Values in columns followed by the same letter do not differ significantly at the 5-percent level of probability. Means separated by Duncan's multiple range test.

[3]Rates were 1.75 to 2.0 times greater than intended due to an error in nozzle size.

[4]Number of ears.

[5]Damage in centimeters.

[6]Number of larvae.

Table 14.--*Comparison of carbaryl formulations in percent control*[1] *of western bean cutworm as indicated in 4 tests*

Formulations	Rate	Applications	1978[2] (table 6)	1979[2] (table 6)	1977[3] (table 10)	1979[3] (table 12)
	Lb AI/A	*No.*	*Percent*			
Sevimol	1	1		98a		
	2	1	75a	57ab	52a	54 bc
	2	2			68a	
SL-2	2	1	100a		52a	90ab
	2	2			79a	
XLR	1	1		98a		
	2	1		76ab		

[1]Values in columns followed by the same letter do not differ significantly at the 5-percent level of probability. Means separated by Duncan's multiple range test.

[2]Ground application to beans.

[3]Aerial application to sweet corn.