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PROBLEMS IN COLORADO POTATO BEETLE (COLEOPTERA: CHRYSOMELIDAE) MANAGEMENT IN INDIANA

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ABSTRACT: Reports of problems in controlling Colorado potato beetles (CPB) on potatoes have been increasing in recent years. Populations from potato producing regions in northeast and southwest Indiana were found to be resistant to esfenvalerate, carbofuran, phosmet, and endosulfan. Two CPB insecticide trials conducted in the Lafayette area showed CPB in that area to be susceptible to all insecticides tested. Several *Bacillus thuringiensis* based insecticides were found to be effective for control of CPB larvae. The use of alternative control strategies should be encouraged to avoid exacerbating the current resistance problems.

INTRODUCTION

The Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is the most important pest of potatoes east of the Rocky Mountains. CPB feeds exclusively on solanaceous plants and is a pest of potato, tomato, pepper, and eggplant. Both adults and larvae are voracious feeders on potato foliage, potentially causing dramatic yield losses because of severe defoliation (Ferro, 1985).

During the mid-19th century, potato growers did not have insecticides available to them that would effectively control CPB, but they were not defenseless. Walsh (1865) recommended handpicking and crushing the insects or "turning in the turkeys." An entrepreneur named Benson also invented a horse-drawn potato beetle collector (Walsh, 1866). As early as 1861, it was noted that there were some potato varieties that were much preferred by the CPB (Edgarton, 1861). If the less preferred variety was planted alone, it would be devoured, but it was recommended that preferred varieties be planted around fields of less preferred varieties to act as a trap crop (Bethune, 1872; Riley, 1871). Early entomologists also recommended crop rotation, planting early, reduced nitrogen use, and killing vines prior to harvest as methods for reducing CPB damage (Walsh, 1866; Riley, 1869; Bethune, 1872; Hardenberg, 1949).

By 1872, C.V. Riley was recommending Paris green as an insecticide for controlling CPB. Paris green and other arsenical insecticides were used fairly effectively in the 1940's. There were some reports of loss of effectiveness with arsenicals as early as 1912, but this was not recognized as resistance, because resistance had not been noted for any insect species at that time (Gauthier, *et al.*, 1981). During the modern insecticide era, which began when DDT became available in 1945, CPB has shown an amazing ability to develop resistance to various insecticides. Resistance typically occurs because the insect has found some way to detoxify the insecticide. Since chemicals of the same insecticide class generally have a similar mode of action, when an insect develops resistance to one member of that class, it also or soon will be resistant to other members

Table 1. Development of resistance in CPB to various insecticides in New York (adapted from Forgash, 1985).

Insectide	Introduced	Control Failure
Arsenicals	1880	1940s
DDT	1945	1952
Dieldrin	1954	1957
Carbaryl	1959	1963
Azinphosmethyl	1959	1964
Phosmet	1973	1973
Disulfoton	1973	1974
Carbofuran	1974	1976
Oxamyl	1978	1978
Fenvalerate	1979	1981
Permethrin	1979	1981
Fenvalerate + PBO	1982	1983

of that class.

Table 1 summarizes the rate of development of resistance on Long Island, New York. Note that initially insecticides were effective for 5 to 7 years, but that the pyrethroids had an effective life of only about two years (Forgash, 1985). The same pattern of resistance developed all along the eastern seaboard where large acreages of potatoes are grown as well as in the major potato producing areas of the upper Midwest. In some of these areas, the only effective materials for controlling CPB are aldicarb, a synthetic soil insecticide that is applied at planting and provides excellent early season control of CPB and other insects, rotenone, cryolite, and, most recently, some of the newer strains of *Bacillus thuringiensis* (BT) that have shown efficacy against Coleoptera. Aldicarb is not legal for use in some areas, because of groundwater contamination problems.

Indiana is not a major potato producing state, ranking 19th in total production, and, therefore, does not have a history of heavy insecticide use for controlling CPB. However, some isolated regions of the state grow substantial amounts of potatoes. Indiana has not experienced the severe CPB control problems that have been reported in other areas of the country. During the fall and winter of 1989-90, several reports were received from growers who indicated great difficulty controlling CPB in their fields during the 1989 growing season with foliar insecticides. In addition, during the spring of 1990, aldicarb was voluntarily recalled by the manufacturer because of some reports of residue problems, eliminating that chemical as a control alternative.

The objective of this study was to evaluate the efficacy of several insecticides for control of the Colorado potato beetles in a susceptible population and to determine if resistance were the primary factor involved in the poor control obtained by several Indiana potato growers.

MATERIALS AND METHODS

An insecticide trial to evaluate the efficacy of several insecticides for control of Colorado potato beetles on potatoes was conducted at the O'Neall farm near Lafayette, Indiana, during the summer of 1989. There are no major potato producers near Lafayette, so the CPB in the area have not been exposed to heavy selective pressure from

Table 2. Treatments included in 1990 potato insecticide trial.

Trt No	Insecticide	Rate/ Acre	When Appl.	6/19	6/25	7/2	7/17	7/24	7/31
1	M-One	2.0 qts.	W[1]	X	X	X	X	X	X
2	Asana XL	4.8 oz	W	X	X	X	X	X	X
3	Sevin 80S	1.25 lb	W	X	X	X	X	X	X
4	Thiodan	1.0 qt	W	X	X	X	X	X	X
5	Kryocide	11.5 lb	W	X	X	X	X	X	X
6	M-One	2.0 qts	T[2]	X	X	X	X	X	X
7	Asana XL	4.8 oz	AN[3]			X		X	X
8	Sevin 80S	1.25 lb	AN			X		X	X
9	Asana XL/ M-One	4.8 oz/ 2.0 qts	AN	M	M	M		A	A
10	MYX-1806	2.0 qts	W	X	X	X	X	X	X
11	Untreated Check								
12	MXY-1806	2.0 qts	T	X	X	X	X	X	X
13	Trident	1.5 qts	W	X	X	X	X	X	X
14	Trident	2.0 qts	W	X	X	X	X	X	X

[1] Weekly

[2] Timed; when small larvae (1st and 2nd instar) were present.

[3] As needed; when defoliation reached 20%.

insecticide use and can be considered a susceptible population. The trial was planted on June 6 with "Katahdin" seed. The plots were one row by 25 feet long with 10 feet between rows. Seed pieces were placed one foot apart within each row. The trial was arranged in a randomized complete block design with four replications.

Treatments were applied with a tractor-mounted CO_2 powered sprayer in 40 gallons of water per acre at 40 psi. The spray boom had two nozzles above the plants and on each side directed inward toward the plants. Application dates were June 30, July 6, 13, 21, 27, August 3, and 10.

On July 14, five plants were rated for defoliation based on a 1 to 5 scale (1 = no damage; 2 = minor damage; 3 = moderate damage; 4 = heavy damage; and 5 = severe damage). Direct counts of CPB larvae and adults were made on 5 plants per experimental unit on August 14. First and second instar larvae were considered small and third and fourth instar larvae were considered large.

A similar insecticide trial was conducted during the summer of 1990. The potato cultivar "Katahdin" was planted on April 30 at the O'Neall Farm. Seed pieces had been cut one week earlier and allowed to suberize. Seed pieces were placed by hand 12 inches

Table 3. Damage ratings for Colorado potato beetles on potatoes (1 = no damage, 5 = severe damage), July 14, 1989, and mean number of larvae and adults per 5 plants on August 14, 1989[1].

Chemical	Rate/Acre	Damage Rating	Larvae	Adults
Asana X1	2.5 oz	1.4 a	0.00 a	0.00 a
Vydate	2 pts	1.5 a	0.00 a	0.00 a
Ambush	6.4 oz	1.7 ab	0.00 a	0.00 a
Sevin 80S	1.25 lb	1.8 abc	0.00 a	0.00 a
Monitor	1.5 pts	2.1 abcd	0.00 a	0.00 a
Thiodan	2 pts	2.3 abcd	0.00 a	0.00 a
Kryocide	11.5 lb ai	2.3 abcd	0.00 a	0.50 a
M-One	2 qts	2.5 abcde	0.00 a	0.50 a
Trident	4 qts	2.7 bcdef	0.00 a	1.25 b
MYX-1806	3 qts	2.8 cdef	0.00 a	0.75 ab
Ditera	1 lb	3.0 def	0.00 a	0.00 a
Untreated	----	3.1 def	10.00 a	0.25 ab
Trident	6 qts	3.5 ef	0.00 a	0.00 a
Ditera	2 lb	3.6 f	0.00 a	0.50 ab

[1] Means followed by the same letter are not significantly different (Duncan's 1955 multiple range test, $P < 0.05$).

apart in furrows. Each experimental unit consisted of a single row 25 feet long. The experiment was arranged in a randomized complete block design with 4 replications. Rows within a block were 5 feet apart and 5 foot bare alleyways separated blocks.

The treatment application dates in the study are listed in Table 2. All treatments were applied with a CO_2 powered backpack sprayer at a pressure of 40 psi in 23 gallons of finished spray per acre. The spray boom had three hollow cone nozzles with the middle nozzle centered over the middle of the row. Treatments that were "timed" were applied when small larvae were present in the field. Because small larvae were present in the field most of the time, treatments 1 and 6 and treatments 10 and 12 each received the same number of sprays and were essentially the same treatment. Treatments that were applied as needed were applied when the plot had approximately 20% defoliation.

Treatments were evaluated by making direct counts of small and large larvae and adults on five randomly selected plants per plot. Beetle counts were made on June 18, 22-25, 28, July 5, 23, and August 3. On August 28, all plots were dug with a mechanical potato digger, and all potatoes within a plot were picked up and weighed. Data from both studies were analyzed with analysis of variance procedures and means separated using Duncan's (1955) multiple range test ($P < 0.05$).

To investigate the possibility of insecticide resistance, CPB adults were collected from commercial potato farms in northeast and southwest Indiana and exposed to discriminating doses of various insecticides (Bishop and Grafius, personal communication). A discriminating dose is one that can be used to separate susceptible populations from resistant ones. The insecticides and dosages used were phosmet at 3.2 g ai per liter, endosulfan at 8 g ai per liter, carbofuran at 8 g ai per liter, and esfenvalerate at 0.2 g ai per liter with and without 1 g ai per liter of piperonyl butoxide. The insecticides were applied to filter paper in petri dishes. For each field, twenty beetles were placed in each of the petri dishes for 24 hours and then checked for mortality. An untreated check was also included in the test. The test was not replicated, so no statistical analysis was conducted.

RESULTS AND DISCUSSION

Table 3 summarizes the results of the 1989 insecticide evaluation. The defoliation damage observed on July 14 was mostly the result of adult feeding. All the insecticides

Table 4. Mean number of Colorado potato beetle large larvae (3rd and 4th instar) per five plants in 1990 insecticide trial. The number of applications prior to sampling date are listed in parenthesis after means.[1]

Trt. No.	June 28	July 5	August 3
1	0.25 a (2)	0.00 a (3)	2.00 a (6)
2	0.00 a (2)	0.00 a (3)	1.75 a (6)
3	0.75 a (2)	0.50 a (3)	3.00 a (6)
4	0.00 a (2)	0.00 a (3)	2.25 a (6)
5	0.00 a (2)	0.00 a (3)	0.50 a (6)
6	2.00 a (2)	0.25 a (3)	4.25 ab (6)
7	1.75 a (0)	1.00 a (1)	1.25 a (3)
8	0.50 a (0)	0.50 a (1)	4.00 ab (3)
9	1.50 a (2M-One)	0.25 a (3M-One)	0.75 a (3M-one, 2Asana)
10	0.00 a (2)	0.50 a (3)	2.50 a (6)
11	6.00 b (0)	2.00 b (0)	6.75 b (0)
12	1.50 a (2)	0.50 a (3)	2.75 a (6)
13	0.00 a (2)	0.00 a (3)	1.75 a (6)
14	0.25 a (2)	0.00 a (3)	3.75 a (6)

[1] Means followed by the same letter are not significantly different (Duncan's 1955 multiple range test, $P < 0.05$).

tested effectively controlled larvae and all treatments controlled adults except cryolite and the BT materials, M-One, Trident, Ditera, and MYX-1806, which are not supposed to control adults. We concluded that the population of CPB near Lafayette was a susceptible population.

In the 1990 insecticide trial, the population of CPB was relatively low throughout the growing season. Defoliation never reached extreme levels even in the untreated check. Unfortunately, late in the season, the population of potato leafhoppers, *Empoasca fabae* (Harris), reached extremely high levels, causing pronounced symptoms of leaf curling, hopperburn, and stunting in those treatments that did not control the leafhoppers. Much of the differences in yield can be attributed to the leafhopper injury.

No significant differences in CPB densities were detected on June 18, June 22-25, or July 23 or in the densities of small larvae or adults. Table 4 shows the densities of large larvae from the other three sampling dates. On June 28, all treatments had significantly fewer large larvae than the check. Unfortunately, that included two treatments that had received no applications yet and were therefore checks themselves at that point in the study. On July 5, all treatments had significantly fewer larvae than the untreated. On August 3, treatments 6, 8, and 14 were not different than the untreated. The treatments that reduced the number of large larvae the most were cryolite, endosulfan, esfenvalerate weekly, M-One weekly, Trident at 2 quarts, and MYX-1806.

The yield results (Table 5) show fairly clearly that the treatments that would be expected to control potato leafhoppers had the higher yields. These included endosul-

Table 5. Mean weight (lbs) of potatoes harvested per 25 feet of row in the 1990 trial.[1]

Trt. No.	Insectide	Rate per Acre	Weight (lbs)
1	M-One	2.0 qts	22.9 c
2	Asana XL	4.8 oz	37.7 a
3	Sevin 80S	1.25 lb	36.4 ab
4	Thiodan	1.0 qt	38.0 a
5	Kryocide	11.5 lb	25.3 c
6	M-One	2.0 qts	23.3 c
7	Asana XL	4.8 oz	39.3 a
8	Sevin 80 S	1.25 lb	23.4 c
9	Asana XL/M-One	4.8 oz/2.0 qts	26.1 c
10	MYX-1806	2.0 qts	30.1 abc
11	Untreated	--------	24.4 c
12	MYX-1806	2.0 qts	27.9 bc
13	Trident	1.5 qts	25.2 c
14	Trident	2.0 qts	20.8 c

[1] Means followed by the same letter are not significantly different (Duncan's 1955 multiple range test, $P < 0.05$).

fan, esfenvalerate, and carbaryl. The only exception was the two MYX-1806 treatments which resulted in yields that were substantially higher than the other treatments that would not be expected to control leafhoppers.

Table 6 shows the results of the tests for insecticide resistance. A susceptible population would be expected to have a minimum of 75% mortality when exposed to this rate of the pyrethroid insecticide, esfenvalerate. In each location, the mortality rate was 5%. The addition of a synergist, piperonyl butoxide, increased mortality some what in the northeast but had no effect in the southwest. Carbofuran, a carbamate, caused the death of 35% and 25% of the beetles tested, respectively. Phosmet, an organophosphate, resulted in 40% and 25% mortality. Endosulfan, an organochlorine, caused 60% and 25% mortality, respectively. There was no mortality in the untreated control. These data indicate that in these two pockets of intensive potato production in Indiana, CPB have developed at least moderate levels of resistance to most insecticides.

These results indicate a need to look for alternative methods for controlling CPB in Indiana. We are fortunate to have detected the onset of resistance before it reached the point where no mortality would occur for most of the insectides. The opportunity exists to continue to use some of the tested insecticides on a limited basis and possibly even to reverse the development of resistance. To accomplish this, growers will have to use some of the following alternative control methods, some of which are similar to the recommendations of entomologists over 100 years ago, prior to Paris green. First, growers should rotate potatoes with other crops. The further away potatoes are planted from the previous year's potato fields, the better. Research has shown that rotation can reduce the number of invading beetles by 90% to 99%. Second, growers should plant early and use short season varieties as much as possible. This will reduce the length of time the beetles have potatoes available as a host and will have an overall suppressive effect on the population as well as reduce the time the plants need to be protected. Third, growers should use BT insecticides for control of small larvae, being sure to monitor fields closely to properly time applications. These materials will kill both resistant and susceptible individuals and will serve to dilute the resistant genes present in the population. The BT insecticides are relatively nontoxic to beneficial organisms that also nonselectively feed on resistant and susceptible CPB. Fourth, use insecticides sparingly. Growers need to acknowledge that potaoes are most vulnerable to defoliation at the time of tuber set and can tolerate sub -

Table 6. Percentage of CPB adults dead 24 hours after being exposed to discriminating doses of several insecticides.

Insectide	Expected Mortality[1]	Observed Mortality	
		NE Indiana	SE Indiana
Esfenvalerate	> 75%	5%	5%
Esfenvalerate + PBO	> 75%	20%	5%
Carbofuran	100%	35%	25%
Phosmet	> 80%	40%	20%
Thiodan	> 85%	60%	25%
Untreated	-----	0%	0%

[1] If population is not resistant.

stantial defoliation at other times during their growth. Finally, killing vines either mechanically or chemically prior to harvest will reduce the amount of time CPB have potatoes available for a food source. If Indiana potato growers will adopt these practices, it may not be too late to avoid the severe problems Long Island and other major potato producing areas have had in controlling CPB.

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