The Corn Rootworm Problem in Indiana[1]

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Abstract

A new pest to Indiana corn, the western corn rootworm (*Diabrotica vergifera* LeConte) was found in 37 fields in 9 counties in 1970. This invasion of the northwestern counties is a continuation of a 10-year eastern migration from the Nebraska area. The northern corn rootworm (*D. longicornis* (Say)), present in Indiana for 100 years or more, continued to cause some injury and has required insecticide treatments when corn was grown on the same land for 3 or more years. The first resistance to the cyclodiene insecticides was found in 1969 near Earl Park. In 1970 this beetle population was highly resistant as were western beetles collected in Porter and LaPorte counties. The life cycle of the two species was the same: eggs laid in the soil in corn fields in August and early September, eggs hatched the following June and July, and the larvae fed on corn roots in June, July and early August. Damage consisted of destruction of roots by feeding and tunnelling and often the subsequent lodging of corn plants. Two insecticides applied in the soil, aldrin and heptachlor, gave good protection from the normal northern larvae, but the resistant forms required the use of insecticides in the organophosphate and carbamate groups.

Introduction

The northern corn rootworm, *Diabrotica longicornis* (Say), has been a major corn pest in Indiana for many years. In 1970 two developments in the rootworm situation suggest additional problems for the farmer in the future: first, resistance of the northern rootworm to the commonly used cyclodiene insecticides, and, second, the finding of well-established infestations of the western corn rootworm, *D. vergifera* Leconte.

The northern rootworm species has been a pest of corn since the days of the early settlers. Losses to the Indiana crop have been minor and have been avoided by crop rotation. However, in recent years many farmers have changed to a continuous corn program and thus have had to use a soil insecticide to control the larvae. Two common insecticides, aldrin and heptachlor used either over the row at planting time or broadcast before planting, have given adequate control until this year. Resistance to these materials was reported in Ohio and the corn-producing states west of Indiana as early as 1962 (1, 2, 5).

The western species is a native of the Colorado-New Mexico area and did not become common in southern Nebraska and northern Kansas until the late 1940's (10). Distribution and populations increased in Nebraska in the 1950's and often the western form became the predominant species in corn fields. Resistance to the cyclodiene insecticide was noted in several states as early as 1962 (6). From Nebraska this insect moved north into South Dakota, east into Iowa, and southeast

[1] Journal Paper No. 4277, Purdue University Agricultural Experiment Station.

into Missouri. In 1964 the first beetles were found in northwestern Illinois and four years later 13 counties had destructive populations (11). In Indiana a single beetle was found in 1968 near Foresman in Newton County. In 1969 five more were found in the same vicinity. The present distribution of the western species includes all corn growing areas of Colorado, Nebraska, South Dakota and Iowa, most of Kansas, the northwestern third of Missouri, southern Minnesota and Wisconsin, 47 counties in Illinois north of a line from Quincy to Champaign (11), and Newton County, Indiana.

In our 1968 and 1969 search for the western corn rootworm the counties along the western border were surveyed: Lake, Newton, Benton, Warren and Vermillion plus Tippecanoe, Montgomery and Jasper. The discovery in early August, 1970, of a mating pair in LaPorte County confirmed that an infestation occurred east of the border counties. Surveys soon found one or more beetles in numerous fields in 9 counties. The final count for August and early September was 9 fields in Lake County, 5 in Newton, 13 in Porter, 5 in LaPorte, and 1 each in Starke, Marshall, Fulton, Jasper and Koscuisko (Fig. 1). One field in LaPorte and 2 fields in Porter Counties showed high populations. This survey covered over 500 fields in 22 northwestern Indiana counties, while additional areas of the state were surveyed by Purdue extension and survey entomologists.

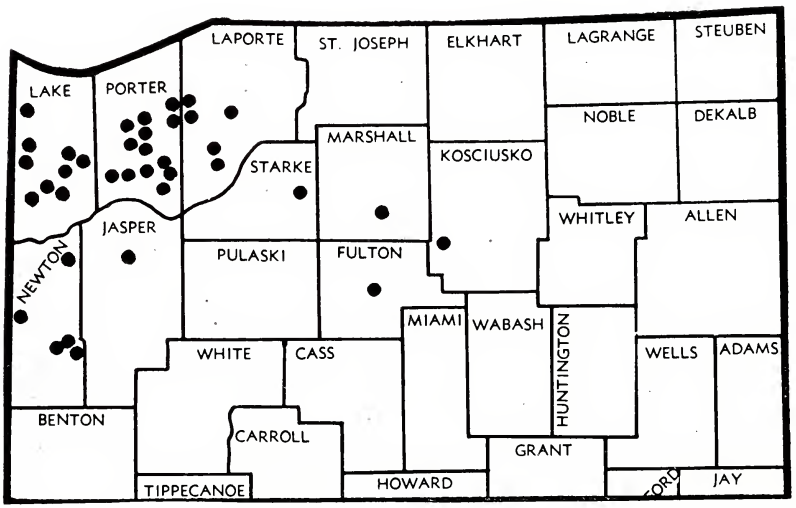

FIGURE 1. *Locations of corn fields where western corn rootworm adults were found in 1968, 1969 and 1970. At the southernmost location in Newton County a single beetle was caught in 1968 and in the adjacent field 5 were found in 1969.*

Methods

Eggs of the rootworm are laid in the soil in late August and early September. To determine field egg populations, soil was dug

in old corn fields in the fall and spring and was brought to the laboratory for examination. A standard sample was a pint taken with a 4-inch hole cutter to a depth of 6 inches. The usual procedure (7) was to take samples from 5 rows, combine them and mix on a plastic sheet. From this, 1 or 2 pints were taken to the laboratory for washing. Normally 5 locations were selected and sampled from each field. The soil washing machine has two revolving screens, one above the other, with four jets of water spraying down on each. The fine soil particles were washed through both screens, while the top screen retained the larger particles and plant debris and the lower screen retained the eggs and some plant debris. The material on the lower screen was washed with water into a quart jar and allowed to stand a few minutes. Then the floating material was poured off and magnesium sulfate added to the remaining water to make a saturated solution. At this point, the eggs floated to the surface and were poured off with water onto a black cloth. This cloth had straight lines of string sewn across it and was held taut in a 6-inch embroidery loop. The cloth was allowed to dry and the material on it was then examined under a microscope to determine the number of eggs.

Several methods were used to determine larval populations and damage to corn roots. The usual procedure was to dig around a corn plant in a 10-inch circle and take up the soil and roots to a depth of 6 inches. The loose soil from the hole and that beaten from the roots was placed in a plastic sheet and examined in the field. By this method we found most 2nd and 3rd instar larvae, pupae and newly emerged beetles, but failed to recover the small 1st instar larvae. In the last 3 years the soil was examined as above and then the corn roots were placed on hardware cloth over a half inch of water in a bucket and allowed to dry 24 to 48 hours. The small larvae left the roots and dropped to the water.

For an evaluation of root damage plants were dug as above and the roots washed to remove all soil. The roots were then examined and damage rated—the rating system was 1 for little or no damage up to 6 for serious destruction of roots. Another method of evaluating root damage was also used. This involved measuring the root strength of corn plants by a method described by Ortman *et al.* (8). A dynamometer was used to record the force required to vertically lift the plant from the soil. In our studies on corn varieties, 3 or more plants were pulled per replication. Since maximum larval damage usually had occurred by July 25, dynamometer readings were made soon after that date and before new roots developed.

Beetle emergence around a single corn plant also gave an accurate estimate of the larval population. For this purpose trap cages were made of galvanized iron 4 inches wide and long enough to give a metal band 12 inches in diameter. This metal band was shoved into the soil around the base of the corn plant and was covered with saran screening. Cages were in place by July 15 and remained there until early September. Beetles emerging from the soil were removed every 3 or 4 days.

Adult beetle surveys were used to establish population estimates for the season. The method was to count beetles seen on silks on 10 plants down a row and repeat in 4 other locations in the field. These counts were not too accurate, as beetles flew readily, especially if the plant was disturbed. In addition, no records were available on the previous cropping history and on previous insecticide applications.

For an evaluation of larval damage, especially on insecticide plots, a count of lodged plants was made in late August or early September. In this procedure 100 plants in 5 field locations were examined for lodging. A plant was considered lodged when it was more than 30° from perpendicular. A second criterion of much interest to farmers was the harvest yield from the different plots. Yields in bushels per acre were obtained by standard agronomic methods—picking ears from a known area, weighing them, testing for moisture, and converting pounds to bushels.

Biology

Observations on the biology of the northern corn rootworm were made in the vicinity of Lafayette. Female beetles laid their eggs in late August and early September in the soil of the corn field. These eggs hatched the following June and early July; larval development occurred from June through July and into early August; pupal development required 6 to 8 days; and new beetles remained in the soil 4 to 6 days before emergence. This emergence period was usually completed by the end of August, but in the 1967 soil cages, 15% of beetles emerged after September 1. The period from egg hatch to beetle emergence from the soil ranged from 60 to 70 days. Workers in other states (6, 9) found that the western and northern species had a similar life cycle, although the stages of the western appear a few days earlier than the northern.

Egg laying started around August 15, reached a peak by September 1, and declined rapidly after that. The female preferred to lay eggs in the old corn row, as indicated by our sampling at various distances from the row. An average of 21 eggs per pint sample was found in the row, 2.5 eggs 5 inches from the row, 3 eggs 10 inches from the row, and 0.3 eggs 20 inches from the row. The depth of egg deposition varied with the soil type and compaction, moisture and possible soil cracks. In a series of observations, soil was removed in 2-inch layers with a soil cutter. In the 25 samples examined from 3 farms, the top 2 inches had an average of 52 eggs per pint, the 2-4 inch layer had 11, and the 4-6 inch layer had 1.6. Plowing drastically changed the location and depth of eggs, as for example in two fields the top 2 inches had an average of 1.5 eggs per pint, the middle 2 inches 5.3, and the bottom 2 inches 2.0. Since most eggs in unplowed fields were in the top 3 inches, soil samples to this depth were standard in 1968, 1969, and 1970.

A sequential life history study was initiated in 1966 in conjunction with several midwest states. Population counts of eggs in the fall and in the spring, larvae in July, and adults in August were made in the

same 5 untreated fields for 2 years. No consistency could be noted in the spring egg count and that of subsequent populations of larvae, adults and fall eggs in either of the 2 years. We did find another field in the summer of 1967 that had a high larval count of 40 per plant. This was followed by 27 eggs per pint in the fall count, 22 in the spring of 1968 count, and 22 in the July larval count.

In checking the larval development, the small size of the first instar made them extremely difficult to find. Our earliest record for the Lafayette area was one found on June 7 in the soil washing procedure. By June 20, larvae were larger and could be found with more ease. Field counts to establish larval population levels were made in the period from July 12 to 30, although life history studies plants were dug from late June to August 20 (Fig. 2). George and Hintz (3), in laboratory studies, found that rootworms required a 65-day developmental period at 20°C from hatch to adult emergence. First instar larvae were found as late as August 20, while new beetles were present in fields around Lafayette as early as July 17.

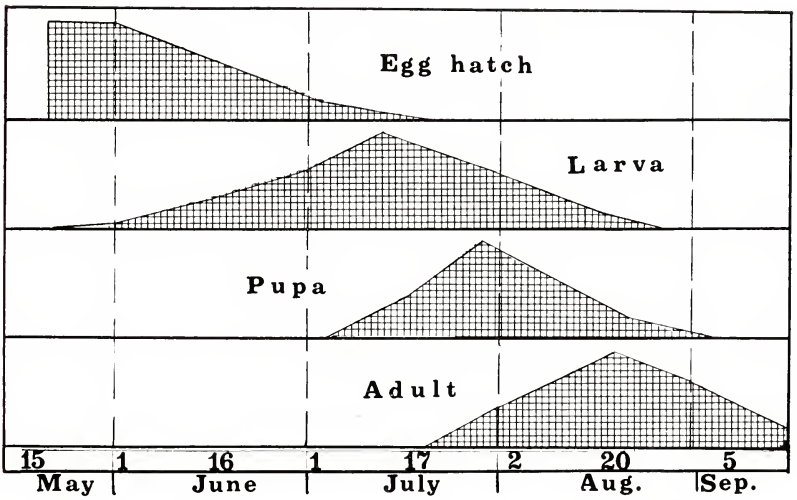

FIGURE 2. *Life cycle chart of the northern corn rootworm at Lafayette. The peaks indicate the greatest abundance of each stage.*

Larval feeding was confined to corn roots where they fed on the small roots and often tunnelled into the larger ones. The normal Indiana populations were marginal in so far as larval feeding reduced corn yields. The highest numbers of larvae observed were in the Wettschurack field in 1967 where the average population was 40 and roots so destroyed that corn plants could be pulled from the soil with two fingers. The average larval populations in all observations were 2.4 per plant in 1965, 3.8 in 1966, 10.1 in 1967, 22.0 in 1968, 3.5 in 1969 and 2.3 in 1970. Peters (9) in Iowa considered a population of 10 per plant as the minimum number for economic losses.

Larval development required 40 to 55 days. At maturity the larva formed a cell in the soil and changed into a pupa. It remained in this cell for 4 to 8 days before changing into the beetle. Most pupae were found in the upper 2 inches of soil, usually in the vicinity of the roots. The beetle remained in the cell for 3 to 6 days before emerging (Table 1).

TABLE 1. *Percentages of the various stages of the northern corn rootworm found around corn roots on various dates, 1967-1970.*

Date	Larval instars			Pupa	Adult[1]
	1st	2nd	3rd		
July 8	40	29	27	3	1
12	45	30	20	2	1
16	22	28	40	8	2
20	15	22	46	15	2
24	11	16	38	25	10
30	5	9	28	29	29
Aug. 6	8	16	16	18	42
12	—	7	12	28	53

[1] Adjusted for prior beetle emergence

The first beetles were observed in the field in the Lafayette vicinity from July 15 to 17. Their food consisted of pollen and silks of the corn plant. Later as these food sources dried up, beetles migrated to greener corn fields or to flowering plants, both cultivated and uncultivated. The male beetle normally emerged first. For example, in 1969 the 50% emergence figure for males was reached on August 6, and that for females on August 15. Beetle populations diminished sharply after September 10, although a few were observed on flowering plants in October.

In recent years many complaints were received of high beetle or larval populations in first year corn. In 1969 two fields of first year corn on the Shelby farm were checked on August 1 and had an average of 3 beetles per ear. To confirm the presence of developing forms in this soil, plants were dug August 10 and 1 larva, 5 pupae and 1 newly emerged beetle were found. On August 18 emergence cages were placed around 6 plants and upon removal 10 days later 3 beetles had emerged. The cropping history of these two fields was corn in 1967 and 1969 and soybeans in 1968, while the adjacent two fields had soybeans in 1967 and 1969 and corn in 1968.

Little is known of the biology of the western corn rootworm under Indiana conditions, as beetles were not found in numbers until August of 1970. Beetles were more difficult to catch than the northern form, as they had a tendency to fly as soon as disturbed. When the exposed silks turned brown in late August, we were able to attract beetles by pulling back the husks to expose new silks. Peters (9) in Iowa reported that the western beetle is a strong flyer and voracious

feeder on silks and leaves. Also the eggs hatched earlier and the larvae matured earlier than those of the northern form.

Resistance Studies

The methods used for establishing LD_{50} values in 1970 were the same as in preceding studies (4). Northern beetles from untreated fields in 1966, 1967 and 1969 had an LD_{50} for aldrin of about 0.070 ug per beetle. Beetles from fields treated 3 to 5 years had an LD_{50} of around 0.085, and from the Umholts field, treated 12 of the past 15 years, a figure of 0.162 was obtained.

The 1970 topical application tests were run by Mr. Gary Finni and included some fields used in preceding years. A total of over 6,000 northern and 3,600 western beetles were used. The LD_{50} figure for beetles from untreated fields was again 0.070 ug. A group of five fields with a history of some aldrin usage had a figure of 0.157. A field at the Throckmorton farm used for biological studies had received no insecticide treatment, but adjacent fields had been treated for 3 or 4 years. The LD_{50} for the beetles from the biological area was 0.083 in 1969 and 0.22 in 1970. A Benton County farmer complained of poor control in 1968. The history of treatments in this large field was the use of a cyclodiene insecticide for 11 of the preceding 14 years. He treated again in 1969 and used 2.8 lbs of actual aldrin per acre. Results were poor and so aldrin again was used in 1970—a total of 13 treatments in the last 16 years. Beetles collected for topical tests in 1969 had an LD_{50} of 0.162 ug or about double that of untreated fields. The figure for 1970 jumped to 29.2 ug or about a 180-fold increase.

For these tests, western beetles were collected in one LaPorte County field and two Porter County fields. Of these, one had a history of 6 or 7 years of aldrin treatment, one had no treatment, and the history of the third was unknown. The LD_{50} for all western beetles was 120.0 ug or about 1,700 times more aldrin than for northern beetles from untreated fields.

With the coming of the western corn rootworm in Indiana and the development of cyclodiene resistance in the northern form, rootworms should become a more important problem to the corn crop than they have been in the past. The western species is highly resistant to aldrin and heptachlor as it enters the State, while pockets of resistance in the northern species, such as in the Benton County field, will undoubtedly develop in other areas.

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