Risk of Western Corn Rootworm (Coleoptera: Chrysomelidae) Damage to Continuous Corn in Virginia[1]

Thomas P. Kuhar, Roger R. Youngman and Curtis A. Laub

Department of Entomology
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0319 U.S.A.

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ABSTRACT Information on the risk of western corn rootworm, *Diabrotica virgifera virgifera* LeConte, damage to continuously-grown corn previously was lacking in Virginia, as well as other mid-Atlantic states. A field study was conducted in 1993 and 1994 comparing root damage, whole-plant yields, and silage quality in insecticide-treated and untreated sections of 32 continuous corn fields in Virginia. Approximately 28% of the fields had serious root damage exceeding a rating of 3.5 (1-6 scale) in sections not treated with a soil insecticide. Also, 19% of the fields had an economic loss in whole-plant yield due to corn rootworm feeding damage. Silage quality, as evidenced by percent crude protein and acid detergent fiber, was not significantly affected by corn rootworm feeding. Because much of the continuous corn acreage in Virginia is treated preventively with soil insecticides for corn rootworms, the results of this study suggest that a large percentage of this insecticide use is unnecessary.

KEY WORDS Corn, western corn rootworm, *Diabrotica virgifera virgifera,* silage quality, feeding damage, risk

The western corn rootworm, *Diabrotica virgifera virgifera* LeConte, is one of the most important pests of continuous corn, *Zea mays* (L.), in the United States (Chiang 1978, Metcalf 1986). Larvae feed voraciously on the root systems of corn resulting in reduced water and nutrient flow in the plant (Kahler et al. 1985, Riedell 1990) and lodging of stalks which may lead to significant reductions in yield (Remison and Akinleye 1978, Sutter et al. 1990, Spike and Tollefson 1991). Reviews of corn rootworm biology, ecology, and management can be found in Chiang (1973), Krysan and Miller (1986), and Levine and Oloumi-Sadeghi (1991).

The western corn rootworm is most likely neotropical in origin (Krysan 1982). Researchers speculate that *D. v. virgifera* became specialized on corn in the tropics and followed the diffusion of corn into temperate North America about 1,000 yr ago (Branson and Krysan 1981). It has been reported as a pest of corn in the United States since the early part of this century (Gillette 1912, Ainslie 1914). Until the 1940's, the distribution of *D. v. virgifera* in the United States remained limited to a handful of states in the Midwest (Smith 1966, Chiang 1973).

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However, following WWII, the advent of cyclodiene insecticides led to dramatic increases in continuous corn acreage and to the development of insecticide-resistant, highly migratory strains of western corn rootworm (Metcalf 1986). As a result, the geographic range of this pest expanded rapidly, and by 1983, *D. v. virgifera* reached the eastern seaboard (Krysan 1986). The species was first reported in southwestern Virginia in 1985, and has since spread throughout virtually all of the corn-growing regions of the state (Youngman and Day 1993).

Several studies conducted in the Midwest have investigated the risk of damage to field corn by western corn rootworm. Research from 1972 to 1974 showed that less than 4% of the corn acreage in Indiana suffered economic loss due to corn rootworm (Turpin and Thieme 1978). Additional research in Illinois (Luckmann 1978) and Nebraska (Stamm et al. 1985) indicated that approximately 10 to 20% of the corn acreage in these states was at risk to serious rootworm damage. In marked contrast, Foster and Tollefson (1986) found the damage risk to be greater than 80% in Iowa corn fields in the early 1980s. More recent research involving 58 corn fields in Illinois has led researchers to suggest that approximately 25% of the fields in the Midwest are at risk to economically-damaging levels of corn rootworms each year (Gray et al. 1993). Information of this nature for mid-Atlantic states such as Virginia is lacking. The objective of this study was to assess the risk of damage caused by western corn rootworm in continuous corn fields in Virginia by comparing root damage, whole-plant yields, and silage quality in insecticide-treated and untreated sections of these fields.

Materials and Methods

Thirty-two corn fields were surveyed in Virginia in 1993 and 1994. Fields were selected from Augusta, Bedford, Floyd, Madison, Montgomery, Pulaski, and Rockingham counties, representing several continuous-corn growing areas of the state. Field size ranged from 2 to 30 ha, and soil types ranged from a fine sandy loam (10.5% clay) to silt loam (20% clay). All fields had been under continuous corn production and treated with a soil insecticide for at least 4 yr prior to each of the years in which this study was done. Preexisting population densities of western corn rootworm, or any other insect pest were not known for any of the fields. In each study year, corn fields were planted no-till during the first 2 wk of May and treated with a soil insecticide at planting, except for a rectangular strip (4 to 8 rows by 70 m) located near the center of each field, which was left untreated. Corn rootworm larval feeding damage was assessed in July on 20 arbitrarily chosen plants dug from the center 2 rows in the treated and untreated sections. Root systems were removed from the field, washed free of soil and evaluated using the standard 1 to 6 root-damage rating system developed by Peters and Eiben (described by Hills and Peters 1971). The categories of this rating system are: (1) no apparent feeding damage; (2) feeding scars evident, but no roots completely chewed off; (3) several roots chewed off, but never an entire node of roots destroyed; (4) one node of roots completely destroyed; (5) two nodes of roots completely destroyed; and (6) three or more nodes destroyed.

Whole-plant yields rather than grain yields were assessed in our study because most of the corn acreage sampled in our study was grown for silage production. Yields were determined on a per field basis using a harvest protocol similar to that of Laub and Luna (1991). Two plots (2 rows x 10 m) were established in both the treated and untreated sections. Stand counts were made by counting all stalks in each plot. All corn plants in each plot were hand-harvested using machetes and weighed in the field using a tripod and scale. Ten stalks from each plot were chopped using a Tomahawk® Chipper/Shredder (Troy-Bilt Manufacturing Co., Troy, NY.). A 1 kg subsample of chopped plant material was removed and dried at 70°C for 48 h to determine percent dry matter. Weights were adjusted to 65% moisture (Davis 1994) and reported in metric tons/ha (1 MT/ha = 0.455 tons/acre). Subsamples of the dried plant matter were ground in a Wiley mill and analyzed at the Virginia Tech Forage Testing Laboratory, Blacksburg, VA, for quality analysis, including % crude protein (CP) and % acid detergent fiber (ADF). Crude protein was determined by measuring the total nitrogen contained in the ground corn samples. In most forages, nitrogen is 16% of the weight of proteins. Thus, % CP was calculated as 6.25 times the % N in the sample. Acid detergent fiber fraction is a measure of the cellulose and other compounds in feed that are only partially utilized by the animal.

Paired t tests were used to compare mean root damage ratings, stand counts, whole-plant yield, % CP, and % ADF in insecticide-treated and untreated sections of the fields. Mean yield losses in untreated corn were compared for various root rating groupings for the purpose of developing an economic root rating level for silage corn in Virginia.

Results

Corn rootworm feeding caused significant differences in root damage and whole-plant yield between insecticide-treated and untreated corn (Table 1). Overall, sections of corn fields treated with an insecticide had a mean root rating of 2.63 which was significantly lower than the 3.37 root rating of the untreated corn (t=5.80; df=31; $P < 0.0001$). In addition, the insecticide-treated corn yielded 46.29 MT/ha compared to 43.81 MT/ha in the untreated corn, a difference of 5.4% which was significant (t=2.52; df=31; $P < 0.05$). Insecticide-treated corn did not differ significantly from untreated corn in stand count (t=1.83; df=31; P=0.08), % crude protein (t=1.81; df=31; P= 0.08), and % acid detergent fiber (t=0.29; df=31; P=0.77).

Of the 32 untreated field sections that we evaluated, 16 (50.0%) had root ratings > 3.0, 9 (28.1%) had root ratings > 3.5, and 5 (15.6%) had root ratings > 4.0. Most of the insecticide-treated corn sections (88.5%) had root ratings ≤ 3.0; however, 4 (12.5%) had moderate damage with root ratings that ranged from 3.1 to 3.2.

Economic loss in whole-plant yield was calculated to be 4.9 MT/ha (at 65% moisture) based on a crop value of $22.00/MT of silage and a treatment cost of $37.00/ha. Seven (21.9%) fields overall suffered economic yield loss in the untreated corn sections (Table 2). Of these 7 fields, 5 (15.6% overall) had serious corn rootworm feeding damage (root ratings ≥ 3.8), which likely explained the yield loss. In the other 2 fields, root damage in the untreated corn was relatively low (root ratings = 3.20 and 2.95) and not substantially different from that in the insecticide-treated corn (root ratings 2.90 and 2.60, respectively). Stand counts in these two fields also were similar in the treated and untreated corn. Although we cannot be certain of the actual cause of the economic loss of yield in these two fields, we do not believe it was related to corn rootworm feeding damage.

Table 1. Mean root damage, stand count, yield and forage quality assessment of granular insecticide-treated and untreated sections of continuous corn fields in Virginia.

Fields (n = 32)	Root rating* (1-6 scale)	Stand count (per 20 row m)	Whole-plant yield** (MT/ha)	Forage quality: % Crude protein†	Forage quality: % Acid detergent fiber‡
Treated	2.63a	92.28	46.29a	6.64	29.89
Untreated	3.37	89.81	43.81	6.87	30.11

*Root rating based on the Peters and Eiben 1-6 scale (Hills and Peters 1971).
** Whole-plant yield weights were adjusted to 65% moisture (1 MT/ha = 0.455 tons/acre).
† Percent crude protein was calculated as 6.25 times the % N in a forage sample.
‡ Percent acid detergent fiber is a measure of the cellulose fraction in a forage sample.
aMeans within a column are significantly different ($P < 0.05$; Student's paired t test).

Table 2. Fields with economic yield loss in corn not treated with a soil insecticide (n = 7).

Root rating*		Stand count		Whole-plant yield**		% Yield reduction†
Treated	Untreated	Treated	Untreated	Treated	Untreated	
3.15	5.35	96	79	33.83	20.36	39.8
3.10	5.00	89	90	37.98	30.99	18.4
2.70	4.90	156	160	65.47	51.51	21.3
2.45	3.95	94	90	49.16	36.60	25.5
2.90	3.80	94	72	60.13	47.20	21.5
2.90	3.20	94	92	38.94	31.24	19.8
2.60	2.95	56	51	39.13	32.23	17.6

*Root rating based on the Peters and Eiben 1-6 scale (Hills and Peters 1971).
**Whole-plant yield wts adjusted to 65% moisture (1 MT/ha = 0.455 tons/acre).
†Percent yield reduction = 100 (yield of insecticide-treated corn – yield of untreated corn)/yield of treated corn.

Whole-plant yield losses for untreated sections of fields were calculated and summarized according to root damage ratings (Table 3). Fields with root ratings >2.50 to 3.0 in the untreated corn had a mean yield loss = 0.39 MT/ha and, fields with root ratings >3.0 to 3.5 had a mean yield loss = 1.19 MT/ha. These losses represented yield reductions of only 0.7% and 1.5%, respectively. However, fields >3.5 to 4.0 had a mean yield loss of 4.94 MT/ha, which exceeded the economic level (4.9 MT/ha) and represents a 8.7% reduction in whole-plant yield. In addition, all fields with root ratings >4.5 experienced a mean yield loss that exceeded the economic level. One field with a root rating of 4.3 in the untreated corn had a mean whole-plant yield loss of only 0.62 MT/ha. Although we cannot account for the low yield loss in this field, it may be that nearly optimal growing conditions negated the deleterious effects of rootworm feeding damage.

Mean percentages for crude protein and acid detergent fiber in the harvested corn samples also were summarized according to root damage ratings in the untreated sections (Table 4). Corn rootworm feeding did not appear to seriously affect the quality of corn harvested in our study. The percentage of crude protein and acid detergent fiber in the ground samples of untreated corn were similar for all root ratings. Davis (1994) also found that corn rootworm feeding did not seriously affect corn silage quality, and suggested that environmental factors such as seasonal climate and crop maturity at harvest have a much greater effect on forage quality than rootworm feeding.

Table 3. Mean yield loss in untreated sections of corn fields according to root damage rating.

Root rating*	No. of fields (n)	Mean whole-plant yield loss** (MT/ha) ± SEM	Mean % yield reduction† ± SEM
2.0-2.5	2	3.44 ± 0.16	7.77 ± 1.28
>2.5-3.0	14	0.39 ± 1.14	0.71 ± 2.62
>3.0-3.5	7	1.19 ± 1.43	1.45 ± 4.14
>3.5-4.0	4	4.94 ± 4.67[a]	8.74 ± 8.98
>4.0-4.5	1	0.62 ± 0.00	1.43 ± 0.00
>4.5-5.0	2	10.48 ± 3.50[a]	19.86 ± 1.46
>5.0	2	8.65 ± 4.84[a]	23.51 ± 16.31

*Root rating based on the Peters and Eiben 1-6 scale (Hills and Peters 1971).

**Whole-plant yield wts adjusted to 65% moisture (1 MT/ha = 0.455 tons/acre).

†Percent yield reduction = 100 (yield of insecticide-treated corn – yield of untreated corn)/yield of treated corn.

[a]Denotes yield loss above the economic level of 4.9 MT/ha based on a crop value of $22.00/MT of silage and treatment cost of $37.00/ha.

Table 4. Mean percentages for crude protein (CP) and acid detergent fiber (ADF) in ground corn samples from untreated sections of fields according to root damage rating.

Root rating*	No. of fields (n)	Mean % CP** ± SEM	Mean % ADF† ± SEM
2.0-2.5	2	6.12 ± 0.50	29.50 ± 1.71
>2.5-3.0	14	6.81 ± 0.13	30.31 ± 1.18
>3.0-3.5	7	7.15 ± 0.33	30.03 ± 2.07
>3.5-4.0	4	6.76 ± 0.43	28.43 ± 2.47
>4.0-4.5	1	7.21 ± 0.00	29.20 ± 0.00
>4.5-5.0	2	6.94 ± 1.32	30.70 ± 2.71
>5.0	2	7.07 ± 0.59	32.80 ± 5.42

*Root rating based on the Peters and Eiben 1-6 scale (Hills and Peters 1971).
**Percent crude protein was calculated as 6.25 times the % N in a forage sample.
†Percent acid detergent fiber is a measure of the cellulose fraction in a forage sample.

Discussion

Knowledge of the risk of damage by a particular pest in a given geographic area is a critical part of the decision-making process in a pest management program. This is particularly true for management of pests such as western corn rootworm, where growers often rely on preventive control measures (Levine and Oloumi-Sadeghi 1991). Recent studies suggest that approximately 25% of the fields grown continuously in corn in the Midwest are at risk to serious damage from western corn rootworm each year (Gray et al. 1993). Our study indicates that, although western corn rootworm has only recently expanded its range to the eastern seaboard (Krysan 1986, Youngman and Day 1993), the risk of damage in this region appears to be similar to that in the Midwest. Just over 28% of the continuous corn fields we investigated had serious root damage which exceeded a rating of 3.5 in sections of the fields not treated with a granular insecticide. In addition, 19% of the untreated field sections suffered economic loss in silage yield due to corn rootworm feeding damage. Several studies conducted in the Midwest have shown that approximately 90% of fields grown continuously in corn are treated preventively each year with a soil insecticide for corn rootworm (Luckmann 1978, Stamm et al. 1985, Gray et al. 1993), a practice which some researchers have suggested is seldom profitable (Turpin and Thieme 1978). Because much of the continuous corn in Virginia is treated preventively with soil insecticides as in the Midwest, the results of our study suggest that a high percentage of this insecticide use is unnecessary.

The relationship between root-damage rating and subsequent yield loss in corn is complex; consequently, there is some discrepancy among researchers in the literature concerning exactly which root damage rating level corresponds to a yield loss in corn equivalent to the cost of applying an insecticide. Initial studies on this relationship suggest that the potential for economic loss in yield exists in a field if root ratings exceed 2.5 to 3.0 on the Peters and Eiben 1 to 6 scale (Turpin et al. 1972, Branson et al. 1980, Mayo 1986). More recent studies suggest that an economic injury index of 3.0 is too low and that a root rating of 4.0 or 5.0 might be more realistic (Sutter et al. 1990, Gray et al. 1993). These studies were conducted on corn grown for grain. According to Davis (1994), however, corn grown for silage suffers greater dollar losses from rootworm injury than corn grown for grain, thus, economic injury levels should be lower for silage corn than for grain corn. In our study, fields with root ratings at or below a level of 3.5 in the untreated corn had a mean whole-plant yield reduction ranging only from 0.7 to 1.5%. Fields with root damage ratings >3.5 to 4.0, however, had a mean yield reduction of 8.7% which exceeded the economic level for yield loss in corn. Thus, for Virginia silage corn at least, 3.5 appears to be the root damage level that induces a yield loss equivalent to or greater than the cost of applying an insecticide. It is important to realize, however, that no single root rating corresponds directly to economic damage all of the time. A number of environmental and agronomic factors, including soil type, soil moisture, nitrogen level, plant density, root regrowth and lodging potential can affect the relationship between root damage and yield loss in corn making it difficult to quantify economic injury levels (Turpin et al. 1972, Chiang et al. 1980, Foster et al. 1986, Spike and Tollefson 1989a, 1989b, 1991).

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