Phytoprotection

Effects of soil insecticide treatments on northern corn rootworm, *Diabrotica barberi* [Coleoptera : Chrysomelidae] populations and on corn yield

Effets des traitements insecticides de sol sur les populations de la chrysomèle des racines du maïs, *Diabrotica barberi* [Coleoptera : Chrysomelidae]

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Résumé de l'article

Durant 3 ans, des essais au champ ont permis d'evaluer les effets de trois insecticides appliqués au sol lors des semis sur les populations de la chrysomèle des racines du maïs (*Diabrotica barberi*). Dans chacune des parcelles, une cage d'émergence a été placée au-dessus d'un plant de maïs (*Zea mays*) et les populations d'adultes ont été suivies hebdomadairement. Les dommages faits par les larves aux racines de maïs ont été évalués et le rendement en grains a été déterminé à la fin de la saison de croissance des plantes. Les traitements insecticides ont réduit significativement le nombre d'adultes émergeant durant la première année seulement. La force d'arrachage était reliée négativement au nombre d'adultes émergeant par plant. Chaque année le rendement en grains des parcelles traitées n'était pas significativement différent de celui des parcelles non traitées. Les traitements insecticides peuvent donc réduire le nombre d'adultes émergeant sans toutefois augmenter les rendements.

Effects of soil insecticide treatments on northern corn rootworm, *Diabrotica barberi* [Coleoptera : Chrysomelidae], populations and on corn yield

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A 3-yr field study was conducted to determine the effects of three soil-applied insecticides on northern corn rootworm (*Diabrotica barberi*) populations. In each plot, an emergence cage was placed over a corn (*Zea mays*) plant, and adult populations were monitored weekly. Larval damage to corn roots was evaluated and corn yield was recorded at the end of the growing season. Insecticide treatments significantly reduced the number of emerging adults in the first yr, but no difference was observed in the following yr. Root strength was negatively correlated to the number of emerging adults per plant. Each yr, corn yields in treated plots did not differ significantly from yield in untreated plots, which suggests that insecticide treatments can reduce the number of emerging adults without increasing yields.

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INTRODUCTION

The northern corn rootworm (NCR), *Diabrotica barberi* Smith and Lawrence [Coleoptera : Chrysomelidae] and western corn rootworm (WCR), *Diabrotica virgifera virgifera* LeConte [Coleoptera : Chrysomelidae], are the most serious pests of corn, *Zea mays* L., in the Midwestern United States (Levine and Oloumi-Sadeghi 1991). The NCR was

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first mentioned in Quebec in 1938 (Chagnon 1938). It was reported on corn in the Napierville area in 1975 (Guibord 1976) and is now found each yr in fairly large numbers throughout southwestern Quebec.

From 1975 to 1992 corn acreage in Quebec increased from 55 000 ha to over 300 000 ha, an increase of over 500% which is responsible for the increased NCR population. Growers changed their crop rotation practices, growing corn on the same fields for more than 1 yr. This cropping practice and the increased acreage created favorable conditions for the rapid increase in rootworm populations (Chiang 1973).

In Midwestern United States in 1977, 90% of the fields seeded to corn for more than 1 yr were treated with insecticides for corn rootworm (Foster *et al.* 1982). In Quebec corn growers began to treat their corn fields in early 1980's despite no knowledge of the rootworm population densities and distribution among fields or its impact on yield. This study was designed to determine rootworm population densities and if insecticide applications result in higher yields by protecting the roots from larval damage.

MATERIALS AND METHODS

The study was conducted from 1981 to 1983 in a field at the L'Acadie Experimental Farm, L'Acadie (lat. 45°19' N, long. 73°21' W), Quebec, where corn was planted in 1980 to ensure adequate rootworm infestation (Hill and Mayo 1974). Soil type in the experimental area was a Sainte Rosalie clay (60% clay, 20% silt, and 20% sand, with 4% organic matter). The test plots were seeded with the corn hybrid Pioneer 3950 at a rate of 67 000 seeds per ha on the first wk of May in 1981 and 1982, and on the third wk of May in 1983. A standard Buffalo four-row seeder and a driving-wheel insecticide applicator were used. Granular insecticides tested were Furadan 10G (carbofuran; 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), Thimet 15G (phorate; O, O-diethyl S-ethylthiomethyl phosphorodithioate) and Counter 15G (terbufos; S-(tert-butylthiomethyl) O,O-diethyl phosphorodithioate) applied at the rate of 1 kg a.i. ha^{-1}. Thimet 15G and Counter 15G are still registered in Quebec to control NCR. In 1981 and 1982, plots were arranged in a randomized complete block design with blocks parallel to a road. Because no block effects were observed during these yr, we used a completely randomized design in 1983. Each yr, treatments were replicated four times. Plots were 3 m wide by 12 m long and consisted of 4 rows planted 75 cm apart with a plant spacing of 20 cm. To maintain high populations of rootworms, part of the field was planted each yr at the end of June in order to have fresh silk to attract ovipositing NCR adults in mid-August.

Adult populations were monitored with emergence cages designed by Fisher (1980). In each plot, a cage (90 cm long by 15 cm wide) was placed over a plant located in one of the center rows. Each cage was placed perpendicular to the row and enclosed the area of one corn plant. Cages were placed in the field on 23 July 1981, 30 June 1982, and on 14 July 1983 and were removed on 29 September 1981, 20 September 1982, and on 11 October 1983. After adult emergence had begun, beetles were removed from cages and counted once or twice per wk until the end of the emergence period.

Root strength of the plants was determined by pulling the plant vertically and recording the force required to remove the plant from the soil. This technique has been accepted as an adequate measure of larval damage to the roots of the corn plants (Donovan *et al.* 1982; Ortman *et al.* 1968). The apparatus used to pull the corn plants from the soil was modified from the one described by Ortman *et al.* (1968). Plants were cut about 50 cm above the ground and the leaves were removed from the stub. A Kelms Grip® was attached to the stub and to the bottom of a 200 kg-capacity dynamometer that was connected to the hydraulic system of a tractor. Depending on the corn stalk, grips of 2.5 and 4.75 cm in diameter were used. In each plot, the root strength of

20 plants was recorded on 20 July 1981. At this date, it was assumed that populations of third instars had peaked and that most of the corn rootworm damage was done (Dominique and Yule 1984; Zuber *et al.* 1971). Since the maximum weight of the dynamometer was 200 kg, higher pulling weights were recorded as 100% and lower weights were assigned proportional values of this maximum. The apparatus was only available for testing root strength in 1981.

Plants were harvested by hand from the two middle rows of each plot on 20 October 1981, 26 October 1982, and 26 October 1983. The seed was removed from harvested ears and weighed. The moisture content of the seed was determined and the final yield was reported as kg per ha of 15% moisture-equivalent grain.

Because soil moisture may influence the effectiveness of NCR control with soil insecticides (Getzin 1981; Gorder *et al.* 1982), data on precipitation were recorded daily at the meteorological station at L'Acadie, about 100 m from the experimental plots.

The number of adults per cage (X) and the relative values of plant root strength (Y) were transformed by log (X + 1) and $\arcsin \sqrt{Y}$, to reduce dependence of variances on means (Sokal and Rohlf 1981). According to the experimental design, either a one-way or a two-way Anova was performed (Proc GLM, SAS Institute, 1985). Significance among means was determined by Fisher's protected least significant difference test (PLSD) (P =0.05). Linear regression analysis was employed to quantify the relationship between root strength, corn yield and the number of NCR adult emergence. All values are presented as untransformed means ± SD.

RESULTS

Adult emergence was reduced among insecticide treatments in 1981 ($F_{3,5}$ = 6.66; P = 0.034) and in 1983 ($F_{3,12}$ = 3.79; P = 0.040) but not in 1982 ($F_{3,9}$ = 0.725; P = 0.562) (Table 1). The highest number of adults found in 1981 and 1982 were in the control plots and in phorate treated plots in 1983. The number of adults found in the control plots in 1981 and 1982 were similar ($F_{1,5}$ = 0.351; P = 0.580) but were about 75% lower in 1983, except in phorate treated plots.

Root strength was significantly higher in insecticide treatments ($F_{3,9}$ = 13.83; P = 0.001) (Table 1) and was negatively related to the number of emerging adults per plant (Fig. 1). Each yr, the number of adults was not related with corn yields (1981: $F_{1,10}$ = 2.95; P = 0.117; 1982: $F_{1,14}$ = 0.01; P = 0.912; 1983: $F_{1,14}$ = 0.14; P = 0.714).

Table 1. Mean number of adults per cage and root strength of corn plants in insecticide treated plots located at L'Acadie, Quebec

	Emerging adults plant^{-1} ± SD			Root strength ± SD[a]
Treatments	1981	1982	1983	1981
Carbofuran	49 ± 6 ab	63 ± 51 a	12 ± 6 b	147 ± 39 b
Terbufos	28 ± 19 c	55 ± 22 a	8 ± 6 b	169 ± 34 a
Phorate	33 ± 10 bc	44 ± 14 a	39 ± 20 a	159 ± 36 ab
Control	64 ± 15 a	72 ± 20 a	12 ± 7 b	117 ± 34 c

[a] Mean vertical pulling weight (kg) per plant.

Means within columns followed by the same letter are not significantly different at P > 0.05 (Fisher's PLSD test).

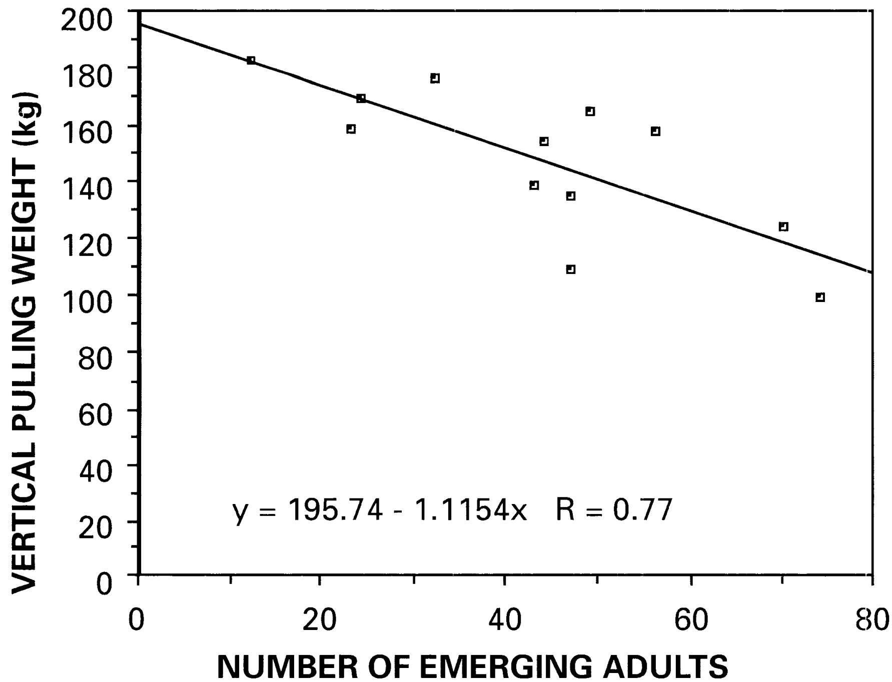

Figure 1. Relation of root strength (vertical pulling weight) with the number of northern corn rootworm adults emerging from plots in 1981.

Corn yields each yr were not significantly different between treatments (1981: $F_{3,9} = 0.01$; $P = 0.999$; 1982: $F_{3,9} = 1.17$; $P = 0.373$; 1983: $F_{3,12} = 1.20$; $P = 0.353$) (Table 2). Yields were lowest in 1982 and were highest in 1983.

Cumulative precipitation from the time of insecticide applications to the end of July was higher in 1981 than in 1982 (Fig. 2). Difference in precipitation was mostly observed in June (JD151-JD171) and July (JD181-JD212), periods in which dryer conditions occurred in 1982. During that yr most of the precipitation occurred around mid-June (JD170) and end of July (JD210).

Table 2. Mean yields of corn grain in insecticide treated plots located at L'Acadie, Quebec, in 1981, 1982 and 1983

	Yields ± SD (t ha^{-1})		
Treatments	1981	1982	1983
Carbofuran	6.10 ± 0.25 a	5.43 ± 0.28 a	6.33 ± 0.38 a
Terbufos	5.69 ± 0.38 a	5.31 ± 0.09 a	6.57 ± 0.27 a
Phorate	5.68 ± 0.18 a	5.49 ± 0.45 a	5.78 ± 0.67 a
Control	5.74 ± 0.55 a	5.34 ± 0.14 a	5.95 ± 0.96 a

Means within columns followed by the same letter are not significantly different at $P > 0.05$ (Fisher's PLSD test).

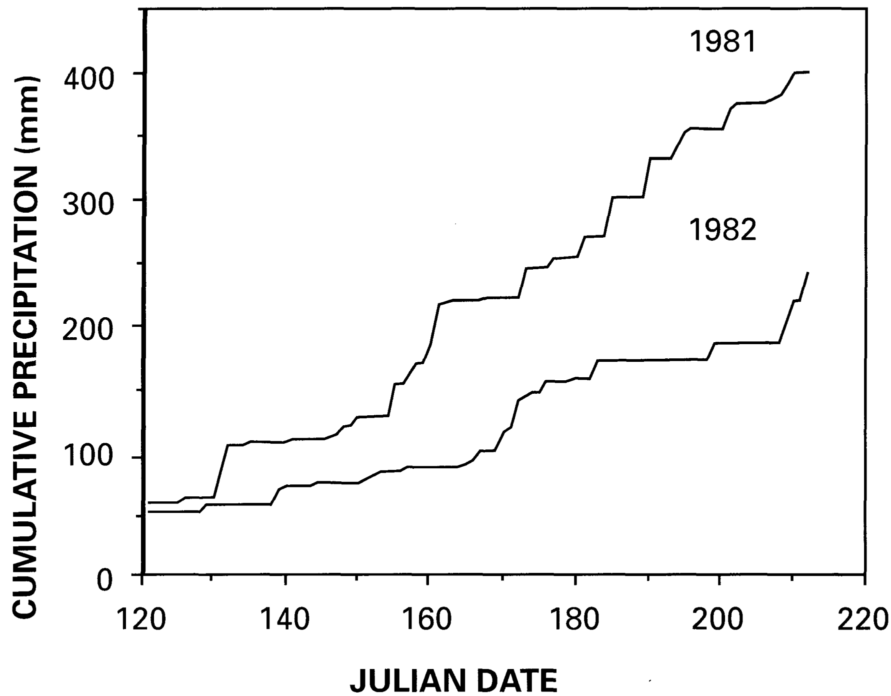

Figure 2. Cumulative precipitation during May, June and July in 1981 and 1982.

DISCUSSION

The differences in the survival of larvae and thus the number of emerging adults in the insecticide treatments in 1981 and 1982 may have been caused by differences in the degradation of the insecticides. Chemical dissolution of soil-applied insecticides is affected by soil moisture (Levine and Oloumi-Sadeghi 1991). In 1981, cumulative precipitation from the time of insecticide application to the end of July, when NCR larvae feed on corn roots, (Dominique and Yule 1984), was about twice that of 1982. Harris (1967) found that insect mortality due to insecticide treatment increased with soil moisture. The insecticidal effects in 1981 on the number of emerging adults may be caused by more available dissolved insecticides. Moreover, the drier conditions of 1982 may have increased insecticide adsorption to soil particles, which lessened availability for larval contact or uptake (Levine and Oloumi-Sadeghi 1991).

In 1983, the low number of emerging adults compared with previous yr may be related to the severe winter. Northern corn rootworm eggs are sensitive to low temperature and survival is reduced to 15% at - 23°C (Patel and Apple 1967). At the L'Acadie Experimental Farm, minimum air temperature reached -25°C on 11 February 1983 and egg survival may have been severely affected by this low temperature. In Quebec, low temperatures combined with low snow cover during winter can increase NCR egg mortality to more than 80% (Matin and Yule 1984).

Ortman *et al.* (1968) observed that root strength is related to the number of roots and the development of secondary roots. Although we did not observe root characteristics, our data indicated that as the number of emerging adults decreased, the root strength or root system development increased ($r = 0.77$, $n = 12$). The lowest number of adults emerged in the terbufos and phorate treated plots. Therefore, fewer larvae attacked the roots of plants in these treatments compared with carbofuran treated or untreated plots, and resulted in a higher root strength for these plants.

The relation between the number of adults with root strength was not observed with corn yields. This suggests that plants can recover from larval injury or the larval density in the plots was too low. Jackson (1996) also did not observe corn yields to be related to the number of WCR adults between treatments. Plots had to be infested with at least 1200 WCR eggs per plant in order to show a significant yield reduction (Chiang *et al.* 1980; Sutter *et al.* 1990). Since NCR causes less damage than WCR (Fisher 1985), an even higher level of infestation is needed to observe yield reduction. In Quebec, about 6% of the eggs found in the soil in spring will complete their development (Matin 1983). At a density of 1200 eggs per corn plant, we can expect about 72 adults to emerge as observed in the control plot in 1982. Fewer adults emerged in all other plots, explaining the lack of yield response to insecticide treatments. Spike and Tollefson (1989) showed that regrowth of injured roots increased at a plant density of 63 000 per hectare. Since the plant density in our plots was 67 000 plants per hectare, regrowth of corn plant roots may have been enhanced.

In Quebec, many growers are uncertain about the need to apply soil insecticides to control NCR (P. Lachance, personal communication). Phorate and terbufos are two soil insecticides currently recommended to control NCR larvae (CPVQ 1996). In our study, these chemicals reduced the number of emerging adults during one of the 3 yr but corn yields were not affected by treatments. Therefore, we estimate that the population density of NCR near L'Acadie, Quebec, has below levels that significantly reduce grain yields. The number of adults found in control plots in 1983 suggest that low temperature during winter maintain NCR populations at low levels. However, a more serious pest, the WCR, is present in Ontario and New York State, two corn-growing areas adjacent to Quebec (Foott and Timmins 1977; Shields *et al.* 1991). If the WCR moves into Quebec, rootworms may become a serious problem, if damage caused by WCR adds to that by NCR.

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