# Population Suppression of Western Corn Rootworm by Adult Control with ULV Malathion

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Published in *Journal of Economic Entomology* 67:5 (October 1974), pp. 651–655; doi: 10.1093/jee/67.5.651

Submitted August 20, 1973; published October 1, 1974.

# Population Suppression of Western Corn Rootworm[1] by Adult Control with ULV Malathion[2]

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**Abstract**
ULV malathion (9.7 oz AI/acre) was applied by air to a 16 square-mile area during August of 1968, 1969, and 1970. Adult *Diabrotica virgifera* LeConte populations were reduced the following season by 39, 54, and 72%. No economic infestations occurred in the treated area the year following any application. Postspray migration of beetles was very limited, but adult migration during the peak emergence period the following season contributed to repopulation of the treated area. Migration and fecundity appear to be density-dependent factors which favor increases under low populations. Area suppression does not appear economically feasible, but adult control in individual fields may be an acceptable alternative to soil insecticides applied for larval control. A model was developed for timing treatments against adults; treatments between Aug. 1–15 should result in adequate population suppression to prevent damage the following season. Mid-August population levels of 1.0 beetle/plant were an acceptable economic threshold for determining the need for control measures.

The western corn rootworm, *Diabrotica virgifera* LeConte, is presently controlled by prophylactic application of soil insecticides at planting time; while preventing larval damage, those treatments may not greatly reduce emerging adult populations (Pruess et al. 1968). Few alternative control methods have been investigated (Hill et al. 1948, Calkins et al. 1970) and suppression for longer than 1 year has not been accomplished by a single treatment or method. The study reported here was conducted to determine the population suppression possible by adult corn root worm control within a large area prior to oviposition.

## Methods

ULV malathion at 8 fl oz/A (9.7 oz AI) was applied aerially to the total environment of a 16 (4 × 4) $mi.^2$ area in Dawson County, Nebraska. Treatment dates were Aug. 22–24, 1968, Aug. 14–16, 1969, and Aug. 10–11, 1970. Flight altitude was 50 ft, air speed 80 mph, and swath width 100 ft. A contiguous 16-$mi.^2$ area served for comparison (control area). Corn comprised 43% and 48% of the total acreage in the treated and control areas, respectively, and alfalfa 46% and 41%. Mean years in continuous corn (6, range 1–20) is largely determined by longevity of alfalfa stands, the only crop with which much rotation is possible.

Rootworm populations were estimated by determining number of eggs (Lawson and Weekman 1966), larvae per plant, and adults per plant. Of these methods, only adult counts were used throughout the study. The same fields, 30–50 fields/area, were sampled throughout the study except for normal attrition and replacement due to crop rotation. First-year corn fields were never observed to have rootworm damage and, except in 1968, were not included in comparisons. Beetle counts were made on 25 consecutive plants in a field, the same sample location being used each sample date. A single person made all counts each year, using a serpentine sampling plan so that an equal number of fields in the treated and control areas were sampled each day under comparable conditions.

## Results

Adult control, adjusted for concurrent population changes in the control area, varied from 89% in 1968 to 96% in 1969 (Table 1). Estimates of population suppression, measured by number of adults the year following treatment, varied with the interpretation employed. Adult counts made at peak emergence (late July), comparing only the same fields sampled the previous year, gave the lowest estimates of suppression. The second, and always higher, estimate given in Table 1 is based on the assumption that, in the absence of our treatment, the 2 areas would have had equal populations.

Results of the 1968 treatment were confounded by farmer-applied adult treatments to individual fields prior to our area treatment; these controls account for the apparent decrease in population prespray in the treated area. The best interpretation would seem that adult control resulted in a 39% population reduction the following year but to a large extent was due to treatment of individual fields rather than the planned suppression program. Based on this experience and the finding that adult emergence occurs earlier than had been anticipated, treatment dates were advanced in 1969 and 1970.

Population suppression, as measured by adults per plant at peak emergence, increased to 54% and 72% following the 1969 and 1970 treatments. Populations in the treated area remained below those in the control area through peak emergence in 1972. However by August 1972 populations were essentially equal in both, areas.

**Table 1.** Mean number of western corn rootworm adults per plant in control and treated areas and % reduction by adult control with ULV malathion, Dawson County, Nebraska, 1968–72

| | Area | | |
|---|---|---|---|
| Date | Treated | Control | % Reduction[c] |
| July 30, 1968 | 1.54 | 1.33 | |
| Aug. 17, 1968[a] | 0.67 | 0.91 | |
| Aug. 26, 1968[b] | 0.08 | 0.96 | 89 |
| July 28, 1969 | 0.27 | 0.44 | 5–39 |
| Aug. 11, 1969[a] | 0.39 | 0.42 | 0–7 |
| Aug. 18, 1969[b] | 0.02 | 0.57 | 96 |
| July 23, 1970 | 0.36 | 0.78 | 50–54 |
| Aug. 8, 1970[a] | 0.59 | 0.81 | 22–28 |
| Aug. 14, 1970[b] | 0.04 | 0.80 | 95 |
| July 30, 1971 | 0.20 | 0.70 | 61–72 |
| Aug. 17, 1971 | 0.48 | 0.85 | 22–43 |
| July 25, 1972 | 0.95 | 1.49 | 0–37 |
| Aug. 9, 1972 | 1.72 | 1.91 | 0–10 |
| Aug. 23, 1972 | 1.10 | 1.04 | 0–0 |

a. Prespray.
b. Postspray.
c. First or single value based on fields sampled both pre- and postspray and adjusted for concurrent changes in control area; 2nd value based on assumption that treated and control area populations would have been identical in absence of treatment.

## Interpretive Research

Complete prevention of root worm damage in the treated area was achieved only for the year following adult control, and no cumulative suppression resulted from repeated treatments. Additional research and observations indicated several factors which should be considered in interpreting these results.

## Adult Emergence

Based on caged plants, 90% adult emergence was reached each year between July 29 and Aug. 6. These dates are consistent with those reported in other studies in central Nebraska (Pruess et al. 1968, Short and Hill 1972, Wedderburn[4]). There were no differences between the treated and control areas and thus no evidence for selection for earlier emergence by repeated adult treatments.

## Seasonal Adult Populations and Oviposition

In 1971, after possible selection for a shorter preoviposition period, adults were collected from 3 fields each in the treated and control areas, and oviposition patterns and fecundity determined. Beetles collected July 23 began oviposition July 30, but mortality was high and only 91 eggs/female resulted. Collections from the same fields on July 30 resulted in 10% of females ovipositing by Aug. 5 and 100% by Aug. 20. Once oviposition began, females laid a mean of 10 eggs/day for a total of 202 eggs/female. This oviposition rate was similar to the 12 eggs/day reported by Branson and Johnson (1973) but total fecundity was lower due to shorter longevity in our experiment. However, laboratory mortality approximated the population decline observed in the field, and this estimate of fecundity was used in subsequent modeling.

Figure 1 summarizes results of laboratory data on oviposition and field data on seasonal populations. The female population is relatively stable Aug. 1–10, mortality equaling new emergents. Populations usually decline slowly until ca. Aug. 25, more rapidly thereafter. Rate of population decline after late August is variable from year to year and may be an important factor in total fecundity.

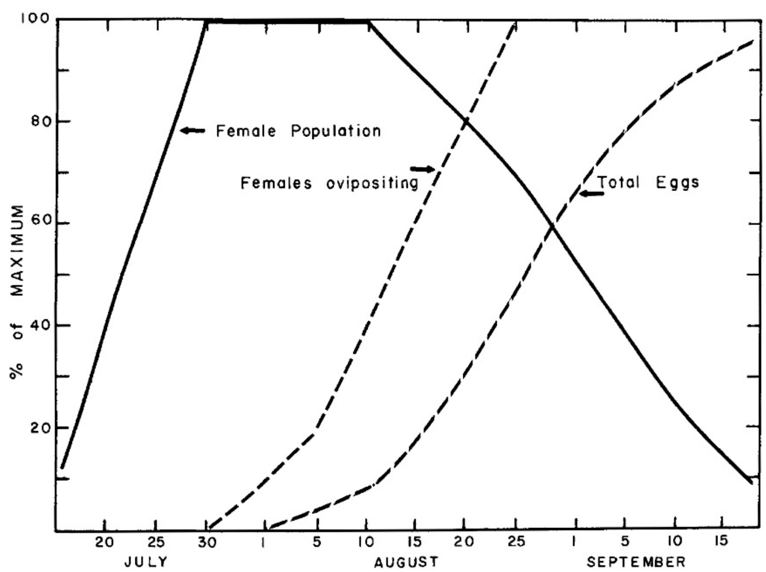


**Figure 1.** Relative seasonal female western corn rootworm populations and oviposition, Dawson County, Nebraska, 1968–71.

## Optimum Date for Adult Control

Using data summarized in Figure 1, a model was constructed to predict optimum date for adult treatment to suppress a population. Suppression will be determined by percent mortality due to the treatment (90% assumed in the model), number of eggs laid prior to treatment, and eggs laid after treatment either by survivors or new emergents.

The model shown in Figure 2 assumes 90% female emergence by Aug. 5 and 100% by Aug. 10 with 202 eggs/female deposited over time as shown in Figure 1. We also assumed that beetles surviving the treatment would lay a normal number of eggs commensurate with their remaining reproductive potential. This assumption is supported by one experiment in which females collected posttreatment in the treated area laid 99 vs. 83 eggs/female for beetles collected at the same time in the control area.

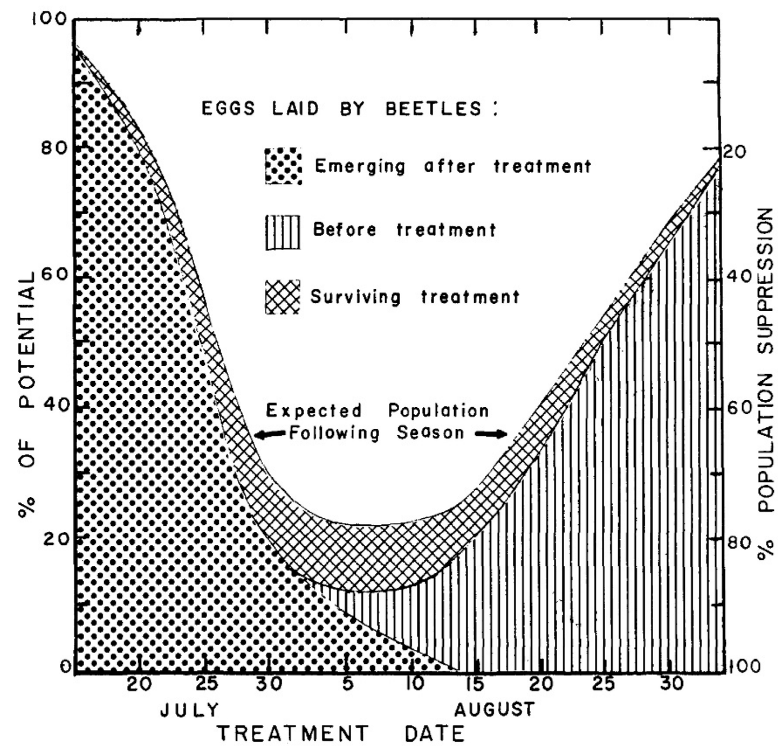


**Figure 2.** Predicted effect of adult western corn rootworm control (90% mortality assumed) on different dates on relative number of eggs laid pretreatment, by beetles surviving treatment and beetles emerging posttreatment.

We also assumed that any beetles emerging posttreatment would lay a full complement of 202 eggs; in view of oviposition studies which indicated high mortality of females shortly after emergence, this assumption may underestimate the potential effectiveness of early treatments for population suppression.

The model indicates that eggs laid by beetles surviving the treatment would be the major contribution to population survival for treatments made Aug. 5–10. Before Aug. 5, beetles emerging posttreatment become of increasing importance, while for treatments after Aug. 10 pretreatment oviposition is the major contribution to survival. Maximum suppression would be expected from treatments made Aug. 5–10 with satisfactory control possible between Aug. 1–15. Individual farmers have achieved satisfactory suppression by treatments applied as early as Aug. 1 in this area.

While population suppression following the 3 years of treatment was proportional to values predicted from the model, on the basis of our sample methods we did not achieve theoretical expectations.

### Sampling Efficiency

In fields where emergence cages were used, the emerging population could be compared with beetles counted outside the cages. In 22 fields in which a mean of 0.97 (range 0.1–2.8) beetles/plant emerged, 0.90 beetles/plant were counted. But in 10 fields with a mean of 13.73 (range 3.1–44.6) beetles/plant emerging, only 3.88 beetles/plant were actually counted. It was observed that beetles were more active and thus difficult to count in fields with high populations. To the extent that we underestimated the higher populations in the control area, suppression was underestimated in the treated area. But it seems doubtful that the low observed populations in some fields with high emerging populations was due solely to inefficient sampling.

### Population Changes in Relation to Density

Using data from the control area for 1968–70, 73 of 126 fields (58%) having less than 1 beetle/plant at peak emergence increased in population by the dates of our prespray counts while 51 of 64 (80%) with densities greater than 1.0 beetle/plant decreased during the same interval. This suggests extensive adult migration during the preoviposition period. The treated area during the 3 posttreatment years (1969–71) had a greater incidence of total increases (76 vs. 45%) than the control during this interval. We conclude that preoviposition migration was not only a major factor in repopulating the treated area each year but caused overestimation of the population actually emerging in the area since emergence was confounded with migration. Consequently, we underestimated the population suppression achieved.

Posttreatment reinfestation by migration was not a problem; however, such migration might be a factor negating our model if only individual fields were treated. Late-season migration into the treated area was detected only within 1/4 mi. of the border of the area by sweeps taken in alfalfa and, though measurable, was negligible in terms of beetles involved. At no time was more than 2% of the beetle population of either area estimated to occur in alfalfa. Thus, treatment of the total environment would not seem essential in any future suppression attempt. These results indicate that late-season migration is primarily between adjacent fields.

### Density and Fecundity

Correlations between adult counts in mid-August and peak emergence counts the following year varied from $r = 0.431^{**}$ to $0.688^{**}$. Positive intercepts for all regression lines indicate a proportionately greater increase by low populations. Of 91 fields with less than 0.6 beetles/plant in mid-August, 66 (73%) had higher populations the following year, while for 57 fields with more than 0.6 beetles/plant in August, 38 (66%) had lower populations. In part, this may have resulted from migration of beetles into fields of lower population densities and confounding with numbers actually emerging. But greater fecundity of low populations also must be considered. In our oviposition study, beetles collected from the field with highest population density laid only 118 eggs/female vs. 234 for beetles from fields with lower densities. This reduced fecundity was found in 3 collections made on different dates. That this may be a real population-dependent factor is supported by egg samples taken in 1968. Converting beetles per plant to females/$ft^2$, we estimated that beetles in populations below the median laid 833 eggs vs. 273 eggs/female in populations above the median. Egg sampling was subject to large error but the difference was statistically significant. The apparent lower fecundity of beetles in high populations would be an important stabilizing factor which was inoperative in the treated area, permitting a more rapid recovery to the former level of abundance. But this effect would not negate the effectiveness of adult control during the 1st posttreatment season, since in neither the oviposition study nor posttreatment collection of beetles did a reduction of the population increase fecundity of beetles previously subjected to whatever stress was involved.

**Insecticide Use**

A multiple regression analysis using beetles in mid-August, use of insecticides the following spring, and beetles at peak emergence the following summer as variables revealed that use of soil insecticides made a significant contribution to the emerging population independent of the ovipositing population. This analysis suggested an average reduction of 60% in peak emergence counts due to use of soil insecticides.

Farmer use of additional chemical treatments in the treated area was virtually abandoned after the 2nd year of our study while their usage continued in the control area. Thus, their use in the control area contributed to an underestimation of the effects achieved solely by adult control in the treated area.

Had no farmer-applied controls been used in the control area, we estimate an average of 27% more beetles at peak emergence than actually occurred. On this basis, suppression in the treated area following the 1968, 1969, and 1970 treatments would have been increased to 51, 64, and 78%.

Ideally, chemical control should be a density-dependent factor, though the multiple regression analysis provided no evidence that present prophylactic use in the control area was predicated on the basis of population density. Mean predicted peak emergence counts in the absence of insecticides were 1.80 beetles/plant for fields treated by farmers with soil insecticides vs. 1.92 for untreated fields.

In view of the several population density-dependent factors operating, we believe our estimates of suppression are conservative and that theoretical suppression limits were in fact achieved. However these same factors preclude a cumulative suppression.

**Evaluation of Suppression Program**

The wide-area approach is justifiable only if the benefits derived are economically or biologically superior to presently utilized means of corn root worm management. The program was successful to the extent that no economic infestations occurred in the treated area during any year following adult control while use of soil insecticides was virtually abandoned in that area. But this achievement was accomplished only by a greater total use of insecticide, applied to the total environment, without cumulative benefits. Results suggest that adult control is an alternative to soil insecticides and that treatment of selected fields is a promising approach, though our experiment was not designed to confirm this.

Regardless of control methods used, greater emphasis should be placed on predicting the necessity for any treatment rather than the method used. Data gathered during this study suggest that, for this area, 1.0 beetle/plant in mid-August is a suitable economic threshold for consideration of control measures to prevent damage the following season.

Adults emerging in a field are related to the number of larvae present at an earlier date. Although underestimating the actual populations involved, adult counts made at peak emergence provided our most usable data on infestations in individual fields. Based on lodging, 1.6 beetles/plant at peak emergence was the minimum population which could be associated with damage. This minimum level was observed only in 1972 when strong winds and heavy rain in July caused slight lodging in a few fields with light root worm infestations; during other years damage was never associated with peak emergence counts below 2.0 beetles/plant. Of 158 fields having less than 1.0 beetle/plant in mid-August, 127 had less than 1.6 beetles/plant the next year. Overall, failure to predict fields having over 1.6 beetles/plant was 13%. Realistically viewed, these prediction errors did not result in true economic losses due to the conservative economic injury level chosen.

Inclusion of other variables should enhance predictability. Turpin et al (1972) obtained 88% predictability in Iowa using only agronomic characters. While soils and irrigation practices were relatively uniform in the area involved in our study, we also observed that certain fields always had populations above the median while other fields had consistently low emerging populations. A combination of edaphic and biological data would seem promising in refining accuracy in prediction.

Considering the predictability presently possible, and the small chance that prediction errors (based on our conservative threshold) will result in yield losses, fully 50% of all rootworm treatments made in the control area were unnecessary.

Since adult control prevented damage for only a single season, there is no justification for suppressing the entire population in a large area unless a high percentage of the fields have economic threshold populations. Yet adult control in individual fields may be an attractive alternative to the use of soil insecticides. The greatest advantage of adult control would seem to lie in the opportunity for evaluating the need for control at the time the treatment is to be applied and that the actual population suppression is potentially greater than that achieved with soil insecticides. Soil insecticides, however, are likely more effective in reducing the larval population in the root zone and thus seem equal to a total population suppression in preventing larval damage.

## Notes

1. Coleoptera: Chrysomelidae
2. Published with the approval of the Director as Paper no. 3665 Journal Series, Nebraska Agricultural Experiment Station, and Contribution no. 373 of the Department of Entomology, University of Nebraska, Lincoln 68503. Research reported was conducted under Project no. 17-016. Received for publication Aug. 20, 1973.
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4. R. N. Wedderburn. 1972. Western and northern corn rootworm populations and damage as influenced by cultural practices. Ph.D. thesis, University of Nebraska, 97 pp.

## References Cited

Branson, T. F., and R. D. Johnson. 1973. Adult western corn rootworms: oviposition, fecundity, and longevity in the laboratory. J. Econ. Entomol. 66: 417–18.

Calkins, C. O., V. M. Kirk, J. W. Matteson, and W. L. Howe. 1970. Early cutting of corn as a method of reducing populations of corn rootworms. Ibid., 63: 976–78.

Hill, R. E., E. Hixson, and M. H. Muma. 1948. Control of corn rootworms with insecticides. Annu. Rep. Nebr. Agric. Exp. Stn. 61: 53–55.

Lawson, D. E., and G. T. Weekman. 1966. A method of recovering eggs of the western corn rootworm from the soil. J. Econ. Entomol. 59: 657–59.

Pruess, K. P., G. T. Weekman, and B. R. Somerhalder. 1968. Western corn rootworm egg distribution and adult emergence under two corn tillage systems. Ibid., 61: 1424–27.

Short, D. E., and R. E. Hill. 1972. Adult emergence, ovarian development and oviposition sequence of the western corn rootworm in Nebraska. Ibid., 65: 1685–89.

Turpin, F. T., L. C. Dumenil, and D. C. Peters. 1972. Edaphic and agronomic characters that affect potential for rootworm damage to corn in Iowa. Ibid., 65: 1615–19.