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# SUSCEPTIBILITY OF *LISTRONOTUS MACULICOLLIS* (COLEOPTERA: CURCULIONIDAE) ADULTS FROM SOUTHERN NEW ENGLAND GOLF COURSES TO CHLORPYRIFOS

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The "annual bluegrass weevil", *Listronotus maculicollis* Kirby (Coleoptera: Curculionidae) is a serious pest of *Poa annua* L. (Poales: Poaceae) turfgrass in the Northeastern U.S. Historically, the primary control strategy has been to intercept adults with insecticide residues as they emerge from overwintering sites (Cowles et al. 2008; Potter 1998; Vittum et al. 1999). Chlorinated hydrocarbons were used to manage weevil populations until around 1969, but in the 1970s and 1980s less persistent organophosphates were utilized; today pyrethroids and chlorpyrifos are used to control adults (Cameron & Johnson 1971; Koppenhöfer & McGraw 2005; Schread 1970; Tashiro 1976).

In 2009 several adult *L. maculicollis* populations from Connecticut, Massachusetts, and Rhode Island demonstrated varying levels of resistance to pyrethroids (Ramoutar et al. 2009ab), but no data are available for *L. maculicollis* resistance to chlorpyrifos, an organophosphate. Tashiro (1976) first communicated diminished organophosphate effectiveness, but there are no further studies conducted on this topic. The objective of this study was to obtain toxicity data on the susceptibility of *L. maculicollis* populations from several golf courses in southern New England to chlorpyrifos.

In 2008 and 2009 from May-Sep adult weevils were collected from 8 golf courses in Connecticut, Massachusetts, and Rhode Island (Fig. 1). Insects were collected by hand from golf course fairways or greens and kept at 21-23°C on *P. annua* plugs until bioassays were conducted, within 48 h of collection. Chlorpyrifos (technical, 99.9% purity) was dissolved in reagent quality acetone (>95% purity) (Sigma-Aldrich, St. Louis, MO) and 1 µL of chlorpyrifos or acetone (control) was applied per insect dorsally to the intersegmental membrane between the prothorax and the elytra (Metcalf 1958; Perez-Mendoza 1999). Mortality data were estimated from 6-8 concentrations and 10-15 unsexed adults per concentration. Applications

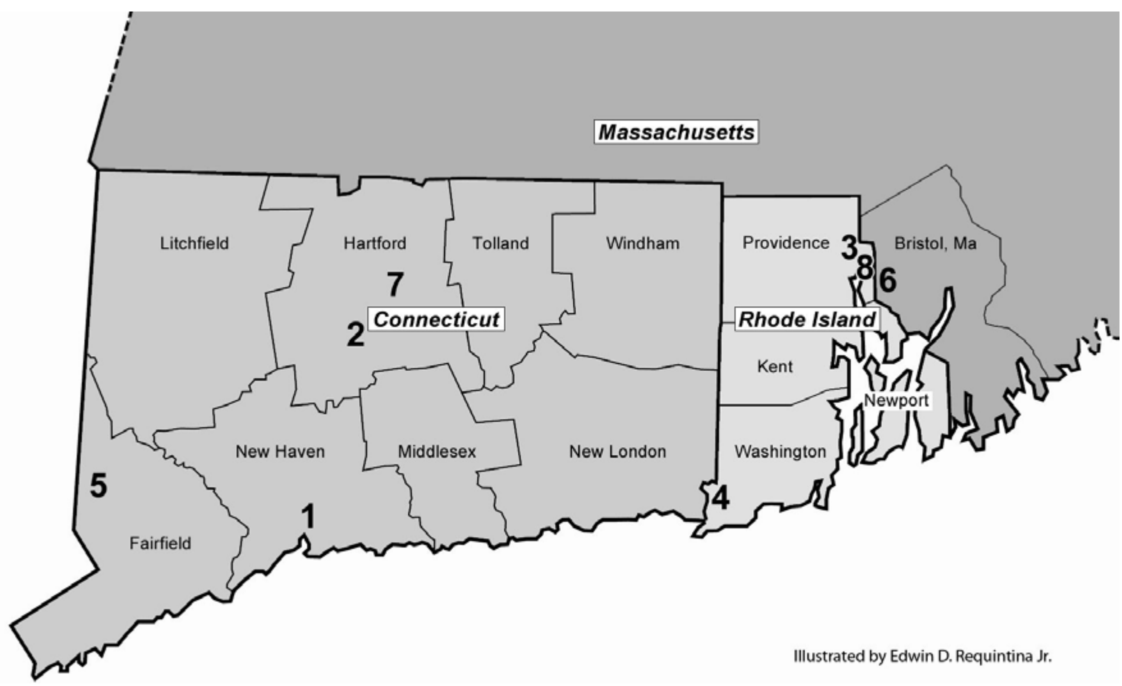


Fig 1. Location of sampling sites in southern New England for *L. maculicollis* chlorpyrifos resistance study; New Haven (1), Farmington (2), Pawtucket (3), Westerly (4), Danbury (5), Seekonk (6), Hartford (7), and Rumford (8).

were made with a Burkhard microapplicator (Burkhard Mfg. Co., Ricksmanworth, UK) equipped with a 1-mL tuberculin syringe. Following dosing, adults were placed in Petri dishes (100 × 15 mm) and held at 25 ± 2°C for 24 h without food or water, after which mortality was recorded. Insects were counted as dead if they displayed no movement when probed. Bioassays were replicated twice for each location and results were pooled across replicates. According to (Yu 2008) the mortality range for performing dose-response experiments should fall between 20% and 80%, in these experiments control mortality was ≤ 5% and mortality at the highest dose was ≥90%.

Mortality data were analyzed by probit analysis with the Statistical Analysis System Version 9.1 program PROC PROBIT (SAS Institute 2003). When comparing $LD_{50}$ values, a failure of 95% confidence limits to overlap was used as a measure to determine significant differences between populations (Robertson & Preisler 1992). Since we did not have a standard susceptible laboratory strain for comparison to field collected populations, the most sensitive field population (New Haven) was used for calculating resistance ratios (Resistance Ratio (RR) = $LD_{50}$ resistant population ÷ $LD_{50}$ most susceptible population) (Perez-Mendoza 1999). In all cases, the likelihood ratio (L.R.) chi-square goodness-of-fit values indicated that the data adequately conformed to the probit model (Robertson & Preisler 1992).

After more than 30 years of insecticide use targeted against *L. maculicollis* the evolution of resistance was probable. The succession of insecticide use against the maize weevil, *Sitophilus zeamais* Motschulsky, is similar to that of the annual bluegrass weevil (chlorinated hydrocarbons → organophosphates → pyrethroids) and today maize weevils exhibit both cross and multiple forms of resistance related to the history of management practices against the species (Fragoso et al. 2007; Guedes et al. 1995; Perez-Mendoza 1999). The $LD_{50}$ values for chlopyrifos among the *L. maculicollis* populations studied here ranged from 0.4-1.5 µg/insect resulting in resistance ratios of 1.25-3.75 (Table 1). In contrast, *L. maculicollis* resistance ratios for pyrethroids ranged from 6.1-306.8 (Ramoutar et al. 2009a). Even though *L. maculicollis* resistance to chlorpyrifos is low, we feel that in order to adequately manage *L. maculicollis* in the future, control strategies should involve proper timing of insecticide applications, mode of action rotation, and integrated pest management techniques.

We thank each of the golf courses, their superintendents and members for allowing us the privilege of conducting research at their facilities. These courses (and superintendents) include the following: Agawam Hunt County Club, Rumford, RI (Drew Cumming), Hartford Golf Club, Hartford, CT (Jonathan Burke), Ledgemont Country Club, Seekonk, MA (William E. Sherman), Misquamicut Club, Westerly, RI (William Morton), Pawtucket Country Club, Pawtucket, RI (Mike Whitehead), Ridgewood Country Club, Danbury, CT (Dave Kerr), Tunxis Plantation Golf Course, Farmington, CT (Charles Babcock), and Yale University Golf Course, New Haven, CT (Scott Ramsey). Funding for the study was provided by grants from the USDA, the New England Regional Turf Foundation and the Tri-State Turf Research Foundation. This is contribution number 5210 of the Rhode Island Agricultural Experiment Station.

## Summary

The $LD_{50}$ values for chlopyrifos among the *L. maculicollis* populations studied here ranged from 0.4-1.5 µg/insect resulting in resistance ratios of 1.25-3.75. We feel that these results provide golf course superintendents with important information concerning management of this pest.

Table 1. Susceptibility of *L. maculicollis* adults to chlorpyrifos.

| Population | State | *n* | Slope (SE) | $LD_{50}$ (µg/insect)[1] | $\chi^2$ (*df*)[2] | 95% FL | RR[3] |
|---|---|---|---|---|---|---|---|
| New Haven | CT | 140 | 2.72 (0.71) | 0.4 a | 6.9 (4) | 0.2-0.5 | — |
| Farmington | CT | 140 | 5.64 (1.83) | 0.5 ab | 2.8 (4) | 0.3-0.6 | 1.25 |
| Pawtucket | RI | 180 | 1.74 (0.25) | 0.5 abc | 3.4 (6) | 0.3-0.7 | 1.25 |
| Westerly | RI | 160 | 4.28 (1.00) | 0.8 bcd | 4.5 (5) | 0.6-1.0 | 2.00 |
| Danbury | CT | 180 | 3.70 (0.71) | 1.0 de | 6.3 (6) | 0.8-1.2 | 2.50 |
| Seekonk | MA | 180 | 1.46 (0.29) | 1.0 cde | 9.2 (6) | 0.7-1.6 | 2.50 |
| Hartford | CT | 180 | 2.87 (0.43) | 1.2 de | 2.5 (6) | 0.9-1.5 | 3.00 |
| Rumford | RI | 160 | 3.50 (0.73) | 1.5 e | 4.2 (5) | 1.1-1.9 | 3.75 |

[1]$LD_{50}$ values followed by the same letter are not significantly different based on overlap of their 95% fiducial limits.
[2]L.R. chi-square goodness-of-fit values. Tabular values at $P = 0.05$ for 4 $df = 9.49$, 5 $df = 11.07$, 6 $df = 12.59$.
[3]Resistant Ratio (RR) = $LD_{50}$ resistant population ÷ $LD_{50}$ most susceptible population.

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