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Differential Susceptibility of Japanese Beetle, Oriental Beetle, and European Chafer (Coleoptera: Scarabaeidae) Larvae to Five Soil Insecticides

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ABSTRACT Efficacy of bendiocarb, chlorpyrifos, diazinon, ethoprop, and isofenphos was evaluated against last-instar larvae of European chafer, *Rhizotrogus majalis* (Razoumowsky), Japanese beetle, *Popillia japonica* Newman, and Oriental beetle, *Anomala orientalis* Waterhouse, by incorporating insecticides into soil at one-half New York State recommended rates in a laboratory bioassay. Mortality was assessed at 1, 2, 3, 4, and 5 wk. The experiment was repeated three times with white grubs collected at different times and from different locations in New York. White grub species differed significantly in their response to some of the insecticides; European chafer was generally least susceptible. Diazinon provided high mortality of Oriental beetle and European chafer grubs but very low mortality of Japanese beetles. Isofenphos provided generally low mortality of all three grub species, although the levels of mortality varied among species. Ethoprop provided uniform mortality of all three grub species. Results of these studies indicate the need to develop species-specific insecticide recommendations for the white grub complex.

KEY WORDS Insecta, scarab grubs, soil insecticides, turfgrass

Scarabaeid white grubs are pests of turf and ornamental plants in the Northeast (Tashiro 1987). Three common species in New York State are the Japanese beetle (*Popillia japonica* Newman), the European chafer (*Rhizotrogus majalis* (Razoumowsky)), and the Oriental beetle (*Anomala orientalis* Waterhouse). Historically, effective long-term control of these and other species of white grubs was achieved with organochlorine insecticides. Less effective control has been achieved with the organophosphate and carbamate insecticides which replaced them (Baker 1986). Many factors including soil pH, organic matter, moisture, thatch, and microbial degradation of insecticides influence the efficacy of currently registered insecticides (Harris 1972, 1982, Kuhr & Tashiro 1978, Tashiro & Kuhr 1978, Chapman 1982, Niemczyk & Krueger 1982, Vittum 1985, Racke & Coats 1987). Resistance to organophosphate insecticides in Japanese beetles also has been documented (Ng & Ahmad 1979, Ahmad & Ng 1981).

Another factor contributing to the variable control in the field is the presence of mixed-species populations of white grubs, which may exhibit species-specific insecticide susceptibilities. Although field insecticide efficacy studies against mixed populations of white grubs have been reported (e.g., York 1986, Edelson 1987), significant treatment effects can be demonstrated only for the most abundant grub species, because secondary species are often present at low densities and their distribution is patchy. Although previous work by Baker (1986) has demonstrated among- and within-species variation in susceptibility of New York populations of Japanese and Oriental beetle larvae to chlorpyrifos, bendiocarb, and isofenphos, insecticide recommendations are often made for white grubs as a group rather than for individual species (e.g., Smith & Wilson 1986).

Our studies were conducted to provide more information on the susceptibility of three economically important white grub species in New York to five currently labelled turf insecticides. We used a laboratory soil bioassay procedure which allowed us to compare insecticide susceptibility of different white grub species while controlling many of the factors that result in variable mortality in the field.

Materials and Methods

Insects. All test insects were collected from turf as last-instar larvae and held at 5 ± 1°C and a photoperiod of 12:12 (L:D) until used in the study. Grubs were held in boxes filled with soil and covered with sod. European chafers were collected from the Drumlins Country Club, Syracuse, N.Y.,

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Table 1. Analysis of variance of percent control (angular transformed) of white grubs (European chafer, Japanese and Oriental beetle larvae) observed in laboratory soil bioassay for 5 wk

Source	df	Sums of squares	F value[a]
		Week 1	
Replicates (R)	2	3,020.039	18.490***
Insecticides (I)	4	7,364.629	22.544***
Grub species (G)	2	258.322	1.582NS
G × I	8	3,329.815	5.097**
Error	26	2,123.370	
		Week 2	
Replicates (R)	2	306.925	0.918NS
Insecticides (I)	4	13,262.192	21.185***
Grub species (G)	2	1,227.624	3.922*
G × I	8	4,743.292	3.789**
Error	26	4,069.076	
		Week 3	
Replicates (R)	2	556.112	1.352NS
Insecticides (I)	4	15,719.480	19.102***
Grub species (G)	2	2,696.593	6.554**
G × I	8	6,694.978	4.068**
Error	26	5,348.938	
		Week 4	
Replicates (R)	2	379.323	0.840NS
Insecticides (I)	4	15,514.485	17.170***
Grub species (G)	2	2,053.585	4.545*
G × I	8	7,446.948	4.121*
Error	26	5,873.359	
		Week 5	
Replicates (R)	2	724.636	1.284NS
Insecticides (I)	4	14,900.275	13.201***
Grub species (G)	2	3,423.630	6.066**
G × I	8	7,346.948	3.255*
Error	26	7,336.729	

[a] NS, $P > 0.05$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

on 28–29 October 1986, and from the New York State Agricultural Experiment Station, Geneva, on 14–31 October 1985. Japanese beetles were collected from the Sleepy Hollow Country Club, Sleepy Hollow, N.Y., on 14–15 October 1986 and 29–30 October 1985. Oriental beetles were collected from the Huntington Country Club, Huntington, N.Y., on 23 October 1986 and from the Pinelawn Cemetery, Pinelawn, N.Y., on 25 September 1985. All white grubs with the exception of those at Pinelawn Cemetery (Oriental beetle 1985) were collected from turfgrass which had not been treated with soil insecticides during the proceeding 12 mo; turfgrass at Pinelawn Cemetery was treated ca. 4 mo before collection with isofenphos 5 granular (G) (2.24 kg [AI]/ha).

Bioassay. Treatments consisted of an untreated control and five turf insecticides at the following rates: bendiocarb (Turcam 2.5 G, Nor-Am Chemical, Wilmington, Del.), 2.4 kg (AI)/ha; chlorpyrifos (Dursban 50% wettable powder [WP], Dow Cemical, Midland, Mich.), 1.7 kg (AI)/ha; diazinon (Diazinon 5G, CIBA-GEIGY AG, Greensboro, N.C.), 3.4 kg (AI)/ha; ethoprop (Mocap 5G, Rhone-Poulenc, Monmouth Junction, N.J.), 5.7 kg (AI)/ha; and isofenphos (Oftanol 5G, Mobay Chemical, Kansas City, Mo.), 0.9 kg (AI)/ha. All insecticides were applied at one-half the rates recommended (1986) for use in turf in New York State.

Research indicates that a large proportion of insecticides applied to control white grubs does not reach the root zone but instead remains at the surface (M.G.V. and R.J.W., unpublished data) or is bound in the thatch layer (Niemczyk 1987); insecticide rates in this study were chosen to approximate crudely the amount of insecticide actually reaching grubs in the field and to provide mortality levels which would differentiate among grub species (M.G.V., unpublished data). Differences in rates used and specific characteristics of individual insecticides make comparisons among treatments suspect and may lead to unwarranted conclusions; in our study, within-treatment interactions among species were of primary interest.

This study was replicated three times over a period of 1 yr. In each replicate, insecticides were thoroughly mixed with soil (loamy sand with 7.6% organic matter and a soil pH of 5.3), then seeded with ca. 1 g of grass seed mixture (49% red fescue, 19% Kentucky bluegrass, 15% perennial ryegrass, 14% chewings fescue, 3% other). Plastic boxes (0.5 liter; 20 by 10 by 6 cm) were filled with treated soil, and 15 grubs were added to each soil-filled box. Initial soil moisture varied between 9 and 12%; final soil moisture (after 5 wk) varied between 8 and 11%. Twenty boxes were set up for each species–insecticide combination (100 per replicate). Boxes were covered with airtight lids and held at 21 ± 2°C with a photoperiod of 12:12. Four boxes from each species–insecticide combination were destructively sampled at weekly intervals for a total of 5 wk, and the number of surviving grubs was recorded. Two replications of the experiment were done with grubs from the 1985 collection dates, and grubs collected from the 1986 collection were used for the third replication.

Data Analysis. Data on total number of surviving grubs per four containers were converted to percent control using Abbott's (1925) formula and transformed to arcsine$\sqrt{(\%/100)}$ before analysis of variance (ANOVA). The data were analyzed for each week separately as a two-way fixed-factor ANOVA for a randomized complete block design. Replicates were treated as a blocking factor. Percent control (untransformed) data for each grub species and insecticide treatment were plotted over time to illustrate the major interactions indicated by the ANOVA.

Results and Discussion

ANOVA of percent control data from the three replicates indicated significant effects in each week caused by insecticides and the interaction of white grub species and insecticides (Table 1). Responses of different white grub species to each insecticide are shown graphically in Fig. 1. Percent survival in check treatments ranged from 91.67 (±1.5) at

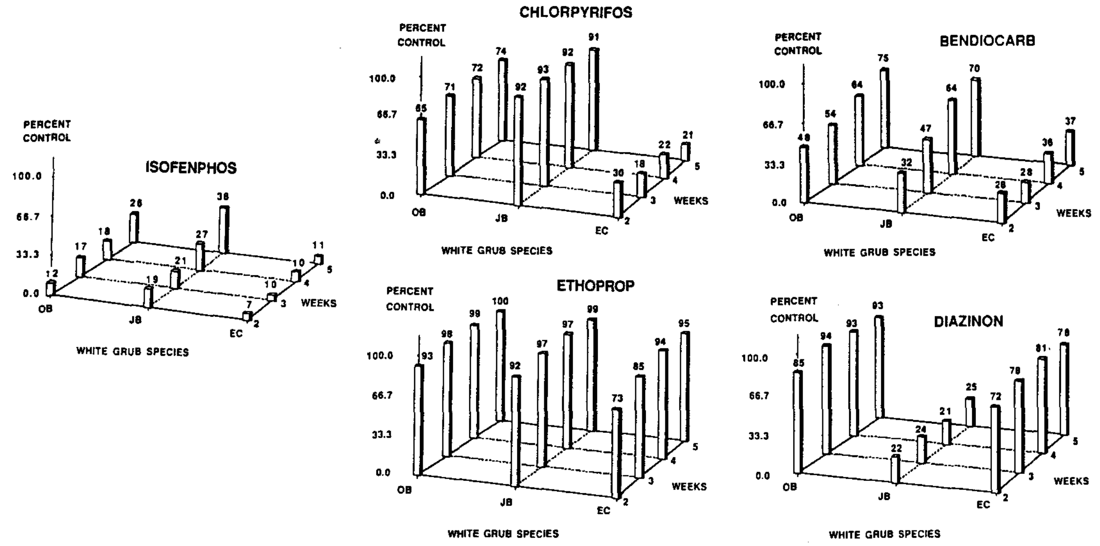

Fig. 1. Efficacy of five turf insecticides against last-instar larvae of three white grub species in a laboratory soil bioassay. Insecticides were incorporated into soil at one-half labelled rates. OB, Oriental beetle; JB, Japanese beetle; EC, European chafer.

week 1 to 54.00 (±4.0) by the end of week 5. Data from weeks 2–5 are averaged over the three replicates because no effects caused by replicates were significant during this time (Table 1); data from week 1 are not included because of significant effects caused by replicates. Possibly, the significant effect caused by replicates in data from week 1 was related to slight differences in vigor of white grubs in the different replicates or to differential susceptibility of populations which caused high initial mortality of susceptible individuals early in the test.

Results of our study indicated that, in general, European chafers are less susceptible to soil insecticides than the other two white grub species (Fig. 1). This finding agrees with reports from extension agents and turfgrass and sod producers in New York State. Several interactions indicated the need to study each species–insecticide combination. The most striking species–insecticide interactions involved diazinon and chlorpyrifos. Diazinon provided good control of Oriental beetle and European chafer grubs but very poor control of Japanese beetles. However, chlorpyrifos provided good control of Japanese beetle and Oriental beetle but very poor control of European chafers. Because behavioral differences among grub species (i.e., their characteristic position in the soil profile in the field, which may influence exposure to insecticides) have been eliminated in these studies, differential mortality of Japanese beetles and European chafers to diazinon and chlorpyrifos may reflect species-specific tolerances to these compounds (if testing of additional populations gives similar results) or localized insecticide resistance. For the Oriental beetle, responses to chlorpyrifos and diazinon differed greatly among replicates. Our results indicated that the relative ranking of the two chemicals changed when grubs from different collection sites (Pinelawn and Huntington, Long Island, N.Y.) were used. This result was largely because of poor control with chlorpyrifos in replicate 3 compared to the other replicates. For example, in week 5 of the first replicate, mortality of Oriental beetles to diazinon and chlorpyrifos was 89% and 93%, respectively, whereas mortality in the diazinon treatment was 98% and chlorpyrifos was 31% in replicate 3, week 5. Such a large difference in susceptibility among experiments was not seen in any other treatments, thus it cannot be due to differences in overall vigor or fitness of the populations. These two sites are ca. 16 km apart, and the results may indicate interpopulation differences in susceptibility to chlorpyrifos.

The relatively low level of mortality observed with all grub species in the isofenphos treatments may be attributed to a number of causes including loss of activity of the compound through microbial degradation due to an "activated" test soil, insufficient initial product, and insufficient time for mortality to become apparent. Ethoprop treatments induced uniformly high mortality with all white grub species tested. New York State will be recommending higher rates of isofenphos and lower rates of ethoprop for controlling white grubs in turfgrass in 1988 (Smith & Wilson 1987).

The results of these studies indicate the need to develop species-specific insecticide recommendations for the white grub complex and to encourage those responsible for insecticide use in turf to be aware of the white grub species present in their areas. In New York, the Japanese beetle, Oriental beetle, and European chafer are three of the most common white grub species attacking turf. Although single-species infestations occur in some areas of New York, mixed populations of Japanese beetles and European chafers (western section of state) or Japanese beetles and Oriental beetles (Long Island) and other white grub species are the rule rather than the exception. Our results suggest that, with some insecticides (e.g., diazinon and chlorpyrifos), intermediate levels of control of the overall white grub population may in fact reflect high mortality of one species and little or no mortality of one or more co-existing species. Depending on the relative abundance of each species at a given site, percent control achieved with each insecticide may vary widely (Fig. 1). Differences in insecticide susceptibility among species of the white grub complex, as well as the possibility of insecticide resistance, microbial degradation, or inadequate application procedures, need to be considered as a possible reason for control failures after the use of turf insecticides.

A final implication of these results is for the design of insecticide efficacy studies concerning white grubs. In vol. 11 and 12 of Insecticide & Acaricide Tests (York 1986, Edelson 1987), 31 reports refer to the control of white grubs in turf. The period of time from insecticide application to treatment evaluation varied greatly (1986, range, 14–70 d; 1987, range, 14–50 d). Results of our study suggest that, for some of the insecticides studied, evaluations made less than 4 wk after treatment could significantly underestimate the total percent control. Because speed of insecticide activity is important to turf managers, reports of efficacy by researchers should reflect not only the rate but the ultimate control of each product evaluated.

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