PROGRESS REPORT
USGA TURFGRASS RESEARCH FOUNDATION
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CULTURAL CONTROL, RISK ASSESSMENT, AND ENVIRONMENTALLY RESPONSIBLE MANAGEMENT OF WHITE GRUBS AND CUTWORMS IN TURFGRASS

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Executive Summary:

The overall goal of this project is to better understand the factors that determine the distribution and abundance of white grubs and cutworms on golf courses. We also seek ways to reduce populations of these damaging insects through modified cultural practices, and with reduced use of broad-spectrum chemical insecticides. Finally, this project will provide a better understanding of the effects of pesticides on natural enemies (predators and parasites), earthworms, and other beneficial species that live in golf course turf.

Fertilization, watering, mowing height, soil compaction, soil pH, and aerification were manipulated in large field plots to determine how these factors affect choice of egg-laying sites, and subsequent populations of Japanese beetle, masked chafer, and green June beetle grubs. Soil moisture was the most important factor determining abundance of white grubs; infestation levels were 2- to 4-fold higher in irrigated plots. In contrast, grubs were less abundant in high-mown turf, and in plots treated with sulfur to lower soil pH. In 1994, for example, total biomass of grubs was reduced by 55% and 77%, respectively, in high-mown and sulfur-treated turf. Liming, fertilization with urea, heavy rolling, and aerification had no effect on white grub populations during this 3-yr study.

The number of grubs required to cause noticeable injury was found to be much higher in all common turfgrasses than suggested by prevailing rule-of-thumb estimates used by the industry. Irrigation and fertilization encouraged regrowth of foliage and enhanced appearance and rooting strength of grub-damaged turfgrasses.

Most eggs of black cutworms were laid singly on the tips of bentgrass leaf blades. Mowing at 1/8" or 3/16" was shown to remove 80-91% of black cutworms laid on bentgrass greens. This suggests that cutworm infestations may originate from larger larvae that migrate onto greens from aprons or roughs. Cutworms showed no preference between aerified and non-aerified areas, but our results suggest that they may be repelled by sand top-dressing. When aerification holes were available, about 60% of cutworms used them as a refuge. Cutworm larvae were most active on greens from midnight until just before dawn. Most larvae were observed grazing, i.e., feeding on the turf surface, rather than suggesting that controls would be most effective if applied in evening or at night.

A study was conducted in 1994 to clarify how long it takes for populations of predators, earthworms, and other beneficial species to return to normal levels following use of broad-spectrum insecticides. Ethoprop (Mocap) applied in April resulted in 100% kill of earthworms. Populations were still reduced by 70 to >90% in both small and large plots at the end of the growing season. Samples containing predators and other beneficials are presently being sorted and analyzed.

Analysis of female extracts by electrophysiology and gas chromatography pinpointed the fraction containing the sex pheromone of masked chafer beetles. Identification of the pheromone is expected soon. Synthesis of this attractant will provide means for monitoring these pests on golf courses and home lawns.

PROGRESS REPORT: 1994

OVERALL GOALS:

The overall goal of this project is to clarify the factors that determine the distribution and abundance of white grubs and cutworms on golf courses. We seek to develop safe, economical and effective methods for managing these pests with reduced use of broad-spectrum insecticides.

OBJECTIVE 1. Examine the effects of environmental variables on the bionomics of white grubs and cutworms, and evaluate the potential for reducing populations of these pests through non-chemical, cultural manipulations.

Effect of Cultural Practices on White Grubs.

Fertilization, watering, mowing height, soil compaction, soil pH, and aerification were manipulated in large field plots to determine how these factors affect choice of egg-laying sites by Japanese beetle, masked chafers, and green June beetle, and subsequent grub populations. Final samples in this 3-yr field study were taken in October 1994.

Soil moisture was the most important factor determining white grub population densities. Irrigation during beetle flight periods in mid-summer resulted in 2-4 fold increases in populations of Japanese beetle grubs relative to those in non-irrigated plots. Grubs from irrigated plots were significant larger, and developed more quickly than those from non-irrigated areas, suggesting that their overwintering survival would probably be higher. Japanese beetles appear to be more strongly attracted to irrigated areas than are masked chafers.

Liming, fertilization with urea, heavy rolling, and aerification had no impact on white grub populations in any year. In contrast, grubs were significantly less abundant, smaller, and slower to develop in high-mown turf, and in plots treated with sulfur to reduce soil pH (pH= 5.3-5.5). Negative effects of these treatments were stronger on masked chafer grubs than on Japanese beetle grubs. In 1994, for example, densities of masked chafer grubs were reduced by 69% and 78%, respectively, in high-mown and sulfur-treated plots. Total biomass of grubs per plot (combined Japanese beetle and masked chafer) was reduced by 55% and 77%, respectively. These patterns were consistent in all three years.

In 1993, we found that green June beetle grubs were significantly (2-3 times) more abundant in plots that had been treated with organic fertilizers (Milorganite or composted cow manure). This experiment was repeated in 1994. The same trends were observed, but variability was high and the differences were not statistically significant.

Damage Thresholds for Japanese Beetle and Southern Masked Chafer Grubs in Cool-Season Turfgrasses.

Relative tolerance of Kentucky bluegrass, perennial ryegrass, creeping bentgrass, hard fescue, and tall fescue to damage by white grubs was evaluated in turfgrass field plots. Enclosures and rooting boxes were infested with varying densities of grubs (0 to 60 per 0.1^2 [about 1 ft^2]) and effects on turf quality, canopy temperature, foliage yield, and root strength were measured. Damage thresholds were variable but were much higher in all grasses than rule of thumb estimates commonly used by the turf industry. Initial densities of at least 15 to 20 grubs per 0.1^2 were required to cause any visible reduction in turf quality of most turfgrasses, and in some cases, densities of 60 grubs per 0.1^2 caused no apparent damage. Canopy temperatures were not a reliable predictor of grub density. Contrary to prevailing thought, damage by masked chafers was equal to, or greater than that caused by Japanese beetles in all grasses. This study illustrates how variability in the turf system complicates use of simple economic injury levels to predict damage from white grubs.

Irrigation and Fertilization Affect Injury by Root-feeding White Grubs in Kentucky Bluegrass and Tall Fescue Turf.

Separate and combined effects of irrigation and fertilization on tolerance of turfgrasses to injury from white grubs were evaluated in greenhouse and field tests. Both Japanese beetle and masked chafer grubs caused significant root loss in both grasses regardless of management regime. Remedial use of fertilizer with irrigation encouraged regrowth of foliage following grub damage. Spring fertilization, followed by fall irrigation, enhanced appearance and rooting strength of grub-infested turfgrasses. Survival of grubs was not affected by fertilization, but was enhanced by irrigation.

Effect of Cultural Practices on Susceptibility of Golf Greens to Cutworms.

Response to Topdressing and Aerification: Field Tests. To determine if populations of black cutworms are affected by cultural management practices, replicated plots were established in bentgrass putting greens at Lexington Country Club and at Spindletop Research Farm, near Lexington. The test was conducted in spring and fall at both sites. Plots were manipulated in the following manner: 1) no aerification of topdressing; 2) sand topdressing; 3) topdressing with 80:20 sand/peat mix; 4) aerification alone; 5) aerification plus sand topdressing; or 6) aerification plus sand/peat topdressing. Plots in the Spring trials were established in early May and sampled in late June. Fall trial plots were established in early September and sampled in mid-October. Two, 1 m^2 samples (soap drenches) were taken within each plot.

There was no site by treatment interaction in the spring trials, so the four replicates at each site were pooled for analysis. Numbers of cutworms were highly variable, with averages ranging from 7.4 larvae/sample in non-aerified, 80/20 plots, to 2.75 larvae/sample in non-manipulated, control plots. There was no significant difference among treatments. No cutworms were recovered from either site in the fall samples. Reasons for this are unknown, but we speculate that the population may have pupated 1-2 weeks earlier. This experiment will need to be repeated before firm conclusions can be drawn.

Response to Topdressing and Aerification: Choice Tests. Choice tests were conducted to determine the behavioral response of larval cutworms to aerification and/or topdressing. Half of each plot was manipulated differently; e.g., aerified or not aerified, with or without sand topdressing. Galvanized steel enclosures were driven into the bentgrass over the boundary between two different management regimes. Cutworms were hatched from eggs and reared on creeping bentgrass clippings until used in the tests. Thirty cutworms were added to each enclosure and allowed establish burrows in the turf on either side. Enclosures were sampled by soap drench. The numbers of cutworms choosing each regime, and the proportion occupying aerification holes was determined.

Contrary to our expectation, cutworms showed no preference between aerified and non-aerified areas in the bentgrass green. This was also true when both the aerified and non-aerified areas had been topdressed with sand. Of those cutworms that became established in the aerified plots without topdressing, most (61%) were in aerification holes. When aerified plots were topdressed with sand, the cutworms significantly preferred the *non-aerified,* non-topdressed (control) turf. Cutworms also significantly preferred plots that were aerified only over those that were both aerified and topdressed.

This experiment suggests that cutworms do not necessarily prefer greens that are aerified, and that most, but not all cutworms in aerified greens will exploit the holes as burrows. Most interesting, our results suggest that black cutworms may be repelled by sand topdressing, and that topdressing in conjunction with aerifying may partially deter colonization by cutworms. This project will be expanded in 1995.

<u>Egg Distributions/Effect of Mowing on Egg Removal</u>. In the laboratory, eggs of cutworms are deposited mainly on the terminal ends of bentgrass leaf blades. We hypothesized that, in the field, mowing would remove most newly-laid eggs. If true, this would be evidence that most cutworm problems originate from migrants which crawl onto greens from collars and roughs. Clipping removal could be critical in eliminating the reservoir source of cutworm larvae.

Plots in a creeping bentgrass green were preconditioned for three days at three mowing heights: 1/8", 3/16", and non-mowed. Black cutworm moths were then caged over the plots for 48 hours. All eggs were counted, and their locations on the grass plants recorded. The plots were then mowed at their appropriate cutting heights and the numbers of eggs remaining were determined.

Most eggs were deposited singly on the bentgrass blades (85.7%, 79.4%, and 74% of eggs were laid as singles on 1/8", 3/16", and non-mowed bentgrass, respectively). Two eggs per plant (doubles) were found 13, 15.7, and 17.0% , respectively. No triples were laid on 1/8" mowed bentgrass, but they occurred 3.9 and 4% of the time on 3/16" and non-mowed grass. 100% of eggs were laid on grass blades (none on stems). Nearly all (95-97%) of eggs were laid on the terminal 25% of the grass blades. *Mowing removed 90.1 and 81.4% of the eggs deposited on the 1/8" and 3/16" turf, respectively.* We conclude that most of the eggs laid on golf greens are likely to be mechanically removed by normal mowing practices. Capacity of eggs to hatch and larvae to re-invade greens will be determined in future trials.

<u>Nocturnal Behavior of Black Cutworms</u>. Activity of cutworms on golf greens was

determined by systematic counting with a flashlight every 2 hours, beginning 1 h before sunset until 1 h after dawn. Numbers of cutworms "grazing" (i.e., feeding exposed on the surface) and "burrow feeding" were recorded. Cutworms became active about 10:30 p.m. but were most active between midnight and 6:30 a.m. Peak numbers were observed between 2:30 and 4:30 a.m. Most (79%) of the 62 cutworms observed were feeding as grazers. Only two (3%) were observed on the collar. These observations suggest that treatments for cutworms should be applied as late in the evening as possible to minimize loss of active ingredient to volatility and photodegradation (as well as exposure of golfers), and to coincide with the larval feeding period. Additional nights of observation will be added in 1995.

Black Cutworm Population Dynamics. Cutworm populations were sampled on six dates to determine their relative abundance, and distribution of instars on greens, collars, and in roughs. We hypothesized that only large cutworms would be found in greens (because of removal of eggs by mowing) and that all instars would be found in roughs. Random samples were taken from around three holes on Tates Creek Golf Course, in Lexington. Three samples were taken from each location (green, collar, rough) from each hole on each date. A total of 148 black cutworms was recovered. Of these, 63.5% were in greens, 31.8% in collars, and only 4.7% in roughs. Larvae were very difficult to observe in the higher mowed turf, which probably biased the data. Analysis of distribution of larval instars will be completed soon. This project will be continued, with refinements, in 1995.

An article by my graduate student, Chris Williamson, on initial aspects of this study was recently published in the USDA Green Section Record.

OBJECTIVE 2. Identify the sex pheromone of northern and southern masked chafers (*Cyclocephala* spp.), determine if parasitic wasps that attack and kill the grubs are exploiting this chemical to locate their hosts underground, and continue to refine a pheromone-based system for predicting locations of damaging white grub infestations on golf courses.

Our work in 1994 focused on identification of the female pheromone. This would allow synthetic lure to be produced in large amounts at low cost, thus increasing the practicality of using the pheromone for mass trapping, monitoring, risk assessment, or attracting parasitoids. We established collaboration with pheromone chemists at Cornell University. Volatile extracts of beetles and grubs collected in Kentucky were analyzed by a powerful procedure linking electrophysiology and gas chromatography. This allowed us to pinpoint the specific chromatography peak representing the active compound. We also confirmed analytically that the female sex pheromone is indeed present in all larval instars, and in both male and female grubs, a finding of considerable scientific interest. Large numbers of virgin beetles and grubs were extracted and shipped to Cornell for mass spectroscopy and further chemical analysis. We are optimistic that the female sex pheromone of *Cyclocephala* will be identified by early 1995.

OBJECTIVE 3. Investigate the dynamics of recovery of populations of beneficial invertebrates following insecticide applications to large turf areas such as golf courses.

A large field study was initiated in 1994 to determine how long it takes for populations of predators, earthworms, and other beneficial species to recover following use of a broad-spectrum, organophosphate insecticide. Ethoprop (Mocap 5G) was applied to large (12.5 x 12.5 meter) or small (4 x 4 m) plots within a (2 acre) stand of Kentucky bluegrass. Corresponding control plots were left untreated. We sampled earthworms and soil microarthropods on four dates following treatment, most recently in mid-October. Samples were taken close to the plot edge, and in the interior of the plots. In addition, we operated pitfall traps continuously throughout the growing season to monitor relative numbers of spiders, ground beetles, rove beetles, ants, and other predators known to feed upon pest insects in turf.

Analysis of earthworm data has been completed for this year. Ethoprop resulted in 100% kill of earthworms at 1-week after treatment. Worm populations were still significantly reduced by 70 to >90% in all plots at the end of the growing season, suggesting that earthworms have very slow recuperative potential, even near plot edges. Pitfall trap samples are still being sorted and identified, a task that will require an estimated 4-6 months. We plan to report on at least the major patterns at a scientific conference in March.

PUBLICATIONS

The following publications have resulted from research supported by this project, or from our previous USGA project which expired in 1994. All papers include acknowledgement of USGA funding. Additional papers, especially related to Objective 1, are in preparation.

A. Refereed Scientific Papers and Book Chapters:

1. Potter, D.A. 1992. Pesticide and fertilizer effects on beneficial invertebrates and consequences for thatch degradation and pest outbreaks in turfgrass. pp. 331-343, In: Fate and Significance of Pesticides in Urban Environments. K.D. Racke & A. Leslie (eds). ACS Books, Washington, D.C.

2. Haynes, K.F., D.A. Potter, & J.T. Collins. 1992. Attraction of males beetles to grubs: evidence for evolution of a sex pheromone from larval odor. Journal of Chemical Ecology 18: 1117-1124.

3. Terry, L., D.A. Potter, C.G. Patterson, & P.G. Spicer. 1993. Insecticide impact on predatory arthropods and predation on Japanese beetles eggs and fall armyworm pupae in turfgrass. Journal of Economic Entomology 86: 871-878.

4. Potter, D.A. 1993. Integrated insect management for turfgrasses: Problems and prospects. Internat. Turfgrass Soc. Research Journal 7: 69-79.

5. Potter, D.A. & K.F. Haynes. 1993. Field-testing a pheromone-based risk assessment system for predicting masked chafer grub densities in golf course turf and home lawns. Journal of Entomological Science 28: 205-212.

6. Potter, D.A., P.G. Spicer, C.T. Redmond, & A.J. Powell. 1994. Toxicity of pesticides to earthworms in Kentucky bluegrass turf. Bulletin of Environmental Contamination and Toxicology 52: 176-181.

7. Potter, D.A. 1993. Impact of turfgrass management practices on beneficial invertebrates and processes. In: Integrated Pest Management for Turfgrass and Ornamentals. A. Leslie (ed). Lewis Publ./CRC Press, Boca Raton, Fl. pp. 59-69.

8. Crutchfield, B.A. & D.A. Potter. 1994. Preferences of Japanese beetle and southern masked chafer grubs among cool-season turfgrasses. Journal of Entomological Science 29: 398-405.

9. Potter, D.A. 1994. Side-effects of pesticides on beneficial insects and earthworms in turf. In: Turfgrass Insect Pests. Entomological Society of America Pest Handbook Series. In Press.

10. Davidson, A.W. & D.A. Potter. 1995. Response of plant-feeding, predatory, and soil-inhabiting invertebrates to *Acremonium* endophyte and nitrogen fertilization in tall fescue turf. Journal of Economic Entomology. In Press.

11. Haynes, K.F. and D.A. Potter. 1993. Sexual response of male beetles to larvae suggests a novel evolutionary origin for a pheromone. American Entomologist. In review.

12. Leal, W.S., K.F. Haynes, D.A. Potter, and J. Meinwald. 1995. Occurrence in masked chafer grubs of the same chemical used by adult southern and northern masked chafers as a sex pheromone. Journal of Chemical Ecology. In Review.

13. Crutchfield, B.A. & D.A. Potter. 1995. Tolerance of cool-season turfgrasses to feeding by grubs of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae). Journal of Economic Entomology. In Review.

14. Crutchfield, B.A. & D.A. Potter. 1995. Irrigation and fertilization affect injury by root-feeding white grubs in Kentucky bluegrass and tall fescue turf. Crop Science. In Review.

15. Crutchfield, B.A. & D.A. Potter. 1995. Survival, growth, and feeding impact of Japanese beetle and southern masked chafer grubs on common lawn weeds. Journal of Entomological Science. In Review.

16. Crutchfield, B.A. & D.A. Potter. 1995. Damage relationships of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs in cool-season turfgrasses. Journal of Economic Entomology. In Review.

B. Industry-oriented papers:

1. Potter, D.A. 1991. Earthworms, thatch, and pesticides. U.S. Golf Assoc. Green Section Record, Sept/Oct issue.

2. Potter, D.A. 1992. Natural enemies reduce pest populations in turf. U.S. Golf Assoc. Green Section Record, Nov/Dec issue.

3. Williamson, R. C. & D. J. Shetlar. Black cutworms: Where are they coming from? U.S. Golf Assoc. Green Section Record, Sept/Oct 1994. (written after RCW came to Kentucky)

4. Numerous other reports in state and local industry bulletins and newsletters

C. Papers presented:

This grant has helped to support a number of papers and lectures on turf insects presented at various professional and industry meetings. These include a Keynote Address at the International Turfgrass Research Conference, 7 papers at national meetings of the Entomological Society of America, and meetings of turf care professionals in several states.

D. Graduate Students Supported:

B.A. Crutchfield (Ph.D, Oct. 1994) is a finalist for a professional position with the West Virginia Cooperative Extension Service.

R. Chris Williamson (Ph.D candidate) is presently being supported. Mr. Williamson will present a paper on his 1994 studies at the National Entomology Conference in Dallas in December 1994.