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USGA TURFGRASS RESEARCH FOUNDATION

INTEGRATING NATURAL ENEMIES, CULTURAL CONTROL, AND PLANT RESISTANCE FOR SUSTAINABLE MANAGEMENT OF INSECT PESTS ON GOLF COURSES

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Executive Summary:

Objectives:

1) Evaluate the role of ants as beneficial predators in golf turf; determine the predominant species inhabiting golf courses; and develop tactics for managing mound-building pest ants on putting greens with reduced environmental risk or impact on beneficial species.
2) Investigate synergism between endophyte-enhanced, resistant turfgrasses and biorational insecticides for improved management of white grubs and black cutworms.
3) Examine the main and interacting effects of cultural practices (mowing height, irrigation, and N fertilization) on nutritional and defensive characteristics of creeping bentgrass, and on relative susceptibility to white grubs and black cutworms.

Ants are important predators on eggs and larvae of cutworms, grubs, and other pests, but on golf courses, these positive aspects must be weighed against the fact that some ant species build mounds on putting greens and tees. Surveys of ants inhabiting golf courses revealed that virtually all nuisance ant problems on putting greens and tees involve one species, *Lasius neoniger*. Surface insecticides usually won't eliminate these ants because the treatments fail to reach the ground-nesting queen. Our research showed that two commercially available baits containing either avermectin (Advance® Granular Carpenter Ant Bait; WhitMire Micro-Gen, Inc.) or hydramethylnon (Maxforce® granular ant bait; Clorox, Inc.) are effective for spot-treating ants in high-profile situations. Minimum effective rates were investigated. In another test, fipronil (Chipco Choice®, Rhone-Poulenc, Inc.), a novel phenyl pyrazole, was found to be effective for season-long suppression of *Lasius* nests and mounds on putting greens. Registration of fipronil for general ant control on golf courses is expected in 2000.

Other field experiments demonstrated that *Lasius neoniger* and other ant species are important in suppressing eggs and larvae of other insect pests. Populations of caterpillars (sod webworms and cutworms) were higher on golf tees where ants were eliminated than where ants were abundant. Thus, it may be beneficial to conserve turf ant populations except on putting greens where the mounds are intolerable. *Lasius* ants were found to cultivate and tend certain root-feeding aphids from which the ants obtain sugary honeydew as food. Root aphids, which appear to cause no damage, were present under all cool-season grasses. The aphids are abundant in fairways and roughs, but apparently are unable to survive in sand-based putting greens and tees. Maintaining access to aphids in close, irrigated rough may be one reason why *Lasius* ant nests are so abundant around the edges of greens and tees. Controlling root aphids may be one means of discouraging buildup of mound-building ants.

Two other studies related to Objective 1 were initiated in 1999. The first involves research on *Tiphia* wasps, which are important native parasites of white grubs. We have begun to characterize the wasps' seasonal life cycle, food plants used as nectar sources by the adults, and means by which populations of these beneficial insects can be augmented on golf courses, e.g., through planting of preferred wildflowers. We also are investigating cues by which the wasps locate grub victims underground. The second study involves evaluation of potential impact of turf insecticides on native pollinators. We found that imidacloprid (Merit®), applied as it would be for grub control, had no adverse effect on native bumblebees foraging on patches of flowering white clover in treated turf.

Our second objective concerns whether use of endophytic grasses in combination with microbially-based insecticides can provide enhanced levels of insect control. We sought to determine if the sublethal stress endured by insect pests feeding on endophytic grass might enhance the activity of microbial controls. Dose-mortality studies with *Bacillus thuringiensis* and spinosad (Conserve®) revealed no such interactions against black cutworms. Spinosad was effective, even at 0.25 label rate, and *B. thuringiensis* was ineffective; regardless of endophyte level of the grass. Similarly, feeding on roots of endophytic grass did not affect Japanese beetle grubs' susceptibility to milky disease bacteria, *Bacillus popilliae*.

Work conducted for Objective 3 in 1999 focused on potential interactions between plant growth regulators (PGR's) and insects attacking creeping bentgrass. We speculated that physiological or nutritional effects of the PGR's might alter the attractiveness or suitability of the turfgrass as food for plant-feeding insects. Large plots of fairway-height creeping bentgrass were maintained under monthly applications of Scott's Turf Enhancer® 2 SC (paclobutrazol), Primo® liquid (trinexapac-ethyl), or as untreated controls. The turf was challenged with cutworms and white grubs, and natural population densities of insect pests also were monitored. Our data suggest that use of paclobutrazol or trinexapac-ethyl on creeping bentgrass will neither increase nor decrease insect populations in the treated turf.

OVERALL GOAL:

The long-term goal of this project is to clarify factors that determine the distribution and abundance of insect pests of golf courses, especially ants, white grubs, and cutworms, and to develop sustainable tactics for managing these pests with reduced reliance on conventional insecticides.

OBJECTIVE 1. Evaluate the role of ants as beneficial predators in golf turf; determine the predominant species inhabiting golf courses; develop tactics for managing mound-building pest ants on putting greens with reduced environmental risk or impact on beneficial species.

Work on this Objective was expanded in 1999. We continued research on the ecology and management of mound-building ants, while adding new studies on biology of parasitic wasps (*Tiphia* spp.) attacking white grubs, and on impact of imidacloprid (Merit®), a widely-used soil insecticide, on native pollinators such as bumblebees.

Ants (other than fire ants) are a mixed blessing on golf courses. Our work indicates that they are important in suppressing insect pests by preying upon the eggs and young larvae. Nevertheless, ants are a significant problem when they build mounds on putting greens and tees. Surface insecticides usually won't eliminate such ants because they fail to reach the ground-nesting queen. During 1999 we summarized much of the first two years of our USGA-funded work in two refereed papers, the Abstracts of which are presented below:

Crop Science (C-5 turfgrass section) *In Press* C99-280(5)
Management of a Mound-building Ant, *Lasius neoniger* Emery, on Golf Putting Greens and Tees Using Delayed-Action Baits or Fipronil. Rolando López, David W. Held, and Daniel A. Potter; Department of Entomology; University of Kentucky

ABSTRACT The ant *Lasius neoniger* Emery can be a serious pest when its nesting and mound-building activities occur on golf putting greens and tees. Controlling turf-infesting ants is difficult because conventional insecticides usually fail to eliminate the subterranean queen. We compared the attractiveness of commercial and experimental ant baits to *L. neoniger* workers, and evaluated baits containing novel, delayed-action toxicants for selective control of *L. neoniger* on creeping bentgrass, *Agrostis stolonifera* L., golf tees. Efficacy of non-bait granular fipronil, a new phenyl pyrazole insecticide, also was evaluated. In choice tests, protein-based baits were more readily taken than baits containing sugar- or oil-based attractants. Abamectin-, hydramethylnon-, or spinosad-based baits significantly reduced numbers of ant mounds and nests when applied either as spot or broadcast treatments. Two commercial baits, Advance Granular Carpenter Ant Bait containing 0.011% abamectin B_1, and Maxforce Ant Killer Granular Bait containing 0.9% hydramethylnon, were especially effective. Spot-treatment with either of these baits, using 1 g of bait per mound, eliminated 88-97% of the mounds within 3 d. Broadcast application of fipronil (0.028 kg AI/ha) on heavily-infested, sand-based creeping bentgrass putting green turf in May provided ≈ 80% reduction of ant mounds at 7 d after treatment, and 86% reduction at 60 d.

Environmental Entomology: *In Press*

Ant Predation on Eggs and Larvae of the Black Cutworm (Lepidoptera: Noctuidae) and Japanese Beetle (Coleoptera: Scarabaeidae) in Turfgrass. Rolando López and Daniel A. Potter; Department of Entomology, University of Kentucky, Lexington, KY 40546-0091

ABSTRACT We studied ant predation on eggs and larvae of the black cutworm, *Agrotis ipsilon* Hufnagel, and on eggs of the Japanese beetle, *Popillia japonica* Newman, on golf courses and lawns in central Kentucky. *Lasius neoniger* Emery, accounted for > 99% of the ant mounds on golf putting greens and collars. Although often regarded as a nuisance pest, *L. neoniger* preyed heavily upon *A. ipsilon* eggs on turfgrass cores implanted into putting greens, collars, fairways, and roughs. Predation on eggs was lower in fairways than in roughs, and in plots where ant populations were reduced by insecticides. When 1600 individual first-instar cutworms were placed near *L. neoniger* nests on putting greens, 62% were attacked and killed upon their first encounter with the ants. Third- and fourth-instar cutworms generally fended off attacks by *L. neoniger* and *Formica pallidifulva nitiventris* Emery, but were invariably killed during encounters with *Formica schaufussi* Mayr and *Formica subsericea* Say, larger ants that are common in lawns and golf roughs. Predation on implanted Japanese beetle eggs also tended to be greater in roughs than in fairways, and fewer grubs were found in areas of golf roughs where ants were abundant than where ants had been controlled. This study suggests that predation by indigenous ants provides an important buffer against pest outbreaks on lawns and golf courses.

Besides these refereed articles, we also published superintendent-oriented articles about ants and ant management in Golf Course Management and Turfax Newsletter. Considerable time was devoted to procuring regulatory clarifications that confirm that use of either of the aforementioned commercial ant baits (MaxForce or Advance) on golf putting greens and tees *is* consistent with the products' labeling (except in CA).

Minimum Rate Bait Test, 1999. In the study abstracted above, minimum effective bait rates had not been determined. We therefore conducted a study at Champion Trace Golf Course (Jessamine Co., KY) in May 1999 to determine bait amounts needed to eliminate *L. neoniger* nests on putting greens and tees. Five replicates of five treatments were applied on 11 May on 10 different greens. The treatments were Advance (abamectin) or MaxForce (hydramethylnon) bait at 1.0 or 0.5 g of bait per ant mound, or untreated controls. all the *L. neoniger* mounds on the greens and tees on the golf course were identified and counted. Plots were blocked by pretreatment mound counts; numbers of active mounds were then counted twice, at 3 and 14 d after treatment. Advance bait was highly effective at both low and high rates; percentage reductions were 93 and 85% at 3 d, and 94 and 88% at 14 d, for the high and low rates, respectively. MaxForce was less effective in this test: reductions averaged 74 and 60% at 3 d, and 49 and 50 % at 14 d, for low and high rates respectively. Irrigation seemed to reduce bait attractiveness; ants were observed to walk around wet bait granules without touching them.

Does Controlling Ants Increase Likelihood of Cutworms or Sod Webworms? This 1999 study tested whether eliminating ants from golf tees would suppress predation and result in higher populations of caterpillars. Pairs of tees with comparable numbers of *L. neoniger* mounds were located on Champion Trace Golf Course. Beginning in mid-May, one tee of each pair was spot-treated twice, 1 week apart, with Advance Granular Carpenter Ant Bait (abamectin). A week after the second application, plastic centrifuge tubes were implanted as pit-fall traps for ants. Three pairs of traps were operated in each plot, one of each pair within the tee, and the other 1.5 m from the edge on the rough outside the tee. Traps were emptied every 2 weeks for 10 weeks and relative numbes of ants in treated and untreated plots was determined. Before treatment, and each month thereafter, the tees were sampled for cutworms using a soap disclosing solution applied to a 1 m^2 section of each tee.

Ants (mainly *L. neoniger*) were nearly eliminated from the treated plots. Samples taken during May, June and July yielded very few cutworms, and cutworm damage also was minimal throughout the golf course (D. Gribler, Superintendent, *personal communication*). Cutworm populations may have been suppressed by extreme, summer-long drought, which produced the driest summer in >100 years. In August, we observed high bird activity on some of the treated tees, but conventional soap drenches (with Joy liquid detergent) continued to indicate few cutworms. Trial and error experimentation with other irritants showed that a dilute drench of Safer insecticidal soap with permethrin was the most effective disclosing solution for the culprit larvae, which were mainly sod webworms, *Parapediasia teterrella.* Larval populations in August were significantly higher on tees from which ants had been eliminated than on tees with abundant ants (13.0± 1.8 vs. 2.6 ± 0.7 larvae per 1m^2 for treated versus untreated tees, respectively; $t = 4.37$, df = 4, $P = 0.012$). The same pattern occurred in September (6.6 ± 0.5 versus 1.0 ± 0.5 larvae, respectively; $t = 8.26$, df = 4, $P < 0.01$). These data suggest that eliminating ants may result in higher incidence of caterpillar pests. Superintendents who practice ant control should be especially vigilant for sod webworms and cutworms.

Relationships Between Golf Course Ants and Root Aphids. We observed that nests of *L. neoniger* usually have associated with them populations of subterannean aphids that feed on the roots of the grass where the ant nest occurs. Mutualism with root aphids was known for *Lasius* in other systems (Pontin 1978), but has not been studied in turf. The aphids may affect the success of *Lasius* nests because the ants feed on the honeydew secretions, and on the aphids themselves (Lopez and Potter, *unpublished data*). We sought to determine the types of grasses and habitats in which the aphids are abundant, suspecting that this might explain the distribution of the ants. Moreover, if the ants and aphids are co-dependent, then controlling the aphids might help to suppress the ants where their mound are intolerable.

Replicated plots of seven cool-season turfgrasses, growing on a Maury silt loam soil at the UK Turfgrass Research Facility, were sampled twice by randomly searching for *Lasius* ant mounds on each plot and removing a 14-cm diameter soil core where ant nests were found. Grasses included Palmer II perennial ryegrass, KY 31 and Falcon tall fescues, common and Adelphi Kentucky bluegrasses, Aurora hard fescue, and Penncross creeping bentgrass. Cores were then taken to the laboratory and the soil and roots were carefully separated. All aphids found with the ants were collected with a moist paint brush and preserved for identification by systematists at the U.S. National Museum (we are still awaiting these ID's). Aphids infesting the different plots were preserved separately because each type of grass seemed to have a different type of aphid. All of the grasses supported abundant populations of root aphids. *Lasius neoniger* seems to be opportunistic, exploiting whatever species of root aphids is abundant in the particular turfgrass in which the ant nest occurs. The relationship appears to be mutualistic: the ants protect the aphids from predators, carry them about, and stroke them for carbohydrate-rich honeydew.

At Champion Trace Golf Course, 5 cm diameter core samples were systematically taken from three greens,and from surrounding collars and roughs, monthly during May, June and July. Similar samples also were taken from teens and roughs. Cores were processed in the manner described earlier. We found that aphids were always abundant in cores taken from Kentucky bluegrass roughs, but aphids were never found in sand-based tees and greens. Possibly, the compacted, sandy soil is unsuitable for the aphids. In just one instance we found two dead (diseased) aphids on the interface between the sand and the native soil in a core from a green. These samples suggest that the typically higher populations of *L. neoniger* ants around the perimeter of putting greens or tees may reflect the ants' exploiting the "best of both worlds"; i.e., using the sandy soil to facilitate their own nest-building, harvesting the abundant protein food (e.g., insect fragments) from the putting green surface, while maintaining satellite chambers with root aphids in close rough.

Another interesting discovery was that *Lasius neoniger* commonly exploits cavities in the roots of plantain (*Plantago* spp.), originally formed by weevil feeding, as "stables" in which to cultivate root aphids. In weedy lawns or roughs with abundant plantain, we invariably found *L. neoniger* nest galleries associated with plantain. In nearly all cases, the taproot of the weed was hollowed out, and colonies of ant-tended root aphids were found within.

Biology of a native *Tiphia* Wasp Parasitizing White Grubs and Possible Use in Biological Control. *Tiphia* wasps are of interest as potential biological control agents for white grubs. Most research done on these wasps was in the 1920's and 30's and focused on species imported for biological control of the Japanese beetle. In 1999, we began studying a native species, tentatively identified as *T. krombeini*, that commonly parasitizes masked chafer grubs. The adult wasps are active in late summer. The female burrows into the soil where she locates a grub, stings to temporarily paralyze it, and then lays an egg on its back. Upon hatching, the larval wasp devours the grub within 2-3 weeks. It then spins a silken cocoon where it overwinters, emerging the following year. *Tiphia* are very abundant on some golf courses, parasitizing > 50% of the grub population at some sites. *Tiphia* wasps are solitary and non-aggressive which makes them potentially valuable for augmentive or conservation biological control.

Beginning in early August, grubs were dug from two sites on a weekly basis to monitor for *Tiphia* eggs and larvae, and to track development of larval *Tiphia* in the field. Adult *Tiphia* wasps were obtained by hand collecting the wasps from beneath grub-damaged turf. Wasps were held in the lab and provisioned with grubs to determine the number of grubs each wasp is capable of parasitizing, as well as adult longevity. More than 175 parasitized grubs were monitored for development of *Tiphia* larvae. A breakthrough was made via the discovery that large numbers of female *Tiphia* could be attracted by spraying dilute sugar water on a turf site. This provides a potential method for manipulating the wasps for biological control in the field.

A 4-arm olfactometer was constructed that will allow us to study the cues used by *Tiphia* adults to locate and parasitize grubs underground. Behavioral interactions between wasp and grub also were observed in plexiglas "ant farms", and the behavioral sequence leading to parasitism was videotaped for the first time. Future work will focus on the biology of the wasp, including grub species parasitized, parasitism rates on golf courses, floral sources utilized by this wasp for nectar. We also will test the feasibility of augmenting natural populations of these beneficial wasps by incorporating preferred wildflowers into golf course landscapes, or by providing supplemental sugar as food.

Is Imidacloprid (Merit) Insecticide Toxic to Bumblebees Foraging on Treated Weedy Turf? Parasitic mites and diseases have contributed to a marked decline in honeybee populations, so that bumblebees and other native pollinators increasingly important. Imidacloprid, a systemic chloronicotinyl insecticide, is the most widely used soil insecticide on golf courses. Applied topically, imidacloprid is toxic to bees, and in small doses it can dramatically affect the behavior of social insects. If a long-term residual insecticide such as imidacloprid was translocated into the nectar or pollen of weeds (e.g., white clover) or other flowering plants, it potentially could endanger bumblebee colonies whose workers forage in treated areas. We therefore evaluated the impact of granular imidacloprid applications on post-treatment foraging and hive health of bumblebees confined on tall fescue with flowering white clover.

Ten large pollination cages were placed on plots paired according to pre-treatment clover density. One plot of each pair was treated with granular imidacloprid at label rate, followed by irrigation to leach the residues into the soil. One week later a commercially-obtained hive of *Bombus impatiens* was placed in each cage. Foraging as well as other behaviors were periodically recorded. On August 7th, 6 wk after treatment, the hives were frozen and dissected for comparison. To test whether bumblebees avoid treated clover, 14 plots were paired according to pretreatment clover densities. Half of the plots were treated as before. Numbers of bumblebees foraging on each plot weres recorded during hourly observations. Our results indicate that, applied as it would be for white grub control, imidacloprid had no adverse effects on colony behavior or hive health. However, foraging workers did not avoid treated areas. Further research on potential impact of surface treatments of imidacloprid on bumblebees therefore is warranted.

OBJECTIVE 2. Investigate synergism between endophyte-enhanced, resistant turfgrasses and biorational insecticides for improved management of white grubs and black cutworms.

Earlier studies in our laboratory showed that endophytic grasses may have sublethal effects on grubs and cutworms (e.g., delayed development, stunted growth) rather than killing them outright. This is important because stressed insects often are more susceptible to pathogens or insecticides. Thus, it is possible that use of endophytic grasses in combination with reduced-risk insecticides could broaden the spectrum of control with these products, or allow use of lower rates. Alternatively, control might be compromised if entomopathogens are sensitive to the same endophyte-produced alkaloids that the insects must cope with.

Dose/mortality studies were done with black cutworms fed increasing concentrations of either *Bacillus thuringiensis* or spinosad (Conserve®) on endophyte-free or endophyte-infected perennial ryegrass. Regardless of grass type, none of the *B. thuriengiensis* formulations was active against black cutworms. All rates of spinosad were highly active, but this, too was independent of endophyte. Finally, interaction between endophytic stress and efficacy of milky disease was studied with Japanese beetle grubs feeding in perennial ryegrass with *Bacillus popilliae* spore powder added. Although we were able to significantly induce milky disease with high rates of powder, there agains were no main effects or interactions with endophyte. Because data from three different series of experiments were negative, we conclude that significant synergism of microbial insecticides by endophyte is unlikely.

OBJECTIVE 3. *Examine the main and interacting effects of cultural practices (mowing height, irrigation, and N fertilization) on nutritional and defensive characteristics of creeping bentgrass, and on relative susceptibility to white grubs and black cutworms.*

Work conducted for this Objective in 1999 focused on potential interactions between plant growth regulators (PGR's) and insects attacking creeping bentgrass. PGR's are used on golf courses to reduce mowing frequency and grass clipping waste, suppress seed head formation, and provide herbicidal control of certain weed species. PGR's can increase root mass, decrease shoot mass, and improve foliage color of turfgrasses. We speculated that such changes might affect the suitability of turfgrass for herbivorous insects. We studied the effects of PGR's on three pests, Japanese beetle grubs(*Popillia japonica*), black cutworm larvae (*Agrotis ipsilon*), and sod webworms (Lepidoptera: Pyralidae).

Tests were conducted on a stand of creeping bentgrass maintained under standard mowing and watering practices for bentgrass fairways. In April 1999, plots (5m x 5m) were established in a randomized complete block with six replicates. Treatments included Scott's Turf Enhancer® 2 SC (paclobutrazol), applied at a rate of 0.25lb AI/acre, Primo® liquid (trinexapac-ethyl), applied at a rate of 0.25 oz prod./acre, and an untreated control. All applications were made on the 20^{th} of each month, from April to September, excluding August. Turf core samples were taken the week following each treatment for protein and carbohydrate analyses. Open bottom cages containing 20 mated Japanese beetles were placed on each replicate on three separate days. Cages were left for 24 h to allow beetles to oviposit in the turf. Each of these areas was later excavated and numbers and weights of grubs were recorded. Irritant soap drenches were used to sample for cutworms and sod webworms. Because cutworm populations were low, the infestation was augmented by confining lab-hatched larvae within PVC rings set into the turf. Larvae were collected 2 wks later, counted, and weighed. Finally, in lab feeding trials, newly-hatched black cutworms were reared on grass clippings from treated or untreated plots, and growth and survival were compared.

Natural populations of grubs and black cutworms were too low for meaningful analysis. By comparison, the irritant drenches yielded large numbers of sod webworms, but there was no significant difference among the treatments. Feeding on PGR-treated creeping bentgrass had no measurable effects on survival or weight of cutworms confined in PVC rings in the field plots, or fed clippings in the laboratory. Our data suggest that use of paclobutrazol or trinexapac-ethyl on creeping bentgrass probably will not significantly increase, or decrease, insect populations feeding on the treated turf.