EXECUTIVE SUMMARY- 1997
USGA TURFGRASS RESEARCH FOUNDATION

CULTURAL CONTROL, RISK ASSESSMENT, AND ENVIRONMENTALLY RESPONSIBLE MANAGEMENT OF WHITE GRUBS AND CUTWORMS IN TURFGRASS

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Goals:

1) Determine factors that affect the distribution and abundance of white grubs and cutworms on golf courses

2) Reduce the use of insecticides by identifying methods to reduce white grub and cutworm infestations through modified cultural practices

3) Provide better information on the effects of pesticides on natural enemies of turfgrass pests and other beneficial species that live in golf course turf

Cooperators: A.J. Powell, K.F. Haynes, R.C. Williamson, R. Lopez-Guterriez

This research seeks better understanding of the causes of insect outbreaks on golf courses. We are also evaluating means by which superintendents can manage white grubs and cutworms with reduced use of broad-spectrum insecticides.

Field studies showed that withholding irrigation during peak flight of beetles, raising cutting height, and light application of aluminum sulfate in spring may help to reduce severity of subsequent infestations of Japanese beetle and masked chafer grubs. Grub densities were not affected by spring applications of lime or urea, but use of organic fertilizers (composted cow manure or activated sewage sludge) may increase problems with green June beetle grubs. Use of a heavy roller was not effective for curative grub control. Soil moisture seems to be the overriding factor determining distributions of root-feeding grubs in turf.

On creeping bentgrass putting greens, black cutworm (BCW) moths laid similar numbers of eggs regardless of cutting height. Nearly all eggs are laid singly, on tips of leaf blades. We found that most (75-97%) of the eggs are removed with clippings each time that greens are mowed; however, many eggs survive passage through the mower blades and will later hatch. Clippings therefore should be discarded well away from greens and tees. BCW also lay eggs in fairways and roughs, but here, most eggs are laid lower down on grass plants where they are not removed by mowing. Thus, reservoir populations may develop in high grass surrounding greens and tees. *Our work shows that cutworms may crawl as far as 70 feet in a single night, and that they often invade greens from peripheral areas.* Thus, when treating for cutworms, a 30 ft buffer zone around the putting green also should be treated.

BCW thrived when fed creeping bentgrass, perennial ryegrass, or tall fescue, but Kentucky bluegrass was highly unsuitable as food. Endophyte-infected cultivars did *not* provide significant resistance. Putting greens surrounded by creeping bentgrass, tall fescue, or perennial ryegrass may be qat greatest risk from invasion from peripheral areas. Unfortunately, none of the 14 cultivars of creeping bentgrass that we tested showed much resistance to BCW.

BCW are most active on putting greens between midnight and just before dawn. Treatments therefore are best applied toward evening. Young cutworms feed mainly by "grazing" on the surface, whereas larger ones feed mainly from aerification holes or self-made burrows. Contrary to expectation, BCW were not attracted to aerified bentgrass, although they tend to occupy aerification holes when they are available. Sand top dressing may partially deter cutworms. Mowing at night, or an hour or so before dawn, may provide substantial control by shredding.

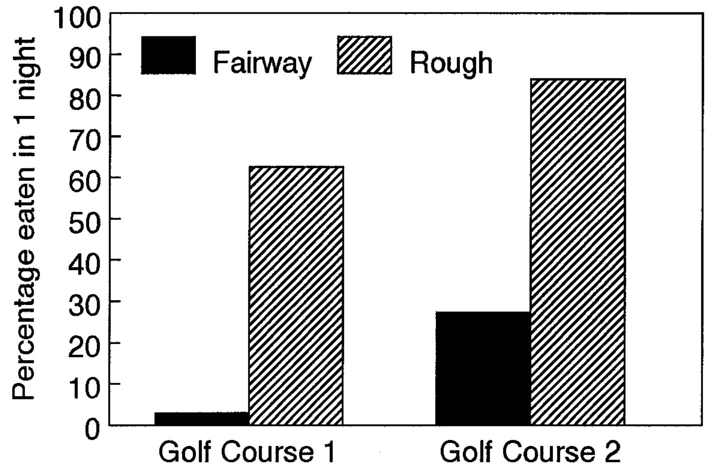
Grubs of northern and southern masked chafers are important pests of golf courses throughout the U.S. Females of both species produce a potent sex pheromone that attracts males. Interestingly, the two species are cross-attractive. In a pilot study, we tested whether grub "hot-spots" on golf courses could be located by trapping males using crude extracts of virgin female beetles. Because the beetle flights are localized, we reasoned that areas with heavy mating flights would be at highest risk from grubs. The results were promising, but the difficulty of getting virgin female beetle extract prohibits practical application. A synthetic lure is needed before this system can be fully tested on golf courses. Thus, we are collaborating with chemists at Cornell University to identify and synthesize the masked chafer sex attractant. The active chemical peak was pinpointed by gas chromatography and electroantennogram/behavioral analysis, and the compound was characterized by mass spectroscopy. A putative molecular formula has been worked out. ID and synthesis of this potent attractant will allow its use for survey, risk assessment, and improved timing of control actions on golf courses.

Insecticides applied to golf courses can adversely affect beneficial or nontarget invertebrates such as predators and earthworms. This sometimes can aggravate pest outbreaks or thatch buildup. We therefore are studying environmental side-effects of two novel soil insecticides, imidacloprid (Merit®) and halofenozide (Mach 2®) as compared to conventional soil insecticides. Our work shows that both Merit and Mach 2 provide excellent control of white grubs, with low impact on beneficial and nontarget species. These findings were requested by the US-EPA in support of final registration of Mach 2 for use on turf.

Finally, we initiated studies on the biodiversity and importance of predatory invertebrates in golf course habitats. The most abundant predators on Kentucky golf courses were ants, together with various mites, spiders, ground beetles, and rove beetles. More than 99% of the ant mounds on putting greens were made by one species, *Lasius neoniger*. When naturally-deposited cutworm eggs were exposed on putting greens or aprons, 92-95% were eliminated in one night by *Lasius* workers. When cutworm or Japanese beetle eggs were exposed in fairways or roughs, predation was much higher in roughs than on fairways on both golf courses (Figure 1). Predation on eggs was closely correlated with abundance of ants. This study will reveal which ant species are most likely to cause damage to putting greens, and which are highly beneficial predators. Ongoing work will seek ways of managing pest ants while conserving those species that are important in buffering golf courses against pest outbreaks.

Figure Legend:

Figure 1. Natural predation on eggs of black cutworm or Japanese beetle exposed on golf courses for one night or two days, respectively. Note high rates of predation in untreated roughs, where predators were abundant, as compared to fairways. Ants were the most important predators on eggs.



Predation on Black Cutworm Eggs

Predation on Japanese Beetle Eggs

FINAL ANNUAL REPORT- 1997
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OVERALL GOAL:

The goal of this project is to better understand the factors determining the distribution and abundance of insect pests, especially white grubs and cutworms, on golf courses. We seek safer, more economical and more effective methods for managing these pests with reduced use of broad-spectrum insecticides. As this project is ending, this report will provide a brief overview of the overall results.

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.*

Cultural practices were manipulated before and during seasonal flights of Japanese beetles (*Popillia japonica*) and masked chafers (*Cyclocephala* spp.) to study effects on subsequent grub densities in turf (Potter et al. 1996). High mowing (18 cm) or application of aluminum sulfate (1223 kg/ha) to lower surface pH reduced total biomass of white grubs by as much as 55 and 77%, respectively. However, where spatial gradients in soil moisture occur, the positive response of grub populations to moisture may override effects of other treatments. Grub densities were not affected by spring applications of lime 9785 kg/ha) or urea (97.8 kg N/ha) or by aerification of plots before beetle flights. However, turf that was irrigated during beetle flight incurred significantly higher grub densities than did nonirrigated turf. Use of a heavy (2247 kg) roller to compact the soil before beetle flights did not affect subsequent grub populations, nor was it effective for remedial control of grubs in the fall. Application of organic fertilizers (activated sewage sludge; composted cow manure) resulted in significantly higher infestations of green June beetle, *Cotinis nitida*. Soil moisture seems to be the overriding factor affecting distributions of Japanese beetle and masked chafer grubs in turf.

Most of the funds from the current grant were used to support a Ph.D. student, Chris Williamson, who is presently Principal Research Entomologist with TruGreen/Chemlawn. Dr. Williamson completed the first study of the egg-laying, feeding, and movement habits of black cutworms (*Agrotis ipsilon*) in golf course turf. This research revealed means by which golf superintendents may be able to manage this pest more effectively.

Black cutworm moths laid similar numbers of eggs on creeping bentgrass putting greens maintained at 1/8", 3/16", or ½" cutting height. Manipulation of cutting height is therefore unlikely to provide deterrence. Nearly all eggs are laid singly, on the tips of grass blades. Each mowing removed 75--97% of the eggs. We found that most eggs can survive passage through the mower blades and will later hatch. We therefore advise golf superintendents to dispose of clippings well away from greens and tees. Cutworm moths also lay eggs on higher-mowed turf in fairways and roughs, but here, most eggs are laid lower down on grass plants, where they would not be removed by mowing. Thus, reservoir populations may develop in high grass surrounding greens and tees. Five to 10% of the eggs were dislodged by the mower roller, which may be a source of residual infestation on putting greens (Williamson and Potter 1997a).

Night-time observations revealed that cutworms are most active on putting greens between midnight and 1 hour before sunrise. Thus, treatments are best applied toward evening. Young cutworms feed mainly by "grazing" on the putting surface, whereas larger ones feed mainly from aerification holes or self-made burrows. Contrary to expectation, cutworms were not attracted to aerified bentgrass, although they tend to occupy aerification holes when such holes are available. Sand top dressing seems to partially deter cutworms. Mowing an hour or so before dawn may provide substantial control by shredding. *Our work shows that cutworms may crawl as far as 70 feet in a single night, and that they often invade greens from peripheral areas.* We therefore suggest that when treating for cutworms, a 30 ft buffer zone around the putting green should also be treated (Williamson and Potter 1997b)

Perennial ryegrass and tall fescue were found to be as suitable for cutworms as creeping bentgrass, but Kentucky bluegrass was highly unsuitable as food. Endophyte-infected cultivars did *not* provide significant resistance. Putting greens surrounded by creeping bentgrass, tall fescue, or perennial ryegrass may be at greatest risk from invasion from peripheral areas. None of the 14 cultivars of creeping bentgrass we tested was significantly resistant. Nevertheless, use of Kentucky bluegrass around greens and tees, coupled with daily mowing of greens and clipping removal should provide substantial cultural control (Williamson and Potter 1997c).

Objective 2. *Identify the Sex Pheromone of Northern and Southern Masked Chafers and Explore Practical Applications of the Pheromone in Golf Course Settings.*

Masked chafers are the most damaging white grubs attacking golf courses and lawns throughout most of the United States (except for New England). Our previous work showed that the females produce a potent chemical sex pheromone that attracts males. Interestingly, northern and southern masked chafers, the two most damaging species, are cross-attractive. Furthermore, we found that the female attractant is present in both male and female grubs, the first discovery of a sex pheromone being present in a larval insect (Haynes and Potter 1995a,b). We tested the feasibility of predicting white grub "hot-spots" on golf courses by using crude female extract to bait traps for the male beetles (Potter and Haynes 1993). Because masked chafer flights are localized, we reasoned that areas with heavy mating flights would be at relatively high risk from grubs. This pilot study was promising, but the difficulty of obtaining crude sex pheromone extract would prohibit practical application. Obviously, a synthetic lure is needed before golf superintendents can use traps to alert them to high-risk grub sites.

We are presently collaborating with pheromone chemists at Cornell University to identify and synthesize this sex attractant. Considerable progress was made during the past year. In the fall of 1996, we collected and extracted 6,500 masked chafer grubs, which we previously determined to be a good source of the same compound that serves as a sex attractant in the adult stage. Our collaborators at Cornell determined the molecular weight of the behaviorally active compound to be 246 amu. Subsequently, they determined using high resolution mass spectrometry that the molecular formula was$C_{17}H_{26}O_1$. Relying on feedback from a gas chromatography-behavioral bioassay, the Cornell group has conducted a series of chemical tests that have helped to characterize the molecule's structure. A hypothetical structure for the pheromone has been proposed that will be challenged with sophisticated GC-Infrared spectrometry this winter. To meet this goal, we collected and extracted 5,500 additional grubs in the Fall of 1997. If the proposed structure is confirmed, the molecule will be synthesized and field-tested during in 1998 flight period.

Identification and synthesis of this potent pheromone will allow several potential applications, including mass trapping, risk assessment, improved treatment timing, and suppression by mating confusion. Furthermore, it has become clear that soil insecticides, especially target-selective products such as halofenozide (Mach 2), may be more active against some grub species than others. This may one cause for poor control. Superintendents therefore should know which species of grubs predominate on their golf course. Grubs of southern and northern masked chafers co-occur across much of the geographic range, but larvae of these species are morphologically indistinguishable. Moreover, we suspect that they are not equally represented in all turfgrass habitats, e.g., one or the other may predominate in fairways, tee banks, or roughs. Because it attracts both species, the synthetic pheromone lure will provide a means by which superintendents can assess which chafer species they are dealing with, allowing them to choose the most effective insecticides for that pest.

Objective 3. *Provide better understanding of the role of beneficial invertebrates (earthworms, predators, parasites) inhabiting golf course turf, and of the effects of pesticides on these species. We seek to identify pest-selective control measures that will preserve the natural checks and balances within the turfgrass system.*

Insecticides that are applied to golf courses can adversely affect beneficial invertebrates such as predators and earthworms. This can sometimes aggravate pest outbreaks or thatch buildup. In 1996, we began a 2-year study of the side-effects of two important new soil insecticides, imidacloprid (Merit ®) and halofenozide (Mach 2®), on beneficial invertebrates in turf. Imidacloprid, a novel chloronicotinyl characterized by long residual activity and relatively low toxicity to vertebrates, is already being widely used on golf courses. Halofenozide, the first molt accelerating compound (MAC) developed for turf use, also has long residual and low environmental hazard. [*Note: our laboratory was first to demonstrate activity of MAC's against white grubs, about 10 years ago*]. Registration of halofenozide recently was granted. Both products have excellent activity against white grubs and billbugs, and halofenozide controls cutworms as well. Together, these products will dominate the insecticide market for golf courses. There is presently no information on the potential side effects of these compounds on beneficial invertebrates.

In 1996 and 1997, replicated plots in golf roughs were treated with imidacloprid, halofenozide, or bendiocarb (a carbamate standard) at labeled rates, and impact on earthworms, beneficial soil arthropods, and predators were monitored throughout the growing season. Predation rates on eggs, larvae, and pupae of black cutworms, and eggs of Japanese beetles were compared between treated and untreated sites in golf courses. Halofenozide had no apparent adverse effects on any beneficial species, or on predation on pest life stages. Imidacloprid caused slight ($\approx$20%) reductions in abundance of earthworms and certain predators, but effects were less severe than with bendiocarb. Both imidacloprid and bendiocarb caused short-term reductions in predation, but levels returned to normal within 2 weeks. *In January 1997, the EPA requested our environmental data in support of the final registration for halofenozide.*

In summer 1997, we also conducted more detailed studies on contact, dietary and residual toxicity of the three insecticides, as well as sublethal effects on a common predatory ground beetle, *Harpalus pennsylvanicus.* This beneficial species is abundant in turfgrass and agricultural systems and has been used as an indicator species in ecotoxicological studies of pollutants. Bendiocarb caused high acute mortality of ground beetles in contact, dietary, and residual tests. Imidacloprid caused temporary moribundity (sublethal neurotoxicological effects) in most tests, but beetles recovered within 3 days. However, Merit-intoxicated beetles were more vulnerable to predation by ants. Halofenozide had no apparent adverse effects on ground beetles (Figure 1). These results suggest that halofenozide and imidacloprid pose much less risk to beneficial invertebrates than does a standard carbamate insecticide. Golf superintendents now have the option of using target-selective soil insecticides that provide excellent pest control while having low impact on beneficial and nontarget species.

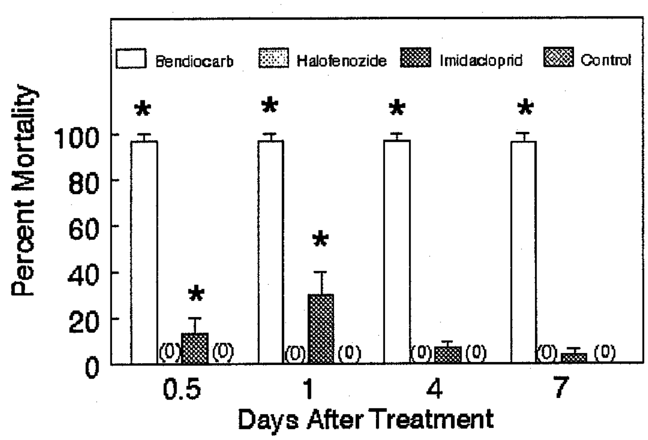

Fig. 1. Mortality of a predatory ground beetle following exposure to insecticides sprayed on turf.

Finally, we initiated a new study in 1997 concerning biodiversity and significance of predators, especially ants, on golf courses. Ants and other predators are extremely abundant in golf roughs and many fairways where they feed on cutworms, grubs, and other pests. Probably no preventive or curative insecticide applied by superintendents is as important as these natural buffers. Of course, mound-building ants are pests on putting greens, so we will examine that aspect as well.

Several hundred pitfall traps were established on six holes of two golf courses in April 1997. The traps are in rows spanning interfaces between roughs and fairways, extending 10 meters into each site. We also trapped high-grass areas bordering golf courses, and home lawns, to compare predator faunas among these habitats. Species of mound-building ants on putting greens were surveyed on six putting greens on each of five golf courses in central Kentucky. Finally, we exposed Japanese beetle and cutworm eggs and larvae on putting greens, and in roughs and fairways to compare predation in different turf habitats.

The first year of this work revealed the most abundant predators on Kentucky golf courses to be the ants *Lasius neoniger* and *Solenopsis molest*, together with various mites, spiders, ground beetles, and rove beetles. More than 99% of the ant mounds on putting greens were made by one species, *Lasius neoniger*. When creeping bentgrass cores with naturally-deposited cutworm eggs were exposed on putting greens or aprons, 92-95% were eliminated in one night by *Lasius* workers. When cutworm or Japanese beetle eggs were exposed in fairways or roughs, predation was much higher in roughs than on fairways on both golf courses (Figure 2). Predation on eggs was closely correlated with abundance of ants.

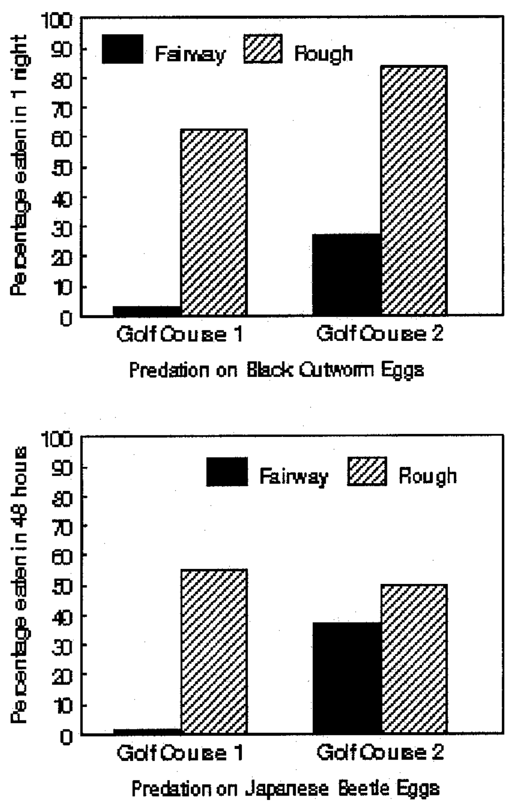

Fig. 2. Predation on eggs of black cutworm (within 1 night) or Japanese beetle (within 2 days) on golf courses.

This is the first study of species diversity and richness of beneficial invertebrates in different golf course habitats. It will reveal which ant species are most likely to cause damage to putting greens, and which are highly beneficial predators. Ongoing work will seek ways of managing pest ants while conserving those species that are important in buffering golf courses against pest outbreaks.

Publications

The following scientific papers were supported, in part, by the current USGA grant (since 1995):

Crutchfield, B. A., D. A. Potter, and A. J. Powell. 1995. Irrigation and fertilization effects on white grub feeding injury to tall fescue turf. Crop Science 35: 1122-1126.

Crutchfield, B. A. and D. A. Potter. 1995. Damage relationships of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs in cool-season turfgrasses. J. Econ. Entomol. 88: 1049-1056.

Crutchfield, B. A. and D. A. Potter. 1995. Tolerance of cool-season turfgrasses to feeding by grubs of the Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae). J. Econ. Entomol. 88: 1380-1387.

Crutchfield, B. A. and D. A. Potter. 1995. Feeding by Japanese beetle and southern masked chafer on lawn weeds. Crop Sci. 35: 1681-1684.

Davidson, A. W. and D. A. Potter. 1995. Response of plant-feeding, predatory, and soil-inhabiting invertebrates to *Acremonium* endophyte and nitrogen fertilization in tall fescue turf. J. Econ. Entomol. 88: 367-379.

Haynes, K. F. and D. A. Potter. 1995. Sexual response of a male scarab beetle to larvae suggests a novel evolutionary origin for a pheromone. American Entomologist 41: 169-175. (Invited Feature)

Haynes, K. F. and D. A. Potter. 1995. Chemically-mediated sexual attraction of male *Cyclocephala lurida* (Coleoptera: Scarabaeidae) and other scarabaeid beetles to immature stages. Environ. Entomol. 24: 1302-1306.

Potter, D. A. 1995. Northern and southern masked chafers. pp. 70-72; In: Handbook of Turfgrass Insect Pests; R. L. Brandenburg and M. G. Villani (eds.); Entomol. Soc. Am.; Lanham, MD.

Potter, D. A. 1995. Beneficial and innocuous invertebrates in turf. pp. 101-104, In: Handbook of Turfgrass Insect Pests; R. L. Brandenburg and M. G. Villani (eds.); Entomol. Soc. Am.; Lanham, MD

Potter, D.A., A.J. Powell, P.G. Spicer, and D. Williams. 1996. Cultural Practices Affect Root-feeding White Grubs (Coleoptera: Scarabaeidae) in Turfgrass. Journal of Economic Entomology 88: 156-164.

Potter, D. A. 1997. Managing scarabaeid pests of turfgrasses: problems and prospects. pp. 124-129, In: Soil Invertebrates. Allsopp, P.G., Rogers, D.J., and L.N. Robertson (eds.). BSES, Brisbane, Australia.

Potter, D.A. and R.C. Williamson. 1997. Behavior and cultural control of black cutworms in golf course turf. pp. 60-62. In: Soil Invertebrates. Allsopp, P.G., Rogers, D.J., and L.N. Robertson (eds.). BSES, Brisbane, Australia.

Potter, D. A. 1998. Environmentally responsible management of white grubs and cutworms on golf courses. In: Clark, J. M. and M. P. Kenna (eds.). Fate of Turfgrass Chemicals and Pest Management Approaches; American Chemical Society, ACS Books, *Invited; in preparation.*

Redmond, C. T. and D. A. Potter. 1995. Lack of efficacy of *In Vivo*- and putatively *In Vitro*-produced *Bacillus popilliae* against field populations of Japanese beetle (Coleoptera: Scarabaeidae) grubs in Kentucky. J. Econ. Entomol. 88: 846-854.

Williamson, R.C. & D.A. Potter. 1997a. Oviposition of black cutworms on creeping bentgrass putting greens and removal of eggs by mowing. Journal of Economic Entomology 90: 590-594.

Williamson, R.C. & D.A. Potter. 1997b. Nocturnal activity and movement of black cutworms and response to cultural manipulations on golf course putting greens. Journal of Economic Entomology 90: 1283-1289.

Williamson, R.C. & D.A. Potter. 1997c. Turfgrass species and endophyte effects on survival, development, and feeding preference of black cutworm larvae. Journal of Economic Entomology 90: 1290-1299.

Popular Articles (since 1995):

Potter. D.A. 1998. New insecticide technology alters traditional views of white grub management. Golf Course Management. *In press.*

Potter. D.A. 1998. Changing philosophies in IPM for white grubs. Bull. Professional Lawn Care Assoc. *In press.*

Williamson, R. C. and D. A. Potter. 1997. Does aerification promote black cutworm infestations? Golf Course Management. Jan. issue.

Williamson, R.C. and D.A. Potter. 1998. Resistance to cutworms: not all turfgrasses are created equal. Golf Course Management. *In press.*

Williamson, R.C. and D.A. Potter. 1998. An innovative approach to black cutworm management. U.S. Golf Assoc. Green Section Record. *In press.*

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