

A. Grant Data, Final Report

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Category: Regional IPM Competitive Grants Program – Northeast Region

Project Title: Integrated management and resistance management of annual bluegrass weevil on golf course turf

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States involved: Connecticut, Massachusetts, New Jersey, New York, Pennsylvania, and Rhode Island

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B. Nontechnical Summary

Annual bluegrass weevil (ABW) is an extremely difficult to manage insect pest for golf course superintendents, especially where insecticide resistance has occurred. This weevil has two to three generations per year in most of the region, and has the ability to build to populations of over 1,000 larvae per square foot, destroying the turf in the process. Prior to the efforts of this project, the predominant approach was to intercept overwintered adults to kill them with a pyrethroid insecticide before they laid eggs. We found that overwintering adults migrate back to low mown turf over an extended interval of time, often in two waves. This emergence behavior, coupled at many sites with resistance to pyrethroid insecticides, often makes the "intercept and kill" strategy ineffective.

Numerous field trials with insect pathogenic nematodes and the insect pathogenic fungus, *Metarhizium anisopliae*, demonstrated that these biological control agents are inconsistent in their ability to suppress ABW populations. In most cases, application of these agents results in insignificant reductions of weevil populations. One test resulted in a delayed effect that increased survival of ABW larvae one weevil generation following nematode application.

Field tests of new insecticides revealed that one product, spinosad (a natural product insecticide approved for organic use), is effective against all stages of developing larvae. This product is expected to be selectively toxic to plant feeders, and so it may be integrated with naturally occurring predators. Two new insecticides, indoxacarb and chlorantraniliprole, were effective against pyrethroid-susceptible ABW, but were mediocre when directed against pyrethroid-resistant ABW. The field reports of failures with these two insecticides, during their first or second season of use, were surprising because they represent modes of action to which these weevils had never been exposed. However, our laboratory studies demonstrated that pyrethroid resistance in several field-collected populations is mediated by multiple detoxification enzyme systems. As the degree of pyrethroid resistance increases, the detoxification ability of the three major enzyme systems also increases. These enzymes may thus be conferring a greater ability to detoxify a wide variety of insecticide substrates. Therefore, intense selection with pyrethroids has jeopardized all other insecticides, too. ABW may present an important cautionary example: mode of detoxification of insecticides may be as important as their mode of action when trying to manage insecticide resistance.

Insecticide synergists were investigated to determine whether, by blocking important metabolic enzymes, they could restore the usefulness of pyrethroids. Demethylation inhibitor (DMI) fungicides, in particular, were found to be able to synergize pyrethroids when tank-mixed. The full potential of this approach needs to be investigated further. The use of synergized pyrethroids may only be appropriate for emergency spot treatments of greens and collar areas where the extremely low mowing height interferes with biological control, makes the turf more easily damaged, and the damage threshold is very low.

Introduction

A recent report by the World Golf Foundation stated that golf contributes \$62.2 billion worth of goods and services each year to the national economy. In the Northeast, the most challenging insect pest affecting golf courses is the annual bluegrass weevil. Unlike products or strategies for managing other turf insect pests, such as white grubs or cutworms, efforts directed to manage annual bluegrass weevil have not been reliably effective. Prior to this project superintendents have reported up to six annual applications of insecticides specifically directed to manage ABW populations, often with little demonstrable benefit. Many of the insecticides used are broad-spectrum products, which can be expected to negatively impact beneficial predator populations. An integrated approach to disease and insect management can help alleviate some of the public concern about pesticide use and benefit the golf industry by increasing the efficiency of pest management efforts.

This project addressed the concerns of golf course superintendents by determining the value of alternative, biologically-based approaches for implementing biological control, determining the most efficient monitoring methods for larval life stages, implementing monitoring for pyrethroid resistance in field populations, and finding newer selective insecticides to suppress weevil populations.

D. Objectives

Research Objectives

1. *To identify and develop new chemical and biological control options for suppressing ABW on golf courses.* This objective was completed. See details under "Progress".
2. *To improve monitoring methods for targeting management of ABW larval stages for control.* This objective was completed. See details under "Progress".
3. *To determine the geographical extent of pyrethroid resistance in annual bluegrass weevil (includes an Extension component).* This objective was completed. Pyrethroid-resistant ABW populations were found in MA, RI, CT, NY, and eastern PA. No resistant populations were found in New Jersey.

Extension Objective

4. *To extend best management practices for ABW to golf course superintendents.* This was an exceedingly successful objective, with full-color publications made available on the web and published in Golf Course Management (subscribed to by virtually all superintendents) and by USGA.

E. Approach

This project relied upon extensive small plot trials, replicated either within trial and state, or in some cases repeated across states by collaborating participants, to provide reliable field evaluations of new pest management options. The extent of pyrethroid

resistance was evaluated in collaboration with golf course superintendents, extension personnel, field representatives of chemical distributors, and technical representatives of chemical companies and the USGA. The extension component (notably the publications in *Golf Course Management* and USGA) involved the entire group in writing and providing photographs.

F. Progress.

Identifying new control options for suppressing ABW populations. Biological options for managing annual bluegrass weevil larvae were found to lack sufficient effectiveness and/or reliability to be practical. Field trials of insect pathogenic nematodes and the insect pathogenic fungus, *Metarhizium anisopliae*, demonstrated that these biological control agents are inconsistent in their ability to suppress ABW populations. In most cases, application of these agents results in statistically insignificant short-term or non-economic reductions of weevil populations. One test investigating longer-term impacts resulted in a delayed effect of 4.6-fold more larvae one weevil generation following nematode application, when compared with the untreated check ($P = 0.002$). We hypothesize that because ABW larvae feed internally, they may be protected from infection through their first three instars, when compared with their carabid predators, which are highly mobile and thus would be continually exposed to nematodes. This hypothesis and the importance of naturally occurring predators in regulating ABW populations needs to be studied further.

Spinosad was found in small plots and from superintendents' applications to be a reliable product for targeting both early- (internal feeding) and late-instar ABW, including pyrethroid-resistant populations. Because spinosad is expected to have limited impact on natural enemies, and has good efficacy against the internally feeding ABW, this product appears to have unique potential for integrated management of ABW.

Among the several new chemical agents identified as having potential against ABW, two (indoxacarb and chlorantraniliprole) were found in small field tests and from superintendents' experience to be unreliable when targeting weevils already resistant to pyrethroids. These two products may have special use in an overall integrated strategy for managing ABW, however. Chlorantraniliprole is known to be effective against white grubs; therefore, it could replace the currently favored neonicotinoids. The overall impact of neonicotinoids vs. chlorantraniliprole on ABW and their naturally occurring predators needs to be studied further. Indoxacarb should have little toxicity to natural enemies (it principally acts through ingestion), and so it can replace pyrethroids and be rotated with other non-pyrethroids (such as spinosad) when managing lepidopteran pests. The moderate efficacy of these two products against pyrethroid-resistant ABW means that their use as primary tools to manage pyrethroid-resistant ABW should be avoided, except where the superintendent has tested the ABW population and found them to be pyrethroid-susceptible.

Synergized pyrethroids were found in field practice to be effective in emergency situations for killing adult weevils and late instars. Superintendents have applied either a pyrethroid with piperonyl butoxide, a well known synergist, or with DMI fungicides (e.g., propiconazole or triadimefon). The ability of these systemic fungicides to block detoxification enzymes (cytochrome P450 enzymes) was discovered in the 1970s, but their synergistic effects had not previously been field tested. Comparison of small scale

field plots, in which the DMI fungicide and pyrethroid were not applied at the same time, and superintendents' results, in which they tank-mixed the products, differed dramatically. Separate applications (several days apart) resulted in no benefit from synergism. The practice of tank-mixing pyrethroids with synergists is not IPM-friendly, because it is inimical to natural enemies. However, natural enemies have little importance on putting greens and collars. Therefore, the benefits and low cost of the ingredients (especially if the fungicide also needs to be applied for disease control) may make this an appropriate option for spot treatment following observation of damage.

Improved monitoring methods. The standard earlier method, using saturated brine, was found to be the only practical approach for quantifying larval populations. However, Ben McGraw, working in Dr. Koppenhöfer's group, found that suction methods (an inverted leaf blower device) provided an effective method to sample adult weevils, and that these population assessments correlated well to later larval populations in turf.

G. Results.

Superintendents now should be able to apply the information that we have provided to them to make much better decisions in managing ABW populations. Emphasis by superintendents on controlling overwintered weevils with pyrethroids as they move to short-mowed turf has already shifted more towards targeting damaging populations of larvae and reduced dependence on pyrethroids for managing other insects.

For courses struggling with pyrethroid-resistant populations, we now can suggest options that are effective and may lead to a balance between chemical and biological control. Best management strategies need to take into account that fairways should be treated differently than greens, collars, and tees, and that management options should be tailored to the aesthetic objective and degree of annual bluegrass growing on the course.

Fairway management: (1) On low-maintenance golf courses, courses with active predator populations, and new golf courses with low annual bluegrass density, insecticides may not be needed to target ABW. This will allow ABW to suppress annual bluegrass so that bentgrass may maintain or reestablish dominance. (2) On courses in which excessive previous pesticide use has excluded predators, where damage thresholds are low, and courses with high populations of annual bluegrass, indoxacarb can be used to target late-instar larvae, or spinosad used to target all instars. This approach should permit reestablishment of predators throughout fairways, the largest area of the golf course and the majority of the ABW population.

Putting greens, collars, and tees: Management of these areas can reasonably include products that are harsh against ants (because ant suppression on putting surfaces is usually needed, anyway) and other predators. Therefore, along with the aforementioned selective options, trichlorfon or a pyrethroid/synergist mixture could be used to kill ABW larvae.

Superintendents still choosing to use pyrethroids to intercept overwintering adult ABW with pyrethroids may still find this to be a useful and inexpensive approach where their weevil populations are determined through testing to be pyrethroid-susceptible. However, experience through southern New England states, New York, and Pennsylvania demonstrates that this approach will eventually result in pyrethroid-resistant populations.

Therefore, continued education on the risks of pyrethroid resistance and the benefits of changing to an integrated management program need to be continued throughout the geographic range of annual bluegrass weevil activity.

H. Impacts.

1. Superintendents shifted away from their prevailing dependence on pyrethroids.

This project, along with the introduction of new insecticide chemistries, has dramatically impacted the management of annual bluegrass weevils on golf courses. In 2008 and 2009, many superintendents shifted from reliance on pyrethroid insecticides. The dominant alternative chemistries adopted to manage ABW were chlorantraniliprole and indoxacarb. Although these insecticides have been effective in some geographical areas, this switch led to unexpected and widespread control failures against pyrethroid-resistant populations. Although the cause of these failures has only partially been explored, the reduced sensitivity to indoxacarb of pyrethroid resistant weevils found in laboratory tests suggests that pyrethroid resistance may lead to multiple insecticide resistance.

2. Superintendents used results from this project to rescue turf following pesticide failure.

In spite of control failures, including sites where chlorantraniliprole or indoxacarb (or both) had been applied, an understanding of insect toxicology developed by this project led to an effective emergency strategy that prevented disastrous loss of turf. In one example, reestablishment of turf would have been impossible through reseeding because a preemergent herbicide had been applied. The dramatically successful chemical control (through the use of a synergized pyrethroid) saved the turf, preventing loss of the playing surface and saving the superintendent's job.

3. An exemplary golf course has adopted a successful integrated approach.

The first golf course to have documented pyrethroid resistance has now experienced two successive years of effective low-cost weevil management. The superintendent relies upon biological control on the fairway, where the only seasonal insecticide application is a single treatment for white grubs. Probably due to the low insecticide use, the fairways of this course have exceptional predatory ground beetle activity and relatively low ABW populations. Greens and tees are treated with indoxacarb to suppress the first larval ABW generation, and then only as needed for any successive generations (in 2008, no additional spraying was needed). While this lower input approach may not provide acceptable results for prestigious golf courses, it demonstrates that superintendents can significantly reduce their insecticide inputs by focusing on greens, tees and collars for managing ABW.

4. Superintendents in all participating states have used insecticide resistance test kits.

These kits have been distributed to chemical distribution field representatives, private turf consultants, chemical company technical representatives, extension agents, cooperators in this project, and directly to superintendents. As a result, superintendents have been better able to make informed decisions regarding their insecticide applications.

5. Superintendents have been taught ABW biology and resistance management.

Articles published in Golf Course Management and USGA's Turf Environmental Research Online reach a wide audience of superintendents (nearly all superintendents subscribe to this publication). This has been complemented by numerous presentations at meetings to superintendents, and by a university-based fact sheet publication.

6. We have advanced the basic understanding of insecticide resistance in ABW, which may be relevant to other pests.

Two publications in Journal of Economic Entomology have identified resistant populations and the underlying nature of the pyrethroid resistance. The publications are: (1) Ramoutar, D., S. R. Alm, and R. S. Cowles. 2009. Pyrethroid resistance in populations of *Listronotus maculicollis* (Coleoptera: Curculionidae) from southern New England golf courses. *J. Econ. Entomol.* 102: 388 – 392. (2) Ramoutar, D., R. S. Cowles, and S. R. Alm. 2009. Pyrethroid resistance mediated by enzyme detoxification in *Listronotus maculicollis* (Coleoptera: Curculionidae) from Connecticut. *J. Econ. Entomol.* 102: 1203 – 1208.

I. Appendices

Please see the attached files:

Cowles et al GCM 2008.pdf
USGA TERO article.pdf
Vittum TERO article.pdf
ABW Peck factsheet.pdf
McGraw and Koppenhofer.pdf