

Northeast Regional IPM Grants Program

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21 September 2006

A. Grant Data

Title: Leveraging Biologicals into the Turfscape: Combining Controls and Exploiting Synergisms for White Grub Management

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State(s) involved: NY

Years funded: 1

Funding amount: \$15,000

B. Nontechnical Summary

White grubs are the most widespread and damaging pests in turfgrass habitats of the Northeast. In this extensive and rapidly expanding component of our urban and rural landscapes, management is highly dependent on the preventive use of chemical insecticides, while biological control alternatives are limited and largely non-efficacious. Integrated pest management would benefit immensely from curative alternatives that would permit sampling and better decision-making, as well as from biological alternatives that could supplant reliance on chemical insecticides. The purpose of this project is to reduce the economic and environmental costs of insecticide dependence in turfgrass systems by evaluating and promoting new approaches to pest management. The main objective is to evaluate and promote biologically based management options for white grubs in turfgrass, with an emphasis on the synergistic interaction between combined biological and chemical control products. In support of future greenhouse and field studies, our approach is to use highly controlled laboratory bioassays to gauge variation in efficacy across white grub species and to preselect a subset of promising combinations that feature sublethal rates of chemical insecticides together with biological products.

C. Introduction

Current white grub control scenarios in turfgrass of the Northeast have essentially closed the door to successful IPM because of dependence on early season preventive applications of imidacloprid. This neonicotinoid insecticide has largely replaced several other products that were

less effective, had higher mammalian toxicity, were withdrawn from registration, or came into disfavor due to FQPA review. Imidacloprid is not effective against large (third instar) grubs, yet earlier life stages (eggs and first instars) are too difficult to target in sampling programs. As a result, imidacloprid is applied early in the season before sampling can assess thresholds, contrary to sound IPM practices. IPM is also compromised by lack of biologically-based control alternatives. The major commercial products based on nematodes and milky spore disease are generally regarded as ineffective, yielding inconsistent results, or too costly for any real role in white grub management. In practical terms, this means that turfgrass managers have no quantitative way to decide when not to spray, and those seeking non-chemical options are stymied by impracticable biological alternatives. IPM of white grubs in turfgrass would benefit immensely from curative alternatives that would permit sampling and better decision-making, and biological alternatives that could supplant reliance on chemical insecticides.

The “critical step” we propose to take in this proposal, is to conduct a series of laboratory bioassays that will launch a systematic and cohesive approach to advance biologically-based management in turfgrass systems. Our focus will be on combining chemical and biological products to yield synergies that offer curative alternatives for control of third instars. Results from these detailed laboratory studies will guide greenhouse and field studies, and in turn integration of new approaches into existing management scenarios.

D. Objectives

The main objective of this project is to evaluate and promote biologically-based management options for white grubs in turfgrass, with an emphasis on the synergistic interaction between combined biological and chemical control products. Five specific objectives were proposed and they are grouped below in three categories of results:

Objective 1a. Screen the efficacy of 15 different registered and experimental bioproducts and curative chemical insecticides to larvae of European chafer in controlled laboratory bioassays.

Objective 1b. Quantify and compare the efficacy of the same products to four white grub species: European chafer, Japanese beetle, Oriental beetle and Asiatic garden beetle.

Outcome. Fourteen products were evaluated in a large concurrent study against third instar larvae of European chafer, Japanese beetle, Oriental beetle and Asiatic garden beetle. Larvae of Japanese beetle, however, suffered such high mortality in the untreated check treatment that the data were not meaningful and this species was discontinued in the trial. Mortality data for the other three species were taken at 10, 20 and 30 days after treatment (DAT). Meaningful data were generated to quantify the variation in efficacy across products, time after treatment and grub species. An experimental fungal entomopathogen product (the fifteenth treatment) could not be included in this trial because of production limitations of the supplier.

Objective 2a. Evaluate and compare the efficacy of different combinations of select bioproducts with three rates of curative chemical insecticides to larvae of European chafer in controlled laboratory bioassays.

Objective 2b. Quantify and compare the efficacy of select chemical/biological combinations to four white grub species: European chafer, Japanese beetle, Oriental beetle and Asiatic garden beetle.

Outcome. Thirty-six combinations of products (two potential chemical synergists, at two rates, with each of nine biological products) were evaluated in a large concurrent study against third instar larvae of European chafer, Japanese beetle and Oriental beetle. Asiatic garden beetle was not included because we were unable to locate collectible fall populations in the field. Mortality data for all three species were taken at 30 DAT. Meaningful data were generated to quantify variation in efficacy across different product combinations and grub species.

Objective 3. Identify the most promising combinations for future greenhouse and field trials by characterizing the interactions as synergistic, additive or antagonistic, and ranking their efficacy and compatibility.

Outcome. The products evaluated in combinations in Objective 2 were also concurrently evaluated as individual applications. Meaningful data were thereby generated to classify the product interactions as synergistic, additive or antagonistic, and to identify the most promising combinations for future greenhouse and field studies. Synergisms were identified for two of three grub species.

E. Approach

We conducted a one-year “critical step” study to initiate a comprehensive and serious evaluation of perspectives for biologically-based management of white grubs in turfgrass systems. To do this, we prescreened white grub control alternatives for a select group of combinations of chemical and biological controls. We sought combinations that (i) featured sublethal rates of a chemical insecticide that served as a synergist in combination with a biological control product, (ii) were efficacious as a curative against third instars, and (iii) gave a high level of control across different white grub species. Our approach was to assess these materials in highly controlled laboratory bioassays.

In the first study, a large concurrent trial was conducted to measure the efficacy of 14 bioproducts and potential chemical synergists against third instar larvae of three white grub species (Table 1). In the second study, a large concurrent trial was conducted to measure the efficacy of 36 combinations of products against three species. The subset of products featured in this experiment were based on the results of the first study. The potential chemical synergists were two neonicotinoid insecticides (imidacloprid and clothianidin), each at two sublethal rates (half and quarter recommended field rates). These were paired with each of nine biological products, which represented three strains of entomopathogenic nematodes, three strains of entomopathogenic fungi, two Bt products, and one product based on the bacteria that causes milky disease. All of these products were also evaluated individually as part of the same concurrent trial. By comparing the efficacy of products applied singly and together, combinations could be identified as synergistic, additive or antagonistic. Based on our three selection criteria, a subset of combinations was identified as the focus of future greenhouse and field studies.

F/G. Progress and Results

Data from the first study on 14 individual products revealed the degree of variation in efficacy across grub species and over the time period of 10, 20 and 30 DAT (Table 2). For instance, chlorpyrifos and trichlorfon demonstrated full efficacy against Oriental beetle within 10 days, but in Asiatic garden beetle and European chafer this was delayed until 20 days. These results reinforce the idea that diagnosis and species identification is relevant to white grub management given the variation in product efficacy across species. This is critical in the Northeast where eight species can be problematic in turfgrass.

One product, *Steinernema scarabaei*, exhibited no variation across species or time of evaluation. This highly pathogenic nematode was isolated and identified by Rutgers University where it remains a focus of biological control studies. Our results confirmed it to be a fast-acting and highly effective biological against third instars white grubs of three species. One limitation to its promotion and use is that it cannot be mass-produced commercially. Given its high efficacy alone, we did not feature this product among the synergisms evaluated in the second study.

Data from the second study revealed promising synergistic combinations (Table 3). For European chafer, both imidacloprid and clothianidin were synergistic with one strain of entomopathogenic nematode. For Japanese beetle, there were synergisms between both of the neonicotinoids and fungal entomopathogens, but antagonism with one strain of Bt. For Oriental beetle, no synergisms were detected, but there were antagonisms with one strain of Bt and two strains of fungal entomopathogens. It is our experience that Oriental beetle is more susceptible to control products in general. We therefore cannot discard the idea that synergisms might be uncovered if lower rates of active ingredients were to be evaluated.

This project was successful in identifying a subset of combinations that feature sublethal rates of least-toxic insecticides with biological controls. Alone, each is ineffective against large late-season grubs, but together they operate synergistically to kill a majority of grubs. The most promising pairs are varying sublethal rates of neonicotinoids (half, quarter and lower rates) in combination with different strains of entomopathogenic nematodes and entomopathogenic fungi. Given the variation across grub species, however, the combinations may have to be tailored to each pest species. This subset is now available for advancement to greenhouse and field trials on its way to incorporation into white grub IPM programs.

H. Impacts

The results from this study broaden future opportunities for biologically-based pest management in three specific ways. First, we have identified promise for new combinations of products. There is published evidence that neonicotinoids and presence of endophytes in the host plant can act as synergists with entomopathogenic nematodes in white grubs. As far as we are aware, however, our results are the first to document a synergy involving fungal entomopathogens in this pest complex. Second, the protocols established here should streamline future evaluations so that even broader combinations of biologicals and synergists can be explored. And third, our prescreening selection has generated a reduced set of promising combinations that is ready to advance to more rigorous studies.

As a result, we have obtained additional funding to move this new approach toward real field application. Scaling out will be done by conducting (i) pot trials in the greenhouse, (ii) microplot field trials with artificially-infested populations, and (iii) small plot field trials with natural populations. The end point will be participatory large-scale field trials on golf course fairways, to compare and contrast traditional preventive and curative controls with the two best synergistic combinations, and to identify curative and reduced-pesticide control alternatives that will be implemented and adopted by stakeholders to improve IPM in turfgrass. Documenting the process of discovery and exploitation of synergistic interactions should guide the development of biologically-based pest management options for soil insect pests in other turfgrass and horticultural systems.

Real-world impacts from this work will only be realized after we complete the series of studies outlined above. At that point, adoption of one or more of the combinations promoted here would supplant the use of trichlorfon with a less toxic alternative and promote gains in human and environmental health. It might even lure pest managers away from preventive use of imidacloprid toward decision-making based on scouting and thresholds and then, if necessary, spot treatment with a curative combination of low rate chemical synergist with a biological. This would promote gains in the implementation of best IPM practices. Given the relatively high cost of biologicals with respect to current chemical insecticides, it remains to be seen how adoption might be limited by expense, or whether adoption would come with economic benefits. New biological products, however, are still being actively developed by the commercial sector. Each product will essentially represent a new opportunity to channel through this research and evaluation approach.

The barriers to biologically-based pest management in turfgrass are still formidable. But we maintain that there is potential for future implementation given aggressive pesticide regulation in certain counties and municipalities of NY, given the growing demand for reduced-pesticide control alternatives by stakeholders, and given the high value, management intensity, and geographic area of the affected commodity. In this scenario we feel that our comprehensive approach is warranted, and we hope that it will open one avenue through which biologicals could be leveraged into the turfcape and broaden opportunities for biologically-based pest management.

I. Appendices

Table 1. White grub control products (17) evaluated in controlled laboratory bioassays against third instars.

Table 2. Variation in the efficacy (% mortality) of different control products against three white grub species measured 10, 20 and 30 days after treatment (DAT).

Table 3. Variation in the efficacy (% mortality) of biological products combined with sublethal rates (1/2 and 1/4 recommended field rates) of neonicotinoid insecticides across three white grub species (30 DAT).

Table 1. White grub control products (17) evaluated in controlled laboratory bioassays against third instars.

Control agent	Active Ingredient	Commercial name	Company	Rate ¹
Biologicals:				
Bacterial pathogen	<i>Paenibacillus popilliae</i>	Milky Spore	St. Gabriel Laboratories	1 lb/400 sq ft
Entomopathogenic nematode	<i>Heterorhabditis bacteriophora</i>	Heteromask	BioLogic	1900 AU/sq ft
	<i>Heterorhabditis</i> sp. NYSAES Nema 1	---	NYSAES	1900 AU/sq ft
	<i>Heterorhabditis</i> sp. NYSAES Nema 2	---	NYSAES	1900 AU/sq ft
	<i>Steinernema scarabaei</i>	---	Rutgers University	103 IJ3/cup
Fungal entomopathogen	<i>Beauveria bassiana</i> GHA	Botanigard ES	Emerald BioAgriculture	2 qts/5000 sq ft
	<i>Metarhizium anisopliae</i>	Met F52	---	1 x 10 ⁸ con/cup
	<i>Metarhizium anisopliae</i>	NYSAES	NYSAES	1 x 10 ⁸ con/cup
Biopesticides:				
<i>Bacillus thuringiensis</i>	<i>Bt</i> SDS502	---	Phyllom	0.12 g/sq ft
	<i>Bt</i> var <i>tenebrionis</i>	Novodor FC	Valent BioSciences	4 qt/acre
Diatomaceous earth	Diatomaceous earth	Concern	Woodstream	0.1 g/cup
Spinosad	Spinosad	Conserve SC	Dow Agrosiences	1538 ml/acre
Chemical insecticide:				
Neonicotinoid	Clothianidin	Arena 50 WDG	Arvesta	448 g AI/ha
	Imidacloprid	Merit 0.2%	Bayer	3 lb/100 sq ft
Organophosphate	Thiamethoxam	Flagship 25 WG	Syngenta	1200 g/ha
	Trichlorfon	Dylox 80	Bayer	3.75 oz/1000 sq ft
	Chlorpyrifos	bait formulation	Grotech	36 g/50 ft
Untreated check	---	---	---	1 ml water/cup

¹ AU = Active units. IJ3 = Third instar infective juveniles. AI = Active ingredient. con = Conidia.

Table 2. Variation in the efficacy (% mortality) of different control products against three white grub species measured 10, 20 and 30 days after treatment (DAT). For each time of evaluation, shaded cells in bold indicate values that are significantly higher than (i) other treatments and (ii) the other two grub species. For instance, efficacy of trichlorfon at 10 DAT for Oriental beetle is significantly higher than (i) all other products evaluated against Oriental beetle except chlorpyrifos and *S. scarabaei*, and (ii) trichlorfon at 10 DAT for Asiatic garden beetle and European chafer.

Treatments	Oriental beetle			Asiatic garden beetle			European chafer		
	10 DAT	20 DAT	30 DAT	10 DAT	20 DAT	30 DAT	10 DAT	20 DAT	30 DAT
<i>B. bassiana</i> GHA	14.0	63.0	83.0	7.0	15.0	51.0	14.0	28.0	54.0
<i>Bt var tenebrionis</i>	11.0	34.0	65.0	12.0	17.0	54.0	19.0	32.4	44.0
<i>Bt</i> SDS502	5.0	48.0	74.0	4.0	28.0	65.0	9.0	27.0	55.0
Chlorpyrifos	89.0	96.0	99.0	69.0	91.0	94.0	45.0	91.0	100.0
Clothianidin	60.0	91.0	99.0	45.0	79.0	100.0	48.3	64.5	85.6
Diatomaceous earth	5.0	29.0	66.0	13.0	24.0	50.0	29.0	40.0	57.0
<i>H. bacteriophora</i>	28.0	51.0	72.0	21.0	28.0	57.0	22.0	32.0	49.0
<i>Heterorhabditis</i> sp. Nema 1	14.0	39.0	69.0	6.0	19.0	59.0	16.0	30.0	54.0
Imidacloprid	10.0	45.0	76.0	40.0	77.0	94.0 a	25.0	51.4	71.6
<i>P. popilliae</i>	16.0	43.0	75.0	8.0	15.0	47.0	14.0	20.2	31.0
Spinosad	10.0	41.0	70.0	15.0	31.0	84.0	19.0	24.0	41.0
<i>S. scarabaei</i>	96.0	94.0	98.0	96.0	98.0	98.0	92.0	99.0	99.0
Thiamethoxam	33.0	65.0	84.0	35.0	47.0	79.0	19.0	26.0	48.0
Trichlorfon	96.0	96.0	97.0	73.0	98.0	100.0	56.0	87.0	94.0
Untreated check	8.0	37.0	22.0	7.0	17.0	20.0	4.0	15.0	19.0

Table 3. Variation in the efficacy (% mortality) of biological products combined with sublethal rates (1/2 and 1/4 recommended field rates) of neonicotinoid insecticides across three white grub species (30 DAT). Shaded cells in bold indicate synergisms. Shaded cells in italics indicate antagonisms.

Treatment	Effect ¹	European chafer				Japanese beetle				Oriental beetle			
		Imidacloprid		Clothianidin		Imidacloprid		Clothianidin		Imidacloprid		Clothianidin	
		1/2	1/4	1/2	1/4	1/2	1/4	1/2	1/4	1/2	1/4	1/2	1/4
<i>H. bacteriophora</i>	+	33.3	30.0	30.0	23.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	X	75.0	80.0	58.3	41.7	100.0	96.9	100.0	91.3	100.0	96.9	100.0	91.3
<i>Heterorhabditis</i> sp. Nema 1	+	11.7	8.3	8.3	1.7	61.7	60.0	40.0	53.3	74.4	99.4	67.5	78.1
	X	13.3	13.3	8.3	6.7	58.3	53.3	63.3	53.3	63.1	67.5	71.9	60.0
<i>Heterorhabditis</i> sp. Nema 2	+	16.7	13.3	13.3	6.7	67.5	81.9	61.3	78.1	67.5	81.9	61.3	78.1
	X	8.3	6.7	11.7	6.7	74.4	76.3	68.8	68.1	74.4	76.3	68.6	68.1
<i>B. bassiana</i> GHA	+	10.0	6.7	6.7	0	58.3	56.7	36.7	50.0	87.5	<i>100.0</i>	80.6	<i>91.3</i>
	X	10.0	10.0	10.0	6.7	75.0	53.3	83.3	80.0	55.0	<i>65.0</i>	73.1	<i>64.4</i>
<i>P. popilliae</i>	+	13.3	16.7	13.3	6.7	62.5	76.9	56.3	73.1	62.5	76.9	56.3	73.1
	X	3.3	1.7	10.0	8.3	76.9	58.2	85.0	46.9	76.9	58.2	85.0	46.9
<i>Bt</i> var <i>tenebrionis</i>	+	8.3	11.7	8.3	1.7	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>	<i>100.0</i>
	X	3.3	3.3	13.3	5.0	<i>71.3</i>	<i>59.4</i>	<i>73.2</i>	<i>3.2</i>	<i>71.3</i>	<i>59.4</i>	<i>73.1</i>	<i>3.1</i>
<i>M. anisopliae</i> Met F52	+	10.0	6.7	6.7	0	61.7	60.0	40.0	53.3	76.9	100	70.0	80.6
	X	6.7	11.7	5.0	1.7	78.3	61.7	78.3	61.7	73.8	75.6	71.9	75.0
<i>M. anisopliae</i> NYSAES	+	15.0	11.7	11.7	5.0	68.3	66.7	46.7	60.0	60.6	75.0	54.4	71.3
	X	23.3	20.0	10.0	11.7	83.3	45.0	66.7	56.7	75.6	71.9	84.4	53.2
<i>Bt</i> SDS502	+	10.0	6.7	6.7	0	68.8	83.1	62.5	79.4	68.8	83.1	66.3	62.5
	X	3.3	1.7	8.3	8.3	78.3	68.2	73.8	66.3	78.1	68.1	79.4	73.8

¹ + = summed efficacy of products when applied individually. X = efficacy of products applied together.