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Developing Optimal Management Programs for Annual Bluegrass Weevil Populations with Different Insecticide Resistance Levels

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Summary: Over 2 years we tested standard adulticides and larvicides for the control of pyrethroid-susceptible, -tolerant (30x), resistant (95x), and highly resistant (343x) annual bluegrass weevil (ABW) populations in field experiments. Results were consistent over the two years and indicated that the efficacy of Talstar, Dursban, Provaunt, and Conserve against ABW adults declines with pyrethroid-resistance level of the populations, starting around the 95x resistance level. These adulticides were completely ineffective against highly resistant populations, and Dursban was not an effective replacement for pyrethroids. Among the early and late larvicides tested, only Ference and Conserve were unaffected by resistance. Provaunt was effective up to the 95x level but completely ineffective against highly resistant ABW larvae. Efficacy of Acelepryn, Arena, and Dylox was strongly reduced at the 95x and 343x levels. Based on our findings, recommendations for sustainable management of ABW populations with different resistance levels are presented.

INTRODUCTION

The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a serious pest of short-mown golf course turf. Severe infestations are now reported from all states of the Northeast and Mid-Atlantic, and beyond. Over the last 10 years ever more courses have experienced increasing problems with managing ABW. Superintendents may make up to 10 applications per season. Insecticide overuse has led to the development of pesticide-resistant populations on an increasing number of golf courses (McGraw & Koppenhöfer 2017a,b). To make matters worse, the efficacy of most insecticides against pyrethroid-resistant ABW populations seems to be reduced based on a summary of efficacy tests (Koppenhöfer et al. 2012). Only spinosad (Conserve, new formulation MatchPoint) and the new anthranilic diamide Ference (cyantraniliprole) seem to be unaffected. But because resistance in ABW seems to be at least in part due to enhanced enzymatic detoxification, a rather non-specific mechanism, overuse of any remaining effective synthetic insecticides will eventually result in resistance to those compounds, too. Careful measures need to be taken to prevent resistance development in new populations and to new chemistries, and to effectively manage already resistant populations.

Using topical bioassays we had determined resistance levels and cross resistance patterns to the major insecticide modes of action in adult ABW (Kostromytska et al. 2018). Populations collected at Rutgers Hort Farm II and two county courses were highly susceptible. Six other populations had various levels of pyrethroid resistance, with Resistance Ratios (RR_{50} = LD_{50} of resistant / LD_{50} of the most susceptible population) ranging 14-343 for bifenthrin and 8-324 for λ-cyhalothrin. Pyrethroid resistant populations also demonstrated elevated tolerance to chlorpyrifos (RR_{50}s 3-16), clothianidin (RR_{50}s 3-10), and spinosad (RR50s 3-5). Lab tests confirmed the role of enzymatic detoxification in ABW resistance. Greenhouse tests showed very similar resistance patterns in adults but also indicated increased tolerance and resistance of larvae to several larvicides, albeit at lower RR50s than for the pyrethroids in adults.
The limited number to-date of field observations on resistance originate from product efficacy testing trials (summarized in Koppenhöfer et al. 2012) that were not designed to truly understand how resistance affects product efficacy and that had at best characterized resistance in simple

yes/no assays. We here tested the commonly used ABW adulticides and larvicides on four golf courses representing the full spectrum of pyrethroid-resistance as clearly characterized in our lab/greenhouse studies.

Field testing
To understand how to put together optimal management programs for different resistance levels, we studied the individual tools separately (different products applied only once at specific times). We tested the efficacy of individual applications of the commonly used adulticides and larvicides on fairways at four golf courses representing the full spectrum of pyrethroid-resistance as clearly characterized in our lab and greenhouse studies. RR_{50}s to the pyrethroid bifenthrin at the four courses were 2, 30, 95, and 343.

Insecticide applications targeting adults were tested in separate experiments from those targeting larvae to keep the size of experiments manageable. Adulticides (Table 1) were applied at the optimal timing to control overwintered adults, i.e., when most adults have moved onto the short mown areas in spring but before females start laying eggs as determined by vacuum sampling of adults, degree day accumulation (base 50 °F; starting March 1: 120 GDD_{50}), and indicator plant phenology (forsythias half gold : half green). Larvicides (Table 1) were applied to target young larvae around late bloom of flowering dogwood (200 GDD_{50}) and mid-size larvae around full bloom of hybrid Catawba rhododendron (400 GDD_{50}). Treatments were evaluated at around 700 GDD_{50} when most developmental stages were around the 5th instar.

These tests were conducted in the first and second project years. The data for the 2 years followed a similar trend so that data from the 2 years of field study with a total two trials conducted at each resistance level were combined for analysis. Because year did not interact statistically significantly with insecticide resistance level or treatment, we present below the data for the 2 years of study combined.

For adulticides, control at 2x and 30x resistance was higher than at 95x, and control was the lowest at 343x. At the 2x and 30x resistance levels, all insecticides significantly reduced ABW populations; at the 100x and 343x levels, none of the insecticides caused significant reduction (Fig. 1, left). Compared to each insecticide's efficacy at the 2x level, Talstar and Conserve efficacy was only significantly reduced at the 343x level whereas Provaunt efficacy was significantly reduced at the 95x and 343x levels. While Dursban efficacy was not significantly affected, at least in part due to its already poor performance against at the 2x level, it clearly did not provide control of the resistant populations.

For larvicides (Fig. 1, right), timing of application did not affect efficacy of Acelepryn, Ference, and Arena except that at the 95x level Arena was less effective when applied against the young larvae. Resistance levels and insecticides interacted significantly. Compared to each insecticide's efficacy at the 2x level, Ference and Conserve were not affected by resistance level, Provaunt was significantly less effective at the 343x level, and all other insecticides were significantly less effective at the 95x and 343x levels. At the 2x and 30x resistance levels, Ference, Conserve, Provaunt and Dylox were the most effective insecticides, whereas Arena and Acelepryn were the least effective insecticides. At 95x, Ference was the most effective insecticide followed by Provaunt and Conserve, whereas Acelepryn (late application), Arena (late application) and Dylox provided only 30-42% control, and the early applications of Arena and Acelepryn provided no significant control. At 343x, only Ference and Conserve provided significant control.

Implications
The pattern of insecticide efficacy against ABW populations with different resistance levels may vary somewhat between different golf courses based on their specific history of insecticide use. Nonetheless, the findings in this study combined with previous observations show a robust pattern that can serve as the base for recommendations for ABW control at different pyrethroid-resistance levels. In view of the serious resistance issues, the following recommendations are made:

1. Minimize applications of synthetic insecticides both in space and time as much as possible, whether managing susceptible or resistant populations.

2. Shift control measures more from management of adults to management of larvae. This allows for more informed decisions on the need for applications. Early larvicides allow monitoring adults past their peak densities in spring. Late larvicides allow monitoring of larval densities which is a more precise predictor of damage potential than adult densities.

3. For ABW populations with bifenthrin RR50s of around 30, even though the efficacy of most insecticides may not be significantly reduced, yet, the first two recommendations should be seriously considered to not further increase the resistance level.

4. For ABW populations with bifenthrin RR_{50}s approaching 95 (possibly starting as low as 50), management efforts should concentrate on larvae using the remaining effective larvicides Ference, Conserve (or new formulation MatchPoint), and Provaunt.

5. Against highly resistant populations, only the remaining effective larvicides Ference and Conserve/MatchPoint are still effective.

6. Against resistant populations, biological and biorational control alternatives in rotation with the remaining effective synthetic insecticide alternatives Ference and Conserve/MatchPoint should be used to delay further resistance development. These approaches need to be complemented with cultural methods.

Effective implementation of the above management recommendations for different insecticide resistance levels in ABW will require efficient resistance detection and monitoring tools. We have developed a simple Petri dish test using formulated bifenthrin and chlorpyrifos that has sufficient discriminating power, accurately reflects resistance levels and is easy to conduct. This test could be used by consultants and diagnostic laboratories to help golf courses determine the resistance level of their ABW populations and thereupon select best management practices and insecticide choices for their ABW populations.

References

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Table 1. Insecticides tested against adults (Ad), young larvae (L1-2), and mid-size larvae (L2-4) of ABW.

Insecticide class	Active ingredient	Trade name	Rate (lb ai/ac)	Targets
Pyrethroid	Bifenthrin	Talstar	0.100	Ad
Organophosphate	Chlorpyrifos	Dursban	1.000	Ad
	Trichlorfon	Dylox	6.000	L2-4
Spinosyn	Spinosad	Conserve	0.400	Ad, L2-4
Oxadiazine	Indoxacarb	Provaunt	0.225	Ad, L2-4
Anthranilic diamide	Chlorantraniliprole	Acelepryn	0.156	L1-2, L2-4
	Cyantraniliprole	Ference	0.156	L1-2, L2-4
Neonicotinoid	Clothianidin	Arena	0.247	L1-2, L2-4

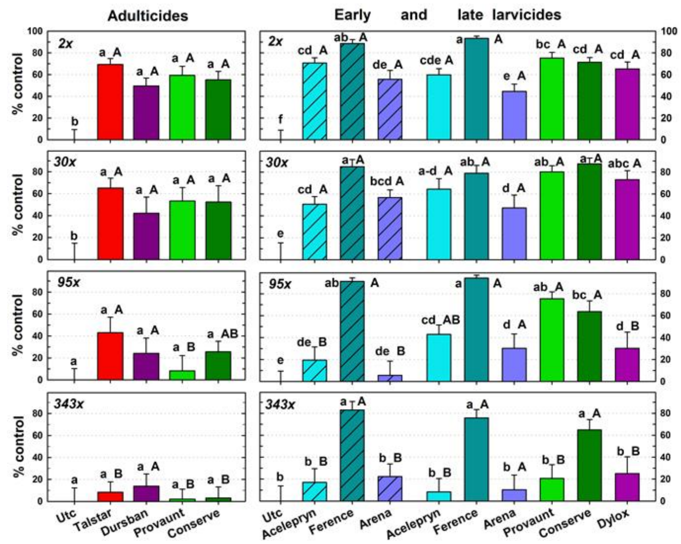

Fig. 1. Effect of pyrethroid resistance level (top to bottom: 2x, 30x, 95x, 343x) on control of annual bluegrass weevil developmental stages in early June (peak 4th to 5th instar) in golf course fairways treated in spring with adulticides at peak densities of overwintered adults (forsythias half gold : half green) (left side panels) or with larvicides targeting young larvae (late bloom dogwood; early larvicides) or mid-size larvae (full bloom rhododendron; late larvicides) (right side panels). Data are combined from two trials over 2 years for each resistance level. Means within each panel with the same lower case letter did not differ significantly (P > 0.05). Means within product and timing (vertical) with the same capital letter did not differ significantly (P > 0.05).

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