2016-22-572

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

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Objectives: The overall goal is to develop a better understanding of the degree and scope of insecticide resistance in ABW populations as a basis for the development of recommendations on resistance management. For this project in particular, the objective is: Compare field efficacy of typical insecticides used against ABW adults and larvae against four ABW populations representing the full scope of insecticide resistance levels observed to date.

Summary Text:
The annual bluegrass weevil (ABW), *Listronotus maculicollis*, is a serious and expanding golf course pest with demonstrated ability to develop resistance to a range of insecticides. Previous and ongoing in depth studies on ABW insecticide resistance have been restricted to laboratory and greenhouse studies. Field observations on resistance originated from product efficacy testing trials that are generally not designed to truly understand how resistance affects product efficacy. 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 studies. Resistance ratios (RR_{50}s) to the pyrethroid bifenthrin at the four courses were 2, 30, 100, 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) (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 Catwba rhododendron, 400 GDD_{50}). Treatments were evaluated at around 700 GDD_{50} when most developmental stages were around the 5th instar. Data from two years of field study with two trials conducted at each resistance level were combined for analysis, and year did not interact with insecticide resistance level or treatment.

For adulticides, we observed no interaction between resistance level and insecticides. Control at 2x and 30x resistance was higher than at 100x, and control was the lowest at 342x. All insecticides caused significant control. Talstar gave higher control than Provaunt, but Dursban and Conserve did not differ significantly from either. At 2x and 30x, all insecticides significantly reduced ABW populations; at 100x only Talstar caused significant reduction; and at 343x none of the insecticides caused significant reduction (Fig. 1, left). All adulticides were significantly affected by resistance.

For larvicides (Fig. 1, right), timing of application did not affect efficacy of Acelepryn, Ference, and Arena except that at the 100x level Arena was less effective when applied against the young larvae. Resistance level and insecticide interacted significantly. 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 100x 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 100x, 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.

Summary Points:

- Efficacy of Talstar, Dursban, Provaunt, and Conserve against ABW adults declines with pyrethroid-resistance level, starting around the 100x resistance level, and they are completely ineffective against highly resistant populations.
- Dursban is not an effective replacement for pyrethroids in control of ABW adults.
- Ference, Acelepryn, and Arena appear to be similarly effective if applied against young larvae or mid-size larvae.
- Ference and Conserve as larvicides appear to be unaffected by resistance to date.
- Provaunt is effective up to the 100x level but completely ineffective against highly resistant ABW larvae.
- Acelepryn, Arena, and Dylox are strongly affected by resistance starting around the 100x level.

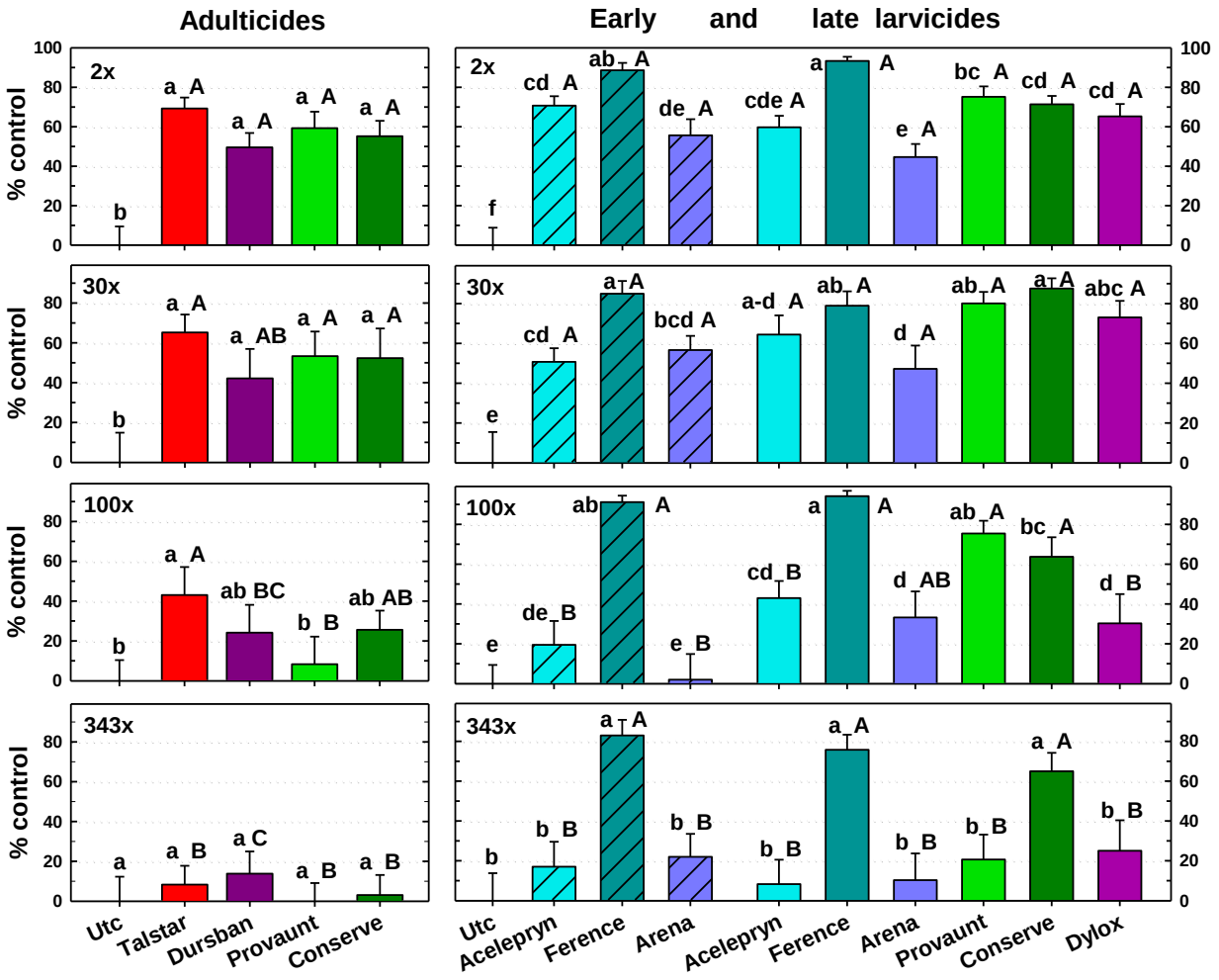

Fig. 1. Effect of pyrethroid resistance level (2x, 30x, 100x, 343x) on control of annual bluegrass weevil developmental stages in early June (peak 4th to 5th instar) in golf course fairways treated in spring with adulticides at peak densities of overwintered adults (forsythias half gold : half green), with early larvicides targeting young larvae (late bloom dogwood), or with late larvicides targeting mid-size larvae (full bloom rhododendron). Data are combined from two trials over two years for each resistance level. Means within product and timing (vertical) followed with the same capital letter did not differ significantly ($P > 0.05$). Means within each panel with the same lower case letter did not differ significantly ($P > 0.05$).

Table 1. Insecticides tested against adults (Ad) and young (L1-2) and older (L2-4) ABW larvae.

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