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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 4 ABW populations representing the full scope of insecticide resistance levels observed to date.

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 (incl. our own) on ABW insecticide resistance have been restricted to laboratory and greenhouse studies. Any to-date field observations on resistance originate from product efficacy testing trials that are generally poorly designed to truly understand how resistance affects product efficacy and that have, if at all, characterized resistance in simple yes/no Petri dish assays. Only by studying the individual tools separately (different products applied only once at specific times) will it be possible to understand how to put together optimal management programs for different resistance levels. Our ongoing research is specifically designed to test 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, 95, and 343.

To keep the size of experiments manageable, insecticide applications targeting adults were tested in separate experiments from those targeting larvae. 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. Timing was 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 5th instar.

For adulticides, we observed no interaction between resistance level and insecticides. Control at 2x and 30x resistance was higher than at 95x, and control was the lowest at 342x. All insecticides caused significant control but there were no differences among insecticides. At 2x and 30x, all insecticides except Dursban significantly reduced ABW populations; at 100x only Talstar caused significant reduction; and at 343x none of the insecticides caused significant reduction (Fig. 1, left).

For larvicides (Fig. 1, right), timing of application did not affect efficacy of Acelepryn, Ference, and Arena. Resistance level and insecticide interacted significantly. Ference was not affected by resistance level; Conserve only showed a difference between 30x and 343x, but not between any other timings; and all other insecticides were significantly affected by resistance, although, due to high variability in the data, not always consistently. Repeating these experiments should further clarify the effects of resistance on the various insecticides. However, the findings already indicate that Ference might be the most effective insecticide against highly resistant ABW population followed by Conserve. Provaunt seems to be the only other insecticides that does not seem to be affected up to the 95x level, but it is completely ineffective at the 343x level.

- Talstar, Dursban, Provaunt, and Conserve efficacy against ABW adults declines with pyrethroid-resistance level, starting around the 95x resistance level, and they are completely ineffective against highly resistant populations.
- Dursban is not an effective replacement for pyrethroids.
- Ference and Conserve as larvicides appear to be unaffected by resistance to date.
- Provaunt is effective up to the 95x level but completely ineffective against highly resistant ABW larvae.
- Acelepryn, Arena, and Dylox are strongly affected by resistance starting around the 95x level.

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	L3-4
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

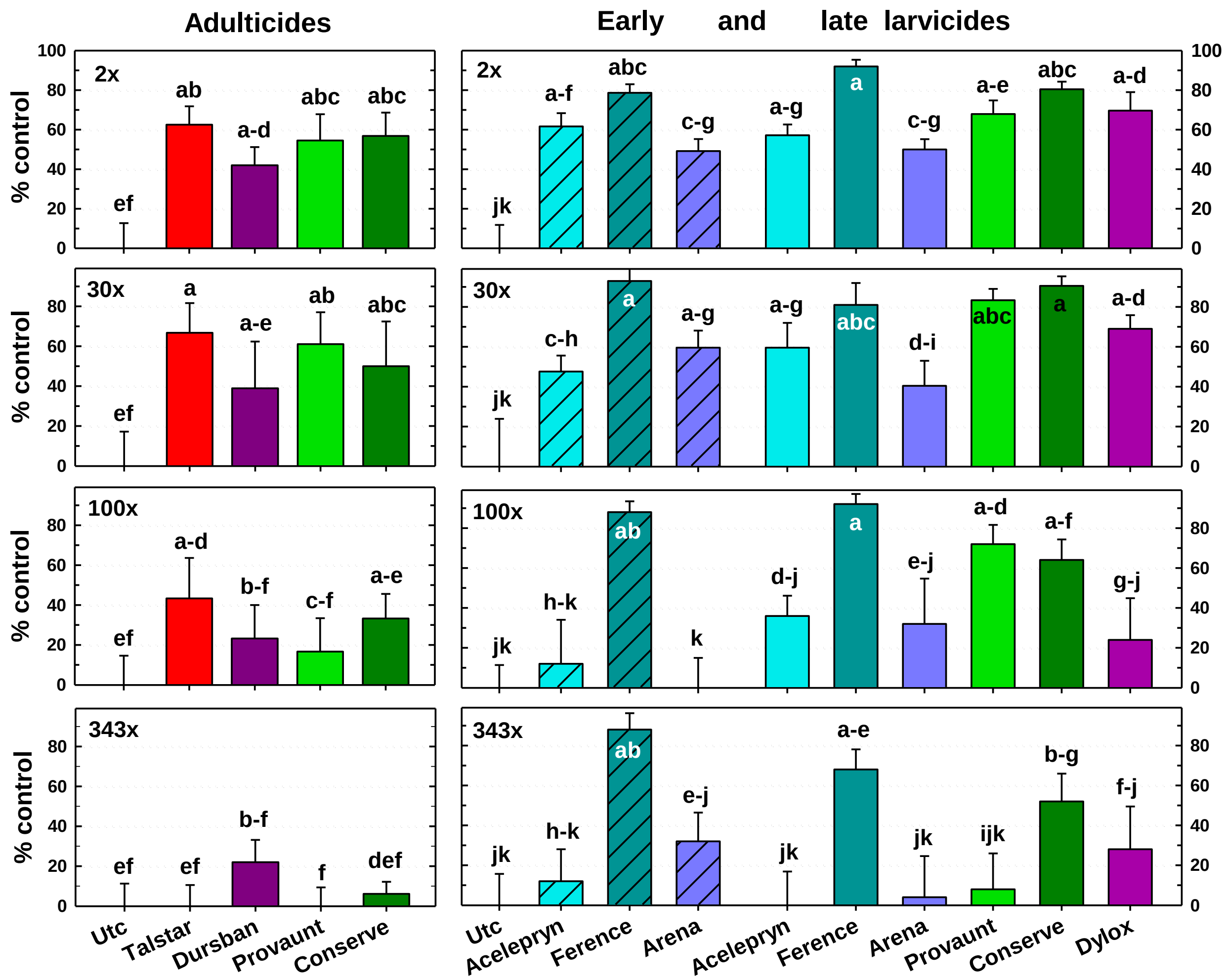

Fig. 1. Effect of pyrethroid resistance level (2x, 30x, 100x, 343x) on control of annual bluegrass weevil developmental stages in early June (peak 4th to 5th instar) in golf course fairways treated in spring with adulticides at peak densities of overwintered adults (forsythias half gold : half green), with early larvicide targeting young larvae (late bloom dogwood), or with late larvicides targeting mid-size larvae (full bloom rhododendron). Means within the four left panels combined and the four right panels combined, respectively, with the same letter did not differ significantly ($P > 0.05$).