Title: Biorational control of important golf turf insect pests

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Objectives: The overall goal is to develop a better understanding of the role that biorational insecticides can play in the management of important golf turf insect pests with particular emphasis on the annual bluegrass weevil to facilitate insecticide resistance management in this difficult-to-control pest.

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. The primary purpose of this project is to develop biorational alternatives for the management of ABW as safer and more sustainable alternatives to traditional synthetic insecticides that will also facilitate better insecticide resistance management. Biorational materials are being tested on golf course fairways against insecticide-susceptible and -resistant ABW adults and larvae. They are also being tested against larvae of white grubs and black cutworm because treatments against these pests could be done at the same time as for ABW, increasing chances of adoption of the biorational controls and further decreasing insecticide applications.

The four biorationals tested are Grandevo (based on *Chromobacterium subtsugae* strain PRAA4-1 and its fermentation products), Venerate (based on heat-killed *Burkholderia* spp. strain A396 bacteria and their fermentation products), BotaniGard ES (based on the entomopathogenic fungus *Beauveria bassiana* GHA strain), and Molt-X (based on the botanical azadirachtin). These products have reasonable costs, product stability, and relatively long shelf lives at room temperature, and have very different modes of action unlikely to be affected by the broad insecticide resistance observed with ABW.

All experiments presented here were conducted with a pyrethroid-resistant ABW population with a resistance ratio (RR_{50}) of around 100x compared to the most pyrethroid-susceptible population determined by us. Molt-X showed some promise when applied when eggs and first to second instar larvae peaked (38 - 49% control) but was ineffective when applied against third and fourth instars (Tables 1, 2). BotaniGard applied against third and fourth instars was ineffective, whether applied alone or in combination with Merit or Molt-X (Table 1).

BotaniGard was unreliable when applied when densities of overwintered adults peaked (0 - 42%) (Figs. 1, 2). The pyrethroid-based product Talstar (AI bifenthrin) alone also was ineffective (0 - 34%) as was the organophosphate-based product Dursban (AI chlorpyrifos). Talstar but not Dursban interacted synergistically with BotaniGard with the BotaniGard-Talstar combinations providing up to 84% control (Figs. 1, 2). Combinations of BotaniGard and Talstar may offer an effective control option in the management of insecticide-resistant ABW populations. The mechanism of this interaction is being studied in the laboratory.

BotaniGard, Molt-X, and their combination were also tested against a white grub population consisting primarily of oriental beetle and Asiatic garden beetle. BotaniGard (1.2 lbs AI/acre)

and Molt-X (0.04 lbs AI/acre) were applied twice 1 week apart in late July targeting primarily 1st instars or in mid-August targeting primarily 2nd instars. However, none of the treatments provided statistically significant control and there were no consistent trends apparent among the different white grub species, products, and application timings.

- The pyrethroid bifenthrin (Talstar) and the organophosphate chlorpyrifos (Dursban) were ineffective against insecticide-resistant ABW adults.
- BotaniGard (AI: *Beauveria bassiana*) was ineffective against ABW larvae and adults.
- Talstar and BotaniGard interacted synergistically providing effective control of ABW adults.
- Molt-X (AI: azadirachtin) is ineffective against larger ABW larvae but shows promise when applied against eggs and young larvae.

Table 1. Densities (± SE) of annual bluegrass weevil developmental stages in early June (peak 4th to 5th instar) in a golf course fairway treated with Merit 75WP, sequential applications of Molt-X and BotaniGard ES, and their combinations.

Treatment	Rate (lb AI/acre)	ABW stage targeted	No. of stages / ft^2 (% control)
Untreated Control	---	---	44.1 ± 9.6
Molt-X	0.04[a] 0.04	E[c] L1	22.5 ± 14.1 (49)
Molt-X	0.04 0.04	L3 L3-4	47.7 ± 16.5 (0)
Merit 75WP	0.30	L3	27.0 ± 6.0 (39)
BotaniGard	0.65[b] 0.65	L3 L3-4	52.2 ± 22.5 (0)
BotaniGard + Molt-X	0.65 + 0.04 0.65 + 0.04	L3 L3-4	45.0 ± 15.4 (0)
BotaniGard + Merit	0.65 + 0.30 0.65	L3 L3-4	48.6 ± 19.4 (0)

No significant difference were observed among treatments ($P = 0.48$).
[a] 0.5 fl oz product/1,000 ft^2; [b] 2 fl oz product/1,000 ft^2; [c] E = egg; L1 - L4 = 1st - 4th instar larvae

Table 2. Densities (± SE) of annual bluegrass weevil developmental stages in early June in a golf course fairway treated with sequential applications of Molt-X.

Treatment	Rate (lb AI/acre)	ABW stage targeted	No. of stages / ft^2 (% control)
Untreated Control	---	---	90.0 ± 22.3 a
Molt-X	0.04[a] 0.04	E[b] L1	54.0 ± 17.0 b (40)
Molt-X	0.04 0.04	L1 L2	55.5 ± 15.2 b (38)

Means with same letter are not signficantly different ($P > 0.05$).
[a] 0.5 fl oz product/1,000 ft^2.
[b] E = egg; L1 - L2 = 1st - 2nd instar larvae

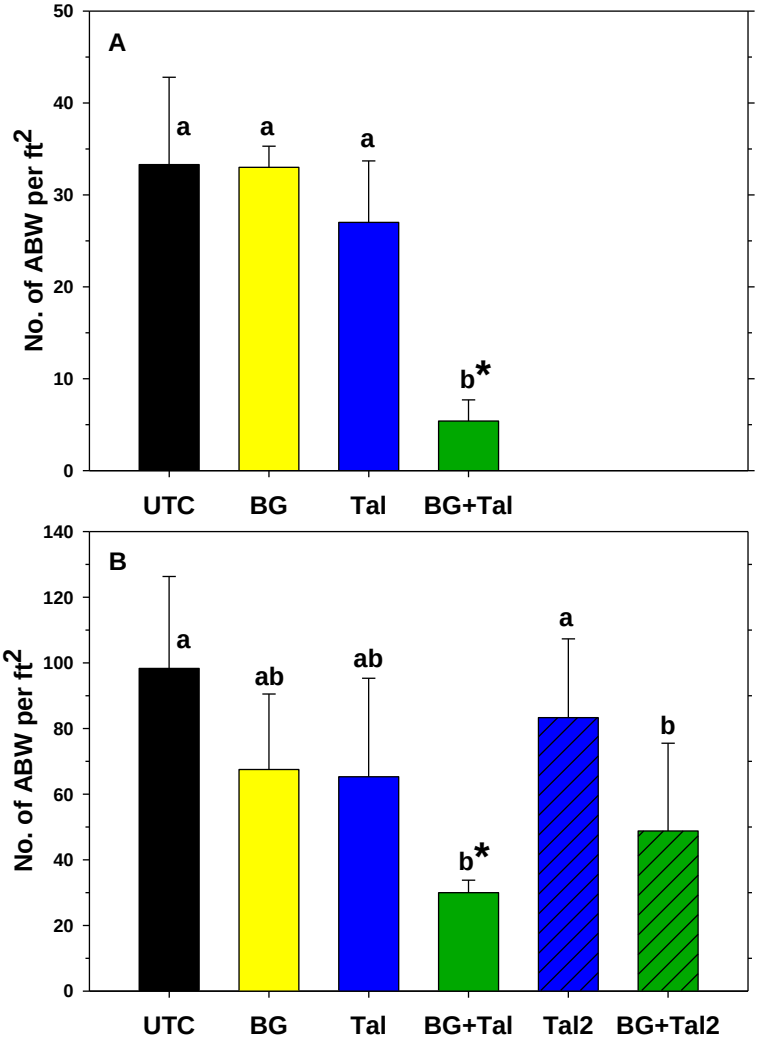

Fig. 1. Densities of annual bluegrass weevil developmental stages in early June (peak 4th to 5th instar) in two golf course fairways (A, B) treated with BotaniGard (BG) (0.65 lbs AI/acre), Talstar (Tal) (0.1 lbs AI/acre), and their combination (BG+Tal). Talstar was applied just before peak densities of overwintered adults, Botanigard just before peak adult densities and again 1 week later. In fairway B, Talstar was also tested applied at half rate 1 week apart, alone (Tal 2) and in combination with BotaniGard. Means with the same letter did not differ significantly (P > 0.05). An asterisk indicates a synergistic interaction.

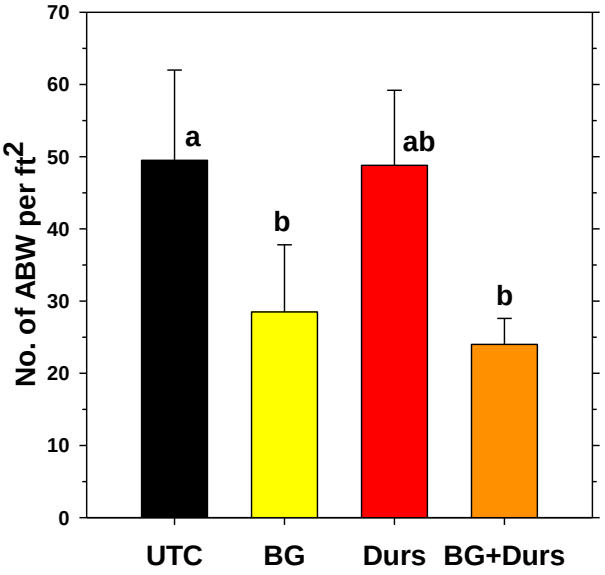

Fig. 2. Densities of annual bluegrass weevil developmental stages (peak 5th instar) in early June in a golf course fairways treated with BotaniGard (BG) (0.65 lbs AI/acre), Dursban (Durs) (1.0 lbs AI/acre), and their combination (BG+Durs). Dursban was applied just before peak densities of overwintered adults, Botanigard just before peak adult densities and again 1 week later. Means with the same letter did not differ significantly ($P > 0.05$).