Advancing integrated management of annual bluegrass weevil

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Objectives:

The overall goal is to develop a basis for more effective and sustainable methods for ABW management. This will be achieved through the following objectives:
1. Determine tolerance/resistance to ABW larval feeding of bentgrass spp. and cultivars.
2. Develop effective and practical monitoring methods for ABW.
3. Develop alternatives to chemical insecticides for curative control of ABW larvae.

Annual bluegrass weevil (ABW) management relies heavily on chemical control. Adulticide application in the spring used to be effective and commonly used strategy. However, development of ABW resistance to insecticides (primarily pyrethroids) accentuated the need for alternative strategies. Host plant resistance has been a focus of our research and we obtained clear evidence that bentgrass are relatively resistant and tolerant to ABW. However, females laid eggs in bentgrasses and ABW could develop from egg to pupa on all bentgrasses tested. Thus, plant resistance may have to be used in combination with other strategies.

Entomopathogenic nematodes can provide acceptable control levels of moderate ABW densities but may be overwhelmed by very high densities. In 2013 we observed that combined application of nematodes and imidacloprid tended to improve nematode efficacy against ABW. To examine the effect of split application on efficacy of nematodes and nematode-imidacloprid combination we conducted a field study in 2014. The nematode *Steinernema carpocapsae* and imidacloprid were either applied alone or in combination at full rate (2.5 billion IJs/ha and 336 g AI/ha, respectively) or half rates either as single (May 30) or split (May 30 + June 5) applications. Larval survival was evaluated 11 days after the first application.

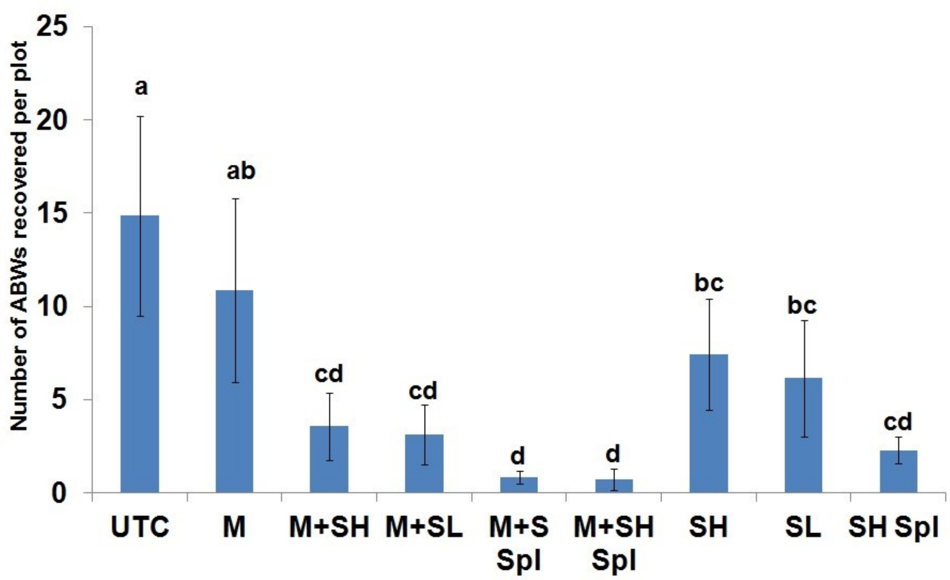

Figure 1. Efficacy of the entomopathogenic nematode *Steinernema carpocapsae* at low (SL) and high (SH) rates, the neonicotinoid insecticide Merit (M), and their combination as single or split (Spl) application against ABW larvae in a field test.

Highly variable ABW densities made detection of significant differences challenging. Nonetheless, all treatments except imidacloprid alone provided significant control (Figure 1). Nematode rate had no significant effect in the single and combination treatments. Nematode imidacloprid combinations (77-78%) but not nematodes alone (50-58% control) were significantly better than imidacloprid alone. Split application of nematodes whether for nematodes alone (88%) or in the

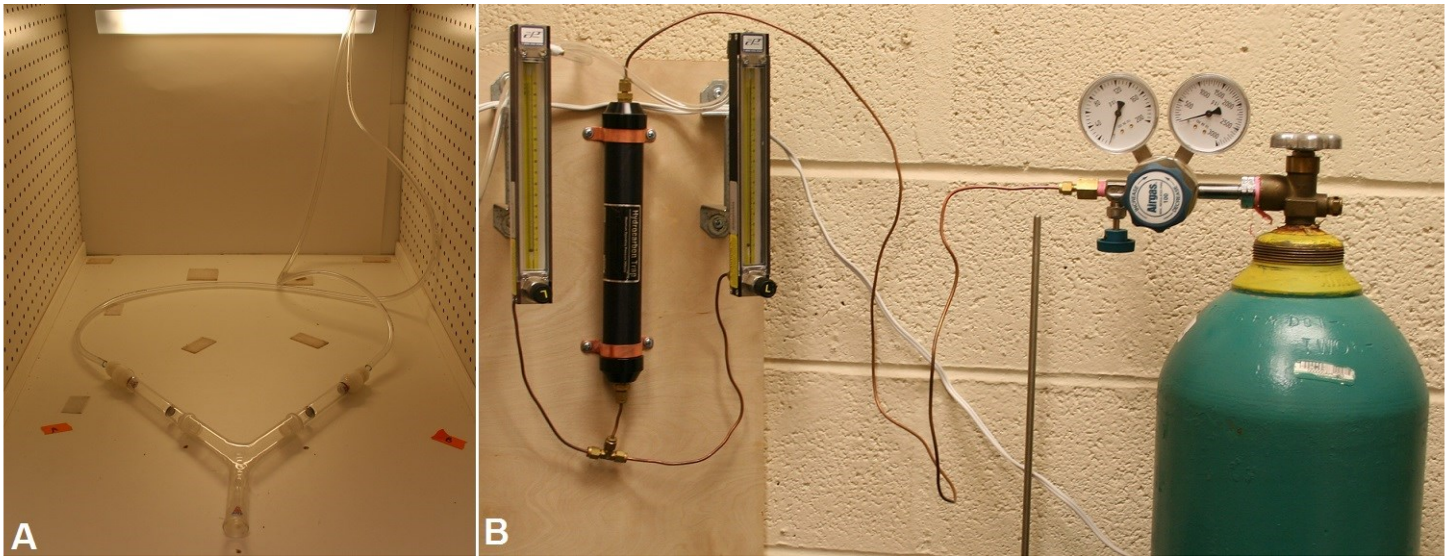

Figure 2. Y-tube olfactometer set up (A) and purified air delivery system (B) used to determine behavioral responses of ABW adults to long distance chemical cues (volatiles)

combinations (both 95%) showed the greatest potential. Where imidacloprid is already used for white grub control, its combination with split nematode application could be a highly effective option for ABW larval control.

ABWs tend to aggregate at the overwintering sites. To investigate whether ABW produce aggregation and/or sex pheromones a series of behavioral bioassays were conducted. The biological significance of ABW headspace volatiles was tested in Y-tube olfactometer (Figure 2) assays. Weevils were given choice between volatiles collected in the head space of males or females feeding on P. annua and of P. annua only. Overwintering adults were not responsive to any tested extracts. Spring generation males (70%) preferred female + P. annua extract to P. annua only extract (G = 4.9, P = 0.01).

Short distance attractiveness of ABW-produced volatiles was tested in pitfall assays. Plastic containers (840-ml) were filled with moistened sand and four wells (1 cm diameter) were arranged in the center. Wells were baited with head space extracts of males + P. annua, females + P. annua, P. annua, and solvent only. Spring generation males and females (20 of each) were placed centrally in the arena. After 24 h the number of weevils in each well and outside of wells was determined. Similarly to the Y-tube assays, only males tended to be attracted to female head space volatiles (Figure 3). Fewer males and females were recovered from non-baited wells than from wells baited with male/female extracts.

To test for presence of aggregation pheromones during overwintering, 20 ABW (males or females) were given a choice between 1) female- or male-baited sides and a control and 2) between male- and female-baited sides of overwintering experimental arenas kept in incubators under overwintering conditions (10 h light, 6°C: 14 h dark, 4°C. Weevil position was recorded after 24 h. Numerically most males and females tended to choose side baited with females (Figure 4A). Male baits had weak effect only on female choices (Figure 4B). No preferences were observed between male or female baits (Figure 4C). In 83% of replicates introduced weevils were found in one group, confirming ABWs tendency to aggregate during overwintering.

Summary Points:

- Combined application of entomopathogenic nematodes and imidacloprid against ABW larvae in spring population is an alternative for ABW management that provides both curative control of ABW larvae and preventive control of white grubs.
- Splitting application of nematodes improves efficacy of nematode alone and nematode-imidacloprid combinations.
- Behavioral studies did not confirm the presence of an aggregation pheromone in ABW headspace volatiles but indicated that males may be attracted to female-emitted pheromones.

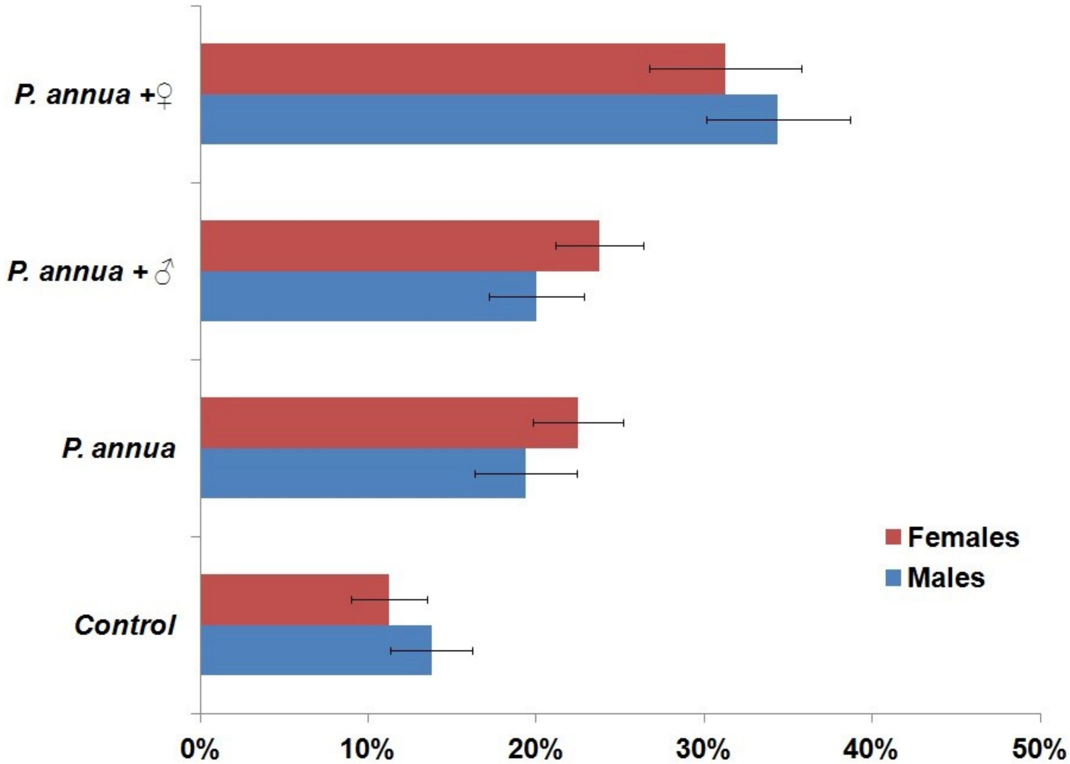

Figure 3. Behavioral responses of ABW males and females to conspecifics in pitfall bioassays.

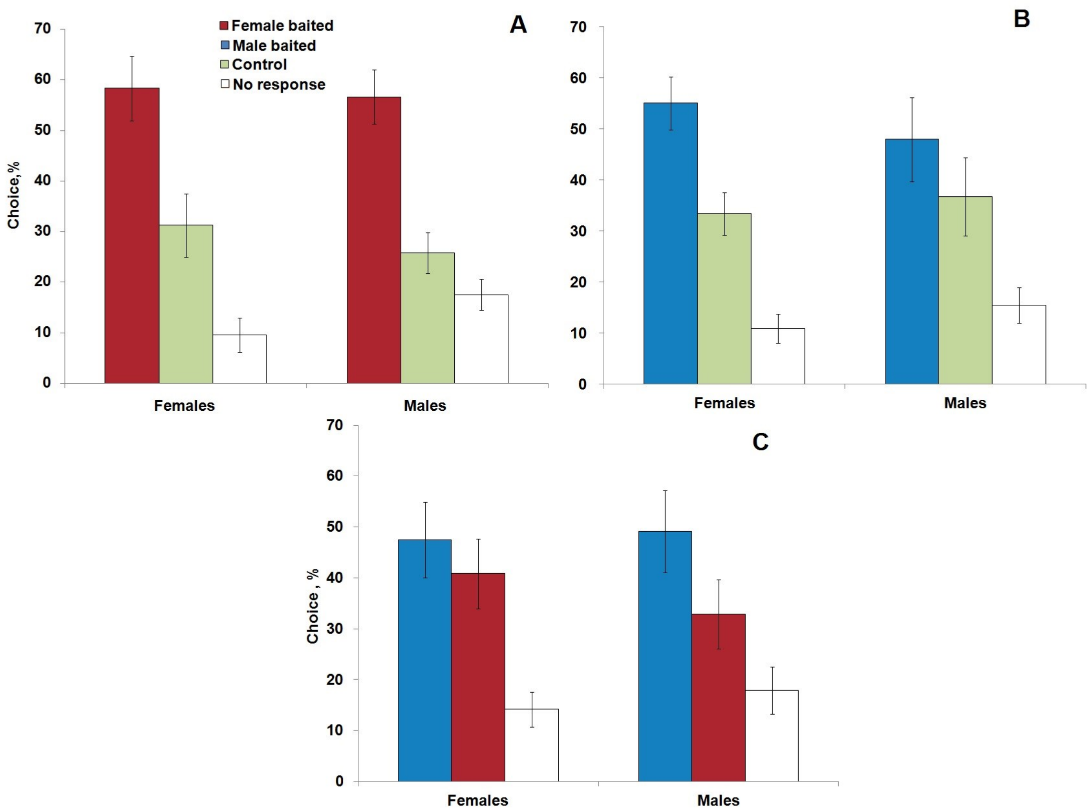

Figure 4. Behavioral responses of overwintering ABW males and females to conspecific males and females in overwintering aggregation assays.