BT CORN ROOTWORM PROTECTED CORN: PERFORMANCE AND RESISTANCE MANAGEMENT

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OVERVIEW

Although field corn pest management has remained largely dependent on restricted-use, broad-spectrum insecticides (organophosphates, carbamates and pyrethroids) for corn rootworm control, this situation is changing rapidly with the 2003–2004 market entry of highly selective tactics, including genetically modified Bt rootworm corn hybrids and nicotinoid insecticidal seed treatments labeled for corn rootworm control. From familiar liquid and granular soil-applied insecticides (full label rate or reduced rate), to new insecticidal seed treatments, crop rotation, and transgenic Bt corn hybrids replete with insect resistance management (IRM) and refuge stewardship requirements, producers and consultants are faced with an unprecedented diversity of individual rootworm control tactics. Well-proven principles of IPM hold the key to structuring a sustainable and affordable corn rootworm management system that does not rely too extensively on any one practice, tactic, chemical, or technology, and will exploit as many strategies for suppressing pest levels as possible (Benbrook, 2000).

All corn rootworm control tactics mentioned above (with the exception of crop rotation) were included in the UW Entomology Dept./Field Crops Extension small plot trials at the Arlington Agricultural Research Station in 2003. A summary of the 2003 corn rootworm efficacy trial results is provided with this abstract as are the principles of corn rootworm IRM when including Bt rootworm corn hybrids (YieldGard® Rootworm) in your production plan. Objectives of this symposium presentation are to discuss the 2003 small plot rootworm efficacy trial results (product performance) within the context of input costs of the different approaches, varying rootworm pressure and producer expectations of control, as well as overall IRM. We will also touch on the most recent Bt corn introduction (winter 2004), YieldGard® Plus, which contains two different Bt genes (one active against corn rootworms and the other active against corn borers) in one plant.

UW CORN ROOTWORM EFFICACY TRIALS 2003

<u>Planting</u>:

Corn plots were mechanically planted on 3 May 2003 by cone seeder at the Arlington Agricultural Research Station. Plots were planted into ground that had a corn rootworm 'trap crop' planted to it the previous summer 2002. The previous trap crop was planted late June (~June 20, 2002) to provide pollinating, silking corn as an attractant to adult corn rootworm beetles during the adult emergence, mating and oviposition period beginning mid-July and extending throughout August. This approach is typical of rootworm efficacy trials throughout the Midwest and historically at the Arlington Agricultural Research Station. The trap crop strategy is designed to encourage corn rootworm (adult beetle) oviposition in the soil, thereby creating a heavy corn rootworm larval pressure the following spring (2003) against which to test corn rootworm insecticides and obtain statistically meaningful treatment differences.

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Treatments and Experimental Design:

Trial A. Ten treatments were evaluated for efficacy against corn rootworm larval injury to corn roots. Treatments included one nicotinoid seed treatment (Cruiser, a.i. thiamethoxam), three pyrethroids (Mustang Max, a.i. zeta-cypermethrin; Capture, a.i. bifenthrin; Force 3G, a.i. tefluthrin), one organophosphate (Counter CR, a.i. terbufos) by both T-band and in-furrow application methods, one organophosphate + pyrethroid (Aztec 2.1G, a.i. tebupirimphos + cyfluthrin), one phenyl pyrazole (Regent, a.i. fipronil), a YieldGard® Rootworm transgenic Bt hybrid, and an untreated check (Table 1).

Trial B. Nine treatments were evaluated for efficacy against corn rootworm larval injury to corn roots. Treatments consisted of two nicotinoid seed treatments (Cruiser; Poncho 1250, a.i. clothianidin), three pyrethroids (Mustang Max, Capture 2EC and Force 3G) one organophosphate (Counter CR), one organophosphate + pyrethroid (Aztec), one phenyl pyrazole (Regent), and an untreated check (Table 2).

Plots were planted 4 rows (30 inch row spacing) wide by 25' long. Treatments were assigned to plots in a completely randomized block design (CRBD), with four replicates per treatment.

Treatment Evaluation:

The Iowa State University 0 to 3 Node Injury Scale was used to evaluate the level of root protection between treatments (Oleson and Tollefson, 2001). This root rating system appraises damage based on each node, and the equivalency of roots pruned to within approximately 1.5 inches of the stalk. For example, a rating of 0.25 represents 25% of one entire node of roots missing or pruned. In other words, 10% of that damage could be observed from one node, while the remaining 15% could be observed from another node. Alternatively, the entire 25% damage could be sustained by one node. Using this system, economic root injury ranges between 0.25 and 0.90 or greater. Typically, root ratings at or above 0.75 are considered to represent economic root injury or less than optimal product performance.

Root ratings were taken on 25 July 2003. Five plants were chosen randomly from within the two middle rows of each plot and labeled by plot ID. These 5 plants were cut to within 6 inches of the ground. Each plant was then dug up and removed from the plot. All roots were soaked in water to remove soil, and then washed with a high pressure power washer to completely clean the roots prior to evaluation.

Results and Discussion:

Results are presented in table format from highest root rating (most rootworm injury) to lowest root rating in descending order (i.e. treatments at the bottom of the table listings were more effective). For example, in Trial A (Table 1) Counter CR applied as a T-band received a root rating of 0.95, equivalent to nearly one full node of roots pruned to 1.5 inches or shorter. This is compared with Regent (0.39) and YieldGard® Rootworm (0.11) in the bottom two rows of the same table, both ratings significantly below 0.75.

An important factor to keep in mind when evaluating these results is that the plots were planted into previous trap crop ground, as explained in the methods above. Thus, rootworm pressure was relatively high in these plots. Nicotinoid seed treatments (Cruiser and Poncho) are labeled and/or marketed toward light to moderate rootworm pressures and may be expected to perform better under more moderate rootworm pressure on-farm. We also observed variability between products at the two study sites. For example, Regent applied in-furrow received a moderate root injury rating of 0.39 in Trial A (Table 1), versus a much higher level of root injury (0.91) in Trial B as a T-band application (Table 2).

The 2003 trial results are also limited to one location. In future studies the rootworm efficacy trials will be expanded again to cover multiple locations in Wisconsin, enter on-farm trials where possible to incorporate a "systems" viewpoint in interpreting rootworm nodal injury ratings. Another proposal is to include yield data with these future trials. Keeping this discussion, and caveats, in mind our results provide product performance rankings from the Arlington, WI location for 2003 and can be used for general reference purposes.

Table 1. Corn rootworm insecticide efficacy Trial A, 2003. Insecticidal seed treatment, soil applied insecticides and YieldGard® Rootworm Bt corn hybrid. Mean nodal injury root rating by treatment (listed from highest level of damage to lowest, in descending order). Arlington Agricultural Research Station, Arlington, WI. 2003.

Treatment	Appl	Rate	Root Injury*
Check (DK537)		------	1.14 a
Cruiser	ST	1.25 mg a.i./kernel	1.06 a
Counter CR	TB	6.0 oz./1000 ft.	0.95 ab
Mustang Max	TB	0.32 oz./1000 ft.	0.79 b
Counter CR	IF	6.0 oz./1000 ft.	0.74 bc
Capture 2EC	TB	0.30 oz. / 1000 ft.	0.55 cd
Force 3G	TB	4.0 oz./1000 ft.	0.45 d
Aztec 2.1G	TB	6.7 oz./1000 ft.	0.42 d
Regent	IF	0.24 oz./1000 ft.	0.39 d
YieldGard®		------	0.11 e

* Nodal injury root rating means followed by a different letter are significantly different at $\alpha = 0.05$ (Fishers exact test).

Table 2. Corn rootworm insecticide efficacy Trial B, 2003. Insecticidal seed treatments and soil applied insecticides. Mean nodal injury root rating by treatment (listed from highest level of damage to lowest, in descending order). Arlington Agricultural Research Station, Arlington, WI. 2003.

Treatment	Appl	Rate	Root Injury*	
Check (Pioneer 3751)		------	1.39	**a**
Mustang Max	TB	0.32 oz./1000 ft.	1.26	**a**
Cruiser	ST	1.25 mg a.i./kernel	0.95	**b**
Regent	TB	0.24 oz./1000 ft.	0.91	**b**
Counter CR	TB	6.0 oz./1000 ft.	0.73	**bc**
Poncho 1250	ST	1.25 mg a.i./kernel	0.70	**bc**
Capture 2EC	TB	0.30 oz./1000 ft.	0.66	**c**
Aztec 2.1 G	TB	6.7 oz./1000 ft.	0.54	**cd**
Force 3G	TB	4.0 oz./1000 ft.	0.36	**d**

* Nodal injury root rating means followed by a different letter are significantly different at $\alpha = 0.05$ (Fishers exact test).

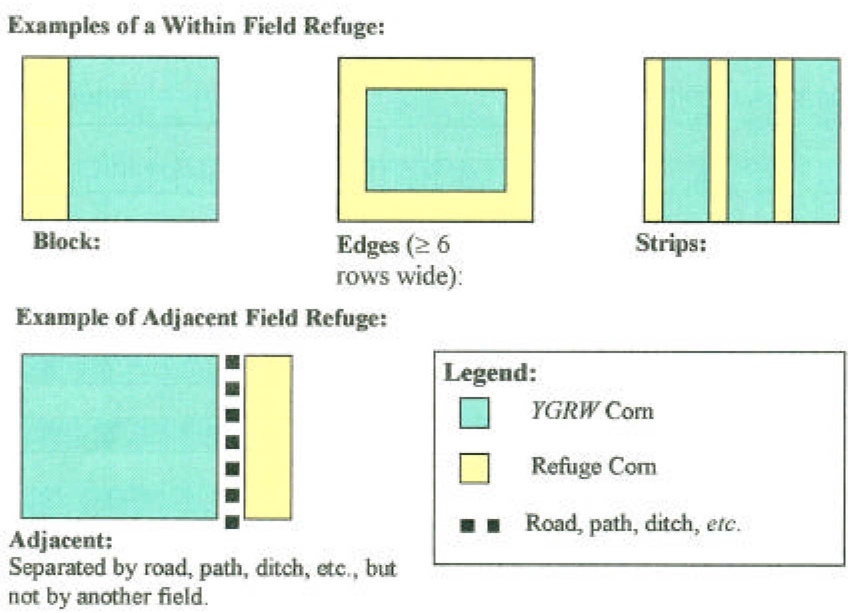
BT CORN ROOTWORM CORN: INSECT RESISTANCE MANAGEMENT (IRM) REQUIREMENTS

IRM plans for transgenic crops such as corn that produce insecticidal protein(s) derived from *Bacillus thuringiensis* (Bt), a soil-dwelling bacteria, are based on the practice of planting a refuge. Bt corn hybrids express an active form of Bt insecticidal protein continuously over the growing season. This provides consistent rootworm control for the producer, but it also exerts a strong population suppression effect and potential for rootworm resistance. A refuge is a block or a strip of corn that does not contain Bt for corn rootworms (*Diabrotica spp.*). The primary purpose, and prevailing theory, of a refuge is to maintain a population of corn rootworm that is not exposed to the Bt protein found in Bt rootworm corn hybrids. This lack of exposure to the rootworm Bt protein provides a source of susceptible rootworms in close proximity to mate with resistant corn rootworm beetles that may emerge from the Bt corn (Monsanto, 2003).

Up to 80% of corn acres on a farm may be planted to a Bt rootworm hybrid. At least 20% of the remaining corn acreage must be planted to a corn refuge that does not contain a Bt gene active against rootworm species. The refuge corn hybrid should be as similar as possible to the Bt rootworm hybrid, with the exception of the Bt gene. Non-Bt refuge corn and Bt rootworm corn should be planted at the same time to ground with a common field history. The refuge must be planted near Bt rootworm fields (within the same field or adjacent to it). Although the corn refuge may be separated from the Bt corn by a ditch or road, it may not be separated by another field. If the refuge is planted to an adjacent field, both areas must be managed by the same grower.

Growers can treat for corn rootworm in the refuge, as long as it is an active ingredient other than Bt. Thus, non-Bt soil applied liquid and granular insecticides (see Table 1 and 2) as well as nicotinoid seed treatments are permitted on refuge acreage. Examples of refuge configurations are illustrated in Figure 1. The 20% corn refuge can be planted as a block, perimeter or strips within the Bt field, or it can be narrowly separated from the Bt field by a ditch or road.

Figure 1. Corn rootworm Bt corn refuge configurations. 80% Bt rootworm corn: 20% Non-Bt refuge corn.



Bt corn hybrids with activity against European corn borer entered the market in 1996. Since that time target insect pests have developed negligible or no resistance to Bt crops under field conditions (Fox, 2003). Bt rootworm hybrids (YieldGard® Rootworm) and combined rootworm-corn borer hybrids (YieldGard® Plus) entered the commercial arena in spring 2003 and winter 2004, respectively. While field-evolved resistance to Bt crops has not been documented yet, lab selected resistance to Bt toxins has been established (Tabashnik et al., 2003). Over 500 species of insects have evolved resistance to one or more conventional insecticides (Fox, 2003). Thus, the risk of insect resistance is real and refuge requirements with IRM plans are a condition of U.S. EPA registration of Bt hybrids. As part of the registration condition for this technology, seed companies will conduct IRM compliance assessments during the growing season to ensure compliance at the field level (Monsanto, 2003).

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