SEED-TREATMENT INSECTICIDES: WHAT CAN WE EXPECT IN TERMS OF BROAD-SPECTRUM CONTROL OF SOIL INSECTS?

Marlin E. Rice - Iowa State University

Corn producers battle a variety of soil dwelling insect pests. Seedcorn maggots, wireworms, white grubs, and several species of cutworms can attack either the seed or seedling plants and reduce plant stand. Corn rootworm larvae feed on corn roots during midsummer and can significantly reduce the uptake of moisture and nutrients. Extensive feeding by corn rootworm larvae can reduce the roots to a point where wind causes plant lodging, subsequently slowing harvest. Grain yields can be reduced even if plants don't lodge.

Corn producers have traditionally relied upon some form of insecticide to control early season insects. Planting time applications of liquid or granular formulations are commonly used and occasionally, seed treatments (such as Agrox D-L Plus and Kernel Guard Supreme) have been considered as an alternative form of control. The performance of these two seed treatments, however, was dependent upon the grower manually mixing the insecticide with the seed to get an adequate coating of material on the seed coat. This required time and effort, and sometimes produced less than the desired protection. Also, these seed treatments did not have systemic action and did not protect against black cutworms or corn rootworms.

In 2004, three systemic insecticides were commercially available as pre-applied seed treatments to seed corn. These insecticides, all in the neonicotinoid chemical family, were clothianidin, imidacloprid, and thiamethoxam. They are sometimes referred to as nicotinoids or cholornicotinyls, and they closely resemble nicotine in their mode of action. They have high activity against sucking insects, such as aphids, but also chewing pests such as beetles and some *Lepidoptera*, particularly as cutworms. These chemicals are highly systemic in the plant roots and new leaf tissue and offer a spectrum of control activity as seed treatments.

These three neonicotinoids have not been widely field tested in the Midwest. Their performance against a variety of corn pest species, such as black cutworms, seedcorn maggots, white grubs and wireworms remains relatively unknown. The objective of this presentation is to provide a brief assessment of neonicotinoid performance against corn rootworms, black cutworms and white grubs.

All neonicotinoids have a mode of action that binds at a specific site (the postsynaptic nicotinic acetylcholine receptor) in the central nervous system of insects. This causes excitation of the nerves and eventual paralysis that leads to death. Due to this mode of action there is no cross resistance to conventional insecticide classes such as carbamates, organophosphates, and pyrethroids. They act as acute contact and stomach poisons, combining systemic properties with relatively low application rates. They are relatively nontoxic to vertebrates (Table 1).

The neonicotinoids must be classified as highly toxic to honey bees. However, toxicity exposure studies indicate that it is very unlikely that honeybees will be lethally affected when the product is seed-applied, and they rarely forage on seedling corn or soybeans. Also, it is very unlikely that commercial bee hives will be adversely affected. Neonicotinoids pose only a low toxicity hazard to adult ground beetles (a predatory insect) and a moderate toxicity hazard to another predator, the green lacewing.

Table 1. Neonicotinoid insecticides used in corn and soybeans as of October 15, 2004.

Common name	**clothianidin**	**imidacloprid**	**thiamethoxam**
Trade name	Poncho	Gaucho	Cruiser
Manufacturer	Bayer	Bayer/Gustafson	Syngenta
Solubility in water	327 mg/L	610 mg/L	4,100 mg/L
LD_{50} (acute rat oral)	>5,000 mg/kg	4,870 mg/kg	5,523 mg/kg
Labeled for corn	Yes	Yes	Yes
Labeled for soybean	No	Yes	No

Studies with clothianidin have shown only a low risk to soil-dwelling invertebrate species since the predicted environmental concentrations are lower than the no-observed effect concentration for the most sensitive tested species. Three rates of clothianidin sprayed to a field in Europe revealed no significant differences between the total numbers or total biomass of earthworms collected from the plots treated at the highest rates (225 grams active substance per hectare) compared to the untreated control.

Of the three neonicotinoids, thiamethoxam is the most soluble in water. This might give it an advantage in dry soil, although other factors such as toxicity, persistence, and soil adsorption are important attributes of overall performance.

Materials and Methods

Corn Rootworm. Treatments were planted at three-four locations across Iowa during 2003 and 2004. Roots from each treatment were dug, washed, and evaluated on the Iowa 0-3 scale for corn rootworm injury. Each treatment also was evaluated for consistency of performance (percent of time root injury was ¼ node or less), lodging, and plant stand. Data were analyzed by analysis of variance.

Black Cutworm. In Experiment 1, treatments consisted of Cruiser 5FS 0.125mg/seed, Cruiser 5FS 0.25mg/seed, Poncho 1250 0.25 mg/seed, Warrior (0.02 lb./acre) applied with a handheld sprayer on June 2, Force 3G (0.12 oz./1,000 row feet) applied at planting and incorporated into the soil, and an untreated check. Five-gallon plastic buckets that had the bottoms removed were set in the field. Seeds of a single treatment were planted inside each bucket on May 20 and thinned to five plants at emergence. Each treatment was replicated four times. At the V1 plant stage on June 2, three fourth-stage black cutworm larvae per plant (15 total) were placed in each bucket. The number of cut plants was recorded three, eight, and 14 days after infestation.

In Experiment 2, soil was placed in 10-gallon plastic tubs to approximately ¾ full. Ten seeds per treatment were planted in a single tub in two rows on May 8. On May 16, three larvae (approximately 90 percent fourth and 10 percent fifth instars) per plant were placed in the tubs (30 larvae total per tub). There were four replications of each treatment. The number of cut plants was recorded three, seven, and 15 days after infestation.

White Grub. Treatments consisted of untreated corn seed and seed treated with Poncho 250 or Poncho 1250.

White grub (*Phyllophaga* sp.) larvae and soil were collected from a field during early and mid-May. Soil was sifted and placed in 10-gallon plastic tubs to approximately ¾ full. In Experiment 1, five seeds per treatment were planted in a single tub at a depth of one inch in a single row at a density of two grubs per plant. In Experiment 2, 10 seeds per treatment were planted in a single tub at a depth of one inch in two rows and a density of ½ grub per plant. Grubs were buried at a depth of one inch between the two rows of seeds. There were four replications of each treatment. Treatments were evaluated three-four weeks after planting.

For Experiments 3-5, soil was sifted and two seeds of each treatment were planted in Sweetheart 16 ounce paper cups in a greenhouse with a density of ½ white grub per plant. For Experiments 6-8, soil was sifted and four seeds of each treatment were planted in Sweetheart ½ gallon paper cups in a greenhouse with a density of two white grubs per plant. Treatments were replicated six-eight times and were evaluated two-three weeks after planting.

The number of live plants, number of dead grubs, extended leaf heights, and total dry plant weights were recorded. Data were analyzed by analysis of variance.

Results and Discussion

Corn Rootworms. The most consistent protection of corn roots from corn rootworm larvae was provided by YieldGard Rootworm corn and several of the granule insecticides (Table 2). The lowest level of protection against corn rootworms was from Poncho and Cruiser seed treatments. The consistency of root protection was only 25 percent for Poncho and 10 percent for Cruiser. Lodging also was severe in the Cruiser plots with 20 percent of the plants falling over in the row. Neither of the seed treatments provided adequate protection against corn rootworms under the conditions of heavy feeding pressure in the test plots. These two seed treatments may provide adequate root protection in fields where small or moderate rootworm populations exist, but knowing this information before spring planting would require scouting the field for adult beetles the previous summer.

White Grubs. Poncho 250 and Poncho 1250 provided very good protection of seedling corn plants against true white grub injury even when the insect density was two grubs per plant (Table 3). In eight different tests, live corn plants in both Poncho treatments averaged 98.6-100 percent compared to only 67.1 percent live plants in the untreated check. Plants in the Poncho treatments also were consistently taller and had greater dry plant weight because of root protection provided by the insecticide.

Black Cutworms. Neither of the two rates of Cruiser nor the low rate of Poncho provided very good protection against black cutworm damage (Tables 4 and 5). By comparison, the high rate of Poncho in Experiment 2 gave good protection as only 7.5 percent of the plants were cut in these cages that had very high cutworm densities.

In conclusion, the neonicotinoids will be valuable tools in the pest management arsenal for some soil dwelling insects. Neonicotinoids appear to be effective against white grubs and black cutworms (at the higher rate) but more research is needed to determine if results will be consistent. In contrast, the effectiveness of the neonicotinoids against corn rootworm larvae has been disappointing. High levels of root injury indicate that either transgenic rootworm corn or the traditional granular insecticides will be necessary to prevent injury in fields with economically damaging populations of corn rootworms.

Acknowledgement

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Table 2. Two-year (2003-2004) summary of corn rootworm insecticides. Iowa State University.

Treatment	Placement[1]	Node Injury[2,3,4]	Consistency[4,5,6]	Lodging[4,7]	Plant Stand[8,9]
YieldGard	----	0.03 a	98 a	1 a	27.35
Aztec 2.1G	Furrow	0.24 ab	82 ab	0 a	28.15
Force 3G	T-band	0.26 ab	79 b	0 a	27.29
Force 3G	Furrow	0.26 ab	82 ab	0 a	27.50
Aztec 4.67G	T-band SB	0.27 ab	81 ab	0 a	27.70
Aztec 4.67G	Furrow SB	0.29 ab	74 b	1 a	28.03
Aztec 2.1G	T-band	0.33 b	70 b	0 a	27.71
Fortress 2.5G	Furrow	0.38 bc	71 b	1 a	27.73
Fortress 5G	Furrow SB	0.61 cd	63 bc	2 a	27.68
Lorsban 15G	T-band	0.70 d	51 cd	2 a	28.09
Capture 2EC	T-band	0.72 d	42 de	2 a	27.62
Poncho ST	ST	0.84 d	25 ef	3 a	27.24
Cruiser ST	ST	1.34 e	10 fg	20 b	27.68
Check	----	1.69 f	2 g	26 c	27.18

[1] T-band & Furrow = insecticide applied at planting time; SB = SmartBox application; ST = seed treatment.

[2] Means based on 170 observations; replications with insufficient larval feeding pressure to challenge a product's performance (UTC rep mean <0.75 of a node injured) were deleted from the analysis (19 of 20 replications analyzed).

[3] Iowa State Node-Injury Scale (0-3). Number of full or partial nodes completely eaten.

[4] Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P \leq 0.05$).

[5] Product consistency = percentage of times nodal injury was 0.25 (¼ node eaten) or less.
[6] Means based on 170 observations.
[7] Means based on 34 observations (plants lodged in 17.5 row-ft.).
[8] Means based on 34 observations (number of plants in 17.5 row-ft.).
[9] No significant differences between means (ANOVA, P $\leq$ 0.05).

Table 3. Performance of Poncho seed treatments in corn against true white grubs. Iowa, 2004.

Experiment	Treatment	Grubs/ plant	% live plants	% dead grubs	Mean leaf height (cm)	Mean dry plant weight (gm)
1	Poncho 250	2	100	--	--	--
	Poncho 1250	2	100	--	--	--
	Check	2	100	--	--	--
2	Poncho 250	½	10	--	--	--
	Poncho 1250	½	95	--	--	--
	Check	½	90	--	--	--
3	Poncho 250	½	100	--	33.3	0.869
	Poncho 1250	½	100	--	34.1	0.890
	Check	½	65	--	29.1	0.586
4	Poncho 250	½	100	0	31.5	0.713
	Poncho 1250	½	93.8	12.5	33.9	0.681
	Check	½	87.5	6.3	30.2	0.556
5	Poncho 250	½	100	66.7	34.4	0.408
	Poncho 1250	½	100	83.3	36.2	0.542
	Check	½	83.3	16.7	32.6	0.375
6	Poncho 250	2	100	72	38.8	0.583
	Poncho 1250	2	100	62	37.1	0.564
	Check	2	6.3	19	30.1	0.310
7	Poncho 250	2	100	78.5	32.1	0.721
	Poncho 1250	2	100	64.5	31.9	0.693
	Check	2	71.5	7.3	29.6	0.517
8	Poncho 250	2	100	58.3	40.3	0.667
	Poncho 1250	2	100	37.5	43.8	0.725
	Check	2	33.3	16.7	25.8	0.333

Table 4. Performance of insecticides against black cutworms in seedling corn, Experiment 1. Iowa, 2004.

Treatment	**Cut Plants**			
	Day 3	**Day 8**	**Day 14**	**% Total**
Cruiser 5FS (0.125mg/seed)	3.25c	5c	5c	100
Cruiser 5FS (0.25mg/seed)	1.75b	4.75c	4.75bc	95
Poncho 250 (0.25 mg/seed)	1.75b	3.5b	3.5b	70
Warrior (0.02 lb/acre)	0a	0.25a	1.5a	30
Force 3G (0.12 oz/1K ft)	0a	1a	1a	20
Check	3.25c	5c	5c	100
LSD 0.05	*1.26*	*0.94*	*1.49*	

Table 5. Performance of insecticides against black cutworms in seedling corn, Experiment 2. Iowa, 2004.

Treatment	**Cut Plants**			
	Day 3	**Day 7**	**Day 15**	**% Total**
Poncho 250	3a	4.75b	5.5b	55
Poncho 1250	0.75a	0.75a	0.75a	7.5
Check	9.5b	9.5c	9.5c	95
LSD 0.05	*3.36*	*1.55*	*2.36*	