THE NEONICOTINOID INSECTICIDES—INSECT MANAGEMENT WITH SEED TREATMENTS IN CORN

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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 the 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 the plants to lodge. Lodged plants slow harvest and grain yields can be reduced from both the root injury and the lodging.

Corn producers have traditionally relied upon some form of insecticide to control early season insects. Planting time applications of either a liquid or granular formulation are commonly used and occasionally seed treatments, such as Agrox D-L Plus and Kernel Guard Supreme, have been historically 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 in an attempt 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 they 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 are clothianidin, imidacloprid and thiamethoxam and are in the neonicotinoid chemical family. Imidacloprid is also labeled for use in soybean and thiamethoxam is expected to be labeled for soybean in time for the 2005 planting season.

These insecticides sometimes are 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 the cutworms. These chemicals are highly systemic—being moved into the plant roots and new leaf tissue—and offer a spectrum of control activity as seed treatments.

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 which 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 are 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. It is very unlikely that commercial bee hives will be adversely affected. They pose a low toxicity hazard to predatory ground beetles and moderate toxicity hazard to another predator—the green lacewing—that can be common on foliage.

Table 1. Neonicotinoid insecticides used in corn and soybeans[1].

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[2]

[1] As of October 15, 2004.

[2] Soybean labeling expected for 2005 planting season.

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 the 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 conditions, although other factor such as toxicity, persistence and soil adsorption are important attributes of overall performance.

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 has remained relatively unknown. The objective of this presentation is to provide a brief assessment of neonicotinoid performance against corn rootworms, black cutworms and white grubs.

Materials and Methods

Corn Rootworm. Treatments (Table 2) were planted at 3-4 locations across Iowa during 2003 and 2004. Roots from each treatment were dug, washed and evaluated on the Iowa Node Injury Scale (0-3) for corn rootworm injury. Each treatment was additionally 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 two experiments, plants for each treatment (Tables 3-4) were contained in either five-gallon plastic buckets (with the bottoms removed) or in 10-gallon plastic tub filled ¾ full with soil. Buckets contained five plants; tubs contained 10 plants. Each treatment was replicated four times. At the V1 plant stage on May 16, three larvae (approx 90% 4th and 10% 5th instars) per plant were placed in each tub (total of 30 larvae per tub). At the V1-plant stage on June 2, three 4th stage black cutworm larvae per plant were placed in each bucket (total of 15). The number of cut plants was recorded at three time intervals after infestation. Data were analyzed by analysis of variance.

White Grub. True white grubs (*Phyllophaga* sp.) and soil were collected from the field. For Experiments 1-3, soil was sifted and two seeds of each treatment (Table 5) were planted in Sweetheart 16 oz. paper cups in a greenhouse at a density of ½ white grub per plant. For Experiments 4-6, soil was sifted and two 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 6-8 times and were evaluated 2-3 weeks after planting.

The number of live plants, number of dead grubs, extended leaf height and total dry plant weight were recorded. Data were analyzed by analysis of variance. Statistical analysis allowed for a combining of data in Experiments 1-3. Data from Experiments 4-6 could not be combined.

Results and Discussion

Corn Rootworms. The highest level of consistency in corn root protection from corn rootworm larvae was provided by YieldGard Rootworm corn and several of the granule insecticides (Table 2). However, no product was 100 percent consistent in providing total root protection during the two-year study. From a statistical standpoint, YieldGard Rootworm, Force 3G (in-furrow), Aztec 2.1G (in-furrow), and Aztec 4.67G (T-band SmartBox) had the best consistency in root protection. There were no differences in plant populations across products.

The lowest level of protection against corn rootworms was from both 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 while all other products were equal in protecting against lodging except Cruiser seed treatment. 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 sized rootworm populations exist but knowing this information before spring planting would require that the field be scouted for adult beetles the previous summer.

Yields were similar, statistically speaking, across a number of products. As an example, the average YieldGard Rootworm yield was 171 bushels yet it was not significantly different from Poncho seed treatment with 162 bushels, or any other yield followed by the small letter “a”. Although there are no significant differences among some of these average yields this does not prove that some of the products had no effect. There is always the possibility that there was a real treatment effect but the experiments were not sensitive enough to detect differences at the 5% level of probability. As stated in the statistical book, *Agricultural Experimentation*, the conclusions you make concerning an experiment should be your own and should be based on more than statistical evidence. Another way of evaluating the information is to consider the percent of time that the yield was significantly larger than the untreated check yield (last column).

There is an abundance of data to consider when selecting a corn rootworm product for next season. Other factors worthy of consideration might be cost of product, pounds of active ingredient being applied per acre, ease of handling, application equipment needed, other pests controlled, restricted use labeling, potential hazards to surface water, or spray drift with liquids.

Black Cutworms. Neither rate of Cruiser nor the low rate of Poncho provided very good protection against black cutworm damage (Tables 3-4). 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 densities of 4th instar cutworms.

White Grubs. Both 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 5). Across all six different tests, the percent of live corn plants in both Poncho treatments averaged 98.6-100 percent compared to only 67.1 percent live plants in the untreated checks. Plants in the Poncho treatments also were consistently taller and had greater dry plant weight because of root protection provided by the insecticide.

Corn Flea Beetles. No tests for corn flea beetles were conducted in 2004. However, a previous study by Pataky et al. (2000) in Illinois indicates that seed treatments can be effective in controlling this pest and the bacterial wilt, ***Erwinia stewartii***, also known as Stewart's wilt, that it vectors, particularly in susceptible and moderately susceptible sweet corn varieties. From their interpretive summary, Pataky et al. (2000) states that, "Yield of resistant and moderately resistant hybrids is reduced significantly when plants are infected prior to the 3- to 5-leaf stages. Plants are infected when bacteria are introduced into wounds caused by flea beetle feeding. Presently, host resistance is the most effective method to control Stewart's wilt, but this disease also can be controlled if flea beetles are killed before they transmit ***E. stewartii*** to plants. Conventional applications of insecticides to foliage or in furrows at planting have had varied success at controlling flea beetles. This research demonstrated that two insecticides, imidacloprid and thiame-thoxam, applied to sweet corn seed reduced the incidence of Stewart's wilt by 50 to 85% under field conditions with naturally occurring populations of corn flea beetles. These seed treatment insecticides controlled Stewart's wilt during the very early growth of corn plants when applications of conventional, foliar insecticides are ineffective and when the effectiveness of host resistance varies depending on the proximity of flea beetle feeding sites to the plant's growing point. Commercial use of these compounds should increase the number of varieties that can be grown successfully when Stewart's wilt is expected due to mild winter conditions that favor large populations of flea beetles."

In conclusion, the neonicotinoid seed treatments will be valuable tools in the pest management arsenal for some soil dwelling insects. They appear to be effective against white grubs, black cutworms (Poncho 1250 only) and corn flea beetles. More research is needed to determine if the black cutworm and white grub results will be consistent over time. In contrast, the effectiveness of the neonicotinoids against corn rootworm larvae has been disappointing. High levels of root injury with the seed treatments indicate that either transgenic rootworm corn or the traditional granule insecticides will be necessary to prevent injury in fields with economically damaging populations of corn rootworms.

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References

J. K. Pataky, J. K., P. M. Michener, N. D. Freeman, R. A. Weinzierl, and R. H. Teyker. 2000. Control of Stewart's wilt in sweet corn with seed treatment insecticides. Plant Disease (on-line) http://www.apsnet.org/pd/summaries/top.asp#Pataky2

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

Insecticide	Placement[1]	Node-Injury[2,3,4]	Product Consistency[4,5,6]	Percent Lodging[4,7]	Stand Count[8,9]	Yield (bu/a)[4,10]	% Times Yield >Check[11]
Aztec 2.1G	Furrow	0.24 ab	82 ab	0 a	28.15	161 ab	20%
Aztec 2.1G	T-band	0.33 b	70 b	0 a	27.71	155 bc	20%
Aztec 4.67G	Furrow SB	0.29 ab	74 b	1 a	28.03	157 abc	20%
Aztec 4.67G	T-band SB	0.27 ab	81 ab	0 a	27.70	157 abc	20%
Capture 2EC	T-band	0.72 d	42 de	2 a	27.62	155 bc	20%
Cruiser ST	ST	1.34 e	10 fg	20 b	27.68	158 abc	20%
Force 3G	Furrow	0.26 ab	82 ab	0 a	27.50	164 ab	20%
Force 3G	T-band	0.26 ab	79 b	0 a	27.29	164 ab	40%
Fortress 2.5G	Furrow	0.38 bc	71 b	1 a	27.73	157 abc	20%
Fortress 5G	Furrow SB	0.61 cd	63 bc	2 a	27.68	158 abc	20%
Lorsban 15G	T-band	0.70 d	51 cd	2 a	28.09	156 bc	20%
Poncho 1250	ST	0.84 d	25 ef	3 a	27.24	162 ab	40%
YieldGard RW[12]	----	0.03 a	98 a	1 a	27.35	171 a	80%
CHECK	----	1.69 f	2 g	26 c	27.18	145 c	--

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

[2] Means based on 170 root injury 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. 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 root injury 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, $P \leq 0.05$).

[10] Means based on 19 observations.

[11] Percent of time that yield was statistically different from check for individual trials.

[12] Hybrid DKC60-12 used in YieldGard trials; DKC60-15 used in all insecticide treatments.

Table 3. Performance of seed treatments against black cutworms in seedling corn, Experiment 1. Iowa, 2004.

	Cut Plants[1]			
Treatment	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	--

[1] Means sharing a common letter do not differ significantly by analysis of variance, Fisher's Protected LSD ($P \leq 0.05$).

Table 4. Performance of insecticides against black cutworms in seedling corn, Experiment 2. Iowa, 2004.

	Cut Plants[1]			
Treatment	**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	--

[1] Means sharing a common letter do not differ significantly by analysis of variance, Fisher's Protected LSD ($P \leq 0.05$).

Table 5. Performance of Poncho seed treatments in corn against true white grubs. Iowa, 2004.

Experiment	Treatment	Grubs/ plant	% live plants[1]	% dead grubs[1]	Mean leaf height (cm)[1]	Mean dry plant weight (gm)[1]
1-3	Poncho 1250	½	98	50.0a	34.5a	0.73a
	Poncho 250	½	100	28.6ab	33.0a	0.70a
	Check	½	77	14.3b	29.1b	0.50b
4	Poncho 1250	2	100a	62a	37.1a	0.56a
	Poncho 250	2	100a	72a	38.8a	0.58a
	Check	2	6.3b	19b	3.8b	0.40b
5	Poncho 1250	2	100	64.5a	31.9	0.69
	Poncho 250	2	100	78.5a	32.1	0.72
	Check	2	71.5	7.3b	25.4	0.44
6	Poncho 1250	2	100a	37.5ab	43.8a	0.73a
	Poncho 250	2	100a	58.3a	40.3a	0.67a
	Check	2	33.4b	16.7b	12.9b	0.17b

[1] Means sharing a common letter do not differ significantly by analysis of variance, Fisher's Protected LSD ($P \leq 0.05$).