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Agriculture and Natural Resources
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SEED TREATMENTS FOR WIREWORM CONTROL IN FIELD CORN

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ABSTRACT

Wireworms are the soil-dwelling larvae of click beetles. Wireworms feed on the seed and roots of various crops and are a particular pest of field corn in the Sacramento-San Joaquin River Delta region. Wireworms are generally managed by seed treatments or treatments at planting. The objective of this study was to evaluate the efficacy of a new chemistry (active ingredient chlorantraniliprole) against wireworms. We evaluated it at different rates, in combination with other products and stabilizing polymers, and alongside commercial standards (active ingredients clothianidin and thiamethoxam) by measuring corn growth and yield. Several treatments outperformed the untreated controls in growth. While numerical differences in yield existed, statistical differences were less consistent than growth differences. Results from this study illustrate that there are different chemistries available for combatting wireworms in field corn, and growers have several options for controlling these pests.

INTRODUCTION

Wireworms (*Limonius* spp.) are the larvae of click beetles. Wireworms are yellow to brown in color, cylindrical, and have tough skin. They live in the soil and may live three or more years depending on species, conditions, and food supply (UC IPM Guidelines, 2014). Wireworms feed on a variety of plants, including corn, and cause damage by feeding on the seed or roots of an emerging seedling. They can be particularly damaging to a corn crop that follows a crop with dense roots, like pasture, small grains, or alfalfa. Wireworm management in corn is generally by seed treatment or treatment at the time of planting. Cultural practices – like crop rotation, flooding, or cultivation – are generally ineffective because wireworms have a wide host range and are adaptable to different environments (Andrews et al., 2008). Delaying planting to allow soils to dry and warm may improve corn emergence because wireworms retreat deeper in the soil under these conditions (McLeod and Studebaker, 2003), but this is a management practice that may not always be possible.

Many wireworm control studies focus on evaluating insecticide efficacy. Studies show that certain chemistries, like the neonicotinoids thiamethoxam and imidacloprid, are as effective at controlling wireworms as organophosphates (Kuhar and Alvarez, 2008), the latter having environmental and wildlife persistence (Elliott et al., 2011). Neonicotinoids, however, have been implicated in bee population declines (Hopwood et al., 2012); thus, alternatives to neonicotinoids are being sought.

Researchers have found that seed treatments are as effective at controlling wireworms as granular treatments at the time of planting (Wilde et al., 2004). Seed treatments are easier to apply than granular treatments, but having a range of chemistries available would allow for chemical rotations as part of an integrated pest management program.

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DELTA TRIAL

In 2015, two trials were conducted in the Sacramento-San Joaquin River Delta region, one each on Staten and Tyler Islands. The soil at both locations is a Rindge muck, which characterizes around 57,000 acres in the Delta. The soil series has approximately 45 percent organic matter in the top 15 inches. The Rindge muck is considered very poorly drained, and the soil stays cool and damp into late spring and early summer. The sites were chosen based on their crop history and wireworm pressure. Both sites had been cropped with corn in the previous year, and at neither site was the ground worked after harvest. In the spring before planting, ground preparation at the Staten Island site utilized a rotary reel chopper, disk ripper, and field cultivator, and the Tyler Island site was disked and plowed.

Approximately two weeks before planting, the fields were baited with carrots to confirm wireworm presence. Carrots were buried over large swaths of the fields. The GPS coordinates of the carrots were recorded, and the carrots were collected one week later. Wireworms were counted on each carrot to determine where the pressure was highest, and the plots were located accordingly.

The Staten Island trial was planted on April 15, 2015, and the Tyler Island trial was planted on June 9, 2015, using the variety Pioneer P1948R. The soil was moist at the time of planting. The Staten Island trial had four replicate blocks of ten insecticidal seed treatments plus control, and the Tyler Island trial had eight insecticidal seed treatments plus two controls. All treatments also had a fungicide seed treatment, except for one of the two controls at the Tyler Island site. Each plot consisted of four 30-inch beds on a row length of 50 feet. Seed was planted approximately two inches deep and six inches apart down the row, for an approximate planting density of 35,000 seeds per acre. Subsurface irrigation by “spud ditch” was employed six times during the season on Staten Island and three times on Tyler Island. Nitrogen was applied preplant as UN 32 (Staten) and aqua ammonia (Tyler), and starter fertilizer was applied at planting as 3-8-11 (Staten) and 8-24-6 (Tyler). At both sites, one glyphosate application served to control weeds, and no miticide was applied.

Three of the treatments used at one or both of the sites are commercially available for the management of wireworm (Poncho®, Poncho® Votivo®, and Cruiser®), and the other treatments were different rates and combinations of a new product called Lumivia™ (Table 1). The objective for the Staten Island trial was to evaluate the efficacy of different rates of Lumivia™ as a stand-alone product, Lumivia™ in combination with bifenthrin, and commercial neonicotinoid products. The objective of the Tyler Island trial was to evaluate Lumivia™ with different polymers, which are used to help hold seed treatments in place but can also affect traits such as stability, release rate, and plant uptake.

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Table 1. Seed treatments and chemistry information for the 2015 UCCE seed treatment study.

Product	Company	Active Ingredient	Chemistry Class
Lumivia™	DuPont	Chlorantraniliprole	Anthranilic Diamide
Poncho®	Bayer CropScience	Clothianidin	Neonicotinoid
Poncho® Votivo®	Bayer CropScience	Clothianidin + Bacillus firmus I-1582	Neonicotinoid + biological
Cruiser®	Syngenta	Thiamethoxam	Neonicotinoid
Various products	FMC Corporation	Bifenthrin	Pyrethroid

Growth parameters of interest were emergence, stand count, vigor, damaged plants, dead plants, and height (Tables 2-5). These parameters were measured from approximately one to six weeks after planting. Emergence and stand counts were the number of plants in a 10-foot length. Vigor was a visual rating on a scale of 1-10, where Poncho® Votivo® was the standard and always rated 5. Damaged and dead plants were counts out of 25 consecutive plants. Height was measured from the soil to the tip of the last fully emerged leaf.

On the second week of evaluations, ten seedlings were lifted, and dead and live wireworms were counted on the seeds, roots, and surrounding soil (Tables 2-3). The seedlings were given a visual rating on a scale of 0-3, where 0 indicated no damage, 1 indicated some root feeding but overall good plant health, 2 indicated moderate feeding and declining plant health, and 3 indicated dead plants.

The trials were harvested on September 30th and October 14th (Staten and Tyler Islands, respectively). Two 20-foot lengths from the middle two rows were hand harvested for each plot, and the number of plants in the harvested area were counted. Additionally, at the Staten Island trial, weed pressure was high, particularly Johnson grass, so Johnson grass plants were also counted for a 20-foot length. The kernels were threshed from the cobs using a Kincaid® 18-inch bundle thresher, and the moisture and bushel weight were read using a Dickey-John® GAC 2100b moisture meter. Yield for the harvested area was scaled up to tons per acre and adjusted to 15 percent moisture (Tables 6-7).

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Table 2. Emergence and wireworm counts of the Staten Island seed treatment trial.

Date:	**April 27th**			
Treatment*	**Emergence (#/10 feet)**	**Live Wireworms (#/10 plants)**	**Dead Wireworms (#/10 plants)**	**Damage Rating (0-3 scale, 10 plants)**
Cruiser® 250	20	25 ab	3 a	0.93 bcd
Lumivia™ 250 + Cruiser® 250	20	19 ab	1 ab	1.10 abc
Lumivia™ 250	18	20 ab	1 ab	1.23 ab
Lumivia™ 500	17	22 ab	1 ab	1.28 ab
Lumivia™ 750	16	28 a	1 ab	1.08 bcd
Lumivia™ 250 + bifenthrin 125	18	8 b	1 ab	0.48 cd
Lumivia™ 500 + bifenthrin 125	17	16 ab	1 ab	1.28 ab
Lumiva™ 750 + bifenthrin 125	18	10 ab	0 ab	0.80 bcd
Poncho® Votivo® 1250	17	19 ab	3 a	0.58 cd
Poncho® 500	20	15 ab	2 ab	0.40 d
Untreated control	14	15 ab	0 b	2.00 a
Treatment P value	**0.1426**	**0.0139**	**0.0186**	**<0.0001**
Standard Error	**1.60**	**3.65**	**0.62**	**0.16**

* Numbers following product names indicate the micrograms of active ingredient per seed (μ a.i./seed).

Table 3. Emergence and wireworm counts of the Tyler Island seed treatment trial.

Date:	**June 16th**	**June 23rd**		
Treatment*†	**Emergence (#/10 feet)**	**Live Wire-worms (#/10 plants)**	**Dead Wire-worms (#/10 plants)**	**Damage Rating (0-3 scale, 10 plants)**
Cruiser® 250 + Disco™	20 ab	3	0	0.40 cd
Lumivia™ 250 + Cruiser® 250 + Disco™	18 ab	4	0	0.20 d
Lumivia™ 250 + Cruiser® 250 + PSF 1006	20 ab	3	0	0.53 cd
Lumivia™ 250 + Cruiser® 250 + FR1197	19 ab	5	1	0.35 d
Lumivia™ 750 + FR1197	19 ab	4	1	1.13 ab
Poncho® Votivo® 1250	20 a	4	1	0.38 cd
Lumivia™ 250 + Cruiser® 250 (no polymer)	20 a	4	0	0.43 d
Lumivia™ 750 (no polymer)	19 ab	4	1	0.50 cd
Untreated control (w/ fungicide)	17 c	7	0	1.30 a
Untreated control (w/o fungicide)	18 bc	6	0	1.13 ab
Treatment P value	**<0.0001**	**0.6887**	**0.2772**	**<0.0001**
Standard Error	**0.46**	**1.33**	**0.35**	**0.19**

* Numbers following product names indicate the micrograms of active ingredient per seed (μ a.i./seed).
† Disco, PSF 1006, and FR1197 are polymers used with the seed treatments.

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Table 4. Growth parameters of the Staten Island seed treatment trial.

Date:	**All Dates (Weekly from May 7th to June 4th)**				
Treatment*	**Stand Count (# plants/10 feet)**	**Vigor (Poncho® Votivo® is standard, 5)**	**Damaged Plants (#/25 plants)**	**Dead Plants (#/25 plants)**	**Height (inches)**
Cruiser® 250	18 abc	4.35 abc	5 bcde	1 c	21 cd
Lumivia™ 250 + Cruiser® 250	19 abc	4.30 abc	6 abcd	0 c	20 d
Lumivia™ 250	15 d	3.60 cd	8 ab	3 ab	19 d
Lumivia™ 500	16 cd	3.95 bc	10 a	2 ab	19 d
Lumivia™ 750	11 e	2.65 de	9 ab	6 a	17 e
Lumivia™ 250 + bifenthrin 125	16 cd	3.60 cd	9 a	0 c	19 d
Lumivia™ 500 + bifenthrin 125	17 bcd	4.35 abc	7 abcd	1 bc	23 bc
Lumivia™ 750 + bifenthrin 125	18 abcd	5.10 a	4 cde	0 c	25 ab
Poncho® Votivo® 1250	18 abcd	5.00 ab	3 e	0 c	22 bc
Poncho® 500	20 a	5.25 a	4 de	0 c	26 a
Untreated control	9 e	2.45 e	8 abc	4 a	20 d
Treatment P value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Standard Error	**0.87**	**0.27**	**1.02**	**0.79**	**0.52**

* Numbers following product names indicate the micrograms of active ingredient per seed (µ a.i./seed).

Table 5. Growth parameters of the Tyler Island seed treatment trial.

Date:	**All Dates (Weekly from June 23rd to July 13th)**				
Treatment*†	**Stand Count (# plants/10 feet)**	**Vigor (Poncho® Votivo® is standard, 5)**	**Damaged Plants (#/25 plants)**	**Dead Plants (#/25 plants)**	**Height (inches)**
Cruiser® 250 + Disco™	20 a	4.9 ab	1 c	0 b	36 abc
Lumivia™ 250 + Cruiser® 250 + Disco™	20 a	4.6 b	1 c	0 b	37 abc
Lumivia™ 250 + Cruiser® 250 + PSF 1006	19 a	4.7 ab	2 c	1 ab	35 bc
Lumivia™ 250 + Cruiser® 250 + FR1197	19 a	4.7 ab	1 c	0 b	37 abc
Lumivia™ 750 + FR1197	19 ab	4.2 b	3 bc	1 ab	35 cd
Poncho® Votivo® 1250	20 a	5.0 ab	1 c	0 b	38 ab
Lumivia™ 250 + Cruiser® 250 (no polymer)	20 a	4.8 ab	3 c	0 b	35 cd
Lumivia™ 750 (no polymer)	20 a	5.4 a	3 bc	0 b	38 a
Untreated control (w/ fungicide)	17 bc	3.0 c	5 ab	0 ab	33 d
Untreated control (w/o fungicide)	15 c	2.6 c	7 a	2 a	30 e
Treatment P value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Standard Error	**0.44**	**0.17**	**1.02**	**0.29**	**3.16**

* Numbers following product names indicate the micrograms of active ingredient per seed (µ a.i./seed).
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Table 6. Harvest results of the Staten Island seed treatment trial.

Date:	September 30th				
Treatment*	Total Plants (# plants/40 feet)	Moisture (%)	Bushel Weight (lbs/bu)	Yield at 15% Moisture (tons/acre)	Johnson Grass Pressure (# plants/20 feet)
Cruiser® 250	48 abc	11.7	60.13 a	3.82 ab	16 ab
Lumivia™ 250 + Cruiser® 250	61 a	11.6	59.35 ab	5.04 a	8 b
Lumivia™ 250	29 abc	11.5	57.28 ab	2.30 ab	23 ab
Lumivia™ 500	32 abc	11.5	57.78 ab	2.24 ab	20 ab
Lumivia™ 750	9 c	11.1	55.44 b	0.36 b	38 a
Lumivia™ 250 + bifenthrin 125	42 abc	11.8	58.73 ab	3.30 ab	14 ab
Lumivia™ 500 + bifenthrin 125	50 abc	11.8	59.83 a	4.66 ab	12 b
Lumiva™ 750 + bifenthrin 125	42 ab	11.8	59.88 a	3.55 ab	7 b
Poncho® Votivo® 1250	55 ab	11.8	59.43 ab	4.21 ab	10 b
Poncho® 500	58 a	11.6	59.35 ab	3.89 ab	14 b
Untreated control	15 bc	11.5	58.2 ab	1.10 ab	27 ab
Treatment P value	**0.0012**	**0.0728**	**0.0147**	**0.0205**	**0.0015**
Standard Error	**8.78**	**0.12**	**0.67**	**0.98**	**4.95**

* Numbers following product names indicate the micrograms of active ingredient per seed (μ a.i./seed).

Table 7. Harvest results of the Tyler Island seed treatment trial.

Date:	October 14th			
Treatment*†	Total Plants (# plants/40 feet)	Moisture (%)	Bushel Weight (lbs/bu)	Yield at 15% Moisture (tons/acre)
Cruiser® 250 + Disco™	79 a	22.1	54.15	4.15
Lumivia™ 250 + Cruiser® 250 + Disco™	81 a	21.5	54.95	5.18
Lumivia™ 250 + Cruiser® 250 + PSF 1006	80 a	22.4	53.95	4.40
Lumivia™ 250 + Cruiser® 250 + FR1197	82 a	22.2	54.53	5.09
Lumivia™ 750 + FR1197	75 ab	21.3	54.83	4.85
Poncho® Votivo® 1250	80 a	22.0	54.58	4.59
Lumivia™ 250 + Cruiser® 250 (no polymer)	81 a	22.2	54.33	4.47
Lumivia™ 750 (no polymer)	78 a	21.7	54.05	5.03
Untreated control (w/ fungicide)	66 bc	22.8	53.65	4.41
Untreated control (w/o fungicide)	63 c	21.8	54.15	4.40
Treatment P value	**<0.0001**	**0.6134**	**0.9397**	**0.1231**
Standard Error	**2.67**	**0.54**	**0.66**	**0.29**

* Numbers following product names indicate the micrograms of active ingredient per seed (μ a.i./seed).
† Disco, PSF 1006, and FR1197 are polymers used with the seed treatments.

INTERPRETATION OF RESULTS

When interpreting the results, keep the following in mind. The mean is equal to the sum of values divided by the number of values. When evaluations occurred on only one date, the mean

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was calculated for the four replicate blocks. For stand count, vigor, damaged plants, dead plants, and height, however, evaluations were made weekly over multiple weeks. The means for these parameters were calculated across all of the dates. The statistical method used to compare the means, called Tukey's range test, compares all means against each other. Treatments were considered statistically different if their P value was less than 0.05, or 5 percent. This means that when differences between treatments exist, we are 95% certain that the differences are not due to random chance. Differences between treatments are indicated by different letters following the mean. For example, a treatment that has only the letter "a" after the mean is different from a treatment that is followed by only the letter "b", but it is ***not*** different from a treatment whose mean is followed by both letters ("ab").

At the Staten Island trial, differences in plant growth among the treatments became evident two to three weeks after planting. Stand counts, vigor, damage rating, and height for Poncho®, Poncho® Votivo®, and Lumivia™ 750 + bifenthrin 125 were better and statistically different than those for the untreated control. Cruiser® and Lumivia™ 250 + Cruiser® 250 often performed better than the untreated control but not as consistently as the three aforementioned treatments. At harvest, statistical differences only separated Lumivia™ 250 + Cruiser® 250 from Lumivia™ 750, which yielded worse than the untreated control. The poor result of Lumivia™ 750 may be explained by uncontrollable factors, namely, bird damage (data not shown) and high wireworm pressure (Table 2). Yields at this site were highly variable, and both wireworm and weed pressure may have contributed to this variability. Johnson grass pressure was especially high in treatments where plant stands were compromised by wireworms or birds. High weed pressure can be a consequence of poor wireworm control because stands that are compromised do not provide the consistent shading to out-compete weeds. Yields can suffer as a result.

In general, the polymer treatments that were tested at the Tyler Island site showed no growth or yield benefits over the non-polymer treatments. Both the polymer and non-polymer treatments showed growth improvements over the control treatments, and they performed as well as the commercial standard, Poncho® Votivo®. There were no statistical yield benefits of the seed treatments, so we cannot attribute the numerical differences in yield to treatment differences. Nevertheless, three Lumivia™ treatments (Lumivia™ 250 + Cruiser® 250 + Disco™, Lumivia™ 250 + Cruiser® 250 + FR1197, and Lumivia™ 750 (no polymer)) yielded over 5 tons per acre compared to yields in the 4 tons per acre range.

Considering both trials, results suggest that Lumivia™ 250 + Cruiser® 250 provides good wireworm control. Higher rates of Lumivia™ (500 or 750 µ a.i./seed) in combination with bifenthrin also appear to provide good wireworm control. The commercial standards Poncho®, Poncho® Votivo®, and Cruiser® also performed well. Results for Lumivia™ as a stand-alone product are inconclusive, particularly because the high rate of Lumivia™ performed best at one site but worst at the other.

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SUMMARY

Wireworms are the soil-dwelling larvae of click beetles, and they are a pest of field corn in the organic soils of the Delta. In 2015, we evaluated the efficacy of the seed treatment Lumivia™ at different rates, in combination with other products and stabilizing polymers, and alongside commercial seed treatment standards (Poncho®, Poncho® Votivo®, and Cruiser®) by measuring corn growth and yield at two trial locations. Across both trial locations, results suggest that Lumivia™ 250 + Cruiser® 250, Lumivia™ (500 or 750) in combination with bifenthrin 125, and commercial standards Poncho®, Poncho® Votivo®, and Cruiser® provide good control against wireworms in the weeks after planting when corn is in the seedling stages. This control and resulting better stands have the potential to improve yields over non-treated seeds.

The trial results illustrate that growers have several options for managing wireworms. The two Poncho® products are commercially available from Bayer CropScience, and Cruiser® is commercially available from Syngenta. Lumivia™, a Dupont product, is not yet commercially available as a corn seed treatment in California, but if it were to become so, it would provide growers with an alternative to the neonicotinoid treatments. When making decisions on products, growers should consider their wireworm pest pressure and other soil-dwelling pests that could limit their production. Growers should also consider which seed treatments they have been using and whether those are still controlling pests. If not, rotating to a different chemistry might be a way to bring pests back under control. Integrated pest management practices recommend rotating chemistries for insect resistance management.

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