Insecticidal control of invasive crane flies in the northeastern U.S.

Initial research has shown that some products control crane fly larvae, but additional work is needed to evaluate other products and to refine control strategies.

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Two invasive crane flies, the European crane fly (*Tipula paludosa* Meigen) and the common crane fly (*T. oleracea* L.), were detected in New York state for the first time in 2004 (7). Both are damaging pests of turfgrass and other horticultural systems in North America where establishment has already been documented (6,10,11,13).

Known as "leatherjackets" for the pupal case left behind by the emerging adult, crane fly larvae can be a problem in any grass-based system (2,9). They inhabit the top layer of the soil, where they feed on the roots and crowns of their hosts (5,14). By pruning and disrupting below-ground portions of the plant, they cause turfgrass damage like that of white grubs, which leads to severe thinning of the sward and extensive dieback when damaged turf is water-stressed. Larvae also reside in the thatch, emerging at night to feed on above-ground portions of the stem and foliage. Because the two species have different life histories (*T. paludosa* has one generation a year, *T. oleracea* has two), the timing of control interventions is a critical element of successful management.

The main objective of our research was to evaluate insecticidal options for the suppression of invasive crane fly larvae in the field. Because crane fly larvae are an emerging pest in turfgrass, relatively few products are actually labeled for their control. We therefore tested a variety of active ingredients, products and rates, including some that are not currently registered for crane flies or golf courses (Table 1). The study was also designed to measure variation in the efficacy of control products between preventive and curative control windows. We chose to work with *T. paludosa* because of the availability of field sites with reliable populations and an absence of *T. oleracea.* In New York state, *T. paludosa* adults emerge in late fall. Developing larvae overwinter, complete growth by early June, and then aestivate the rest of the summer until pupation in autumn. Insecticidal control is preventive in late autumn (larvae are too small to scout and damage is uncommon) and curative in early spring (larvae are large

A larva of the invasive crane fly *Tipula paludosa.* Photo by J. Ogrodnick enough to scout and damage is common).

Materials and methods

Experimental design

Four independent experiments were conducted over a two-year period from spring 2005 to fall 2006. The experimental plots were established in the rough on two golf courses in western New York (Niagara County) where relatively high populations of *T. paludosa,* but not *T. oleracea*, had been detected in previous and concurrent surveys. Across these sites, grass composition was predominantly perennial ryegrass, with Kentucky bluegrass, annual bluegrass and tall fescue. Cutting height was 3-3.5 inches (7.6-8.9 centimeters).

Over the course of the four experiments, a total of 22 formulations of 14 active ingredients were tested, representing nine classes of compound and one dual compound. We evaluated 13 to 22 treatments in each experiment, including an untreated check where we substituted an equivalent amount of water for the product. The treatments were arranged in each experiment as a randomized complete block design with three to six replications. Treatment plots were 10 × 10 feet (3 × 3 meters), including a 1-foot (0.3-meter) treated buffer where insect sampling did not take place.

In spring and autumn 2005, liquid and wettable powder formulations were applied in 2 gallons (7.5 liters) of water using a watering can. Granular formulations were applied using a shaker jar, followed by the same amount of water. In spring 2006, liquid and wettable powder formulations were applied using a 1-gallon (3.8-liter) hand-pumped pressurized sprayer unit at about 11 psi (76 kilopascals) through a flat-fan sprayer nozzle, followed by 1 gallon (3.8 liters) of water applied with a watering can. In fall 2006, treatments were applied using a backpack carbon dioxide sprayer calibrated to deliver 0.7 gallon of material/1,000 square feet (28.5 milliliters/square meter) at 30 psi (207 kilopascals) through two flat-fan sprayer nozzles. Granular formulations were applied with a hand-held broadcast spreader.

To evaluate larval populations, a standard cup cutter, 4 inches (10 centimeters) in diameter, was used to extract soil cores to a depth of 4 inches. Nine cores were taken from each plot in 2005, and six in 2006. After transport to the lab, larvae were separated from the soil cores.

Application timing

Preventive applications were made in fall when target populations were mostly first and second

Registration status of active ingredients for crane fly control in the U.S. and New York state

Active ingredient	U.S.	New York
Azadirachtin	no	no
Beauveria bassiana strain ATCC 74040 *	yes	yes
Beauveria bassiana strain GHA	no	no
Bifenthrin	yes	yes
B.t. products	no	no
Carbaryl	yes	yes
Chlorantraniliprole	yes	no
Chlorpyrifos	yes†	yes†
Clothianidin (only dualin a combination product with bifenthrin)	(yes)	no
Cyfluthrin (only in a combination product with imidacloprid)	(yes)	(yes)
Cyhalothrin*	yes	yes
Deltamethrin*	yes	yes
Dinotefuran	no	no
Halofenozide	no	no
Imidacloprid + bifenthrin	yes	yes
Imidacloprid	yes	yes
Indoxacarb	yes	yes
Permethrin*	yes	yes
Thiamethoxam (only in a combination product with bifenthrin)	(yes)	no
Trichlorfon	yes	yes

Caveats. This table is based on information available at the National Pesticide Retrieval System website (http://state.ceris.purdue.edu); output was generated by searching for "turf" and "European crane fly"; some active ingredients are not necessarily available for golf course applications. The information is current, to the best of the authors' knowledge, as of January 2009. Inclusion in this study should not be construed as a recommendation for a product or active ingredient.

*Not included among the active ingredients tested in this study.

†Production of Dursban 50WSP will begin in the first quarter of 2009 under a new label that will not include golf course applications. Dursban product currently in the channel of trade is labeled for use on golf courses and can be used through 2010. Read and follow all label directions for use sites.

Table 1. Summary of active ingredients and their registration status for control of crane fly larvae in turfgrass.

instars, based on observations on the timing of adult flights. In 2005, applications were made on Oct. 6-7, and plots were rated by collecting soil cores four weeks after treatment. In 2006, applications were made on Oct. 16, and plots were rated by collecting soil cores three weeks after treatment.

Curative applications

Curative applications were made in spring when target populations were mostly late third or fourth (ultimate) instars. In 2005, applications were made on May 12, except for Ornazin 3EC (azadirachtin), which was applied on May 24. Plots were rated by collecting soil cores four weeks after treatment. In 2006, applications were made on May 30, and plots were rated by collecting soil cores one week after treatment.

Data analysis

Data from each experiment were initially analyzed separately to test for a significant effect of treatments with respect to the untreated check. For each plot, an estimate of absolute larval density was made by pooling the counts across the soil core extractions. For each replication and treatment, population suppression was calculated with

Preventive fall treatments

Active ingredient	Product/formulation	Company name	Rate (a.i.) per acre	Rate (a.i.) kilograms/hectare	Mean % larval reduction (±SE)† 2005	Mean % larval reduction (±SE)† 2006
Azadirachtin	Ornazin 3EC	SePro Corp.	0.2 ounces	0.017	94.4 ± 2.8***	39.6 ± 22.9 NS
Beauveria bassiana	BotaniGard 11.3EC	Mycotech	2.5 pounds	2.76	83.3 ± 12.7***	63.6 ± 21.9 NS
Bifenthrin	Talstar 0.2G	FMC Corp.	6.4 ounces	0.45	94.4 ± 5.6***	—
Bifenthrin	Talstar 7.9ES	FMC Corp.	6.4 ounces	0.45	—	94.9 ± 4.0**
Bt israelensis	Gnatrol 6.38EC	Valent	4.0 ounces	0.28	58.3 ± 29.3 NS	25.0 ± 25.0 NS
Carbaryl	Sevin 43SL	Bayer	7.0 pounds	7.89	97.2 ± 2.8***	70.1 ± 23.5*
Chlorantraniliprole	Acelepryn 18.5SC/1.67SC‡	DuPont	1.7 ounces	0.12	94.4 ± 5.6***	46.4 ± 27.0 NS
Chlorantraniliprole	Acelepryn 18.5SC‡	DuPont	3.6 ounces	0.25	100.0 ± 0.0***	—
Chlorantraniliprole	Acelepryn 18.5SC‡	DuPont	4.1 ounces	0.29	—	80.4 ± 7.4*
Chlorantraniliprole	Acelepryn 18.5SC‡	DuPont	7.0 ounces	0.49	94.4 ± 5.6***	—
Clothianidin	Arena 50WDG‡	Valent	3.1 ounces	0.22	—	79.0 ± 100.1*
Clothianidin	Arena 50WDG‡	Valent	4.9 ounces	0.34	—	100.0 ± 0.0***
Clothianidin	Arena 50WDG‡	Valent	5.4 ounces	0.38	100 ± 0.0***	—
Cyfluthrin	Tempo Ultra 10WP	Bayer	1.6 ounces	0.11	80.6 ± 19.4***	—
Cyfluthrin	Tempo 20WP	Bayer	2.1 ounces	0.15	77.8 ± 12.1**	45.6 ± 16.5 NS
Dinotefuran	Safari 20SG‡	Valent	8.6 ounces	0.60	100 ± 0.0***	62.5 ± 21.7 NS
Halofenozide	Mach 2. 1.5G	Dow AgroSciences	1.0 pound	2.24	55.6 ± 29.4 NS	—
Imidacloprid	Merit 0.5G/0.2G	Bayer	2.6 ounces	0.18	86.1 ± 10.0***	44.3 ± 25.6 NS
Imidacloprid	Merit 0.5G	Bayer	3.0 ounces	0.21	94.4 ± 5.6***	31.5 ± 15.0 NS
Imidacloprid	Merit 0.5G	Bayer	4.0 ounces	0.28	88.9 ± 11.1***	57.3 ± 20.0 NS
Imidacloprid + bifenthrin	Allectus 9SC	Bayer	1.2 + 0.96 ounces	0.083 + 0.067	94.4 ± 5.6***	73.5 ± 9.4*
Imidacloprid + bifenthrin	Allectus 0.36G	Bayer	3.1 + 2.6 ounces	0.22 + 0.18	94.4 ± 5.6***	46.2 ± 26.9 NS
Indoxacarb	Provaunt 14.5SC	DuPont	1.1 ounces	0.078	100 ± 0.0***	—
Indoxacarb	Provaunt 14.5SC	DuPont	1.9 ounces	0.13	—	44.0 ± 17.7 NS
Indoxacarb	Provaunt 14.5SC	DuPont	3.6 ounces	0.25	—	63.6 ± 21.3 NS
Indoxacarb	Provaunt 14.5SC	DuPont	6.4 ounces	0.45	100 ± 0.0***	—
Trichlorfon	Dylox 80WP	Bayer	8.2 pounds	9.16	91.7 ± 4.8***	77.8 ± 19.9**

†For each year, means are significantly different from the untreated check at p-values of *0.05, **0.01 and ***0.001 (Dunnett's Method).

‡Arena 50WDG, Acelepryn and Safari 20SG are not registered in New York state.

Table 2. Efficacy of insecticides in fall for the preventive control of first- and second-instar Tipula paludosa in golf course roughs.

respect to the untreated check. The plot values were used to establish overall means for density and population suppression.

Data were also assessed to determine whether the application window (preventive or curative) affected product efficacy. This was tested individually for the six products that were included in each of the four trials: Arena 50WDG (clothianidin), Safari 20SG (dinotefuran), Merit 0.2G/0.5G (imidacloprid), Allectus 0.81SC/0.36G/9SC (imidacloprid + bifenthrin), Provaunt 1.25SC/14.5SC (indoxacarb) and Dylox 80WP (trichlorfon). When more than one rate was tested, the products were examined three ways: with data from only the lowest rate examined in each trial, data from only the highest rate and data from all rates pooled. Given similarity in the results, data are only presented for pooled rates, where percent control was calculated for each repetition and pooled to yield treatment scores, and then averaged across all trials within each control window.

Results

Preventive applications

2005 treatments. In 2005, mean larval popu-

Curative spring treatments

Active ingredient	Product/formulation	Rate (a.i.) per acre	Rate (a.i.) kilograms/hectare	Mean % larval reduction (±SE)† 2005	Mean % larval reduction (±SE)† 2006
Azadirachtin	Ornazin 3EC	1.6 pounds	1.78	20.9 ± 9.9 NS	—
Beauveria bassiana	BotaniGard 11.3EC	2.6 pounds	2.88	29.2 ± 17.3 NS	—
Bifenthrin	Talstar PL0.2G	1.6 ounces	0.11	—	16.7 ± 10.3 NS
Bt israelensis	Gnatrol 6.38EC	4.3 ounces	0.30	48.2 ± 22.4*	
Carbaryl	Sevin 43SL	8.0 pounds	8.97	—	39.1 ± 10.2**
Chlorantraniliprole	Acelepryn 18.5SC‡	2.0 ounces	0.14	44.2 ± 16.5 NS	—
Chlorantraniliprole	Acelepryn 18.5SC‡	4.0 ounces	0.28	56.8 ± 19.2*	—
Chlorantraniliprole	Acelepryn 18.5SC‡	8.0 ounces	0.56	39.6 ± 18.1 NS	—
Clothianidin	Arena 50WDG‡	4.0 ounces	0.28	—	70.9 ± 10.1***
Clothianidin	Arena 50WDG‡	5.3 ounces	0.37	97.1± 2.9***	—
Clothianidin	Arena 50WDG‡	6.4 ounces	0.45	—	78.6 ± 6.5***
Chlorpyrifos	Dursban 23.5EC§	1.0 pound	1.12	—	56.2 ± 13.3***
Cyfluthrin	Tempo Ultra 10WP	1.6 ounces	0.11	50.7 ± 17.7*	—
Cyfluthrin	Tempo 20WP	2.1 ounces	0.15	32.5 ± 18.8 NS	—
Dinotefuran	Safari 20SG‡	8.6 ounces	0.60	98.8 ± 1.2***	83.7 ± 5.9***
Imidacloprid	Merit 0.2G	4.0 ounces	0.28	59.6 ± 15.3*	—
Imidacloprid	Merit 0.5G	6.3 ounces	0.44	—	63.7 ± 5.7***
Imidacloprid + bifenthrin	Allectus 0.81SC	2.0 + 1.7 ounces	0.14 + 0.12	45.8 ± 16.4*	—
Imidacloprid + bifenthrin	Allectus 0.81SC	3.3 + 2.6 ounces	0.23 + 0.18	35.2 ± 14.9 NS	—
Imidacloprid + bifenthrin	Allectus SC	4.0 + 3.3 ounces	0.28 + 0.23	—	25.1 ± 9.3 NS
Indoxacarb	Provaunt 1.25SC	7.0 ounces	0.49	94.1 ± 3.6***	—
Indoxacarb	Provaunt 14.5SC	7.0 ounces	0.49	—	48.8 ± 15.4***
Indoxacarb	Provaunt 1.25SC	1.1 ounces	0.078	72.2 ± 10.2***	—
Indoxacarb	Provaunt 14.5SC	1.7 ounces	0.12	—	24.9 ± 11.9 NS
Indoxacarb	Provaunt 14.5SC	3.4 ounces	0.24	—	34.6 ± 15.8*
Trichlorfon	Dylox 80WP	8.2/8.1 pounds	9.15/9.08	69.1 ± 7.5**	61.6 ± 13.3***

†For each year, means are significantly different from the untreated check at p-values of *0.05, **0.01 and ***0.001 (Dunnett's Method).

‡Arena 50WDG, Acelepryn and Safari 20SG are not registered in New York state.

§Production of Dursban 50WSP will begin in the first quarter of 2009 under a new label that will not include golf course applications. Dursban product currently in the channel of trade is labeled for use on golf courses and can be used through 2010. Read and follow all label directions for use sites.

Table 3. Efficacy of insecticides in spring for the curative control of third- and fourth-instar Tipula paludosa in golf course roughs.

Larvae (known as leatherjackets) of the invasive crane fly *Tipula paludosa.* Photo by D. Peck

lations in the untreated check plots were 12.7/square foot (137.1/square meter). Five of 22 treatments achieved 100% control: Acelepryn 18.5SC (3.6 ounces a.i./acre), Arena 50WDG (5.4 ounces a.i./acre), Safari 20SG (8.6 ounces a.i./acre) and Provaunt 14.5SC (1.1-6.4 ounces a.i./acre) (see Table 2 for metric units). Sevin 43SL (7 pounds a.i./acre) gave 97% control. Only Gnatrol 6.38EC (*B.t. israelensis*, 4 ounces a.i./acre) and Mach 2 1.5G (1 pound a.i./acre) did not significantly reduce populations (Table 2). Acelepryn 18.5SC (two rates, 94%-100% control), Provaunt 14.5SC (two rates, 100%) and Merit (0.5G, two rates, 89%-94%) did not show a positive rate response, but such a response may have been obscured by the relatively high control given by all products.

2006 treatments. In 2006, mean larval populations in the untreated check plots were 34.8/square foot (375.4/square meter). Only seven of 20 treatments provided significant control (all >70%): Arena 50WDG (3.1-4.9 ounces a.i./acre), Talstar 7.9ES (6.4 ounces a.i./acre), Acelepryn 1.67SC (4.1 ounces a.i./acre), Dylox 80WP (8.2 pounds a.i./acre), Allectus 9SC (2.1 ounces a.i./acre) and Sevin 43 SL (7 pounds a.i./acre) (Table 2).

Variation in efficacy. For all 12 treatments applied in both years, efficacy declined from 2005 to 2006. Dylox 80WP (8.2 pounds a.i./acre) was the least affected by year, declining from 92% control in 2005 to 78% in 2006. The most variable was Merit 0.5G (3 ounces a.i./acre), which declined from 94% to 32% between years. It is unclear how or if the variation in efficacy between years was linked to variation in insect densities.

Curative applications

2005 treatments. In 2005, mean larval populations in the untreated check plots were 10.2/square foot (109.7/square meter). Of the 17 treatments, Safari 20SG (8.6 ounces a.i./acre), Arena 50WDG (5.3 ounces a.i./acre) and Provaunt 1.25SC (7.0 ounces a.i./acre) showed the best curative control (94%-99%) (Table 3). Provaunt 1.25SC (1.1 ounces a.i./acre), Dylox 80WP (8.2 pounds/acre), Merit 0.2G (4 ounces a.i./acre), Acelepryn 18.5SC (4 ounces a.i./acre), Allectus 0.81SC (3.7 ounces a.i./acre), Tempo Ultra 20WP (1.6 ounces a.i./acre) and Gnatrol 6.38EC (4.3 ounces a.i./acre) also showed significant control. The remaining treatments did not provide significant control (21%-44% suppression).

2006 treatments. In 2006, mean larval populations in the untreated check plots were 10.6/square foot (115.0/square meter). Of the 12 treatments tested, nine provided significant control: Safari 20SG (8.6 ounces a.i./acre, 84%), Arena 50WDG (4.0-6.4 ounces a.i./acre, 71%-79%), Merit 0.5G (6.3 ounces a.i./acre, 64%), Dylox 80WP (8.1 pounds a.i./acre, 62%), Dursban 23.5 EC (1 pound/acre, 56%), Provaunt 14.5SC (3.4-7.0 ounces a.i./acre, 35%-49%) and Sevin 43SL (8 pounds a.i./acre, 39%) (Table 3). Allectus 9SC (7.3 ounces a.i./acre), Talstar PL (1.6 ounces a.i./acre) and the lowest rate of Provaunt 14.5SC (1.7 ounces a.i./acre) did not suppress populations relative to the untreated check.

Variation in efficacy. For two of the three treatments applied in both years, variation in efficacy was relatively small. The difference between years was only 15% for Safari 20SG (8.6 ounces a.i./acre) and 7% for Dylox 80WP (8.1 pounds a.i./acre). The efficacy of Provaunt 14.5SC/1.25SC (7 ounces a.i./acre), however, declined considerably from 2005 (94%) to 2006 (49%). It is unclear how this variation might be linked to the change in formulation between years. The three rates of Arena 50WDG tested over the two years gave consistently good results (71%-99%).

Preventive vs. curative applications

Among the six products tested in all four experiments, there was a significant effect of window of application (preventive or curative) for two of them. Safari 20SG was significantly more effective when used as a curative (90.8% ± 8.49% control) than as a preventive (61.1% ± 9.81%). In contrast, Allectus 0.81SC/0.36G/9SC was significantly more effective as a preventive (63.6% ± 7.80%) than as a curative (49.5% ± 7.97%). There was no detectable effect of application window

Pupal cases are left behind after the emergence of invasive crane fly adults. Photo by J. Ogrodnick for Arena 50WDG, Merit 0.2G/0.5G, Provaunt 1.25SC/14.5SC or Dylox 80WP.

Discussion

Our results show that highly efficacious products are currently available for the insecticidal control of *Tipula paludosa* during both preventive and curative control windows. Table 4 provides a summary of overall product efficacy with respect to window of application based on these two years of experiments. In order to further refine this information into reliable recommendations for product selection and application timing, broader field studies are necessary on these same products as well as on others that are currently labeled for the control of crane fly larvae but were not included in this series of studies (12). Success of any insecticidal control program will also depend on tailoring the timing of applications to the species of concern in the geographic region of concern, that is, the Northeast versus the Pacific Northwest, and *T. paludosa* versus *T. oleracea.*

Preventive vs. curative control

Theoretically, IPM practices would benefit through the curative control of *T. paludosa* larvae, especially since insecticidal options are available. Owing to the small size of first and second instars, scouting in autumn is not feasible under most circumstances. In the spring, third and fourth instars are large enough for sampling programs to assess densities through visual inspection of soil cores. Application decisions could then be made on the basis of action thresholds. This approach would allow natural population regulation, such as harsh winters and vertebrate predation, to have a role in reducing populations. Damage thresholds vary considerably depending on overall turf health; 15-25 larvae/square foot is regarded as a general treatment threshold (1). Based on our observations across New York state, damage attributed to *T. paludosa* is common in spring, but thus far unreported in autumn.

This approach may not be relevant for the other invasive species, *T. oleracea.* Adults of both invasives emerge in the same window of time in autumn, but *T. oleracea* completes larval development by early spring and would not be vulnerable to insecticides once pupation begins. It is unclear whether *T. oleracea* causes meaningful damage in early spring and, if so, whether fourth instars could be targeted in the relatively narrow window of time after cold temperatures recede and before pupation begins. Because adult emergence in western New York takes place from late April to mid-May (D.C. Peck, unpublished), preventive control might be the best approach at sites

Product efficacy for invasive crane fly control

Application window	Acceptable	Variable	Unacceptable
Preventive	bifenthrin	azadirachtin	*Bt israelensis*
	carbaryl	*Beauveria bassiana*	
	chlorantraniliprole	cyfluthrin	
	clothianidin	dinotefuran	
	trichlorfon	imidacloprid	
		imidacloprid+bifenthrin	
		indoxacarb	
Curative	clothianidin	imidacloprid	imidacloprid+bifenthrin
	dinotefuran	indoxacarb	
		trichlorfon	

Note. Acceptable active ingredients provided ≥70% control in each of two trials; unacceptable products provided ≤50% control or nonsignificant control in each of two trials; variable products provided mixed or intermediate results between two trials.

Table 4. Efficacy of control products for Tipula paludosa in turfgrass with respect to window of application.

Feeding by a *Tipula paludosa* larva caused scalping damage to the surface of a putting green. Photo by D. Peck

The research says

➔ There are efficacious products for the insecticidal control of invasive crane fly larvae in turfgrass during both preventive and curative application windows.

➔ The most efficacious active ingredients to target early instars in late-fall applications were Talstar, Sevin, Acelepryn, Arena and Dylox 80WP. Results varied for Ornazin 3EC, BotaniGard 11.3EC, Tempo and Tempo Ultra, Safari, Merit and Provaunt.

➔ The most efficacious insecticides to target large instars in spring applications were Arena and Safari. Results varied for Merit, Allectus, Provaunt and Dylox.

➔ Among the best-performing products, Arena and Safari are not labeled for control of invasive crane flies, and neither is registered in New York. Acelepryn is labeled for control of crane fly larvae, but is not yet registered in New York.

➔ Continuing studies are necessary to strengthen product recommendations and generate information on how to best tailor insecticidal controls to crane fly species, seasonal application window and geographic region.

where *T. oleracea* appears alone or together with *T. paludosa*. This underscores the importance of distinguishing between the two species before deciding on the best control window. Tailoring management strategies to each species will depend on studies that better define the time of insecticide application and the speed of kill (8).

As reported here, our experience with the insecticidal control of invasive crane fly larvae in the Northeast spans only two years. Other studies are ongoing to confirm these results, evaluate the efficacy of other products and strengthen our ability to make reliable recommendations for their insecticidal control. Best management practices will ultimately depend on how insecticidal control tactics can be integrated with other management tactics to reduce the impact and curtail the spread of these troublesome invasive pests in turfgrass.

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