Hessian Fly (Diptera: Cecidomyiidae) Management Using Seed Treatments in Winter Wheat[1]

G. David Buntin[2]

Department of Entomology, University of Georgia, Griffin Campus, 1109 Experiment Street, Griffin, GA 30223 USA

J. Entomol. Sci. 60(1): 129–140 (January 2025)
DOI: 10.18474/JES24-05

Abstract The Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), is a potentially severe pest of wheat, *Triticum aestivum* L. em Thell, in the southeastern United States. Plant resistance is an effective method to control Hessian fly, but when adapted high-yielding varieties with effective resistance are not available, neonicotinoid insecticide seed treatments may provide an alternative method of control of Hessian fly on susceptible varieties of winter wheat. A series of experiments were conducted to examine the efficacy of neonicotinoid seed treatments for control of Hessian fly in winter wheat. Infestations and immature numbers per tiller were assessed during the vegetative stages in autumn and winter and the wheat reproductive stage during the spring. Both imidacloprid 480FS at 0.31 g active ingredient (a.i.)/kg of seed and clothianidin at 0.39 g a.i./kg or higher rates provided consistent reductions in Hessian fly infestations during autumn and early winter. Lower rates were less effective, and they did not provide consistent reductions in autumn infestations. Thiamethoxam was evaluated at one rate in two experiments and was similar in efficacy to imidacloprid and clothianidin at the same rate. None of the seed treatments provided effective control of spring infestations during the wheat reproductive stage. Imidacloprid and clothianidin at rates of 0.31 g a.i./kg of seed or higher rates had a positive yield response in eight of nine comparisons, with an average increase of 285.9 ± 92.7 kg/ha. Neonicotinoid insecticide seed treatments at higher rates provide a useful method for managing Hessian fly on susceptible varieties of winter wheat.

Key Words Hessian fly, *Mayetiola destructor*, imidacloprid, clothianidin, seed treatments, wheat

The Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), is a potentially severe pest of wheat, *Triticum aestivum* L. em Thell, in the southeastern United States. This insect species was one of the first exotic, invasive pests in North America. It was first reported near Brooklyn, NY, in the 1770s and is speculated to have been introduced in infested straw (Schmid et al. 2018). The Hessian fly was documented to have spread from New York and reached Georgia in the 1850s (Webster 1899), although multiple sources of introduction are possible (Schermerhorn et al. 2015). Increased winter wheat production in the Southeast in the 1980s lead to outbreaks that cause extensive damage and losses (Buntin

[1]Received 10 January 2024; accepted for publication 4 February 2024.
[2]Correspnding author (email: gbuntin@uga.edu).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

et al. 1992). Winter wheat is still widely grown in a double-crop system in the Southeast, and the Hessian fly periodically causes considerable damage.

The Hessian fly is a gall-forming insect, although galls by this insect are indistinct. It is a cool-season insect and aestivates in wheat stubble as a puparia during the summer (McColluch 1923). Infestations occur in the fall and winter in vegetative stages of wheat and during the spring in wheat reproductive stages. Injury is caused by larval feeding at the base of the vegetative-stage plants or on stems above the nodes of reproductive-stage plants. Larval feeding injects toxic substances into plants that may cause stunted growth, seedling or tiller death, and increased susceptibility to cold temperature injury (Buntin 1999). In reproductive-stage plants, larvae feed on the stem above the nodes, where they weaken and disfigure the stems, which reduces grain filling and may cause stem lodging. In the Midwest and northern areas, there usually is a single autumn and single spring generation (McColloch 1923, Walton and Packard 1930). But, in the southeastern United States, there usually are two autumn generations, a winter generation, and a spring generation (Buntin and Chapin 1990).

Hessian fly management has historically been with the use of resistant wheat varieties and delayed planting of wheat to avoid autumn infestations. Reduced or no-tillage practices and lack of control of volunteer wheat during the summer can enhance Hessian fly abundance (Buntin et al. 1991, Chapin et al. 1991). Delayed autumn planting until after a certain date is based on the historical date when adult activity normally ceases or becomes limited because of cold weather. These dates for a given location are referred to as the "fly-free" dates and were developed >100 yr ago for most of the eastern United States (Walton and Packard 1930). Fly-free dates are still effective in most areas, but delaying planting must be balanced with the reduced yield potential of late-planted winter wheat. The fly-free date approach is not effective in the coastal plain region for the southern United States because early plantings are at risk of infestation, but although late plantings may avoid the fall generation injury, they may be heavily attacked by the winter and spring infestations (Buntin et al. 1990). Plant resistance has been widely used to control Hessian fly for many decades (Painter 1951, Ratcliffe et al. 2000), with at least 37 resistance (R) genes being identified (Li et al. 2013, Zhao et al. 2020). However, only a small number of the known R genes may be effective in an area and only a small number have been deployed in commercial wheat varieties (Cambron et al. 2010, Shukle et al. 2016). Indeed, the four original R genes (H3, H5, H6 and H7H8) that were widely deployed in the past in wheat have become completely infective in the eastern United States (Shukle et al. 2016). When resistance fails in an area, it may occur rapidly without time to develop and deploy high-yielding agronomically acceptable varieties with new sources of resistance.

Insecticides are another option for Hessian fly management. In the past, Hessian fly infestations could be controlled using systemic insecticides, such as disulfoton, phorate, and carbofuran (Bigger et al. 1965, Brown 1960, Buntin 1990, Chapin et al. 1991, Morrill and Nelson 1976). These insecticides were applied as granules in-furrow at planting for best results. Seed applications of these type of insecticides caused phytotoxicity to germinating seed, and broadcast applications were not effective except at unacceptable high rates (Bigger et al. 1965, Brown 1960). Furthermore, these organophosphate and carbamate insecticides are no

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

longer available or registered for use on cereal grains in North America. Neonicotinoid seed treatments are now available on a wide variety of crops, including cereal grains. Few studies have examined the efficacy of neonicotinoid seed treatments for management of Hessian fly. Wilde et al. (2001) showed that imidacloprid and thiamethoxam reduced autumn Hessian fly infestations, but did not control spring infestations, in Kansas. In North Carolina, imidacloprid partly reduced autumn infestations in winter wheat, but control was variable and effect on yield was not measured (Howell et al. 2017). Winn et al. (2023) also found that imidacloprid at twice the maximum labeled rate (3.13 ml/kg of seed [4.8 fl oz/100 lb of seed]) partly reduced Hessian fly infestations, with a significant increase in yield in two of three susceptible wheat varieties. Control of Hessian fly using foliar applied insecticides is inconsistent and difficult to achieve good results because the spray must be timed to coincide with adult peak egg laying (Buntin and Hudson 1991, Howell et al. 2017).

The objective of this study was to examine the efficacy of neonicotinoid seed treatments for control of Hessian fly in the Coastal Plain region of Georgia where the insect has multiple generations per season. Studies were conducted when these insecticides were being developed for this purpose for winter wheat in the 1990s and more recently when insecticide seed treatments were widely available to growers.

Materials and Methods

Experiments were conducted at the University of Georgia Southwest Branch Experiment Station near Plains (Sumter Co.) in all years (1993, 1994, 1995) and in a farmer's field located 11 km (7 mi) south of Sandersville (Washington Co.) in 1993 and 1994. Soil types were a Tifton sandy loam at Plains and a Marlboro sandy loam at Sandersville. Tillage was conventional with plowing or disk-harrowing before planting. At Plains, a 5-m-wide strip of a Hessian fly–susceptible cultivar was sown around the plot area in late August to encourage the buildup of Hessian fly populations. A complete fertilizer (5–10–15, N-P-K) was applied at the rate of 560 kg/ha and incorporated before planting. Experiments were planted with a small-plot grain drill in 17.8-cm rows at a soil depth of 1.3 cm at the rate of 66 seeds per m of row or 101 kg of seed per ha. Plots measured 14 rows (3.1 m) by 6.1 or 7.8 m. Experiments were planted on 12 and 19 November 1993 at Plains and Sandersville, respectively, and on 9 and 10 November at Plains in 1994 and 1995, respectively. Plots at Plains were irrigated with 1.3 cm of water at 7 and 21 d after planting. Plots were not irrigated at Sandersville. Ammonium nitrate fertilizer was top-dress applied in February at 247 kg N per ha. Diclofop-methyl (Hoelon) 3EC at 3.16 L/ha (Bayer CropScience, St. Louis, MO) and Harmony Extra (thifensulfuron-methyl + tribenuron-methyl) SG at 31.5 g/ha (FMC Corp., Philadelphia, PA) were applied to plots to control annual ryegrass (*Lolium multiflorum* Lam.) and broadleaf weeds, respectively.

Seed of the Hessian fly–susceptible wheat 'Savannah' was treated with imidacloprid (Gaucho 480FS) insecticide by Gustafson Inc. (now Bayer CropScience) in late September in 1993, 1994, and 1995. Treatments are listed in Tables 1 and 2. An untreated check and a standard of disulfoton (DiSyston) 15G at 1.12 kg active ingredient (a.i.)/ha applied in-furrow at-planting were included in each experiment.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Table 1. Effect of imidacloprid (Gaucho 480FS) seed treatments (ST) on mean ± SE[a] Hessian fly infestation and immatures per stem in susceptible ('Savannah') winter wheat at Plains and Sandersville, GA, in 1993–1994.

Treatment	Rate (kg a.i./ha or g a.i./kg of seed	Rate (lb a.i./acre or fl oz/CWT)	March Sample		Grain Yield (kg/ha)
			Infested Stems (%)	Immatures/Stem	
1993–1994: Plains					
Untreated check	—	—	5.48 ± 2.72a	0.07 ± 0.03a	5,041 ± 93.5a
DiSyston 15G	1.12	1.0 lb	0b	0b	4,931 ± 105.7a
Dimethoate	0.56	0.5 lb	1.65 ± 0.68b	0.02 ± 0.01b	5,022 ± 171.6a
Gaucho 480FS ST	0.157	0.5 oz	0b	0 b	5,369 ± 179.5a
Gaucho 480FS ST	0.235	0.75 oz	0.60 ± 0.57b	0.01 ± 0.01b	5,215 ± 114.8a
Gaucho 480FS ST	0.313	1.0 oz	0b	0b	5,230 ± 145.3a
F (df = 5, 21)			3.04	3.29	1.45
P			0.0083	0.0051	0.2045
1993–1994: Sandersville					
Untreated check	—	—	8.81 ± 4.43a	0.09 ± 0.03a	3,321 ± 309.8a
DiSyston 15G	1.12	1.00 lb	0b	0b	2,965 ± 304.8a
Dimethoate	0.56	0.5 lb	6.98 ± 2.16a	0.07 ± 0.02a	3,360 ± 153.9a
Gaucho 480FS ST	0.157	0.5 oz	0b	0b	3,685 ± 181.0a
Gaucho 480FS ST	0.235	0.75 oz	1.18 ± 0.25b	0.01 ± 0.01b	3,059 ± 286.3a
Gaucho 480FS ST	0.313	1.0 oz	0b	0b	2,977 ± 280.4a
F (df = 5, 21)			3.78	3.75	1.38
P			0.0020	0.0022	0.2317

[a] Means within columns followed by different letters are significantly different ($P < 0.05$; least significant difference test). Statistical analyses are based on transformed values [percentage = angular square-root transformation; counts = log(x + 1)]. CWT = hundredweight.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Table 2. Effect of imidacloprid (Gaucho 480FS) seed treatments (ST) on mean ± SE[a] Hessian fly infestation and immatures per stem in susceptible ('Savannah') winter wheat at Plains, GA, in 1994–1995 and 1995–1996.

Treatment	Rate (kg a.i./ha or g a.i./kg of seed	Rate (lb a.i./acre or fl oz/CWT	Winter Sample		Spring Sample		Grain Yield (kg/ha)
			Infested Stems (%)	Immatures/Stem	Infested Stems (%)	Immatures/Stem	
1994–1995: Plains							
Untreated check	—	—	19.6 ± 2.98a	0.26 ± 0.65a	37.5 ± 9.3a	0.82 ± 0.28a	3,444 ± 189a
DiSyston 15G	1.12 kg	1.0 lb	2.1 ± 1.08b	0.02 ± 0.01c	35.0 ± 3.8a	0.68 ± 0.08a	3,607 ± 201a
Dimethoate	0.56 kg	0.5 lb	19.8 ± 5.26a	0.29 ± 0.08a	38.3 ± 3.7a	0.76 ± 0.11a	3,282 ± 252a
Gaucho 480FS ST	0.157g	0.5 oz	18.4 ± 3.82a	0.24 ± 0.07a	43.3 ± 6.8a	0.95 ± 0.18a	3,539 ± 159a
Gaucho 480FS ST	0.313 g	1.0 oz	9.2 ± 7.04ab	0.11 ± 0.07ab	40.0 ± 5.0a	0.83 ± 0.19a	3,683 ± 174a
Gaucho 480FS ST	0.626 g	2.0 oz	6.1 ± 2.06b	0.08 ± 0.03b	32.5 ± 5.5a	0.58 ± 0.17a	3,857 ± 146a
F (df = 5, 15)			3.75	2.61	0.52	0.67	0.87
P			0.0210	0.0688	0.7566	0.6517	0.5263
1995–1996: Plains							
Untreated check	—	—	47.3 ± 4.97a	1.11 ± 0.21a	23.95 ± 5.37a	0.43 ± 0.12a	3,826 ± 101bc
DiSyston 15G	1.12 kg	1.00 lb	2.1 ± 1.64c	0.02 ± 0.02c	6.6 ± 0.94b	0.10 ± 0.01b	3,721 ± 76c
Karate 2.08SC	0.028 kg	0.025 lb	18.7 ± 6.17b	0.33 ± 0.03b	15.9 ± 2.08ab	0.27 ± 0.03ab	4,264 ± 184ab
Gaucho 480FS	0.157 g	0.50 oz	20.4 ± 4.03b	0.28 ± 0.03bc	14.7 ± 1.75ab	0.23 ± 0.02ab	4,330 ± 153a
Gaucho 480FS	0.235 g	0.75 oz	12.0 ± 2.81b	0.16 ± 0.01bc	15.8 ± 2.02ab	0.28 ± 0.03ab	4,189 ± 78ab
Gaucho 480FS	0.313 g	1.00 oz	14.4 ± 2.33b	0.19 ± 0.01bc	7.0 ± 1.04b	0.08 ± 0.01b	4,545 ± 98a
F (df = 5, 15)			15.34	5.24	4.52	3.10	5.94
P			0.0001	0.0056	0.0103	0.0386	0.0005

[a] Means within columns followed by different letters are significantly different ($P < 0.05$; least significant difference test). Statistical analyses are based on transformed values [percentage = angular square-root transformation; counts = log(x + 1)]. CWT = hundredweight.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

In 1993 and 1994, a treatment of dimethoate (Dimethoate 4E, FMC Corp.) at 0.56 kg a.i./ha applied as a foliar spray at 30 d after planting was included. In 1996, dimethoate was replaced with lambda cyhalothrin (Karate 2.02SC, Bayer CropScience) at 0.028 kg a.i./ha. Imidacloprid seed treatments in all years also were treated with triadimenol (Baytan) 30FL at 81.25 ml/100 kg of seed and captan (Captan) 400 at 130 ml/100 kg of seed (Bayer CropScience).

In Experiment 1 in 2012, seed of the Hessian fly–susceptible 'USG 3295' winter wheat was treated with various rates listed in Table 3 of clothianidin (NipsIt Inside) combined with metconazole (0.44%) and metalaxyl at (0.99%) fungicides by Valent BioSciences (Libertyville, IL). In Experiment 2 in 2012, USG 3295 wheat seed was treated with selected rates of imidacloprid (Attendant 480) combined with Rancona fungicide (ipconazole at 2.29% + metalaxyl at 1.94%) by Chemtura Corp. (Philadelphia, PA). Treatment plots in all experiments were arranged in a randomized compete block design with four or five replications.

Plant stand was measured at 25–40 d after planting by counting all plants in two 1-m sections of row per plot. Hessian fly populations were assessed in March at grain head emergence stage in 1993–1994 and in early February at fill tiller stage and late April at milk-early dough stage in 1995 and 1996. Infestations in 2013 were assessed on 12 December, 9 January, 4 February, and 24 April when plants were in the three-leaf, three- to four-tiller, full tiller, and milk stage of development (Feekes 10.5), respectively. Hessian fly populations were sampled by collecting a 30-cm section of row from each plot and dissecting all tillers or stems. The number of Hessian fly immatures (larvae and pupae) per plant and the proportion of infested tillers per stem were recorded. Insect samples were collected in one half of each plot. The other half was harvested with a Hege small plot combine in late May each year to measure seed weight, test weight, and moisture content. Grain yields were calculated and adjusted to 13.5% moisture content.

Data in each experiment were analyzed with a one-way analysis of variance for a randomized complete block design with treatment modeled as a fixed effect and replication modeled as a random effect by using PROC MIXED (SAS Institute 2013). Degrees of freedom were calculated using the Kenwood–Rogers method. To normalize data, percentage values were transformed with an angular transformation before analysis and insect counts and yield were transformed with a $\log(x + 1)$ before analysis. Means and SEs from PROC MEANS are presented. When significance was indicated, LS means were separated using pairwise *t* test of the PROC PLM procedure at $\alpha = 0.05$ (SAS Institute 2013).

Results

Plant stands at 25–40 d after planting were not affected by treatments at Sandersville in 1993 ($P = 0.4568$) and Plains in 1994 ($P = 0.2336$), but were significantly lower in the disulfoton treatment than the untreated check and seed treatments at Plains in 1993 ($P = 0.03571$) and 1995 ($P = 0.0167$; data not shown). In the 2012 and 2013 experiments, the plant stand was less in the untreated check than all of the fungicide and insecticide plus fungicide seed treatments at 22 d after planting ($F = 5.24$; df = 7, 21; $P = 0.0014$ and $F = 4.38$; df = 7, 21; $P = 0.0039$, respectively). At 35 d after planting, plant stands were lower in

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Table 3. Effect of clothianidin (NipsIt Inside) seed treatments (ST) on mean ± SE[a] Hessian fly infestation and immatures per stem in winter wheat in Experiment 1 near Plains, GA, 2012–2013.

Product[b]	Rate (ml/100 kg of seed)	Effective Insecticide Rate (g/kg-fl oz/100 lb seed)	Hessian Fly Sample 12 December		Hessian Fly Sample 9 January		Hessian Fly Sample 4 February		Hessian Fly Sample 24 April (Spring)		Grain Yield (kg/ha)
			Infested Plants (%)	Immatures/ Plant	Infested Plants (%)	Immatures/ Plant	Infested Stems (%)	Immatures/ Stem	Infested Stems (%)	Immatures/ Stem	
Untreated check	—	0	7.63 ± 2.0a	0.05 ± 0.01a	53.01 ± 11.17a	1.07 ± 0.24a	55.0 ± 10.16a	1.28 ± 0.36a	75.0 ± 11.90a	3.55 ± 0.71a	4462 ± 236a
NipsIt Suite Cereal	325	0.098–0.25	3.57 ± 3.57b	0.02 ± 0.01a	46.0 ± 7.76ab	0.69 ± 0.12ab	53.0 ± 12.37a	1.03 ± 0.24a	87.5 ± 4.33a	3.01 ± 0.28a	4839 ± 102a
NipsIt Suite Cereal NipsIt Inside	325 16.25	0.196–0.50	1.72 ± 1.72b	0.03 ± 0.01a	18.22 ± 3.66c	0.34 ± 0.06bc	48.0 ± 4.90a	0.80 ± 0.06a	75.0 ± 13.07a	2.24 ± 0.61a	474 ± 164a
NipsIt Suite Cereal NipsIt Inside	325 32.5	0.293–0.75	1.90 ± 1.11b	0.02 ± 0.01a	25.5 ± 3.81c	0.40 ± 0.09bc	47.8 ± 7.76a	1.06 ± 0.21a	85.0 ± 7.07a	2.81 ± 0.30a	4428 ± 353a
NipsIt Suite Cereal NipsIt Inside	325 48.75	0.391–1.00	0b	0a	25.34 ± 6.13bc	0.37 ± 0.10bc	56.7 ± 15.80a	1.25 ± 0.35a	65.0 ± 19.25a	2.49 ± 0.69a	4,664 ± 154a
NipsIt Suite Cereal NipsIt Inside	325 100.1	0.700–1.79	0b	0a	3.81 ± 2.22d	0.06 ± 0.04c	29.9 ± 6.18a	0.53 ± 0.09a	77.5 ± 4.33a	3.51 ± 0.76a	5,034 ± 282a
Cruiser 5FS Dividend Extreme	48.75 130	0.295–0.75	5.17 ± 2.17ab	0.07 ± 0.01a	24.88 ± 9.80bc	0.38 ± 0.22bc	50.3 ± 10.27a	1.03 ± 0.24a	72.5 ± 9.46a	2.15 ± 0.36a	4,823 ± 275a
Gaucho 600 Proceed concentrate	48.75 65	0.295–0.75	0b	0a	20.65 ± 5.88c	0.29 ± 0.07bc	49.8 ± 7.75a	0.92 ± 0.23a	70.0 ± 13.35a	2.11 ± 0.56a	4,645 ± 125a
F			2.96	1.51	5.64	4.38	0.75	1.03	0.60	1.10	0.97
P			0.0253	0.2181	0.0009	0.0039	0.6307	0.4375	0.7498	0.3988	0.4779

[a] Means within columns followed by the same letter are not significantly different (least significant difference test, $\alpha = 0.05$).

[b] Nipsit Inside is clothianidin at 47.8%; NipsIt Suite Cereals is clothianidin at 2.93%, metconazole at 0.44%, and metalaxyl at 0.99%; Dividend Extreme is difenoconazole at 7.73% and mefenoxam at 1.93%; and Proceed concentrate is prothioconazole at 6.88%, tebuconazole at 1.38%, and metalaxyl at 2.75%. All NipsIt treatments also had Release plant gibberellic acid (GA3) growth regulator at 1.0 fl oz per hundredweight.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

the untreated check than the other treatments, but these differences were not significant ($F = 1.85$; df = 7, 21; $P = 0.1308$ and $F = 1.95$; df = 7, 21; $P = 0.1118$; data not shown).

Hessian fly infestations and immature numbers per stem were significantly lower in all seed treatments and the disulfoton treatment than the untreated control at both locations in 1993 and 1994 (Table 1). In 1994 and 1995, only the disulfoton and the 0.62-g rate of imidacloprid (Gaucho 480FS) had reduced Hessian fly infestation and immatures per stem compared with the untreated check in the winter sample in January at 105 d after planting (Table 2). The 0.155- and 0.31-g rates of imidacloprid did not reduce infestation and immature numbers per stem. Dimethoate had lower infestation at Plains in 1993 and 1994, but did not reduce infestations at Sandersville in 1993 and 1994 and at Plains in 1994 and 1995. Spring infestations in April 1995 at 185 d after planting were similar to those of the untreated check in all treatments. In the 1995–1996 experiment, all treatments significantly reduced the winter infestations in late January at 77 d after planting, but disulfoton was the most effective treatment with the imidacloprid seed treatments being partly effective in reducing infestations (Table 2). The disulfoton and 0.31-g rate of imidacloprid (Gaucho 480FS) also reduced the spring infestation, but the 0.155- and 0.233-g rates did not as compared to the untreated check.

For Experiment 1 in 2012 and 2013, all clothianidin seed treatments significantly reduced Hessian fly infestations and immature numbers per stem on 12 December and 9 January, except for the lowest rate of 0.098 g a.i./kg of seed (Table 3). On 9 January, the highest rate of clothianidin at 0.70 g a.i./kg (1.79 fl oz) was more effective than the lower rates. Hessian fly infestations and immature numbers were not significantly different among treatments in the 4 February and 24 April samples at full tiller and anthesis stage, respectively. For Experiment 2 in 2012 and 2013, all the Attendant imidacloprid (Attendant 480) seed treatments had significantly lower infestations and immature numbers than the two fungicide seed treatments and the untreated check on 12 December, 9 January, and 4 February (Table 4). The spring infestations on 24 April were not significantly different among treatments. The thiamethoxam (Cruiser 5FS + Dividend Extreme) standard also reduced Hessian fly infestations and immature numbers, but was less effective than the imidacloprid treatments on 9 January.

Grain yield was not significantly affected by treatments at either location in 1993 and 1994 (Table 1). Treatments also did not significantly affect grain yield at Plains in 1994 and 1995, although the 0.313- and 0.626-g rates of imidacloprid (Gaucho 480FS) yielded 239 and 413 kg/ha more than the untreated check (Table 2). Grain yield in 1995 and 1996 was significantly lower in the disulfoton and untreated check than the 0.157- and 0.313-g rates of imidacloprid (Table 2). These treatments yielded 504 and 719 kg/ha more, respectively, than the untreated check. Grain yields in Experiment 1 in 2012 and 2013 with clothianidin seed treatments were not significantly different among treatments, even though the 0.70 g a.i./kg rate of clothianidin yielded 572 kg/ha more than the untreated check (Table 3). In Experiment 2 in 2012 and 2013, the thiamethoxam at 0.32 g a.i./kg and imidacloprid (Attendant + Foothold fungicide) at 0.50 g a.i./kg of seed yielded significantly more than the untreated check and fungicide-only treatments (Table 4).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Table 4. Effect of imidacloprid seed treatments on mean ± SE[a] Hessian fly infestation and immatures per stem in winter wheat Experiment 2 near Plains, GA, in 2012–2013.

Product[b]	Rate (ml/100 kg)	Effective Insecticide Rate (g/kg or fl oz/100 lb seed)	Hessian Fly Sample 12 December		Hessian Fly Sample 9 January		Hessian Fly Sample 4 February		Hessian Fly Sample 24 April		Grain Yield (kg/ha)
			Infested Plants (%)	Immatures/ Plant	Infested Tillers (%)	Immatures/ Tiller	Infested Tillers (%)	Immatures/ Tiller	Infested Stems (%)	Immatures/ Stem	
Untreated check	—	0	14.09 ± 5.29a	0.19 ± 0.02a	49.17 ± 6.82ab	0.85 ± 0.16ab	56.71 ± 5.20a	1.29 ± 0.19a	68.75 ± 6.25a	3.71 ± 1.28a	4465 ± 117bc
Rancona CTS fungicide	60	0	7.80 ± 4.70a	0.09 ± 0.01abc	42.47 ± 2.56b	0.70 ± 0.09b	42.46 ± 5.84a	0.85 ± 0.19bc	61.25 ± 21.05a	2.30 ± 0.94a	4313 ± 211c
Foothold fungicide	325	0	9.86 ± 3.70a	0.12 ± 0.01ab	60.69 ± 4.22a	1.02 ± 0.06a	58.00 ± 3.46a	1.22 ± 0.11ab	83.75 ± 2.39a	2.70 ± 0.22a	4648 ± 174bc
Cruiser 5FS Dividend Extreme	53 130	0.32–0.81	0.83 ± 0.83b	0.02 ± 0.01bc	15.88 ± 3.10c	0.17 ± 0.04c	34.56 ± 9.89b	0.60 ± 0.16cd	90.00 ± 3.54a	2.41 ± 0.32a	5077 ± 43.4a
Attendant 480 in Rancona Crest	325	0.50–1.60	0b	0c	3.82 ± 1.24d	0.03 ± 0.01c	24.95 ± 5.49b c	0.46 ± 0.12cd	70.00 ± 6.12a	1.90 ± 0.18a	5066 ± 130a
Rancona CTS Attendant 480	60 104	0.50–1.60	0b	0c	1.64 ± 0.96d	0.03 ± 0.02c	24.82 ± 8.68bc	0.45 ± 0.19cd	70.00 ± 12.75a	1.78 ± 0.38a	4628 ± 190bc
Foothold + Attendant 480	325 104	0.50–1.60	0b	0c	1.09 ± 1.09d	0.01 ± 0.01c	34.52 ± 3.60b	0.61 ± 0.13cd	76.25 ± 8.98a	1.85 ± 0.24a	5050 ± 258a
Rancona CTS Attendant 480 + Consensus	60 104 35	0.50–1.60	0b	0c	5.21 ± 2.30d	0.05 ± 0.02c	14.00 ± 2.58c	0.19 ± 0.04d	68.75 ± 8.75a	2.28 ± 0.41a	4811 ± 132ab
F			6.10	3.48	38.25	36.75	5.88	6.65	0.67	1.16	4.58
P			0.0006	0.0124	0.0001	0.0001	0.0007	0.0003	0.6973	0.3648	0.0031

[a] Means within columns followed by the same letter are not significantly different (least significant difference test, $\alpha = 0.05$). Percentage values were transformed with arcsin square root transformation before analysis. Original percentage values are listed.

[b] Attendant 480FS = imidacloprid at 40.23%; Racona CTS = ipconazole at 2.29% + metalaxyl at 1.94%; Rancona Crest = imidacloprid at 14.1%, ipconazole at 0.42%, and metalaxyl at 0.56%; Foothold is tebuconazole at 0.5% and metalaxyl at 0.67%; Dividend Extreme is difenoconazole at 7.73% and mefenoxam at 1.93%; Cruiser 5FS = thiamethoxam at 47.6%; Consensus is a plant health vigor promotor.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Grain test weights were not significantly affected by treatments in any experiment ($P > 0.10$; data not shown).

Discussion

The most effective insecticide treatment in the first three experiments was an in-furrow application of disulfoton at 1.12 kg a.i./ha, but disulfoton is no longer available for use in the United States (U.S. EPA 2016). None of the foliar applied insecticide treatments were effective in controlling Hessian fly infestations. All the neonicotinoid seed treatments tested provided control of Hessian fly infestations in the autumn after planting of winter wheat. Both imidacloprid (Guacho 480FS and Attendant 480) at 0.31 g a.i./kg of seed (1.0 fl oz/100 lb of seed) and clothianidin 600FS at 0.39 g a.i./kg (1.0 fl oz/100 lb of seed) or higher rates provided consistent reductions in Hessian fly infestations during autumn and early winter. The lower rates of these products were less effective and did not provide consistent reductions in autumn infestations. Thiamethoxam was only evaluated at the rates of 0.295 and 0.32 g a.i./kg of seed (0.75–0.81 fl oz/100 lb of seed) in two experiments and was less effective at this rate than the highest rates of imidacloprid and clothianidin, but was similar in efficacy to imidacloprid and clothianidin at the same rates. None of the seed treatments persisted to control spring infestations during the wheat reproductive stage, which is consistent with results of previous studies (Howell et al. 2017, Wilde et al. 2001, Winn et al. 2023).

Yield responses were variable, with significant yield differences occurring on two of the five experiments. Nevertheless, considering the numerical yield differences in yield between the untreated check and imidacloprid and clothianidin at 0.31–0.62 g a.i./kg of seed (1.0–2.0 fl oz per 100 lb of seed) in all experiments, the average yield response was positive in eight of nine comparisons and equaled 285.9 $\pm$ 92.7 kg/ha or 4.76 bushels/acre at 60 lb per bushel. The price of soft red winter wheat in November 2023 (U.S. Wheat Associates 2023) was approximately $US0.22/kg (US$6.00/bushel), which indicates the seed imidacloprid treatments at 0.31 g a.i./kg of seed and clothianidin treatments at 0.39 g a.i./kg of seed or more provided an average benefit of US$70.57/ha. The current cost for an insecticide-fungicide seed treatment at a standard seeding rate is approximately US$37.00/ha, based on price quotations from seed dealers in Georgia. Therefore, the use of neonicotinoid seed treatments at high rates may be justified when the risk of Hessian fly damage is present for susceptible varieties. Although the use of plant resistance is the most effective method to control Hessian fly (Buntin et al. 1992), when adapted high-yielding varieties with effective resistance are not available and the risk of Hessian fly damage is present, neonicotinoid insecticide seed treatments provide an alternative method of control of Hessian fly on susceptible varieties of winter wheat.

Acknowledgments

The author thanks B. Byous and W.R. Slaughter for technical assistance and the numerous temporary student workers who assisted with field sampling and processing of Hessian fly samples. This research was funded in part by grants from Gustafson Inc. (Bayer CropScience), Valant Biosciences, and Chemtura Corp. and by Hatch project funds (accession no. 1009397) from the USDA National Institute of Food and Agriculture.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

References Cited

Bigger, J.H., P.E. Johnson and W.O. Weibel. 1965. Controlling Hessian fly with phorate and disulfoton. J. Econ. Entomol. 58: 1083–1085.

Brown, H.E. 1960. Insecticidal control of the Hessian fly. J. Econ. Entomol. 53: 501–503.

Buntin, G.D. 1990. Hessian fly (Diptera: Cecidomyiidae) management in winter wheat using systemic insecticides at planting. J. Agric. Entomol. 7: 321–331.

Buntin, G.D. 1999. Hessian fly (Diptera: Cecidomyiidae) injury and loss of winter wheat grain yield and quality. J. Econ. Entomol. 92: 1190–1197.

Buntin, G.D. and R.D. Hudson. 1991. Spring control of the Hessian fly (Diptera: Cecidomyiidae) in winter wheat using insecticides. J. Econ. Entomol. 84: 1913–1919.

Buntin, G.D. and J.W. Chapin. 1990. Hessian fly (Diptera: Cecidomyiidae) biology in the southeastern United States: Geographic variation and temperature-dependent phenology. J. Econ. Entomol. 85: 1015–1024.

Buntin, G.D., B.M. Cunfer and D.C. Bridges. 1991. Impact of volunteer wheat on wheat insects in a wheat-soybean doublecrop system. J. Entomol. Sci. 26: 401–407.

Buntin, G.D., S.L. Ott and J.W. Johnson. 1992. Integration of plant resistance, insecticides, and planting date for management of the Hessian fly (Diptera: Cecidomyiidae) in winter wheat. J. Econ. Entomol. 85: 530–538.

Cambron, S.E., G.D. Buntin, R. Weisz, J.D. Holland, K.L. Flanders, B.J. Schermerhorn and R.H. Shukle. 2010. Virulence in Hessian fly (Diptera: Cecidomyiidae) field collection from the southeastern United States to 21 resistance genes in wheat. J. Econ. Entomol. 103: 2229–2235.

Chapin, J.W., M.J. Sullivan and J.S. Thomas. 1991. Disulfoton application methods for control of Hessian fly (Diptera: Cecidomyiidae) on southeastern winter wheat. J. Agric. Entomol. 8: 17–28.

Howell, F.C., D.D. Reisig, H.J. Burrack and R. Heiniger. 2017. Impact of imidacloprid treated seed and foliar insecticide on Hessian fly abundances in wheat (*Triticum aestivum* L.). Crop Protect. 98: 46–55.

Li, C., M. Chen, S. Chao, J. Yu and G. Bai. 2013. Identification of a novel gene, H34, in winter wheat using recombinant inbred lines and single nucleotide polymorphism markers. Theor. Appl. Genet. 126: 2065–2071.

Morrill, W.L. and L.R. Nelson. 1976. Hessian fly control with carbofuran. J. Econ. Entomol. 69: 123–124.

Painter, R.H. 1951. Insect Resistance in Crop Plants. MacMillan, New York.

SAS Institute. 2013. SAS version 9.4 user's manual. SAS Institute, Cary, NC.

Schermerhorn, B.J., Y.M. Crane and C.F. Crane. 2015. The evolution of Hessian fly from old world to the new world: Evidence from molecular markers. Insect Sci. 22: 768–784.

Schmid, R. B., A. Knutson, K.L. Giles and B.P. McCornack. 2018. Hessian fly (Diptera: Cecidomyiidae) biology and management in wheat. J. Integr. Pest Manag. 9: 1–12.

Shukle, R.H., S.E. Cambron, H.A. Moniem, B.J. Schermerhorn, J. Redding, G.D. Buntin, K.L. Flanders, D.D. Reisig and M. Mohammadi. 2016. Effectiveness of genes for Hessian fly (Diptera: Cecidomyiidae) resistance in the southeastern United States. J. Econ. Entomol. 109: 399–405.

[U.S. EPA] U.S. Environmental Protection Agency. 2016. Disulfoton facts. 10 January 2024. (https://archive.epa.gov/pesticides/reregistration/web/html/disulfoton_fs.html).

U.S. Wheat Associates. 2023. November 2023 price report. (https://www.uswheat.org/market-information/price-reports/).

Walton, W.R. and C.M. Packard. 1930. The Hessian fly and how losses from it can be avoided. USDA Farmer's Bull. 1627.

Webster, F.M. 1899. The Hessian fly. Ohio Agric. Exp. Stn. Bull. 107.

Wilde, G.E., R.J. Whitworth, M. Claassen and R.A. Shufran. 2001. Seed treatment for control of wheat insects and its effect on yield. J. Agric. Urban Entomol. 18: 1–11.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access

Winn, Z.J., D. Reisig and J.P. Murphy. 2023. Yield protection afforded by imidacloprid during Hessian fly infestation in six genotypes. Agron. J. 115: 1059–1068.

Zhao, L., N. R. Abdelsalam, Y. Xi, M.-S. Chen, Y. Feng, L. Kong and G. Bai. 2020. Identification of two novel Hessian fly resistance genes H35 and H36 in a hard winter wheat line SD6165. Theor. Appl. Genet. 133: 2343–2352.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-02 via free access