The Great Lakes Entomologist

Volume 25
Number 3 - Fall 1992 *Number 3 - Fall 1992*

Article 7

October 1992

Control of Aphids on Spring Oats and Winter Wheat With Slow Release Granular Systemic Insecticides

Jaime E. Araya
Purdue University

Sue E. Cambron
Purdue University

CONTROL OF APHIDS ON SPRING OATS AND WINTER WHEAT WITH SLOW RELEASE GRANULAR SYSTEMIC INSECTICIDES[1]

Jaime E. Araya[2] and Sue E. Cambron[3]

ABSTRACT

Aphid infestations (Homoptera: Aphididae) on spring oat (*Avena sativa*) cv. 'Ogle', and during the fall on winter wheat (*Triticum aestivum*) cv. 'Clark', composed mainly of *Rhopalosiphum padi* and *Macrosiphum avenae*, were reduced with applications at the 2–3 leaf stage of slow release granular formulations of acephate, carbofuran, and disulfoton, compared with carbofuran 15G and untreated controls, in field trials during 1990–1991 in northwestern Indiana. These field results corroborated those obtained by previous studies with the same formulations and dosages in the laboratory.

In oat, all insecticide treatments reduced aphid populations and percentage aphid-infested plants, with a residual action of ca. 25 d. Barley yellow dwarf virus-like visual symptoms were reduced with disulfoton. In winter wheat, the residual action of all insecticide treatments in the fall lasted up to 19 d. The carbofuran treatment on winter wheat seedlings caused earthworms to move out of the soil, where they died; an effect requiring further study. Percentage of aphid-infested plants revealed relatively wider differences among tratments than total number of aphids in both test crops. Predation by *Coleomegilla maculata* (Coleoptera: Coccinellidae) contributed to the overall reduction of spring populations of cereal aphids in wheat and oat. Aphid mummies parasitized by micro-hymenopterans were common in oat plants.

Cereal aphids (Homoptera: Aphididae), specifically the bird cherry-oat aphid, *Rhopalosiphum padi* (L.), and English grain aphid, *Macrosiphum (Sitobion) avenae* (F.), are important pests of small grains (Rabbinge and Rijsdijk 1984, Araya et al. 1986). They damage plants by direct feeding on phloem sap and are vectors of plant viruses (Hinz et al. 1979), most importantly barley yellow dwarf virus (BYDV) (Bruehl 1961, Stern 1967, Kolbe 1973). Severe losses due to BYDV infection have been reported (Caldwell et al. 1959, Tothman et al. 1959, Palmer and Sill 1966, Gill 1980, Carrigan et al. 1981). Damage may be severe when winged migrants colonize winter wheat in the fall (Endo and Brown 1963) or in early spring (Arretz and Araya 1978).

Economic infestations of cereal aphids can be controlled easily with foliage sprays of various insecticides. Araya et al. (1990a) summarized that the

---

[1]Purdue Univ. Agr. Exp. Stn. Journal Paper No. 13,121.

[2]Research Associate, Small Grain Insects and Weed Control Research Unit, USDA-ARS, Department of Entomology, Purdue University, W. Lafayette, IN 47907. Current address: Facultad de Ciencias Agrarias y Forestales, Universidad de Chile, Casilla 1004, Santiago, Chile.

[3]Research Assistant, Department of Entomology, Purdue University, W. Lafayette, IN 47907.

most important advantages of using granular formulations of systemic insecticides applied to the soil, compared with foliage sprays, are the protection of natural enemies of aphids and the reduced exposure of toxicants and effective placement of formulated chemicals to control the target pest.

Acephate, carbofuran, and disulfoton were selected for this study because of their acceptability and wide solubility in water (Oetting et al. 1984). Acephate has low toxicity to non-target organisms, including diverse hymenopteran parasitoids (Fitzpatrick et al. 1978, Lange et al. 1980, Flanders et a. 1984, Hsieh and Allen 1986) and predators (Whalon and Elsner 1982). Acephate residues decline rapidly in plants (Frank et al. 1984) and even faster in the soil (Szeto et al. 1979, Yamazaki et al. 1982). Soil applcations of granular carbofuran and disulfoton have systemically controlled cereal aphids (DePew 1974, van Rensburg et al. 1978, Arretz and Araya 1978, 1980, Mize et al. 1980, Araya et al. 1990b). Insect predators are spared with soil incorporated carbofuran (e.g. Gholson et al. 1978, Semtner 1979, Edwards et al. 1980), while spray residues of carbofuran are highly toxic to parasitoids (Dumbre and Hower 1977).

Our research studied the effects of the slow release granular formulations of systemic insecticides tested in the laboratory by Araya et al. (1990a, 1990b) on cereal aphids on spring oat (*Avena sativa*), and winter wheat (*Triticum aestivum*) under field conditions in northwestern Indiana.

MATERIALS AND METHODS

Field trials using spring oat and winter wheat, both at the Purdue University Agronomy Farm, located northwest of West Lafayette, Tippecanoe Co., Indiana, were conducted during 1990–1991.

I. Spring oat.

The insecticide treatments listed (formulation, concentration, and g/plot) were applied on 8 May 1990, on 2–3 leaf stage 'Ogle' spring oat seedlings (growth stage 1–2 of Feekes scale [Large 1954]) with 23% of the plants infested (mean: 3 aphids/100 plants), using 0.5 x 1 m plots (0.5 m^2) and 5 replicates. All dosages were adjusted to a standard of 10 kg/ha of carbofuran 10G. The description, preparation and effectiveness of these formulations have been described by Araya et al. (1990a, 1990b), Shasha et al. (1984),and Wing et al (1987), respectively. The granular insecticide treatments were applied by hand with a 0.5 l plastic cylindrical container. Granular clay was used as inert carrier to facilitate an even distribution of the formulation over the respective plots.

t1. Acephate ps (pearl starch granules; 10.1%; 0.495 g).
t2. Acephate cf (corn flour granules; 9.7%; 0.516 g).
t3. Carbofuran ps (pearl starch granules; 8.1%; 0.618 g).
t4. Carbofuran cf (corn flour granules; 8.3%; 0.603 g).
t5. Carbofuran (15G; 0.334 g).
t6. Disulfoton ps (pearl starch ganules; 2.7%; 1.853 g).
t7. Disulfoton (wax granules; 12.9%; 0.338 g).
t8. Control without insecticide.

II. Winter wheat.

In the winter wheat test, the cv. Clark and 0.75 x 1 m plots were used; 2-leaf seedlings (growth stage 1 of Feekes scale [Large 1954]) were treated on 2 Nov. 1990. Treatment No. 6 (t6: disulfoton) was applied at 8% AI (0.938 g/plot); all the other treatments were the same as in the spring oat test.

Periodic counts of cereal aphids and percentage aphid-infested plants in the test plots were recorded in both tests when aphids were present in the field. Results were analyzed statistically using single factor ANOVAs with repeated measures (percentage data were previously normalized with the ln(1+x) transformation); significantly different ($P \leq 0.05$) means were separated using Fisher's PLSD tests (Statview 512+™Statistical Software, Abacus Concepts, Inc. 1986).

RESULTS AND DISCUSSION

Both *R. padi* and *M. avenae* were commonly found. Bird cherry-oat aphids were usually more abundant late in the fall and early in the spring than English grain aphids, revealing a probable better adaptation to cooler temperatures of the former species; the later was more abundant later in spring, and was concentrated, but was not exclusively on the heads of maturing plants. A few greenbugs, *Schizaphis graminum* Rondani, were found in late spring, as this species may be better adapted to warmer temperatures (Araya et al. 1983).

I. Spring oat.

All insecticide treatments reduced significantly ($P \leq 0.05$) aphid populations and the percentage of aphid-infested oat plants (Table 1), with residual action lasting ca. 25 days. Rain 1 d after application may have accelerated the incorporation of the active ingredients (AI) in the soil, so the insecticide effects were noticed at the first aphid count, 6 days after applicaton. When the effects of the insecticide treatments were averaged by AI to visualize the average effect of the AI (Table 2), carbofuran [(t3+t4+t5)/3 = average of three formulations] offered the best protection, followed by disulfoton and acephate [averages of two formulations each: (t7+t8)/2 and (t1+t2/2), respectively].

On 4 June 1990 (27 days after application), some plants at the growth stage 10 (booting) of the growth scale of Feekes (Large 1954) exhibited barley yellow dwarf virus (BYDV)-like symptoms. An ANOVA showed that both formulations of disulfoton presented less plants with these symptoms than the other treatments (Table 3). Thus, disulfoton may have prevented BYDV infection. It is unclear, however, whether these visual symptoms may have been caused by plant infection with BYDV alone or in conjunction with one or more small grain viruses. Further tests are required.

Observations of natural enemies of aphids, including counts of aphids wih mycelia of *Enthomophthora*, mummified aphids, and the different stages of the ladybird beetle, *Coleomegilla maculata* DeGeer, are presented on Table 4.

Counts of dead aphids covered with *Enthomophthora* are not quantitative because and unknown number of these infected aphids fall to the ground. They provide, however, an indication of the period when this beneficial control agent was detrimental to cereal aphids.

Aphid mummies parasitized by microhymenopterans were common in the oat test, from plant growth stages 6 through 10.1 of Feekes. The maximum

Table 1. — Mean number of aphids per plant, and mean percentage of aphid-infested spring oat plants ±S.E. in field plots treated with different insecticide formulations[1]

Insecticides	Days from application – Feekes growth stage[2]					
	6–5	10–6	15–7	21–8–9	27–10	34–10.1
a. *Aphids per plant*						
1. Acephate 10.1 ps	0.56±0.19b	0.80±0.24ab	1.06±0.12b	1.14±0.31b	0.44±0.09a	0.08±0.04a
2. Acephate 9.7 cf	0.56±0.07b	0.50±0.14bc	0.88±0.14b	1.00±0.26b	0.58±0.48a	0.10±0.08a
3. Carbofuran 8.1 ps	0.26±0.09b	0.20±0.07cd	0.28±0.07c	0.58±0.10b	0.16±0.08a	0.06±0.04a
4. Carbofuran 8.3 cf	0.28±0.10b	0.12±0.04d	0.24±0.09c	0.58±0.15b	0.12±0.05a	0.04±0.02a
5. Carbofuran 15 G	0.34±0.15b	0.32±0.08cd	0.56±0.26bc	0.54±0.09b	0.24±0.05a	0.20±0.18a
6. Disulfoton 2.7 ps	0.50±0.08b	0.34±0.08cd	0.82±0.16bc	0.96±0.12b	0.16±0.08a	0.00±0.00a
7. Disulfoton 12.9 wax	0.46±0.07b	0.38±0.07cd	0.62±0.14bc	0.92±0.17b	0.28±0.21a	0.00±0.00a
8. Control	1.00±0.21a	1.00±0.11a	1.92±0.41a	2.74±0.45a	0.34±0.16a	0.08±0.06a
F test/*P* values	3.340/0.0103	6.365/0.0002	7.055/0.0001	10.681/0.0001	0.582/0.7684	0.802/0.5928
b. *% aphid-infested plants*						
1. Acephate 10.1 ps	34.0±10.30ab	38.0±3.74ab	60.0±5.48ab	52.0±4.90a	20.0±4.47a	6.0±2.45a
2. Acephate 9.7 cf	34.0±5.10ab	38.0±8.00ab	56.0±2.45ab	50.0±6.33ab	10.0±0.00a	6.0±4.00a
3. Carbofuran 8.1 ps	18.0±5.83b	16.0±5.10de	20.0±4.47e	38.0±5.83ab	12.0±5.83ab	4.0±2.45a
4. Carbofuran 8.3 cf	24.0±9.27b	12.0±3.74e	16.0±4.00e	28.04±.90b	10.0±4.47a	4.0±2.45a
5. Carbofuran 15 G	20.0±7.07b	22.0±2.0bcde	28.0±8.00de	32.0±7.35ab	6.0±2.45a	6.0±4.00a
6. Disulfoton 2.7 ps	38.0±4.90ab	32.0±8.00abc	38.0±5.83cd	46.0±5.10ab	8.0±3.74a	0.0±0.00a
7. Disulfoton 12.9 wax	30.0±3.16ab	30.0±3.16abcd	46.0±5.10bc	52.0±6.63ab	12.0±5.83a	0.0±0.00a
8. Control	60.0±10.95a	64.0±6.0a	78.0±6.63a	50.0±17.03ab	18.0±6.63a	6.0±4.00a
F test/*P* values	1.894/0.1084	3.644/0.064	13.370/0.0001	1.337/0.2702	0.913/0.5113	0.899/0.5211

[1]Insecticide formulation treatment means in a column for each of the two parameters with different letters are significantly different ($P \leq 0.05$), according to Fisher's PLSD tests.
[2]Application on 5.8.90; growth stages of Feekes (Large 1954).
[3]F test and P values for treatments were obtained from single factor ANOVAS with repeated measures (Statview 512+™Statistical Software; Abacus Concepts, Inc. 1986).

Table 2.—Average number of aphids per plant, and average percentage of aphid-infested spring oat plants ±S.E. in field plots treated with different insecticides (averages of 2, 3, and 2 formulations of acephate, carbofuran, and disulfoton, respectively).

	Days from application–Feekes growth stage[2]					
Insecticides	6–5	10–6	15–7	21–8–9	27–10	34–10.1
a. *Aphids per plant*						
–Acephate	0.56±0.12a	0.56±0.12b	0.97±0.12b	1.07±0.26b	0.59±0.27a	0.09±0.46a
–Carbofuran	0.53±0.21a	0.21±0.04b	0.42±0.10b	0.57±0.04b	0.17±0.03a	0.10±0.06a
–Disulfoton	0.56±0.06a	0.36±0.05b	0.72±0.07b	0.94±0.13b	0.22±0.12a	0.00±0.00a
–Control	1.00±0.21a	1.00±0.11a	1.92±0.41a	2.74±0.45a	0.34±0.16a	0.08±0.06a
F test/*P* values	1.479/0.2697	8.591/0.0026	9.008/0.0021	15.550/0.0002	1.038/0.4107	0.770/0.5326
b. *% aphid-infested plants*						
–Acephate	34.0 ±05.79b	38.00±5.15b	58.00±3.39b	51.00±4.00a	15.00±2.24a	6.00±2.92a
–Carbofuran	20.67±3.06c	16.66±2.11c	21.33±3.59d	32.67±1.94a	12.67±2.67a	4.67±1.70a
–Disulfoton	34.00±1.87b	31.00±3.32b	42.00±1.23c	49.00±2.92a	10.00±4.47a	0.00±0.00a
–Control	60.00±10.95a	64.00±6.00a	78.00±6.63a	50.00±17.03a	18.00±6.63a	6.00±4.00a
F test/*P* values	9.196/0.002	17.197/0.0001	47.436/0.0001	0.945/0.4494	0.665/0.5894	1.597/0.2417

[1]Insecticide treatment means in a column for each of the two parameters with different letters are significantly different ($P \leq 0.05$), according to Fisher's PLSD tests.
[2]Application on 5.8.90; growth stages of Feekes (Large 1954).
[3]F test and P values for treatments were obtained from single factor ANOVAS with repeated measures (Statview 512+™Statistical Software; Abacus Concepts, Inc. 1986).

The Great Lakes Entomologist, Vol. 25, No. 3 [1992], Art. 7

Table 3. — Percentage of spring oat plants[1] with BYDV-like symptoms 27 days from application[2].

Treatments	% plants with BYDV-like symptoms	Treatments averaged by Active Ingredient	
1. Acephate 10.1 ps	14.00±2.45ab		
2. Acephate 9.7 cf	14.00±2.45ab	Acephate: (t1+t2)/2	14.00±1.87b
3. Carbofuran 8.1 ps	16.00±7.48ab		
4. Carbofuran 8.3 cf	10.00±5.48ab		
5. Carbofuran 15 G	14.00±4.00ab	Carbofuran: (t3+t4+t5)/3	13.33±2.58b
6. Disulfoton 8.0 ps	8.00±3.74b		
7. Disulfoton 12.9 wax	12.00±5.83b	Disulfoton: (t6+t7)/2	10.00±3.16b
8. Control	36.00±5.10a	Control: (t8)	36.00±5.10a
F test/*P* values[3]	1.366/0.2579		6.959/0.0057

[1]Growth stage 10 (booting) of Feekes scale (Large 1954). Insecticide formulation treatment means in a column for each of the two parameters with different letters are significantly different (P≤0.05), according to Fisher's PLSD tests.

[2]Application on 5.8.90.

[3]*F* test and *P* values were obtained from single factor ANOVAS with repeated measures (Statview 512+ ™Statistical Software; Abacus Concepts, Inc. 1986).

density of mummies occurred on plants during the growth stages 8–9, when aphid counts were greatest (Table 1), and declined gradually thereafter, following the decline in density of aphids and revealing the importance of microhymenopteran parasitoids in reducing populatons of cereal aphids.

Adult *C. maculata* ladybird beetles were observed throughout the test, except for the last aphid count. Their greatest density also occurred when aphids were most abundant. Oviposition of these predators, occurrence of larvae, and pupation started 2, 3, and 4 wk after the first aphid count, respectively.

II. Winter wheat.

a. Fall of 1990. Insecticide treatments were applied on relatively humid soil 1 d after rain on 2 November 1990, when the population density averaged 0.19 aphids per plant. Even though the population density of aphids was low, the treatments were applied to avoid population growth and provide insecticide protection to the plants when they were most susceptible to both cereal aphids and BYDV (Endo and Brown 1963, Smith 1967). The initial aphid count, 5 d after insecticide application, revealed a statistically significant effect of disulfoton, both in the mean number of aphids per plant and percentage aphid-infested plants (Table 5). The low population density may have contributed to mask the effect of the other treatments, which were not significantly different from the control in both parameters measured. The average insecticide effect of the treatments grouped by AI (Table 6) was clear at the first aphid count, 5 d after application. The residual action of all insecticide treatments in the fall lasted up to 19 d. Aphid counts wre stopped afterwards due to cold weather. Winter migrant aphids are particularly important in the fall for the transmission of BYDV (Araya et a. 1987), a virus disease that can severely damage crops when the plants are inoculated at the seedling stage (Endo and Brown 1963, Smith 1967). Thus, the protection period of at least 3 wk obtained with the insecticide treatments is a very valuable result. Overall, the lowest aphid numbers and percentage of aphid-infested wheat plants (Tables 5 and 6) were observed with the formulations of disulfoton [(t6+t7)/2].

https://scholar.valpo.edu/tgle/vol25/iss3/7
DOI: 10.22543/0090-0222.1787

Table 4. — Aphids infected with ***Entomophthora*** sp. and aphids mummified with parasitoids observed on 40 spring oat and winter wheat field plots (10 plants per plot), and number of ***Coleomegilla maculata*** present on all plots (total of 20 m^2 per field trial).

Days after treatment and plant stage[1]	No. aphids infected with ***Entomophthora***	No. of mummified aphids	*Ladybird beetles* adults	egg masses	larvae	pupae	Other insects[2] adult mh	ch larvae	larvae om
a. Spring oat, 1990									
6 – 5	0	0	1	0	0	0	1	0	0
10 – 6	4	1	10	0	0	0	0	0	0
15 – 7	6	8	2	1	0	0	0	1	0
21 – 8-9	1	35	17	5	4	0	3[3]	0	0
27 – 10	0	8	3	10	3	14	3	1	0
34 – 10.1	0	1	5	4	0	19	3	0	2
41 – 10.4	0	0	0	3	0	0	0	0	0
b. Winter wheat, 1990–91									
5 – 2	0	0	0	0	0	0	0	0	0
10 – 2-3	0	2	0	0	0	0	0	0	0
14 – 3	0	1	0	0	0	0	0	0	0
19 – 3-4	0	0	0	0	0	0	1	0	0
Winter recess									
165 – 7	0	0	3	0	0	0	0	0[4]	0
173 – 8	0	0	3	0	0	0	0	0	0
181 – 9	0	0	1[5]	0	0	0	0	0	0
188 – 10.1	1	0	10	0	0	0	1	0	0
195 – 10.5	4	0	32	1	2	0	0	0	0
202 – 11	6	0	3	0	11	3	0	0[6]	1

[1]Applied to oat and wheat on may 8, and Nov. 2, 1990, respect.; Feeked growth stages (Large 1954).
[2]mh = mycrohymenopterans observed flying near the plants; ch = chrysopid; om = ***Oulema melanopa*** L.
[3]One of these mummies was parasitized by ***Praon*** sp.
[4]One ***Nabis*** sp.
[5]This speciment was parasitized by ***Perilitus*** sp.
[6]One syrphid larva.

Table 5.—Mean number of aphids per plant, and percentage of aphid-infested winter wheat plants ±S.E. in field plots treated with different insecticides[1]

		(Fall 1990)		Days from application—Feekes growth stage[2]				(spring 1991)		
Insecticides	5–2	10–2–3	14–3	19–3–4	165–7	173–8	181–9	188–10.1	195–10.5	202–11
a. *Aphids per plant*										
1. Acephate 10.1 ps	0.48±0.11a	0.16±0.05bc	0.06±0.02b	0.12±0.07bc	0.40±0.02a	0.40±0.02a	0.00±0.00a	0.00±0.00a	0.30±0.23a	0.08±0.04a
2. Acephate 9.7 cf	0.18±0.07bc	0.26±0.07ab	0.08±0.04b	0.16±0.05ab	0.20±0.02a	0.60±0.06a	0.00±0.00a	0.00±0.00a	0.16±0.07a	0.42±0.37a
3. Carbofuran 8.1 ps	0.32±0.04ab	0.10±0.08bc	0.04±0.02b	0.02±0.02c	0.60±0.04a	0.00±0.00a	0.00±0.00a	0.04±0.02a	0.16±0.11a	0.36±0.23a
4. Carbofuran 8.3 cf	0.18±0.06bc	0.12±0.04bc	0.02±0.02b	0.12±0.04bc	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.08±0.08a	0.34±0.12a	0.04±0.02a
5. Carbofuran 15 G	0.38±0.05a	0.06±0.02c	0.08±0.06b	0.06±2.02bc	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.08±0.08a	0.14±0.09a	0.00±0.00a
6. Disulfoton 8.0 ps	0.04±0.04c	0.02±0.02c	0.08±0.04b	0.02±0.02c	0.12±0.12a	0.20±0.02a	0.00±0.00a	0.02±0.02a	0.46±0.24a	0.08±0.04a
7. Disulfoton 12.9 wax	0.00±0.00c	0.00±0.00c	0.06±0.06b	0.06±0.04bc	0.00±0.00a	0.60±0.04a	0.02±0.02a	0.06±0.04a	0.66±0.51a	0.02±0.02a
8. Control	0.36±0.09ab	0.38±0.11a	0.24±0.07a	0.24±0.07a	0.00±0.00a	0.20±0.02a	0.00±0.00a	0.12±0.05a	0.78±0.35a	0.04±0.04a
F test/*P* values	7.274/0.0001	4.522/0.018	2.539/0.0372	3.333/0.0104	0.817/0.5815	0.770/0.6172	1.000/0.4520	0.758/0.6189	0.805/0.5901	1.192/0.3394
b. *% aphid-infested plants*										
1. Acephate 10.1 ps	30.00±6.33a	10.00±3.16ab	6.00±2.45ab	12.00±7.35abc	4.00±2.45a	4.00±2.45a	0.00±0.00a	0.00±0.00b	10.00±3.16a	8.00±3.74a
2. Acephate 9.7 cf	16.00±5.10a	20.00±3.16a	8.00±3.74ab	16.00±5.10ab	2.00±2.00a	6.00±6.00a	0.00±0.00a	0.00±0.00b	12.00±5.83a	6.00±2.45ab
3. Carbofuran 8.1 ps	26.00±2.45a	8.00±5.83bc	4.00±2.45ab	2.00±2.00c	6.00±4.00a	0.00±0.00a	0.00±0.00a	4.00±2.45ab	8.00±3.74a	8.00±3.74a
4. Carbofuran 8.3 cf	14.00±4.00a	10.00±3.16ab	2.00±2.00b	12.00±3.74ab	0.00±0.00a	0.00±0.00a	0.00±0.00a	2.00±2.00b	12.00±3.74a	4.00±2.45ab
5. Carbofuran 15 G	22.00±4.90a	6.00±2.45bc	4.00±2.45ab	6.00±2.45bc	0.00±0.00a	0.00±0.00a	0.00±0.00a	2.00±2.00b	10.00±5.48a	0.00±0.00b
6. Disulfoton 8.0 ps	4.00±4.00b	2.00±2.00cd	8.00±3.74ab	2.00±2.00c	12.00±12.00a	2.00±2.00a	0.00±0.00a	2.00±2.00b	22.00±8.60a	4.00±2.45ab
7. Disulfoton 12.9 wax	0.00±0.00b	0.00±0.00d	2.00±2.00b	6.00±4.00bc	0.00±0.00a	6.00±4.00a	2.00±2.00a	4.00±2.45ab	18.00±4.90a	2.00±2.00ab
8. Control	32.00±4.90a	26.00±5.10a	18.00±4.90a	24.00±6.78a	2.00±2.00a	0.00±0.00a	0.00±0.00a	8.00±2.00a	14.00±2.45a	2.00±2.00ab
F test/*P* values	10.615/0.0001	5.360/0.0006	1.521/0.2009	2.776/0.0252	0.808/0.5883	1.181/0.3449	1.000/0.4520	1.727/0.1431	0.766/0.6201	1.208/0.3309

[1]Insecticide treatment means in a column for each of the two parameters with different letters are significantly different ($P \leq 0.05$), according to Fisher's PLSD tests.
[2]Application on 11.2.90; growth stages of Feekes (Large 1954).
[3]F test and P values for treatments were obtained from single factor ANOVAS with repeated measures (Statview 512+™Statistical Software; Abacus Concepts, Inc. 1986).

https://scholar.valpo.edu/tgle/vol25/iss3/7
DOI: 10.22543/0090-0222.1787

Table 6.—Average number of aphids per plant, and percentage of aphid-infested winter wheat plants ±S.E. in field plots treated with different insecticides (averages of 2, 3, and 2 formulations of acephate, carbofuran, and disulfoton, respectively)[1]

	(Fall 1990)		Days from application – Feekes growth stage[2]					(spring 1991)		
Insecticides	5 – 2	10 – 2-3	14 – 3	19 – 3-4	165 – 7	173 – 8	181 – 9	188 – 10.1	195 – 10.5	202 – 11
a. *Aphids per plant*										
1. Acephate	0.33 ± 0.06a	0.21 ± 0.04ab	0.07 ± 0.02b	0.14 ± 0.05ab	0.03 ± 0.01a	0.05 ± 0.04a	0.00 ± 0.00a	0.00 ± 0.00b	0.23 ± 0.14a	0.25 ± 0.18a
2. Carbofuran	0.29 ± 0.02a	0.09 ± 0.03bc	0.05 ± 0.02b	0.07 ± 0.02b	0.02 ± 0.01a	0.00 ± 0.00a	0.00 ± 0.00a	0.07 ± 0.04ab	0.22 ± 0.08a	0.13 ± 0.08a
3. Disulfoton	0.00 ± 0.02b	0.01 ± 0.01c	0.07 ± 0.05b	0.04 ± 0.02b	0.06 ± 0.06a	0.04 ± 0.02a	0.07 ± 0.07a	0.04 ± 0.02ab	0.56 ± 0.23a	0.05 ± 0.02a
4. Control	0.36 ± 0.09a	0.38 ± 0.11a	0.24 ± 0.07a	0.24 ± 0.07a	0.00 ± 0.00a	0.01 ± 0.01a	0.00 ± 0.00a	0.12 ± 0.05a	0.78 ± 0.35a	0.04 ± 0.04a
F test/ *P* values	9.065/0.0021	6.887/0.0060	5.398/0.0139	6.614/0.0069	0.573/0.6435	0.901/0.4693	1.000/0.4262	2.117/0.1514	1.358/0.3023	1.165/0.3636
b. *% aphid-infested plants*										
1. Acephate	23.00 ± 3.39a	15.00 ± 1.58ab	7.00 ± 2.00ab	14.00 ± 4.85ab	3.00 ± 1.23a	5.00 ± 3.87a	0.00 ± 0.00a	0.00 ± 0.00b	10.00 ± 3.54a	7.00 ± 2.55a
2. Carbofuran	21.27 ± 3.06a	8.00 ± 2.00b	3.33 ± 1.06b	6.00 ± 1.25bc	2.00 ± 1.33a	0.00 ± 0.00a	0.00 ± 0.00a	2.67 ± 1.25ab	10.00 ± 2.79a	4.00 ± 1.25ab
3. Disulfoton	2.00 ± 2.00b	1.00 ± 1.00c	5.00 ± 2.74b	4.00 ± 1.87c	6.00 ± 6.00a	1.00 ± 1.00a	1.00 ± 1.00a	2.00 ± 0.82ab	20.00 ± 5.24a	3.00 ± 1.23ab
4. Control	32.00 ± 4.90a	26.00 ± 5.10a	18.00 ± 4.90a	24.00 ± 6.78a	1.00 ± 1.00a	0.00 ± 0.00a	0.00 ± 0.00a	8.00 ± 2.00a	14.00 ± 2.45a	2.00 ± 2.00b
F test/*P* values	27.891/0.0001	26.736/0.0001	2.313/0.1278	9.938/0.014	0.325/0.8075	1.445/0.2785	1.000/0.4262	3.465/0.0509	1.772/0.2060	1.859/0.1903

[1]Insecticide treatment means in a column for each of the two parameters with different letters are significantly different ($P \leq 0.05$), according to Fisher's PLSD tests.
[2]Application on 11.2.90; growth stages of Feekes (Large 1954).
[3]F test and P values for treatments were obtained from single factor ANOVAS with repeated measures (Statview 512+™Statistical Software; Abacus Concepts, Inc. 1986).

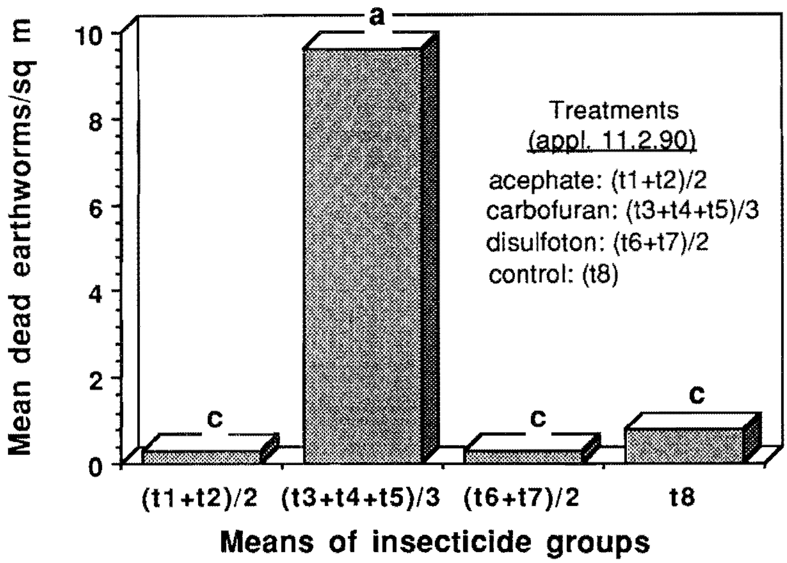

Figure 1. Mean number of dead earthworms per square meter on the surface of the plots, 5 d after application of different insecticide treatments on winter wheat [columns with different letters are significantly ($P \leq 0.05$) different, according to single factor ANOVAS with repeated measures and Fisher's PLSD test (Statview 512+ ™Statistical Software; Abacus Concepts, Inc. 1986)].

The average effect of the disulfoton treatments on the number of aphids and percentage of aphid-infested plants was noted at the first aphid count, 5 d after application (Table 6), while those of acephate [(t1+t2)/2] and carbofuran [(t3+t4+t5)/3] started to show later.

In the fall, natural enemies were almost nonexistent; a total a 3 mummified aphids and 1 adult mycrohymenopteran parasitoid were observed on the plants randomly selected for aphid counts at this time (Table 4). This low density of natural enemes may favor a rapid growth of populations of cereal aphids during the fall, at a stage when plants are most susceptible to damage by these BYDV vectors. If environmental conditions are favorable for cereal aphids, they will also be so for natural enemies, but because of the time-lag produced betwen the growth of populations of aphids and their natural enemies, most of the damage caused by these aphids during the fall will be done before they are controlled by beneficial arthropods.

Infestation of Hessian fly, *Mayetiola destructor* (Say), during the fall in these plots was minimal, as only two dead larvae were found 5 d after application in one of the plants sampled from the control plots.

A number of dead earthworms, *Lumbricus* sp., were counted 5 d after application (Figures 1 and 2) over the surface of the plots treated with the three formulations of carbofuran. The three formulations of this insecticide caused statistically significant earthworm mortality, with a relative greater effect of carbofuran 8.3 cf. Reduced populations of lumbricid earthworms were reported by Martin (1978) on carbofuran-treated plots of pasture in New

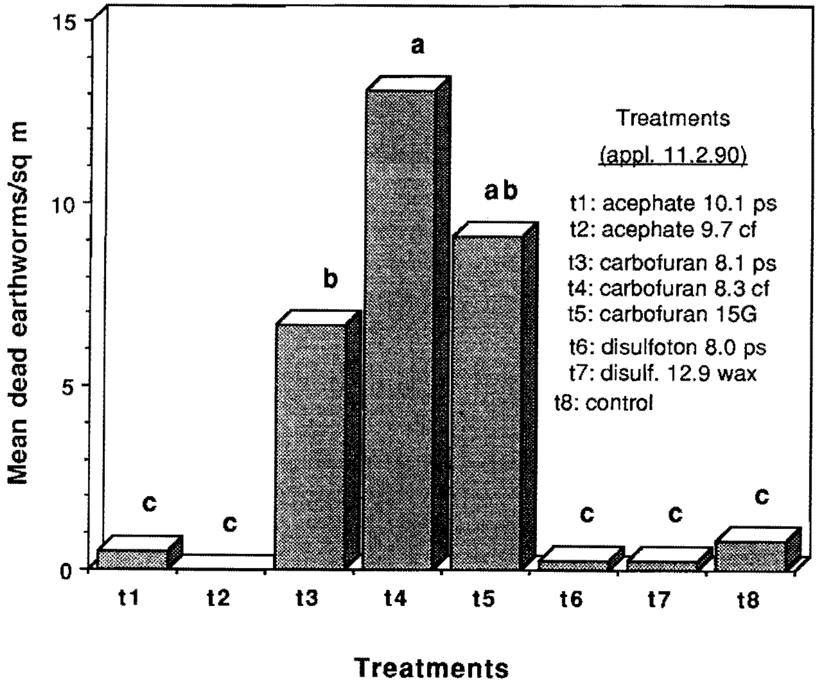

Figure 2. Mean number of dead earthworms per square meter on the surface of the plots, 5 d after application of different insecticide treatments on winter wheat (averages of 2, 3, and 2 formulations of acephate, carbofuran, and sidulfoton, respectively) [columns with different letters are significantly ($P \leq 0.05$) different, according to single factor ANOVAS with repeated measures and Fisher's PLSD test (Statview 512+ ™Statistical Software; Abacus Concepts, Inc. 1986)]

Zealand. It is not known whether carbofuran or the other AI caused eathworm mortality below the soil surface. Further tests are required.

b. Spring of 1991. Aphid counts were stopped during winter and resumed in spring. Aphid populations were small, with a relatively minor increase from days 188 through 202 after application (plant growth stages 10.1 and 11 of the Feekes scale [Large 1954], respectively) (Tables 5 and 6). Population density peaked on day 195, when plants were at the 10.5 Feekes growth stage.

Aphids killed by *Enthomophthora* were observed in late spring (Table 4), on maturing wheat plants. No activity of microhymenopteran parasitoids was observed, but adult *C. maculata* ladybird beetles were often observed as soon as cereal aphids were found in the field. The other stages occurred later, as observed the previous year on spring oat. This coccinellid may play an important role in reducing cereal aphid populations on winter wheat during the spring, making it unnecessary to protect the maturing plants with organosynthetic aphicides.

Using slow release formulations of acephate encapsulated in pearl corn starch or corn flour granules in laboratory studies, Araya et al. (1990a) achieved >50% mortality of *R. padi* from days 15 and 17 through days 31.5 and 32.8 after seeding, respectively. The corresponding granular formulations of carbofuran provided control (>50% mortality) from days 13.3 through 17.9 and 31.6 and 35.5 after seeding, respectively. Foliar sprays of acephate and carbofuran applied 12 d after seedling emergence provided control for 18.3 and 36.2 d from application, respectivly. Further laboratory studies (Araya et al. (1990b), testing similar formulations and dosages of acephate and carbofuran and higher dosages of disulfoton encapsulated in pearl corn starch granules, controlled *R. padi*, the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), and rose-grain aphid, *Metopolophium dirhodum* (Walker), corroborating results obtained first with *R. padi*.

ACKNOWLEDGMENTS

The authors express their appreciation to Rick Foster, John J. Roberts, and Stanley G. Wellso for critically reviewing the manuscript.

LITERATURE CITED

Abacus Concepts, Inc. 1986. Statview 512+ Statistical Software. BrainPower, Inc., Calabasas, California.

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265–267.

Araya, J. E., and J. E. Foster. 1983. A key for identification of some economically important species of cereal aphids (Homoptera: Aphididae). Purdue Univ., Agric. Exp. Stn. Bull. 429:1–11.

Araya, J. E., J. E. Foster, and S. E. Cambron. 1987. A study of the biology of *Rhopalosiphum padi* (L.) (Homoptera: Aphididae) in winter wheat in northwestern Indiana. Great Lakes Entomol. 20:47–50.

Araya, J. E., J. E. Foster, M. M. Schreiber, and R. Wing. 1990a. Residual action of slow release systemic insecticides on *Rhopalosiphum padi* (Homoptera: Aphididae) on wheat. Great Lakes Entomol. 23:19–27.

Araya, J. E., J. E. Foster, M. M. Schreiber, R. Wing, A. Fereres, J. Tadeo, and P. Castaera. 1990b. [Early control of aphid vectors of barley yellow dwarf virus with slow release systemic insecticides in granular formulations.] Boletn Sanidad Vegetal, Plagas (Spain) 1:178–186. (in Spanish).

Araya, J. E., J. E. Foster, and S. G. Wellso. 1986. Aphids as cereal pests. Purdue Univ., Agric. Exp. Stn. Bull. 509:1–27.

Arretz, P., and J. E. Araya. 1978. [Control of aphids on barley with systemic insecticides applied to the soil, seed, and foliage, in two localities of the central zone of Chile.] Investigacin Agrcola (Chile) 4:79–86. (in Spanish).

______. 1980. [Aphid control on wheat with granular systemic insecticides applied to the soil, seed treatments, and foliage sprays.] Simiente (Agron. Soc. of Chile) 50:50–56 (in Spanish).

Bruehl, G. W. 1961. Barley yellow dwarf, a virus disease of cereals and grasses. Monograph No. 1, Amer. Phytopath. Soc. 52 pp.

Caldwell, R. M., J. F. Schafer, L. E. Compton, and F. L. Patterson. 1959. Yellow dwarf infection on oats and wheat in Indiana in 1959. Plant Dis. Rep. Suppl. 262:333.

Carrigan, L. L., H. W. Ohm, J. E. Foster, and F. L. Patterson. 1981. Response of winter wheat cultivars to barley yellow dwarf virus infection. Crop Sci. 21:377–380.

DePew, L. J. 1974. Controlling greenbugs in grain sorghum with foliar and soil insecticides. J. Econ. Entomol. 67:553–555.

Dumbre, R. B., and A. A. Hower. 1977. Contact mortality of the alfalfa weevil parasite *Microctonus aetiopoides* from insecticide residues on alfalfa. Environ. Entomol. 6:893–894.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1–42.

Edwards, C. R., E. C. Berry, and T. A. Brindley. 1980. Effect of insecticide applications on insect predators of the European corn borer (*Ostrinia nubilalis*) in central Iowa. Iowa State J. Res. 54:361–366.

Endo, R. M., and C. M. Brown. 1963. Effects of barley yellow dwarf virus on yield of oats as influenced by variety, virus strain, and developmental stage of plants at inoculation. Phytopathology 53:965–968.

Fitzpatrick, G., R. H. Cherry, and R.V. Dowell. 1978. Short-term effects of three insecticides on predators and parasites of the citrus blackfly. Environ. Entomol. 7:553–555.

Flanders, R. V., L. W. Bledsoe and C. R. Edwards. 1984. Effects of insecticides on *Pediobus foveolatus* (Hymenoptera: Eulophidae), a parasitoid of the Mexican bean beetle (Coleoptera: Coccinellidae). Environ. Entomol. 13:902–906.

Frank, R., G. Ritcey, H. E. Braun, and F.L. McEwen. 1984. Disappearance of acephate residues from beans, carrots, celery, lettuce, peppers, potatoes, strawberries and tomatoes. J. Econ. Entomol. 77:1110–1116.

Gholson, L. E., C. C. Beegle, R. L. Best, and J. C. Owens. 1978. Effects of several commonly used insecticides on cornfield carabids in Iowa. J. Econ. Entomol. 71:416–418.

Gill, C. C. 1980. Assessment of losses on spring wheat naturally infected with barley yellow dwarf virus. Plant Disease 64:197–203.

Hinz, B., F. Daebeler, and W. Lucke. 1979. [Injurious effects of the cereal aphid (*Rhopalosiphum padi* (L.)) and barley yellow dwarf virus on spring barley and oats.] Archiv fr Phytopathologie und Pflanzenschutz 15:405–413. (in German).

Hsieh, C. Y., and W. W. Allen. 1986. Effects of insecticides on emergence, survival, longevity, and fecundity of the parasitoids *Diaeretiella rapae* (Hymenoptera: Aphididae) from mummified *Myzus persicae* (Homoptera: Aphididae). J. Econ. Entomol. 79:1599–1602.

Kolbe, W. 1973. Studies on the occurrence of cereal aphids and the effect of feeding damage on yields in relation to infestation density levels and control. Pflanzenschutz Nachrichten bayer 26:396–410.

Lange, W. H., G. G. Agosta, K. S. Goh, and J. S. Jishiyama. 1980. Field effect of insecticides on chrysanthemum leafminer (*Phytomyza syngenesiae*) and a primary parasitoid, *Chrysocharis ainsliei* on artichokes (*Cynara scolimus*) in California, USA. Environ. Entomol. 9:561–562.

Large, E. C. 1954. Growth stages in cereals. Illustrations of the Feekes scale. Plant Pathol. 3:128–129.

Martin, N. A. 1978. Effect of four insecticides on the pasture ecosystem: VI. Arthropoda dry-heat-extracted from small soil cores, and conclusions. New Zealand J. Agric. Res. 21:307–320.

Mize, T., G. Wilde, and M. T. Smith. 1980. Chemical control of chinch bug (*Blissus leucopterus leucopterus*) and greenbug (*Schizaphis graminum*) on seedling sorghum with seed, soil and foliar treatments. J. Econ. Entomol. 73:544–547.

Oetting, R. D. 1984. Systemic activity of acephate, butoxycarboxim, and butocarboxim for control of *Myzus persicae* on ornamentals. J. Georgia Entomol. Soc. 17:433–438.

Palmer, L. T., and W. H. Sill, Jr. 1966. Effect of BYDV on wheat in Kansas. Plant Dis. Rep. 50: 234–238.

Rabbinge, R., and F. H. Rijsdijk. 1984. Epidemiological and crop physiological foundation of EPIPRE. Chapter 26: 227–235, *In:* Gallagher, E. J. (ed.), Cereal Production. Proc. 2nd Intl. Summer School in Agriculture, The Royal Dublin Soc.

Rothman, P. G., D. H. Bowman, and S. S. Ivanoff. 1959. Occurrence of barley yellow dwarf on oats in Mississippi, 1959. Plant Dis. Rep. Suppl. 262:348–350.

Semtner, P. J. 1979. Insect predators and pests of tobacco following applications of systemic insecticides. Environ. Entomol. 8:1095–1098.

Shasha, B. S., D. Trimnell, and F. H. Otey. 1984. Starch-borate complexes for EPTC encapsulation. J. Appl. Polym. Sci. 29:67–74.

Smith, H. C. 1967. The effects of aphid numbers and stage of plant growth in determining tolerance to barley yellow dwarf virus in cereals. New Zealand J. Agric. Res. 10:445–466.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill, New York. 481 pp.

Stern, V. M. 1967. Control of aphids attacking barley and analysis of yield increases in the Imperial Valley, California. J. Econ. Entomol. 60: 485–490.

Szeto, S. Y., H. H. MacCarthy, P. C. Oloffs, and R. F. Shepherd. 1979. The fate of acephate and carbaryl in water. J. Environ. Sci. Health, Part B, Pestic. Food Contam. Agric. Wastes 64:635–654.

van Rensburg, J. B. J., M. C. Walters, and G. P. Stemmet. 1978. A preliminary study on the application of carbofuran granules to the soil for the control of grain sorghum pests. Phytophylactica 10:28–30.

Whalon, M. E., and E. A. Elsner. 1982. Impact of insecticides on *Illinoia pepperi* and its predators. J. Econ. Entomol. 75:356–358.

Wing, R. E., S. Maiti, and W. M. Doane. 1987. Factors affecting release of butylate from calcium ion modified starch-borate matrices. J. Controlled Release 5:79–89.

Yamazaki, M., M. Sakai, and F. Goto. 1982. [Behavior of acephate and metamidophos in tobacco plants treated with granular formulations.] J. Pestic. Sci. (Nihon Noyaku Gakkaishi) 7:175–180. (in Japanese).

https://scholar.valpo.edu/tgle/vol25/iss3/7
DOI: 10.22543/0090-0222.1787