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Comparison of 'Fayette' Soybean, Aldicarb, and Experimental Nematicides for Management of *Heterodera glycines* on Soybean[1]

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Abstract: The efficacies of *Heterodera glycines*-resistant 'Fayette' soybean and aldicarb for managing *H. glycines* were compared to the experimental nematicides DS-47187 10F, DS-47357 10F, DS-48145 10F, DS-48165 10F, DS-46995 10F and 5G, and DS-38697 5G during 1981–83. Yield of Fayette was greater than yield of the *H. glycines*-susceptible cultivar treated with nematicide in 1981 and 1983. Yield of aldicarb-treated soybean was greater than yield of soybean treated with experimental nematicides in 1983. There were no yield differences in 1982. Fewer white females were recovered from Fayette 5 weeks after planting than from soybean treated with nematicides in 1981 and 1982, but not in 1983. Fewer white females were recovered from aldicarb-treated soybean than from experimental nematicide-treated soybean in 1983 but not in 1981 and 1982. In 1983 numbers of first generation white females at 5 weeks and the ratio of those white females to gravid cysts at planting were negatively correlated with soybean yield when soybean was severely damaged by the nematode, but the ratio of final eggs and second-stage juveniles to initial eggs and second-stage juveniles was not correlated with yield.
Key words: aldicarb, chemical control, *Glycine max, Heterodera glycines,* management, population dynamics, resistance, soybean, soybean cyst nematode.

The current government crop diversion program that seeks to divert maize hectarage to other crops is causing many midwestern farmers to plant soybean (*Glycine max* (L.) Merr.) on land with known infestations of the soybean cyst nematode (SCN), *Heterodera glycines* Ichinohe. Rotation crops such as grain sorghum are included in the maize base and cannot be planted if the grower participates in the program. When a grower cannot rotate, use of a resistant soybean cultivar, if available, or treatment of a susceptible cultivar with a nematicide are control options. In Illinois, aldicarb is the most widely used nematicide for SCN control on soybean, but it is used on less than 30,000 ha, mostly as an in-furrow application (4). Because of the large number of SCN-infested hectares (1.8 million) in Illinois, there is considerable interest in the development of an expanded nematicide market. This paper reports the field evaluation of several experimental nematicides and compares their efficacy to that of the SCN-resistant soybean 'Fayette' (2) and aldicarb.

Materials and Methods

Experiments were conducted from 1981 to 1983 in Illinois at a different location each year on land infested with *H. glycines* race 3. Plots were planted and treated on 29 June 1981 at Opdyke (Jefferson County), 10 May 1982 at Royal (Vermillion County), and 26 May 1983 at Dix (Jefferson County). Soil types were Hoyleton silt loam (Aquollic Hapudalf) at Opdyke and Dix and Drummer silty clay loam (Typic Haplaquoll) at Royal. Southern Illinois soils typified by the Jefferson County locations average less than 2% organic matter, whereas those of Vermillion County in central Illinois average about 5% organic matter. P1 (available P), K, and pH averaged 97 kg/ha, 278 kg/ha, and 5.5, respectively, at Opdyke and 38 kg/ha, 208 kg/ha, and 7.5 at Dix. Soil pH, P1, and K were not determined at Royal. Previous crops were *H. glycines*-susceptible soybeans at Opdyke and Dix and maize at Royal. Numbers of gravid cysts at planting ranged from 3 to 147, 20 to 225, and 127 to 447/250 cm^3 soil at Opdyke, Royal, and Dix, respectively. The fields received minimum

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TABLE 1. Influence of *Heterodera glycines*-resistant 'Fayette' soybean, aldicarb, and experimental nematicides on soybean yield and first generation population development of *H. glycines* at Opdyke, Illinois, in 1981.

Treatment and rate† (g a.i./100 m of row)	Yield‡ (kg/ha)	No. white females per 250 cm^3 soil§	Rf‖
Control	2,433	31	0.76
Fayette	2,748	0	0.00
Aldicarb 10.2	2,505	44	1.08
Aldicarb 20.3	2,607	5	0.50
DS-47187 10F 5.6	2,425	34	0.75
DS-47187 10F 10.2	2,479	13	0.44
DS-47187 10F 20.3	2,499	56	1.06
DS-47357 10F 5.6	2,395	36	1.00
DS-47357 10F 10.2	2,502	48	0.94
DS-47357 10F 20.3	2,432	96	1.06
CV%	8.0	40.8	43.3

† Control and nematicide treatments planted with 'Williams 79' soybean.

‡ $P = 0.02$ for orthogonal contrast of Fayette yield vs. all nematicides; other contrasts were not significant.

§ $P = 0.02$ for orthogonal contrast of aldicarb 10.2 g vs. aldicarb 20.3 g; $P = 0.06$ for orthogonal contrast of DS-47187 vs. DS-47357; Fayette was not included in the analysis since white females were not recovered.

‖ Rf = white females at 5 weeks/gravid cysts at planting. $P = 0.03$ for orthogonal contrast of aldicarb 10.2 g vs. aldicarb 20.3 g; $P = 0.10$ for orthogonal contrast of DS-47187 vs. DS-47357; Fayette was not included in the analysis since white females were not recovered.

tillage before initiation of experiments. Herbicides and cultivation were used to control weeds. Metolachlor was preplant incorporated at the rate of 1.96 kg a.i./ha and bentazon applied postemergence at the rate of 0.84 kg a.i./ha at Opdyke. Alachlor was preplant incorporated at the rate of 2.8 kg a.i./ha at Royal. Trifluralin was preplant incorporated at the rate of 0.84 kg a.i./ha and bentazon applied postemergence at the rate of 0.84 kg a.i./ha at Dix. Rainfall was monitored at Royal and Dix with a recording rain gauge.

Treatments in each experiment were arranged in a randomized complete block design with four replications. Each experimental unit consisted of four 7-m rows on 76-cm centers. 'Williams 79' was used at Opdyke and Royal and 'Williams 82' at Dix for all treatments with a susceptible cultivar. Fayette soybean was compared to the 15G formulation of aldicarb, the 10F formulations of DS-47187, DS-47357, DS-46995, DS-48145, and DS-48165, and the 5G formulations of DS-46995 and DS-38697 (Diamond Shamrock Corporation, Painesville, Ohio). Tables 1–3 list the chemicals and rates of application of each location. All nematicides were applied in an 18-cm-wide band and incorporated 2–4 cm into the soil using an 18-cm-wide rake. Granular nematicides were applied with a Precision Machine (Precision Machine, Lincoln, Nebraska) single-row applicator equipped with a Noble (Sac City, Iowa) metering device. Liquid nematicides were applied with a four-row CO_2-pressurized backpack sprayer at 7.03×10^{-2} kg/cm^2 pressure and 748 liter/ha delivery rate through four Delvan (West Des Moines, Iowa) LE3 80° nozzles.

Nematode populations were determined at planting, at approximately 5 weeks after planting, and at harvest. Twenty cores were

TABLE 2. Influence of *Heterodera glycines*-resistant 'Fayette' soybean, aldicarb, and experimental nematicides on soybean yield and first generation population development of *H. glycines* at Royal, Illinois, in 1982.

Treatment and rate† (g a.i./100 m of row)	Yield‡ (kg/ha)	No. white females per 250 cm^3 soil§	Rf‖
Control	2,542	21	0.58
Fayette	2,499	1	0.15
Aldicarb 5.6	2,527	17	0.63
Aldicarb 10.2	2,535	19	0.61
Aldicarb 20.3	2,481	17	0.57
DS-46995 10F 5.6	2,509	23	0.82
DS-46995 10F 10.2	2,577	14	0.63
DS-46995 10F 20.3	2,540	10	0.56
DS-48145 10F 5.6	2,464	16	0.73
DS-48145 10F 10.2	2,516	15	0.66
DS-48145 10F 20.3	2,505	10	0.54
DS-48165 10F 5.6	2,462	18	0.58
DS-48165 10F 10.2	2,371	14	0.57
DS-48165 10F 20.3	2,605	13	0.64
CV%	6.7	22.9	27.9

† Control and nematicide treatments planted with 'Williams 79' soybean.

‡ No significant differences in yield.

§ $P = 0.0001$ for orthogonal contrast of Fayette vs. all nematicides.

‖ $P = 0.0001$ for orthogonal contrast of Fayette vs. all nematicides.

TABLE 3. Influence of *Heterodera glycines*-resistant 'Fayette' soybean, aldicarb, and experimental nematicides on soybean yield and population development of *H. glycines* at Dix, Illinois, in 1983.

Treatment and rate† (g a.i./100 m of row)	Yield‡ (kg/ha)	No. white females per 250 cm^3 soil§	Rf‖	Pf/Pi¶	
				Cysts	Eggs + J2
Control	996	99	0.63	0.98	0.99
Fayette	1,851	10	0.31	0.85	0.84
Aldicarb 20.3	1,716	9	0.20	0.91	1.00
Aldicarb 27.2	1,743	15	0.38	0.95	0.97
DS-46995 5G 10.2	1,292	55	0.60	0.88	0.93
DS-46995 5G 15.4	1,489	37	0.40	0.91	0.95
DS-46995 5G 20.3	1,579	7	0.23	0.87	0.87
DS-38697 5G 15.4	1,489	5	0.21	0.89	0.88
CV%	12.7	56.1	56.5	12.7	6.7

† Control and nematicide treatments planted with 'Williams 82' soybean.
‡ $P = 0.0001$ for orthogonal contrast of control vs. all others; $P = 0.009$ for orthogonal contrast of Fayette vs. all nematicides; $P = 0.004$ for orthogonal contrast of aldicarb vs. experimental nematicides.
§ $P = 0.02$ for orthogonal contrast of control vs. all others; $P = 0.10$ for contrast of DS-38697 vs. DS-46995.
‖ $P = 0.01$ for orthogonal contrast of control vs. all others; $P = 0.10$ for contrast of DS-38697 vs. DS-46995.
¶ Pf/Pi = ratio of final population at harvest to the initial population at planting. There were no significant orthogonal contrasts for Pf/Pi cysts. Significant orthogonal contrasts for Pf/Pi eggs + J2 were control vs. all others ($P = 0.05$), Fayette vs. all nematicides ($P = 0.02$), and aldicarb vs. experimental nematicides ($P = 0.009$).

collected in a zig-zag pattern from the two center rows of each plot 3–7 cm from the base of plants and to a depth of 15 cm, using a 2-cm-d soil sampler. After kneading and mixing the soil in each sample, nematodes were extracted from 250-cm^3 aliquants by Cobb's gravity sieving technique (3) using 850-μm-pore and 180-μm-pore sieves. Cysts recovered from samples taken at planting were hand picked and crushed to determine the presence of eggs and second-stage juveniles (J2). In 1983, the number of eggs and J2 in cysts was also determined at harvest. White females recovered 5 weeks after planting were washed from the 180-μm-pore sieve and counted. Data were transformed to $\log_{10}(x + 1)$ for statistical analysis. Changes in nematode populations were compared by calculating a reproductive factor (Rf = white females at 5 weeks/gravid cysts at planting) for all 3 years, and by determining the ratio between the final cyst and initial cyst populations (Pf/Pi cysts) and between the final egg and J2 and the initial egg and J2 populations (Pf/Pi eggs + J2) in 1983.

Yield was determined by harvesting 4.7 m of each of the two center rows of the four-row plots. Seed was cleaned, dried, and weighed. Moisture content was adjusted to 13%.

An analysis of variance was conducted for population and yield data and the treatment sum of squares partitioned into orthogonal contrasts. The following comparisons were made for both population and yield data for each of the 3 years: (1) control vs. all other treatments, (2) Fayette vs. all nematicides, (3) aldicarb vs. experimental nematicides, (4) low rate of aldicarb vs. high rate of aldicarb, and (5) experimental nematicide (all rates) vs. experimental nematicide (all rates). In 1982, one additional experimental nematicide was compared, since there were three candidate compounds.

RESULTS

H. glycines suppressed soybean yield in 1981 and 1983 but not in 1982 (Tables 1–3). Fayette yields were greater than yields of nematicide-treated Williams 79 in 1981 ($P = 0.02$; Table 1) and Williams 82 in 1983 ($P = 0.009$; Table 3). Yield of the control did not differ from all other treatments in 1981 but was less ($P = 0.0001$) in 1983. Aldicarb-treated soybean yielded more than soybean treated with experimental nematicides in 1983 ($P = 0.004$) but not in 1981.

White females were not recovered from Fayette in 1981 (Table 1). Numbers of white females recovered from aldicarb-treated Williams 79 did not differ from the experimental nematicides, but the two aldicarb rates differed ($P = 0.02$). Numbers from DS-47187 over the three rates were less ($P = 0.06$) than those from DS-47357 over all three rates. In 1982, numbers of white females recovered from treated soybeans did not differ among the nematicides or among aldicarb rates (Table 2). Fewer white females were recovered from Fayette, however, than from all nematicides ($P = 0.0001$). The number recovered from Fayette in 1983 (Table 3) did not differ from Williams 82 treated with nematicides. The number of white females recovered from the control was greater ($P = 0.02$) than the number from Fayette and nematicide-treated Williams 82. Fewer ($P = 0.10$) white females were recovered from DS-38697-treated Williams 82 than from DS-46995-treated Williams 82 over all three rates.

Analysis of Rf gave results similar to that of white female numbers (Tables 1–3). In 1981 (Table 1), Rf for aldicarb-treated Williams 79 did not differ from experimental nematicides, but the two aldicarb rates differed ($P = 0.03$). Rf for DS-47187 over all three rates was less ($P = 0.10$) than Rf for DS-47357 over all three rates. In 1982, Rf for Fayette was different ($P = 0.0001$) than Rf for all nematicides (Table 2). There were no differences among nematicides or among aldicarb rates. Rf for the control in 1983 (Table 3) was greater than Rf for all other treatments ($P = 0.01$). Fayette and Williams 82 treated with nematicides did not differ. Rf for DS-38697-treated Williams 82 was greater ($P = 0.10$) than Rf for DS-46995-treated Williams 82 over all three rates.

Although the Pf/Pi values between cysts and eggs + J2 for individual treatments were similar, the results of orthogonal comparisons were dissimilar (Table 3). There were no significant comparisons of Pf/Pi values for cysts, but for Pf/Pi values for eggs + J2, the contrasts for control vs. all others, Fayette vs. all nematicides, and aldicarb vs. experimental nematicides were significant at $P = 0.02$, $P = 0.05$, and $P = 0.009$, respectively. The CV% was lower and the r^2 was greater for Pf/Pi eggs + J2 when compared with Pf/Pi cysts (CV% = 6.7 vs. 12.7 and $r^2 = 0.54$ vs. 0.22).

In 1981 and 1982, yield was not significantly correlated with white females developing at 5 weeks after planting or with Rf (Table 4). In 1983, however, there was a highly significant negative correlation between yield and white females and between yield and Rf. Neither Pf/Pi cysts nor Pf/Pi eggs + J2 were correlated with yield in 1983.

Rainfall from July to September 1981 at a weather station 15 km from Opdyke was 278.2 mm, which was 11.7 mm greater than normal. Because of equipment malfunction, rainfall at Royal was not measured, but from planting to midseason (May–July) 1982 rainfall at a weather station 30 km distant was 381.8 mm, which was 108.2 mm greater than normal. During the 1983 growing season at Dix, rainfall measured 274.0 mm which was about 77% of normal.

Discussion

The small yield suppression in 1981 and absence of damage in 1982 were unexpected, since both sites had a long history of reduced soybean yield due to SCN. Yields in a soybean breeding plot at Opdyke in 1980 were reduced 70%, and in a breeding plot adjacent to the 1981 nematicide trial Fayette outyielded Williams 79 by 605 kg/ha (Noel, unpubl.). Since nematode damage occurred in an adjacent experiment planted on the same day as the nematicide trial, the late planting date at Opdyke in 1981 probably did not contribute to the small yield difference in the nematicide test. The experiment was probably placed in an area of the field where initial populations were relatively low. Excess moisture which occurred through mid-season at Royal probably contributed to the absence of SCN-induced damage by alleviating moisture stress. Soybeans grown at Dix in 1983 did not appear stressed by the lower than normal rainfall.

Fayette was more effective than nema-

TABLE 4. Correlations between soybean yield and *Heterodera glycines* populations during 1981–83.

	White females	Rf	Pf/Pi†	
			Cysts	Eggs + J2
1981	r = 0.0083 P = 0.96	r = −0.0903 P = 0.60		
1982	r = 0.1016 P = 0.45	r = 0.1042 P = 0.44		
1983	r = −0.5649 P = 0.0008	r = −0.5812 P = 0.0005	r = −0.0812 P = 0.65	r = −0.2209 P = 0.25

† Pf/Pi data missing for 1981 and 1982.

ticide-treated Williams 79 and Williams 82 in reducing SCN populations, but at Dix the higher Rf associated with Fayette indicated that there was a greater gene frequency for parasitism in that population than at Opdyke and Royal. The low Rf values for two of the three locations were unexpected. Sampling for white females at Royal was delayed approximately 10 days because of wet conditions, but at Opdyke and Dix sampling occurred on day 35 after planting. At other locations during the same years that the experiments reported herein were conducted, Rf values were between 2.0 and 3.0 for Williams 79 not treated with nematicide (5). Since the two southern Illinois fields used in this study had a long history of both continuous cropping of SCN-susceptible soybeans and *H. glycines* infestation, various organisms may have acted as biological control agents, thus preventing large nematode population increases. The field at Opdyke was planted with SCN-susceptible soybean in 1982 and 1983, but nematode damage was not observed. The field at Dix was subsequently planted with a resistant cultivar.

Significant orthogonal contrasts for Pf/Pi for eggs + J2 but not white females or Rf indicated that Pf/Pi ratios provided better data for comparing nematicide effects. Pf/Pi values for eggs + J2 in contrast to those from white females or Rf values were not correlated with yield in 1983 when *H. glycines* was most damaging. Determining numbers of gravid cysts and white females is less labor intensive and time consuming than determining numbers of eggs and J2. For studies of population dynamics, eggs and J2 data may be more meaningful (1), but for evaluation of experimental nematicides white female counts and Rf may provide more useful information, since nematode damage is most severe during development of the first generation.

In Illinois, crop rotation is recommended most often for control of *H. glycines*, but it is not practiced optimally for several reasons, including government programs and other economic considerations. Fayette soybean may be grown where late maturity group II, group III, and early group IV soybeans are produced and normally is recommended over nematicide use. Aldicarb application is a viable control option for SCN, however, when certain economic constraints are considered or the grower needs to avoid continuous or frequent cropping of resistant soybeans (6).

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