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Effects of Aldicarb on Nematodes, Early Season Insect Pests, and Yield of Soybean[1]

D. A. HERBERT,[2] R. RODRÍGUEZ-KÁBANA,[2] P. A. BACKMAN,[2] AND T. P. MACK[3]

Abstract: The effects of aldicarb on soybean cyst (*Heterodera glycines*) and root-knot (*Meloidogyne incognita* and *M. arenaria*) nematode populations, early season insect pests and soybean (*Glycine max*) yield were evaluated in five field experiments in northern and southern Alabama. Aldicarb significantly ($P = 0.05$) reduced nematode populations in only two cases: *M. arenaria* in Centennial soybean in the Wiregrass site and *M. incognita* in Bedford soybean in a Tennessee Valley site. No significant difference ($P = 0.05$) in mean percentage main stem or petiole girdling by threecornered alfalfa hopper (*Spissistilus festinus*) or in mean number of plants damaged by lesser cornstalk borer (*Elasmopalpus lignosellus*) occurred among treatments in any experiment. Soybean yields were significantly ($P = 0.05$) increased in only two cases: in the nematode susceptible Essex and Cobb cultivars planted in the Tennessee Valley and Gulf Coast sites, respectively. Unusually dry 1986 weather conditions may have reduced the activity of aldicarb.

Key words: Meloidogyne arenaria, Meloidogyne incognita, Heterodera glycines, Spissistilus festinus, Elasmopalpus lignosellus, aldicarb, soybean, *Glycine max.*

A model for aiding in the management of nematode, insect, and disease pests of soybean (*Glycine max* (L.) Merr.) is being developed for Alabama growers. The model offers pest management decision alternatives to the user. The acceptability of any decision is determined by its profitability: the value of the protected crop yield minus treatment costs. All management tactics (i.e., pesticide applications or cultural techniques) are evaluated relative to their efficacy against pests and effects on yield. In field experiments validating the nematode management submodel, aldicarb treatments were tested against endemic field populations of soybean cyst (*Heterodera glycines* Ichinohe) and root-knot (*Meloidogyne incognita* (Kofoid and White) Chitwood and *M. arenaria* (Neal) Chitwood) nematodes using resistant and susceptible soybean cultivars. The development of early season lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller)) and threecornered alfalfa hopper (*Spissistilus festinus* (Say)) infestations provided an opportunity to evaluate aldicarb against those species. Activity of aldicarb against certain soybean insect pests is well documented. Lentz et al. (8) reported that aldicarb applied at planting suppressed *Empoasca fabae* (Harris) and reduced *Sericothrips variabilis* (Beach) and *Cerotoma trifurcata* (Forster) populations in soybean at 36 and 21 days after treatment, respectively. Caron (1) found significant reductions in numbers of hemipterous species at 7 weeks and control of *S. variabilis* for 6 weeks posttreatment. This report contributes data on the combined efficacy of aldicarb, soil incorporated at planting, against cyst and root-knot nematodes, threecornered alfalfa hopper, and lesser cornstalk borer and the effect on soybean yields.

MATERIALS AND METHODS

Five experiments were conducted at four Alabama Agricultural Experiment Station Substations in 1986. Nematode populations were documented for all sites at planting time using sampling procedures discussed below. Sites 1 and 2 were at the Tennessee Valley Substation in north-central Alabama in a Decatur silt loam soil (28% sand, 45% silt, 28% clay, 1.0% organic matter). Sites 1 and 2 were naturally infested at planting time with a mean of 20 *H. glycines* and 50 *M. incognita* juveniles/

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[1] Journal Series No. 18-871269 of the Alabama Agricultural Experiment Station, Auburn University, Auburn, AL 36849.

[2] Postdoctoral Research Associate, Professor, and Professor, respectively, Department of Plant Pathology, Auburn University, Auburn, AL 36849.

[3] Associate Professor, Department of Entomology, Auburn University, Auburn, AL 36849.

100 cm^3 soil, respectively. Site 3 was at the Sand Mountain Substation in northeastern Alabama in a Hartsell fine sandy loam soil (60% sand, 25% silt, 15% clay, 1.0% organic matter) naturally infested at planting time with a mean of 20 *H. glycines* juveniles/100 cm^3 soil. Site 4 was at the Wiregrass Substation in southeastern Alabama in a Dothan sandy loam soil (70% sand, 20% silt, 10% clay, 1.0% organic matter) naturally infested with a mean of 150 *M. arenaria* juveniles/100 cm^3 soil. Site 5 was at the Gulf Coast Substation in southwest Alabama in a Malbis fine sandy loam soil (55% sand, 27% silt, 18% clay, 1.0% organic matter) naturally infested with a mean of 35 *H. glycines* juveniles/100 cm^3 soil. The soybean cultivars tested in the Tennessee Valley and Sand Mountain sites were Bedford, resistant to *H. glycines*, races 3 and 4, and *M. incognita* (13) and Essex, susceptible to *H. glycines*, races 3 and 4, and *M. incognita* (6). Braxton soybean, resistant to *M. incognita* and *M. arenaria* and susceptible to *H. glycines* (7), and Centennial, resistant to *H. glycines*, race 3, and *M. incognita* and susceptible to *M. arenaria* (4) were tested at the Wiregrass site. Kirby soybean, resistant to *H. glycines*, *M. incognita*, and *M. arenaria* (5), and Cobb, resistant to *M. incognita* and susceptible to *M. arenaria* and *H. glycines* (5), were tested at the Gulf Coast site.

Conventional cultural practices were used in all experiments. A 76-cm row spacing was used at the Tennessee Valley and Gulf Coast sites, whereas 91-cm row spacing was used at the Sand Mountain and Wiregrass sites. Weed control and fertilization programs were according to recommendations for each site (3). At the Wiregrass site, treatment replicates were established in both irrigated and nonirrigated Braxton soybean. The Centennial cultivar at this location was planted into wheat stubble using strip-tillage with an in-row subsoiler. Planting dates were 9 June for Tennessee Valley and Sand Mountain sites, 26 May and 9 June for the Braxton and Centennial cultivars, respectively, at the Wiregrass Substation, and 5 June for the Gulf Coast Substation site.

A randomized complete block design was used in all experiments. Replicate numbers, which varied among substations due to space availability, were as follows: 12 replicates at the Tennessee Valley, Sand Mountain, and Wiregrass (Centennial soybean only) sites; 8 replicates in the Braxton soybean at the Wiregrass site; and 16 replicates at the Gulf Coast site. Plots were 12 rows × 15.2 m in length. Aldicarb (Temik 15G) was applied at planting in front of the planter press wheel with a Gandy applicator (2–3-cm depth soil incorporated) to all rows of treated plots. All applications were in 30-cm bands. The rate used in the Tennessee Valley and Gulf Coast sites was 8.5 g/100 m (76-cm row spacing), the equivalent of 1.12 kg a.i./ha overall. Sand Mountain treatments received 10.3 g/100 m (91-cm row spacing), the equivalent of 1.12 kg a.i./ha overall. Wiregrass treatments received 20.5 g/100 m (91-cm row spacing), the equivalent of 2.24 kg a.i./ha overall.

Nematode numbers were estimated just before harvest using 20 soil cores (2.5 cm d × 15–20 cm deep) taken adjacent to plant stem bases and composited from the center two rows of each plot. A 100-cm^3 subsample was analyzed for nematodes using a modified Baermann funnel technique (11). Insect damage to plants, rated 7 weeks after planting, was used to measure damage accumulated over the period when aldicarb should have been at highest levels in treated plants and most available to plant feeders. Lesser cornstalk borer damage was assessed by counting the number of damaged plants of 20 selected per plot. Two plants were randomly selected and uprooted from each of the 10 center rows of each plot. Plants with visible stem borings or silken larval tubes were recorded as damaged. Larval density was estimated by counting the number of larvae associated with the 20 uprooted plants per plot. Roots and soil (ca. 200 cm^3) from near the plant stem bases and split plant stems were searched for larvae. Threecornered alfalfa hopper damage was assessed by counting the number of main stem girdled plants in

TABLE 1. Effect of aldicarb on juvenile *Meloidogyne incognita* and *Heterodera glycines* numbers in soil at harvest, accumulated threecornered alfalfa hopper damage to soybean 7 weeks after planting, and soybean yield, Tennessee Valley Substation.

				Site 1			
					Threecornered alfalfa hopper damage		
Cultivar	Treatment	g/100 m	N	*H. glycines* mean no./ 100 cm³ soil	Mean % plants stem girdled	Mean no. petiole girdles/20 trifoliates	Mean yield (kg/ha)
Essex	aldicarb	8.5	12	8.8 a	10.4 a	12.0 a	2,707 a
(susceptible)	none	0.0	12	13.3 a	9.5 a	12.8 a	2,347 b
Bedford	aldicarb	8.5	12	17.2 a	12.1 a	8.3 a	2,791 a
(resistant)	none	0.0	12	64.7 a	14.1 a	7.3 a	2,622 a

				Site 2			
					Threecornered alfalfa hopper damage		
Cultivar	Treatment	g/100 m	N	*M. incognita* mean no./ 100 cm³ soil	Mean % plants stem girdled	Mean no. petiole girdles/20 trifoliates	Mean yield (kg/ha)
Essex	aldicarb	8.5	12	29.2 a	3.7 a	7.3 a	2,378 a
(susceptible)	none	0.0	12	43.8 a	9.4 a	6.5 a	2,225 a
Bedford	aldicarb	8.5	12	22.7 b	18.6 a	8.5 a	2,056 a
(resistant)	none	0.0	12	71.7 a	11.0 a	4.0 a	2,131 a

All mean comparisons were done within cultivar; means followed by the same letter are not significantly different (Duncan's multiple-range test, $P = 0.05$).

two randomly selected 5-row m samples per plot. Canopy damage was assessed by counting the number of petiole girdles on 20 trifoliates randomly selected from the upper canopy of each plot. After crop maturity, the center two rows of each 12 row plot were harvested using conventional harvesting equipment and seeds were weighed (corrected for percent moisture). All data were analyzed using analysis of variance and differences among means were compared using Duncan's multiple-range test ($P = 0.05$) (12). Weather data were monitored at, or just adjacent to, each field experiment and were compiled by the National Weather Service (10).

TABLE 2. Effect of aldicarb on juvenile *Meloidogyne arenaria* numbers in soil at harvest and accumulated lesser cornstalk borer damage to soybean 7 weeks after planting and soybean yield, Wiregrass Substation.

						Lesser cornstalk borer damage		
Cultivar	Tillage system	Treatment	g/100 m	N	*M. arenaria* mean no./ 100 cm³ soil	Mean % damaged plants	Mean no. larvae/20 plants	Mean yield (kg/ha)
Centennial	minimum	aldicarb	20.5	12	0.3 b	100.0 a	5.8 a	—†
(susceptible)		none	0.0	12	14.3 a	98.0 a	5.7 a	—†
Braxton	conventional	aldicarb	20.5	8	1.5 a	46.9 a	1.9 a	1,668 a
(resistant)	(dry)	none	0.0	8	8.8 a	48.1 a	2.3 a	1,553 a
Braxton	conventional	aldicarb	20.5	8	13.3 a	9.4 a	0.6 a	2,112 a
(resistant)	(irrigated)	none	0.0	8	15.4 a	7.5 a	0.4 a	2,109 a

All mean comparisons were done within cultivar and tillage system; means followed by the same letter are not significantly different (Duncan's multiple-range test, $P = 0.05$).

† Due to extreme damage by insect pests, no seeds were formed.

TABLE 3. Effect of aldicarb on juvenile *Heterodera glycines* numbers in soil at harvest and accumulated threecornered alfalfa hopper and lesser cornstalk borer damage to soybean 7 weeks after planting and soybean yield, Sand Mountain Substation.

Cultivar	Treatment	g/100 m	N	*H. glycines* mean no./100 cm³ soil	Threecornered alfalfa hopper damage: Mean % plants stem girdled	Threecornered alfalfa hopper damage: Mean no. petiole girdles/20 trifoliates	Lesser cornstalk borer damage: Mean % damaged plants	Lesser cornstalk borer damage: Mean no. larvae/20 plants	Mean yield (kg/ha)
Essex	aldicarb	10.3	12	90.6 a	5.3 a	5.0 a	40.6 a	2.1 a	2,004 a
(susceptible)	none	0.0	12	77.3 a	7.7 a	3.3 a	28.1 a	0.9 a	2,347 a
Bedford	aldicarb	10.3	12	147.3 a	4.6 a	6.3 a	13.1 a	0.3 a	2,481 a
(resistant)	none	0.0	12	152.8 a	4.4 a	4.0 a	16.9 a	0.8 a	2,623 a

All mean comparisons were done within cultivar; means followed by the same letter are not significantly different (Duncan's multiple-range test, $P = 0.05$).

RESULTS AND DISCUSSION

Efficacy of aldicarb against targeted nematode pests was not clearly demonstrated. Aldicarb significantly ($P = 0.05$) reduced numbers in only two cases: *M. incognita* in the Bedford soybean at the Tennessee Valley site 2 (Table 1) and *M. arenaria* in the Centennial soybean at the Wiregrass site (Table 2). Neither of these reductions resulted in increased yields.

Threecornered alfalfa hopper infestations developed at the Tennessee Valley and Sand Mountain sites. Main stem girdling by this species has been reported to reduce yields significantly if more than 65% of the soybean plants were girdled (9). Populations did not build to these injury levels in our experiments; main stem girdling never exceeded 20%. No significant differences ($P = 0.05$) in main stem or petiole girdle damage indices measured at 7 weeks after planting occurred among treatments in either Tennessee Valley or Sand Mountain sites (Tables 1, 3).

Lesser cornstalk borer infestations occurred at the Sand Mountain and Wiregrass sites. Infestations at Sand Mountain were moderate, causing plant damage means of 13.1–40.6% (Table 2). Mean numbers of lesser cornstalk borer larvae at 7 weeks after planting were low, 0.3–2.1 per 20 plants sampled. Three distinct lesser cornstalk borer infestation levels developed in the Wiregrass experiment. The infestation in the minimum tillage Centennial cultivar was extreme; 100% of the plants were damaged (Table 2) and virtually none developed to maturity. Mean larval density 7 weeks after planting was approximately 6 per 20 plants sampled. Minimum tillage soybean was planted later than the conventionally tilled replicates during an unusually hot, dry period, and lesser corn-

TABLE 4. Effect of aldicarb on juvenile *Meloidogyne arenaria* and *Heterodera glycines* numbers in soil at harvest and soybean yield, Gulf Coast Substation.†

Cultivar	Treatment	g/100 m	N	*M. arenaria* mean no./100 cm³ soil	*H. glycines* mean no./100 cm³ soil	Yield (kg/ha)
Cobb	aldicarb	8.5	16	21.5 a	742.4 a	2,862 a
(susceptible)	none	0.0	16	34.9 a	638.6 a	2,425 b
Kirby	aldicarb	8.5	16	50.3 a	355.3 a	2,512 a
(resistant)	none	0.0	16	37.8 a	350.1 a	2,481 a

All mean comparisons were done within cultivar and tillage system; means followed by the same letter are not significantly different (Duncan's multiple-range test, $P = 0.05$).

† No insect pest infestations developed in the first 7 weeks after planting.

TABLE 5. Departure from normal average temperatures and rainfall amounts for the 1986 growing season at Alabama Agricultural Experiment Substations (10).

Substation	Temperature (C)				Rainfall (cm)			
	June	July	Aug.	Sept.	June	July	Aug.	Sept.
Tennessee Valley	0.6	1.2	−1.0	0.8	6.60	−2.10	19.43	2.53
Sand Mountain	0.8	1.5	−0.7	0.3	−3.83	−3.35	5.80	−7.58
Wiregrass	1.1	1.7	−0.8	−0.4	−4.03	−3.13	0.08	−5.23
Gulf Coast	0.7	0.9	0.2	0.8	−0.98	−8.80	−2.50	−10.28

stalk borers apparently responded to those conditions. Infestation in the nonirrigated, conventionally tilled Braxton soybean was moderate. Approximately 50% of the plants were attacked, and mean number of larvae 7 weeks after planting was 1.9–2.3 per 20 plants (Table 2). Irrigated Braxton soybean sustained the least damage with less than 10% of the plants injured and a mean of 0.5 larvae per 20 plants. Irrigation apparently provided the soil moisture necessary to inhibit lesser cornstalk borer development, a phenomenon consistent with what is known about the biology of the species (2). Aldicarb did not provide protection against early season populations of lesser cornstalk borer under any of the conditions encountered in the 1986 field experiments. No significant differences ($P = 0.05$) in either mean percentage of plants damaged or mean number of larvae occurred among treatments (Tables 2, 3).

Soybean yields were significantly increased ($P = 0.05$) by aldicarb treatments in only two cases: in the nematode susceptible Essex cultivar at the Tennessee Valley site 1 (Table 1) and in the susceptible Cobb cultivar at the Gulf Coast site (Table 4). These treatments were cost effective, as yield values more than offset treatment costs (calculated using a $5.00/bushel soybean market value and a $17.34/pound a.i. aldicarb value).

Aldicarb's general lack of efficacy against nematode and early season insect pests and the reduced effect on yield may have been due to the unusually hot and dry conditions of the 1986 season (Table 5). Average temperatures during June and July exceeded normals for all sites. Rainfall amounts were substantially below normal for the Sand Mountain, Wiregrass, and Gulf Coast regions of Alabama. During the June through September growing season, Sand Mountain received 30 rain events beginning 2 days after planting that totaled 5.9 inches less than normal for that period. The Wiregrass region received 36 rain events beginning 1 day after planting that totaled 4.95 inches less than normal. The Gulf Coast area received 46 events beginning 4 days after planting that totaled 9.02 inches less than normal. Although moisture content of experiment soils was not documented, the effects of high temperature and reduced rainfall dried soils as the season progressed and soybean plants often wilted and became stunted. Low soil moisture may have reduced the movement of aldicarb to plant roots, retarded plant uptake, and thus reduced systemic activity.

These data verify the importance of qualifying conditions for the profitable use of any pesticide when developing profit critical pest management programs. For aldicarb these will include environmental factors such as temperature and rainfall (e.g., projections based on 30-year average National Weather Service data) and cultural factors such as soil type, rotation history, and cultivar susceptibility. Successful models must integrate, as much as possible, the spectrum of pesticide performance under as many conditions as can be documented.

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