EFFECTS OF A LOW RATE OF ALDICARB ON SOYBEAN AND ASSOCIATED PEST INTERACTIONS IN FIELDS INFESTED WITH *HETERODERA GLYCINES*[†]

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ABSTRACT

Koenning, S. R., H. D. Coble, J. R. Bradley, K. R. Barker, and D. P. Schmitt. 1998. Effects of a low rate of aldicarb on soybean and associated pest interactions in fields infested with *Heterodera glycines*. Nematropica 28:205-211.

Field experiments conducted from 1989 to 1991 focused on potential interactions of insects and weeds, as influenced by a low rate of aldicarb (0.84 kg a.i./ha in-furrow application) in the presence of *Heterodera glycines* (SCN). A split-split-plot experimental design was used with whole plots as aldicarb treatments, sub plots designed to manage weed densities and sub-sub plots to manage insects. The sites were planted without pre-emergence herbicides, and post-emergence herbicides were utilized to maintain weed densities as desired. Numbers of SCN females per 3-plant-root systems were less in aldicarb-treated plots in 1989 and 1991, but not in 1990. Aldicarb treatment resulted in increased plant height, canopy width, and number of nodes per soybean plant. The increased canopy growth tended to result in lower weed and lower corn earworm population densities in aldicarb-treated plots. Numbers of corn earworm larvae were greater ($P = 0.05$) in untreated plots in 1989 and 1991. Weed densities were significantly greater ($P = 0.05$) in plots not treated with aldicarb in 1991. Treatment with aldicarb resulted in increases of 100-200 kg/ha soybean seed yield, averaged over 3 years. The data indicate that control of soybean cyst nematode can reduce insect- and weed-pest pressure on soybean, but the net return was economically justifiable in only one out of three years in these experiments.

Key words: aldicarb, corn earworm, *Glycine max*, green clover worm, *Helicoverpa zea*, herbicides, *Heterodera glycines*, pest interactions, *Plathypena scabrra*, soybean cyst nematode, weeds.

RESUMEN

Koenning, S. R., H. D. Coble, J. R. Bradley, K. R. Barker y D. P. Schmitt. 1998. Efectos del uso de bajo niveles de aldicarb en el frijol de soja y de las interacciones de plagas asociadas, en campos infestados con *Heterodera glycines*. Nematrópica 28:205-211.

Desde 1989 a 1991, se condujeron experimentos de campo, dirigidos al estudio de las interacciones potenciales entre insectos y malezas, debido a la influencia del uso de un bajo nivel de aldicarb (0.84kg a.i/ha en aplicaciones en hileras), en presencia de *Heterodera glycines* (SCN). Se utilizó un diseño de parcelas dividas y subdividas, en el que las parcelas como un todo, representaron los tratamientos con aldicarb. Las subparcelas se utilizaron para el manejo de las densidades de malezas, y las sub subparcelas, para el manejo de los insectos. Los sitios fueron plantados sin usar herbicidas de preemergencia, mientras que se utilizaron herbicidas de post-emergencia, para mantener las malezas en las densidades adecuadas. Los números de hembras de SCN por sistema de raíces en tres plantas, fueron menores, en las parcelas tratadas con aldicarb en 1989 y 1991, pero no en 1990. El tratamiento con aldicarb, resultó en un incremento de la altura de la planta, del ancho de la copa, y del numero

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de nodos, por planta de frijol de soja. El incremento en el crecimiento de la copa, tendió a resultar en un menor nivel de malezas y menores densidades poblacionales de cogollero, en las parcelas tratadas con aldicarb. Los números de larvas de cogollero, fueron mayores ($P = 0.05$) en las parcelas no tratadas en 1989 y 1991. Las densidades de las malezas fueron significativamente mayores ($P = 0.05$) en las parcelas no tratadas con aldicarb en 1991. El tratamiento con aldicarb, resultó en aumentos del rendimiento de la semilla de soja de entre 100-200 kg/ha, promediado por mas de 3 años. Los datos indican, que el control del nematodo causal del quiste de la soja, puede reducir la presión de los insectos y malezas en el frijol de soja, sin embargo la recuperación neta, fue económicamente justificable, en solamente uno de los tres años de experimentación.

Palabras claves: aldicarb, cogollero, *Glycine max*, gusano trébol verde, *Helicoverpa zea*, herbicidas, interacciones de plagas, malezas, quiste del frijol de soja, *Plathypena scabrra*.

INTRODUCTION

Soybean cyst nematode (SCN), *Heterodera glycines* Ichinohe, causes severe soybean (*Glycine max* L. Merr.) yield suppression in much of the North and South American soybean hectarage (Wrather *et al.*, 1997). These yield losses from SCN are compounded by interactions with other pests, especially weeds and insects. Poor soybean growth caused by *H. glycines* may result in more severe weed problems since the crop is less competitive than a healthy one (Alston *et al.*, 1991a). Similarly, insect problems may be more severe if soybean canopy closure is prevented or delayed as a result of SCN. Open canopy is more attractive to corn earworm, *Helicoverpa zea*, Boddie (Alston *et al.*, 1991b, 1991c). Although low rates of aldicarb are generally insufficient for control of *H. glycines* (Rodríguez-Kábana, 1992; Schmitt *et al.*, 1987), partial control may enhance soybean growth sufficiently to make the crop more competitive with weeds and less attractive to corn earworm. Additionally, aldicarb has been shown to consistently promote soybean growth (Barker *et al.*, 1988) which may increase biomass and result in early canopy closure. A low rate of aldicarb may thus be economically justified if it eliminates a post-emergence herbicide treatment and (or) insecticide treatment.

The primary objective of this research was the characterization of potential interactions between soybean cyst nematode and certain weed and insect pests on soybean. The secondary objective of this study was to determine the effects of a low rate of aldicarb on *H. glycines* and soybean as related to the presence/absence of weeds and insects.

MATERIALS AND METHODS

Three field experiments were conducted at separate North Carolina locations from 1989-1991. All sites were infested with race 2 of *H. glycines*. Initial SCN population densities were in the range from 3 000-6 000 eggs and juveniles/500 cm^3 soil, depending on year (Table 1).

The experimental design was a split-split plot 2 × 2 × 2 factorial with six replications. Whole plots (+/- aldicarb) were 20 rows-wide with 0.97 m row spacing and 33.5 m long. Half of the whole plots received 0.84 kg/ha (a.i.) aldicarb in-furrow. Sub plots were managed to regulate weed population densities (+/- a second post-emergence herbicide treatment) and sub-sub plots were designed to manipulate numbers of corn earworm (+/- an insecticide treatment, if corn earworm numbers exceeded threshold).

Table 1. Summary of soil types, soil textures (percent sand, silt, clay), organic matter, and mean preplant population densities (Pi) of *Heterodera glycines* (± standard deviation) at experimental sites in North Carolina, USA, from 1989-1991.

Location and Soil type	Year	% Sand	% Silt	% Clay	% O.M.	Pi (eggs and juveniles)
Near Plymouth, NC Araphahoe fine sandy loam	1989	92	7	1	6.0	4 500 ± 1 200
Near Antioch, NC Norfolk loamy sand	1990	90	9	1	1.0	5 000 ± 1 050
Near Weeksville, NC Nixonton very fine sandy loam	1991	48	44	8	1.5	4 900 ± 930

All plots were disked prior to establishment of the test and planted without beds. The SCN susceptible soybean cultivar Deltapine 105 was planted each year in late May at the rate of 26 seeds/m of row. Plots received no pre-emergence herbicide treatments. All plots were treated with a post-emergence application of acifluorfen 0.28 kg/ha (a.i.), tank-mixed with bentazon 0.56 kg/ha (a.i.), and sethoxydim 0.32 kg/ha (a.i.) in mid-June. Plots were cultivated in late June or early July to encourage a second flush of weed growth. Weed-free plots received a directed herbicide treatment of fluazifop 0.22 kg (a.i.)/ha, and bentazon 0.84 kg (a.i.)/ha in mid-July. Insect pressure was light each year, never reaching economic injury thresholds (J. S. Bacheler, personal communication) and insecticide treatments were not used.

Pre-plant and harvest soil samples for nematode analyses were collected from the center two rows of each sub-sub plot. Soil samples consisted of 8-10 2.5-cm-d cores taken to a depth of 20-cm which were processed by elutriation (Byrd *et al.*, 1972) and modified centrifugation (Jenkins, 1964). Three plants from each sub-sub plot were removed with soil 28 days after planting to assess SCN reproduction. Roots were removed from the soil and the numbers of white cysts/three plants were determined.

Insect pests were sampled with a standard 0.91 m beat sheet (ground cloth). Two sites per plot were sampled on each date. Each insect sample consisted of soybean plants on adjacent rows being thrashed over the 0.91 m beat sheet so that each sample was the sum of the number of insects per 2-m of row. Phytophagous insect species sampled were corn earworm (CEW) and Green cloverworm (GCW) *Plathypena scabrra* Fabricius, the only insect pests found in sufficient numbers to warrant counting. Data were collected on plant growth, and late season weed population density from three sites selected at random from the sixth row of each sub-subplot. The middle two rows of each sub-sub plot were harvested the first week of November each year. A significant year effect for the major variables precluded combined analyses over years. Yield, nematode, weed and insect data were analyzed as a split-split plot with six replications by Analysis of Variance (ANOVA). Nematode data were transformed ($\log_{10}[X+1]$) to standardize the variance; arithmetic means are presented in tables for clarity.

RESULTS AND DISCUSSION

Treatment with aldicarb suppressed ($P = 0.05$) numbers of white females (cysts) developing on soybean root systems 28 days after planting (DAP) in 1989 by 31% and in 1991 by 80%, but not in 1990 (Fig. 1). The lack of efficacy of aldicarb in 1990 can possibly be attributed to very dry conditions at planting and immediately thereafter. The soil at the 1990 experimental site was sandy with low organic matter content compared to the other locations, and thus prone to drought. Numbers of *H. glycines* cysts, eggs, and juveniles at soybean harvest were unaffected by aldicarb treatments in any year. There were no significant first or second order interactions.

Canopy width, plant height, and the number of nodes/plant were greater ($P = 0.05$) in aldicarb-treated plots than untreated plots in 1989 and 1991 (Figs. 2-4). Plant growth was unaffected by aldicarb treatment in 1990, however. Although there was a trend toward increased weed biomass in untreated plots in 1989, the difference was not statistically significant. Weed density was too low in 1990 to permit accurate assessment. Enhanced plant growth in response to aldicarb treatment resulted in lower ($P = 0.05$) weed biomass in treated plots compared to untreated plots in 1991 but not in other years (Fig. 5).

Numbers of corn earworm larvae were lower ($P = 0.05$) in aldicarb-treated plots in 1989 and 1991 (Table 2). Corn earworm larval numbers were greatest (n.s.) in aldicarb-treated plots at one sampling date in 1990, but were unaffected at a later sampling. Significantly higher numbers of corn earworm cadavers were found in aldicarb-treated plots in 1989 as a result of parasitism by the fungus *Nomuraca relezi* (Farlow) Sampson. Higher humidity as a result of a denser soybean canopy in response to aldicarb probably accounts for

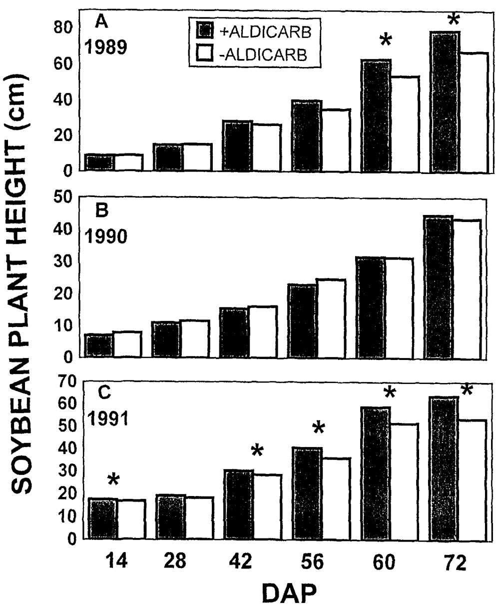

Fig. 2. Effects of in-furrow application of aldicarb at 0.84 kg/ha versus untreated control on soybean plant height at 14 day intervals after planting (DAP) until flowering in the presence of *Heterodera glycines*. Asterisk denotes significant difference ($P = 0.05$) in aldicarb-treated plots compared to untreated controls.

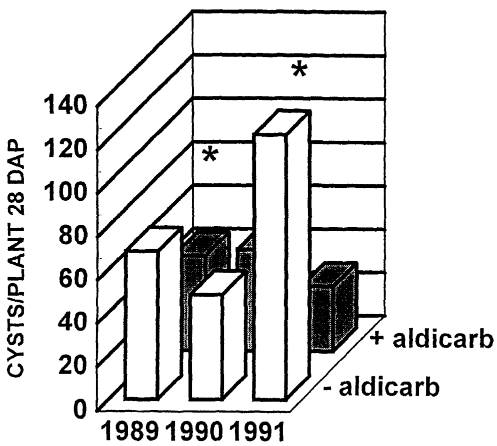

Fig. 1. Influence of in-furrow application of aldicarb at 0.84 kg a.i./ha on number of white cysts of *Heterodera glycines* per plant 28 days after planting (DAP). Asterisk indicates significant difference ($P = 0.05$) in aldicarb-treated plots compared to untreated controls.

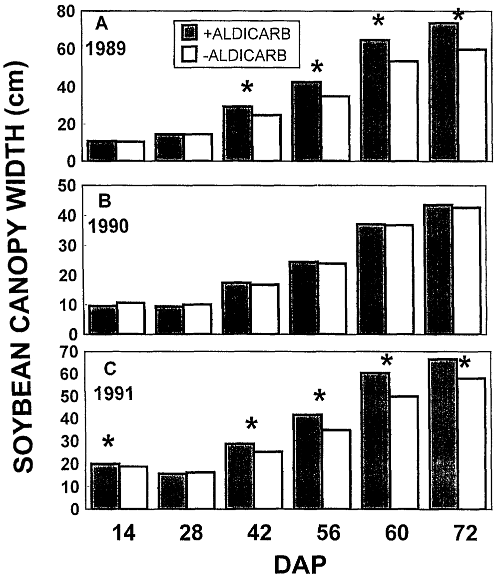

Fig. 3. Response of soybean canopy width to in-furrow application of 0.84 kg a.i./ha aldicarb measured at intervals of 14 days after planting (DAP) until flowering in three years in North Carolina. Asterisk indicates significant differences ($P = 0.05$) in aldicarb-treated plots compared to untreated controls.

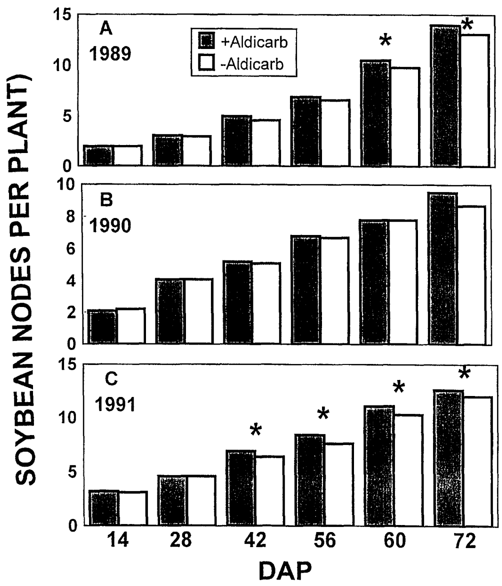

Fig. 4. Comparison of number of soybean nodes in plots treated with an in-furrow application of aldicarb at 0.84 kg a.i./ha versus untreated controls at intervals of 14 days after planting until flowering in three years in North Carolina. Asterisk denotes significant difference ($P = 0.05$) in aldicarb-treated plots compared to untreated controls.

this difference. Green clover worm larvae were significantly lower as a result of aldicarb treatment in 1989, but not in 1991.

The influence of aldicarb treatment on soybean-seed yield was significant (P = 0.05) in 1989 and 1991, but not in 1990 (Fig. 6). Yields were much lower in 1990 than in other years because of the coarse-textured soil and low organic matter percentage. Soybean yield in plots receiving herbicides for weed management were significantly greater ($P = 0.05$) only in 1991. Soybean-seed yield in weed-free plots was 2,366 kg/ha compared to 2,158 kg/ha in weedy plots.

Over the 3 years of the study, the average yield increase associated with application of aldicarb was 157 kg/ha. Assuming a price of $90.00 US/metric ton for soybean, the gross return was $14.13 US/ha. The cost of aldicarb treatment at $33.00 US/kg a.i. is $27.73 US for the rate used in this research assuming no application cost. A net loss of $13.60 US/ha would thus be incurred with this treatment. These data concur with research by Schmitt *et al.*,

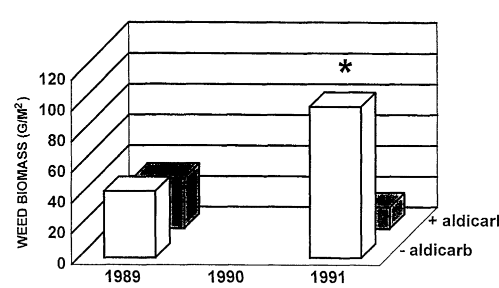

Fig. 5. Weed biomass (g/m^2) in untreated plots versus plots receiving an in-furrow application of aldicarb at 0.84 kg/ha. Asterisk denotes significant difference (P = 0.05) in aldicarb-treated plots compared to untreated controls.

Table 2. Influence of in-furrow application of aldicarb compared to untreated control on numbers of corn earworm *Helicoverpa zea* (CEW), corn earworm carcasses (CEWC, 1989 only), and green clover worm *Plathypena scabrra* (GCW) from 1989-1991.[y]

	1989			1990[z]		1991	
Treatment	CEW	GCW	CEWC	CEW1	CEW2	CEW	GCW
+ aldicarb	0.55 a	0.10 a	3.41 a	6.58 a	1.67 a	2 a	12 a
– aldicarb	5.10 b	5.88 b	0.92 b	3.08 a	1.41 a	6 b	12 a

All data are means of 24 measurements, treatments other than aldicarb and all interactions were not statistically significant.

[y]Means followed by the same letter do not differ ($P = 0.05$).

[z]Corn earworm were sampled on two dates in 1990 (CEW1 and CEW2).

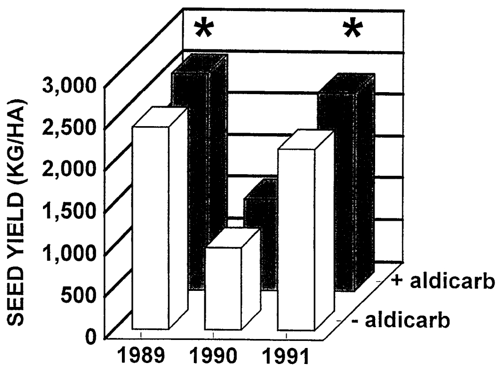

Fig. 6. Soybean-seed yield in response to 0.84 kg/a.i./ha aldicarb in-furrow compared to the untreated control in fields infested with *Heterodera glycines*. Asterisk denotes significant difference ($P = 0.05$) in aldicarb-treated plots compared to untreated controls.

1987, that nematicide usage, including this low rate of aldicarb, for management of *H. glycines* is not economically justifiable with current constraints on price.

If data from 1991 is considered, the only year in which aldicarb suppressed both cysts at 21 DAP and weed densities, then treatment with aldicarb was the most economical of the systems studied (Table 3). Aldicarb treatment did not result in a reduced insecticide usage in this particular study, but the data presented on weed and insect suppression as a result of enhanced soybean growth in fields infested with SCN in response to aldicarb, suggests that aldicarb usage may sometimes reduce or eliminate the need for additional pesticides.

Table 3. Treatment cost, soybean yield, crop value, and net value of treatments applied in 1991.[z]

Treatment	Cost/ha ($US)	Yield (kg/ha)	Value ($US)	Net value/ha ($US)
Control	—	1 993	179.37	179.37
Aldicarb	27.73	2 393	215.37	187.64
Herbicide	44.46	2 336	210.24	165.78
Aldicarb + Herbicide	72.19	2 329	209.61	137.42

[z]Assumes US $90.00 per metric ton of soybean, US $33.00/kg a.i. for aldicarb, US $110.07/kg a.i. for fluazifop, and US $23.80/kg a.i. for bentazon.

In conclusion, low rates of aldicarb applied for management of soybean cyst nematode were not effective in providing profitable control of this soybean pathogen. Enhanced soybean growth in response to aldicarb, however, resulted in lower pest pressure from weeds and insects.

LITERATURE CITED

ALSTON, D. G., J. R. BRADLEY, JR., H. D. COBLE, and D. P. SCHMITT. 1991a. Impact of population density of *Heterodera glycines* on soybean canopy growth and weed competition. Plant Disease 75:1016-1018.

ALSTON, D. G., J. R. BRADLEY, JR., D. P. SCHMITT, and H. D. COBLE. 1991b. Relationship of *Heliothis zea* predators, parasitoids and entomopathogens to canopy development in soybean as affected by *Heterodera glycines* and weeds. Entomologia Experimentalis Applicata 58:279-288.

ALSTON, D. G., J. R. BRADLEY, JR., D. P. SCHMITT, and H. D. COBLE. 1991c. Response of *Helicoverpa zea* (Lepidoptera: Noctuidae) populations to canopy development in soybean as influenced by *Heterodera glycines* (Nematoda: Heteroderidae) and annual weed population densities. Journal of Economic Entomology 84:267-276.

BARKER, K. R., S. R. KOENNING, A. L. BOSTIAN, and A. R. AYERS. 1988. Growth and yield response of soybean to aldicarb. Journal of Nematology 20:421-431.

BYRD, D. W. JR., K. R. BARKER, H. FERRIS, C. J. NUSBAUM, W. E. GRIFFIN, R. H. SMALL, and C. A. STONE. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8:206-212.

JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

RODRÍGUEZ-KÁBANA, R. 1992. Chemical control. Pp. 115-123 *in* R. D. Riggs, and J. A. Wrather, eds. Biology and Management of the Soybean Cyst Nematode. APS Press, St. Paul, MN, U.S.A.

SCHMITT, D. P., H. FERRIS, and K. R. BARKER. 1987. Responses of *Heterodera glycines* races 1 and 2 in different soil types. Journal of Nematology 19:240-250.

WRATHER, J. A., T. R. ANDERSON, D. M. ARYSOD, J. GAI, L. D. PLOPPER, A. PORTAPUGLIA, H. H. RAM, and T. YORINORI. 1997. Soybean disease loss estimates for the top 10 soybean producing countries in 1994. Plant Disease 81:107-110.

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