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Efficacy of Aldicarb to *Rotylenchulus reniformis* and Biodegradation in Cotton Field Soils

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Abstract: The microbial degradation of aldicarb was examined in the greenhouse using soil from four cotton fields with a history of aldicarb use. The addition of aldicarb at 0.59 kg a.i./ha to natural soil increased *Rotylenchulus reniformis* numbers 6.6% in one soil and decreased *R. reniformis* numbers only 25.8% in another soil as compared to the corresponding natural soil without aldicarb. The use of increasing rates of aldicarb did not increase the efficacy of aldicarb in these soils. *Rotylenchulus reniformis* numbers were reduced 39.8, 22.6, and 6.8%, and increased 5.7% for aldicarb applied at 0.29, 0.59, 0.85, and 1.19 kg a.i./ha, respectively, in one natural soil. In another natural soil, *R. reniformis* numbers were reduced 42.5 and 21.9% for aldicarb applied at 0.29 and 1.19 kg a.i./ha, respectively, but increased 19.1 and 10.6% for aldicarb applied at 0.59 and 0.85 kg a.i./ha, respectively. Autoclaving the soils restored aldicarb toxicity in both soils, and *R. reniformis* numbers were reduced 96 and 99%, respectively, as compared to autoclaved soil without aldicarb. Bacterial populations were greater in the natural soils where aldicarb did not reduce *R. reniformis* numbers relative to the same soils that were autoclaved. However, no bacterial species was consistently associated with aldicarb degradation.

Key words: aldicarb, microbial degradation, *Rotylenchulus reniformis.*

Accelerated degradation has been reported in recent years for a growing number of soil-applied herbicides, fungicides, insecticides, and nematicides (Somasundaram et al., 1989). In monoculture production regimes, enhanced degradation is usually linked to repetitive applications of biodegradable pesticides, which often results in a loss of effectiveness against the target pests (Aharonson et al., 1990; Avidov et al., 1990; Roeth et al., 1990). Previous application of a pesticide or a structurally related pesticide compound is considered a major factor in enhanced degradation (Roeth et al., 1990). Repeated pesticide applications also lead to enhanced degradation of the pesticide and the subsequent degradation products (Aharonson et al., 1990; Avidov et al., 1990; Ou et al., 1995; Roeth et al., 1990). Microbial degradation of the nematicides fenamiphos, ethoprop, and 1,3-dichloropropen have been reported (Davis et al., 1993; Johnson et al., 1992; Mojtahedi et al., 1991; Ou and Thomas, 1994; Ou et al., 1995). Ou et al. (1994) concluded fenamiphos degradation was enhanced after one field application at a rate of 4.48 kg a.i./ha and the degradation could be observed for 3 to 4 years. However, fenamiphos degradation accelerated faster in a soil annually treated with fenamiphos for over 15 years. In sweet potato fields, the loss of efficacy of ethoprop and fenamiphos was reported after 2 and 3 years, respectively, of sequential applications of the nematicide (Hall et al., 1988; Johnson et al., 1992). Ethoprop and fenamiphos degradation was determined to be biologically mediated and enhanced by prior exposures to the respective nematicides (Davis et al., 1993; Mojtahedi et al., 1991).

Aldicarb, 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime is a systemic, broad-spectrum insecticide/nematicide that is registered for use on multiple crops, vegetables, ornamentals, and orchards. Aldicarb is registered on cotton to manage early-season insects and plant-parasitic nematodes (Daoji et al., 1993). In a cotton production scheme, aldicarb is applied as a granular formulation and is released by soil moisture. Aldicarb degradation begins immediately with soil microorganisms rapidly oxidizing aldicarb to the metabolite aldicarb sulfoxide, which is then oxidized more slowly to aldicarb sulfone (Jones et al., 1988; Lightfoot et al., 1987; Smelt et al., 1978). Aldicarb sulfoxide and sulfone are of less nematicidal value because their toxicities are relatively low as compared to aldicarb (Jones et al., 1988). Repeated applications of aldicarb have been slow to induce an accelerated transformation by microbial adaptation (Smelt et al., 1995). The half-lives of the aldicarb and the aldicarb metabolites have been reduced to less than 2 weeks in duration in the laboratory; therefore, the efficacy of aldicarb also would be reduced (Smelt et al., 1995).

Loss of efficacy of aldicarb has been observed in mid-South cotton production fields infested with *Rotylenchulus reniformis* Linford and Oliveira (1940). Lorenz et al. (1998) in Arkansas reported a puzzling lack of response to aldicarb when no differences in cotton yield were observed between treatments consisting of a non-treated control and aldicarb applied in-furrow at planting at 0.58, 0.85, and 1.19 kg a.i./ha. Gazaway et al. (2000) reported that aldicarb failed to increase cotton yields in an Alabama field for 2 consecutive years. Lawrence and McLean (2000) found no differences in monthly *R. reniformis* populations and subsequent cotton yield between aldicarb applied in-furrow at planting at 0.58 and 0.85, and 0.85 in-furrow at planting plus 0.85 kg a.i./ha side dress application, and the non-treated control. It is not known if the loss of efficacy by aldicarb was caused by microbial degradation, the evolution of an aldicarb-resistant *R. reniformis* population, or other environmental factors. This study examines

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the toxicity of aldicarb in natural and sterilized cotton field soils as measured by *R. reniformis* population numbers and corresponding effects on the soil mycoflora.

Materials and Methods

Tests were established to determine if the efficacy of aldicarb for the management of *R. reniformis* in cotton field soils is altered by natural soil microorganisms. Soils were collected in bulk from four cotton fields. Aldicarb had been applied in previous years, and a loss of efficacy had been observed in three of the four fields as measured by *R. reniformis* population development and a lack of cotton yield response. Soils were collected in Escambia, Limestone, and Colbert Counties in Alabama and from Washington County, Mississippi. The soil from Washington County (MS) was classified as a silt loam (38%, 52%, 9.2% S-S-C; pH 6.2), the Escambia County soil (ES) was a sandy loam (65%, 25%, 9.75%, S-S-C; pH 6.0), the Limestone County soil (LM) was a loam (36.25%, 38.75%, 25% clay, S-S-C; pH 6.5), and the Colbert County soil (CL) was a silt loam (20%, 57.5%, 22.5%, S-S-C; pH 5.5). Soils from each field location were collected from the top 20 cm of the soil profile, sieved to remove large particles, and mixed thoroughly. One half of the soil from each location was sterilized by autoclaving at 121 °C and 103.4 kPa for 2 hours on 2 consecutive days. The remaining soil was not autoclaved.

In tests series 1, the treatments, arranged in a 2 × 2 factorial, were (i) natural soils or soils sterilized by autoclaving and (ii) aldicarb added at 0.59 kg a.i./ha (0.036 g/pot) or no aldicarb added. In tests series 2, the treatments, expanded to a 2 × 5 factorial, were (i) natural soils or soils sterilized by autoclaving and (ii) aldicarb added at 0.29, 0.59, 0.85, and 1.19 kg a.i./ha, (0.019, 0.036, 0.055, 0.077 g/pot) or no aldicarb added.

Rotylenchulus reniformis was extracted from the natural soils of MS, ES, LM, and CL at the initiation of all tests to determine the population numbers in each of the soils. Nematodes were extracted by combined gravity screening and sucrose centrifugal flotation (specific gravity = 1.13) and enumerated with the dissecting microscope (Jenkins, 1964). The *R. reniformis* inoculum from MS, ES, LM, and CL was incorporated back into the autoclaved soil treatments to return the autoclaved soil to the original natural soil populations. *Rotylenchulus reniformis* was added by pipeting the appropriate nematode suspension into two depressions, 5 cm deep and 1 cm wide. Autoclaved sand was placed in the depressions to prevent dehydration of the inoculum. Aldicarb was incorporated into the top 5 cm of soil in each pot in the selected treatments at the appropriate rates.

Each test was planted with Delta and Pine Land 1218 B/RR cotton seed. Seeds were prepared by surface-sterilizing for 10 seconds in 100% ethyl alcohol followed by a 4-minute wash in 1% sodium hypochlorite. Seeds were then placed on sheets of 26-cm × 39-cm sterile germination paper for 72 to 96 hours. Two seedlings with radicles of 1 to 2 cm in length were placed in each 10-cm-diam. pot.

Plants were grown in the greenhouse for 60 days with a temperature range of 25 to 32 °C. Pots were fertilized weekly with a balanced water-soluble fertilizer. In all tests, treatments were placed in a factorial arrangement as a randomized complete block design with five replications. All tests were repeated at least twice.

At harvest, *R. reniformis* juveniles and vermiform adults were extracted from the soil and enumerated as previously described. Cotton plant heights and weights also were recorded. Fungal and bacterial microorganisms were isolated from the soils by serial dilution plating. Soil from each pot was collected using 3-mm-diam. × 10-mm-deep cores taken from each pot. One gram of the soil was added to 10 ml of sterile distilled water and agitated. Serial dilutions of 10^{-1} to 10^{-4} were plated with a spiral plater (Spiral Systems, Inc., Bethesda, MD) on two media: potato dextrose agar amended with 0.1 g streptomycin sulfate and 0.02 g chlorotetracycline (PDASA) (Difco Laboratories, Detroit, MI) for fungi; and tryptic soy agar (TSA) (Difco Laboratories, Detroit, MI) for culturable bacteria. Dilution plates were incubated at 22 ± 2 °C for 3 days (TSA) and 7 days (PDASA). The resulting bacterial and fungal colonies were enumerated from both dilutions and media. One representative bacterial colony morphology was isolated for further identification. Each bacterium was identified by analysis of fatty acid methyl-esters of total cellular fatty acids (McInroy and Kloepper, 1995). Fungal colonies were identified after 7 days or sub-cultured for future identification.

Data were collected on populations of *R. reniformis* juveniles and vermiform adults in the soil, and bacterial and fungal colonies per gram of soil. Plant heights, and shoot and root dry weights, also were recorded. The reproductive factor (Rf) was calculated by taking the final *R. reniformis* population and dividing it by the initial population and multiplying by 100. All data from the first series of tests were subjected to analysis of variance (SAS Institute, Inc., Cary, NC). Means were compared using Fisher's protected least significant difference test ($P < 0.05$). For the second test series evaluating the increasing aldicarb rates, *R. reniformis* numbers were transformed to $\log_{10}$ values to stabilize variances. Mixed models methodology was implemented in SAS (Littell et al., 1996) to model the response. All fixed effects, including linear and quadratic responses to aldicarb rates, were modeled simultaneously.

Results

Test series 1—Rotylenchulus reniformis numbers: In three of the soils tested, the capacity of aldicarb to de-

TABLE 1. *Rotylenchulus reniformis* numbers per 150 cm^3 soil in four natural and autoclaved soils amended with aldicarb 60 days after planting.

Treatment	Mississippi	Escambia	Limestone	Colbert
Autoclaved	19,464 a	22,724 a	26,391 a	14,295 b
Autoclaved + aldicarb	945 b	769 d	417 b	518 c
Natural	12,030 a	11,627 ab	17,389 a	20,469 a
Natural + aldicarb	12,887 a	5,897 c	12,499 ab	1,939 c
$LSD_{(0.05)}$	8,493	12,723	14,620	7,375

Data are means of three experiments with five replications each.

TABLE 2. Effect of aldicarb in four natural and autoclaved soils on colony-forming units of soil-inhabiting bacteria ($\times 10^{-3}$) per gram of soil 60 days after planting.

Treatment	Mississippi	Escambia	Limestone	Colbert
Autoclaved	72.9 b	95.5	85.1 b	165.9
Autoclaved + aldicarb	146.5 ab	96.0	183.6 ab	149.2
Natural	169.8 ab	133.5	240.5 a	189.2
Natural + aldicarb	195.0 a	179.3	260.1 a	205.9
$LSD_{(0.05)}$	96.74	NS	65.29	NS

Data are means of three experiments with five replications each.
NS = not significant.

TABLE 3. Effect of aldicarb in autoclaved and natural soils on *Rotylenchulus reniformis* numbers at 60 days after planting.

Soil	Treatment	Intercept	Linear		Quadratic		Autoclaved vs. natural
			Estimate	*P* (Est > 0)	Estimate	*P* (Est > 0)	
MS	Autoclaved	8.7	−6.4	<0.001	2.9	0.03	**
MS	Natural	8.7	0.1	0.882			
LM	Autoclaved	7.7	−16.1	<0.001	10.4	<0.001	**
LM	Natural	6.4	0.2	0.741			
ES	Autoclaved	8.1	−13.1	<0.001	6.4	<0.001	**
ES	Natural	8.4	−7.3	<0.001	3.6	<0.006	
CL	Autoclaved	9.1	−10.6	<0.001	4.5	<0.001	NS
CL	Natural	9.1	−10.1	<0.001	5.3	<0.001	

MS = Mississippi site, LM = Limestone site, ES = Escambia site, CL = Colbert site.
NS = not significant.

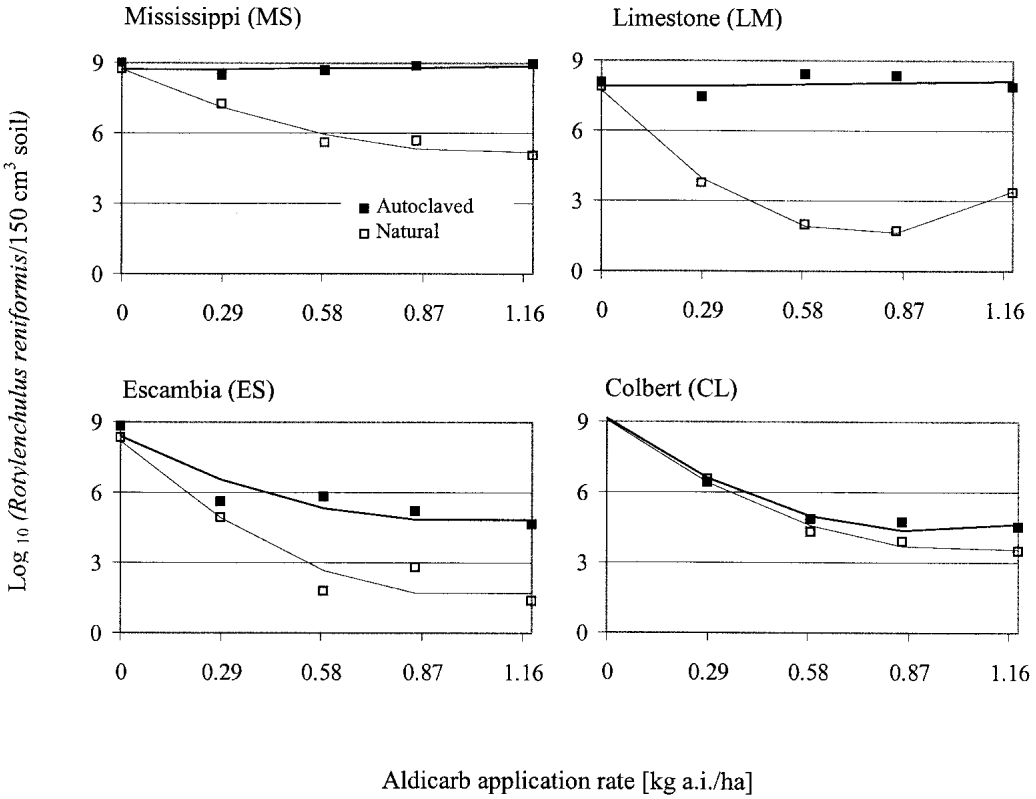

FIG. 1. Relationships between *Rotylenchulus reniformis* numbers 60 days after planting in Mississippi, Escambia, Limestone, and Colbert natural and autoclaved soils to aldicarb applied at increasing rates. *Rotylenchulus reniformis* numbers were transformed to $\log_{10}$ values for regression analysis. Each data point represents a mean of 10 replications.

TABLE 4. Distribution of bacterial species from Tests 1 and 2 in autoclaved and natural soils with and without aldicarb at 60 days after planting.

Taxa	Natural				Natural + aldicarb				Autoclaved				Autoclaved + aldicarb			
	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM	CL
Acidovorax konjaci							+	+								
Acinetobacter radioresistens													+			
Alcaligenes xylosoxydans	+	+														
Alcaligenes piechaudii				+												
Arthrobacter agilis		+														
Arthrobacter globiformis	+	+			+									+		
Arthrobacter histidinolovorans	+															
Arthrobacter ilicis	+	+			+					+				+		
Arthrobacter oxydans						+	+		+	+			+			
Arthrobacter protophormiae/ramosus	+	+								+				+		
Arthrobacter ureafaciens							+								+	
Bacillus cereus	+	+			+	+			+	+				+		
Bacillus coagulans	+								+				+			
Bacillus GC group 22	+								+	+			+			
Bacillus flexus		+														
Bacillus halodenitrificans		+														
Bacillus licheniformis	+	+														
Bacillus marinus	+															
Bacillus megaterium		+			+	+					+				+	+
Bacillus mycoides	+	+	+						+				+			+
Bacillus pumilus		+				+		+						+		+
Bacillus subtilis	+	+							+				+			
Bacillus sphaericus					+											+
Bacillus thuringiensis						+					+					
Brevibacillus agri	+	+			+				+	+						
Brevibacillus brevis	+															
Brevibacillus centrosporus										+						
Brevibacterium mcbrellneri	+	+														
Brevundimonas vesicularis													+			
Burkholderia cepacia		+														+
Burkholderia gladioli																+
Cellulomonas turbata	+				+									+		
Chryseobacterium indologenes	+								+				+			
Chryseobacterium meningosepticum										+						
Clavibacter michiganensis	+		+													
Comamonas acidovorans								+						+		
Curtobacterium citreum	+															
Escherichia coli							+									
Flavobacterium aquatile									+							
Flavobacterium johnsoniae		+	+	+	+	+	+	+	+	+	+			+	+	+
Flavobacterium resinovorum	+															
Gluconobacter cerinus		+														
Kluyvera ascorbata	+															
Kocuria kristinae	+	+			+				+	+			+	+		
Kocuria rosea	+	+					+									
Kocuria varians											+					
Microbacterium esteraromaticum									+				+	+		
Microbacterium liquefaciens		+			+	+							+			
Micrococcus luteus										+						
Micromonospora carbonacea										+						
Nesterenkonia halobia	+															
Nocardia globerula	+														+	
Paenibacillus pabuli		+				+										
Paenibacillus polymyxa																
Pantoea agglomerans			+					+		+				+		
Pedobacter heparinus									+							
Pseudomonas alcaligenes	+					+	+									
Pseudomonas chlororaphis	+	+		+	+			+		+	+	+		+	+	+
Pseudomonas corrugata										+						
Pseudomonas fluorescens	+			+	+	+		+		+	+					
Pseudomonas mendocina		+														
Pseudomonas putida	+	+	+		+	+	+	+	+	+	+			+	+	+
Pseudomonas syringae	+	+				+	+	+		+						
Ralstonia pickettii	+	+			+				+	+			+	+		

TABLE 4. *Continued*

Taxa	Natural				Natural + aldicarb				Autoclaved				Autoclaved + aldicarb		
	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM
Rhizobium radiobacter		+											+		
Rhodococcus luteus									+						
Sphingobacterium spiritivorum													+		
Staphylococcus kloosii													+		
Stenotrophomonas maltophilia									+						
Variovorax paradoxus					+				+						+
Xanthobacter agilis										+					
Xanthomonas axonopodis	+														
Yersinia psuedotuberculosis					+										

[a] MS, ES, LM, and CL correspond to Mississippi, Escambia, Limestone, and Colbert soils, respectively.

crease *R. reniformis* population numbers was reduced in natural soil when compared to autoclaved soil. An interaction was observed between autoclaved and natural soil with and without aldicarb. In the natural soils without aldicarb, *R. reniformis* numbers increased in the MS, ES, LM, and CL soils with Rf values of 4.0, 5.2, 6.6, and 7.6, respectively (Table 1). However, aldicarb was inconsistent in reducing *R. reniformis* population numbers in natural soil. The addition of aldicarb to the LM, ES, and CL natural soils reduced ($P < 0.05$) *R. reniformis* populations 26, 49, and 90%, respectively, and had no effect in the MS soil. In autoclaved soils without aldicarb, *R. reniformis* numbers increased in the MS, ES, LM, and CL soils with Rf values of 7.8, 9.1, 10.5, and 5.6, respectively. *Rotylenchulus reniformis* numbers in the autoclaved MS, ES, LM, and CL soils plus aldicarb were reduced ($P < 0.05$) 95, 97, 99, and 96%, respectively. The mean reduction of *R. reniformis* populations in all four autoclaved soils was 95% as compared to 37% in the natural soils.

Plant parameters: No main effect interactions were observed between autoclaved and natural soil with and without aldicarb for cotton plant height, shoot dry weight, and root dry weight. Soil autoclaving increased plant height and plant dry weights ($P < 0.05$) in MS, ES, and CL soils. The addition of aldicarb to natural and autoclaved soils increased cotton plant dry weights ($P < 0.05$) only in ES and CL soils. Aldicarb reduced ($P < 0.05$) *R. reniformis* populations 49% and 90% in these two soils. An increase in shoot dry weight was not ob-

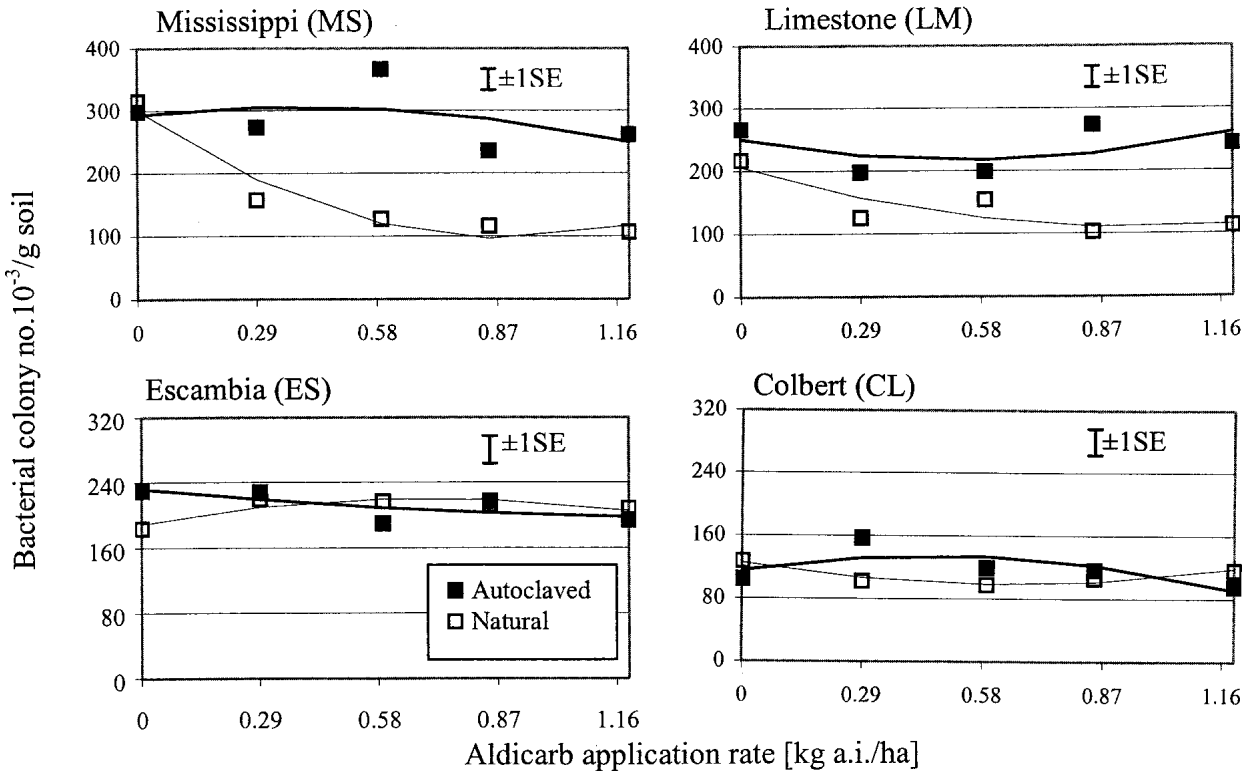

FIG. 2. Relationships between bacterial colony numbers at 60 days after planting in Mississippi, Escambia, Limestone, and Colbert natural and autoclaved soils to aldicarb applied at increasing rates. Each data point represents a mean of 10 replications.

TABLE 5. Effect of increasing rates of aldicarb in autoclaved and natural soils on populations of soil-inhabiting bacteria ($\times 10^{-3}$) per gram of soil 60 days after planting.

Soil	Treatment	Intercept	Linear		Quadratic		Autoclaved vs. natural
			Estimate	*P* (Est > 0)	Estimate	*P* (Est > 0)	
MS	Autoclaved	591.6	65.8	0.311	−86.0	0.100	**
MS	Natural	616.3	−455.8	<0.001	252.9	<0.001	
LM	Autoclaved	493.9	−120.8	0.063	109.3	0.037	**
LM	Natural	370.1	−198.6	0.002	101.8	0.052	
ES	Autoclaved	461.3	−48.7	0.453	16.9	0.746	NS
ES	Natural	422.9	89.4	0.169	−63.5	0.225	
CL	Autoclaved	210.7	80.9	0.212	−85.5	0.102	NS
CL	Natural	239.2	−84.1	0.195	65.8	0.208	

MS = Mississippi site, LM = Limestone site, ES = Escambia site, CL = Colbert site.
NS = not significant.

served in the MS and LM samples where aldicarb also did not reduce *R. reniformis* populations. Root dry weights increased ($P < 0.05$) in autoclaved soil as compared to natural soils in MS and ES soils. An increase in root dry weight was observed only in the CL soil where aldicarb reduced *R. reniformis* populations by 90%.

Microbial numbers: A total of 55 species of bacteria from 15 genera were identified from all treatments. A significant interaction was observed in the MS and LM soils where the addition of aldicarb to the natural soil increased ($P < 0.05$) bacterial populations 63% and 29% as compared to the autoclaved soil (Table 2). However, no differences were observed between autoclaved and natural soil with aldicarb. There were no ($P < 0.05$) differences between total fungal colonies recovered from autoclaved and natural soils with and without the addition of aldicarb (data not shown). Twenty species of fungi from 11 genera were identified from all treatments. No bacterial or fungal species was consistently increased by the addition of aldicarb to natural soil.

Test series 2—Rotylenchulus reniformis numbers: There was a negative quadratic relationship between *R. reniformis* numbers at 60 days after planting and the aldicarb rates for the MS and LM autoclaved soils and both the autoclaved and natural ES and CL soils (Table 3; Fig. 1). No relationship was observed between the aldicarb rates and *R. reniformis* numbers in the MS and LM natural soils (Table 3).

Plant parameters: Cotton plant height was greater ($P < 0.05$) in the autoclaved soil treatments over all aldicarb rates as compared to the natural soil with aldicarb at the 1.19-kg a.i./ha rate. Cotton plant height, and fresh and dry shoot and root weights, were not affected by aldicarb in the ES, LM, and CL soil types, and there was no interaction between aldicarb and soil sterilization (data not shown).

TABLE 6. Mean frequency of fungal species from Test 1 and Test 2 autoclaved and natural soils with and without aldicarb at 60 days after planting.

Taxa	Natural				Natural + aldicarb				Autoclaved				Autoclaved + aldicarb			
	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM	CL	MS	ES	LM	CL
Acremonium strictum	3	1	1	1	1	1	2	1	5	3		1	1	2	3	2
Alternaria alternata		1							1	1						
Aspergillus flavus		1	1				1									
Aspergillus niger		1								1						1
Aspergillus parasiticus	1		1		1				1				1			
Chaetomium aureum		1			1						1					
Cladosporium herbarum	1	6			4	4				6			2	2		
Cladosporium tenuissimum			1											1		
Colletotrichum dematium					2											
Fusarium equiseti		1														
Fusarium oxysporum	1		8		3		7	1	1	4	4		1		5	1
Fusarium semitectum		1								1						
Fusarium solani					1											
Penicillium variable	1	2	9	2	2	2	1	9	2	4		4	1		9	1
Penicillium lilacinum	2	1			1	1			3				1			
Penicillium expansun		1				1										
Penicillium janthinellumy	1															
Phoma spp.	2				1				6					2		
Rhizopus stolonifer		1				2										
Trichoderma harzianum	1	1		1	2			2				2	1			3

[a] MS, ES, LM, and CL correspond to Mississippi, Escambia, Limestone, and Colbert soils, respectively.

Microbial numbers: Sixty-five species of bacteria from 17 genera were identified from all treatments. No bacterial genus or species was consistently associated with the presence of aldicarb (Table 4). Negative quadratic relationships were observed between the number of bacterial colonies and the aldicarb rates in the MS and LM natural soils (Fig. 2). In MS and LM natural soils, the numbers of bacterial colonies were greater at all rates of aldicarb as compared to the autoclaved MS and LM soils based on the differences in slope of the regression lines (Table 5). No differences in bacterial numbers were observed with increasing rates of aldicarb in the ES and CL autoclaved and natural soils as shown by the lack of differences in slopes of the regression lines. Fungal populations were not different between autoclaved and natural soil with or without aldicarb for any soil type at 60 days after planting. Twenty species of fungi from 11 genera were identified from all treatments (Table 6). The mean isolation frequency of *Acremonium strictum, Aspergillus* spp., *Penicillium* spp., and *Tricoderma hirsutum,* was 2.5, 1.0, 2.7, and 1.3%, respectively. No fungal species was consistently associated with the presence of aldicarb. No differences in fungal colony numbers were observed with increasing rates of aldicarb in the autoclaved and natural soils as shown by the lack of differences in slopes of the regression lines (data not shown).

Discussion

The data presented indicate that microbial degradation may be responsible for the loss of aldicarb efficacy to *R. reniformis* in the MS and LM soils. The CL soil was the only natural field soil in which aldicarb effectively reduced *R. reniformis* numbers. Similar enhanced biodegradation and loss of efficacy have been reported previously for other nematicides (Hall et al., 1988; Johnson, 1998; Mojtahedi et al., 1991; Ou et al., 1994). In field studies of sweet potato and onions, ethoprop was effective in lowering *M. incognita* numbers during the first year but did not reduce nematode numbers in the second and third years (Hall et al., 1988). Mojtahedi et al. (1991) reported that in a potato field previously exposed to ethoprop, *M. chitwoodi* recovered from an at-planting application equaled the untreated control. Johnson (1998) reported the diminished efficacy of fenamiphos to *M. incognita* in a sweet potato-sweet corn cropping system. In the last 2 years of this 5-year field study, fenamiphos was unable to reduce *M. incognita* numbers. In turfgrass, there were no reductions of *Belonolaimus longicaudatus* or *Hoplolaimus galeatus* numbers in soil from the fairway or putting green collected before and after the annual fenamiphos application (Ou et al., 1994). The enhanced biodegradation of ethoprop and fenamiphos in association with failure to control multiple genera of nematodes on various host crops has been reported. A similar enhanced biodegradation appears to be developing with aldicarb to *R. reniformis* on cotton.

Increasing the rate of aldicarb did not improve the efficacy to *R. reniformis* in MS or LM natural soils. However, when these soils were autoclaved, aldicarb effectively reduced *R. reniformis* numbers. Mojtahedi et al. (1991) reported increasing concentrations of ethoprop in exposed soil reduced numbers of *M. chitwoodi;* however, the nematode numbers were higher than in the steam-sterilized exposed soil.

The reduction of *R. reniformis* numbers by aldicarb in MS and LM autoclaved soils and not in natural soils suggests that aldicarb degradation was biologically mediated. The trend in increasing numbers of soilborne bacteria in the MS and LM aldicarb-treated natural soils may indicate an increase in biological activity. Microbial oxidation is the major pathway for aldicarb degradation in soils accounting for 80% of the aldicarb conversion under aerobic conditions (Ou, 1991). That aldicarb increases the total mycoflora (bacterial and(or) fungal) numbers in treated soils has been reported (Nicholson and Hirsch, 1998; Ou et al., 1988; Sturz and Kimpinski, 1999). However, diversity of the bacterial community was affected with fewer bacterial genera and species recovered from the aldicarb treated soils (Sturz and Kimpinski, 1999). This is similar to our study, where fewer bacterial species were identified in the MS and LM natural soil with aldicarb. Pathogenic and saprophytic microorganisms have been reported to use aldicarb as a carbon source (Jones, 1976). Aldicarb may inhibit specific genera and species of bacteria, thereby reducing biological competition and enabling aldicarb-tolerant populations to proliferate. Read (1987) reported that repeated applications of aldicarb resulted in the development of strains of microorganisms capable of rapidly breaking down aldicarb. However, high aldicarb concentrations retarded rapid degradation by microbes until the toxic residues had decreased to levels of less than 700 ppm. In our study, fungal population numbers were not different between autoclaved and natural soil with or without aldicarb for any soil types. *Trichoderma harzianum,* which was isolated frequently in this study, has been shown to degrade 96% of the C^{14} aldicarb under controlled laboratory conditions (Jones, 1976). Considerable variability in metabolic breakdown was reported by Jones among fungal species.

In conclusion, this study indicates that the efficacy of aldicarb as a soil nematicide can be adversely affected by aldicarb-degrading microorganisms. The loss of efficacy in natural (nonautoclaved) soils but not in autoclaved soils demonstrates that aldicarb degradation is biologically mediated. Further research is necessary to identify microorganisms involved in the accelerated degradation of aldicarb.

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