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Accelerated Degradation of Aldicarb and Its Metabolites in Cotton Field Soils[1]

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Abstract: The degradation of aldicarb, and the metabolites aldicarb sulfoxide and aldicarb sulfone, was evaluated in cotton field soils previously exposed to aldicarb. A loss of efficacy had been observed in two (LM and MS) of the three (CL) field soils as measured by *R. reniformis* population development and a lack of cotton yield response. Two soils were compared for the first test—one where aldicarb had been effective (CL) and the second where aldicarb had lost its efficacy (LM). The second test included all three soils: autoclaved, non-autoclaved and treated with aldicarb at 0.59 kg a.i./ha, or not treated with aldicarb. The degradation of aldicarb to aldicarb sulfoxide and then to aldicarb sulfone was measured using high-performance liquid chromatography (HPLC) in both tests. In test one, total degradation of aldicarb and its metabolites occurred within 12 days in the LM soil. Aldicarb sulfoxide and aldicarb sulfone were both present in the CL soil at the conclusion of the test at 42 days after aldicarb application. Autoclaving the LM and MS soils extended the persistence of the aldicarb metabolites as compared to the same soils not autoclaved. The rate of degradation was not changed when the CL natural soil was autoclaved. The accelerated degradation was due to more rapid degradation of aldicarb sulfoxide and appears to be biologically mediated.

Key words: Aldicarb, aldicarb sulfone, aldicarb sulfoxide, cotton, microbial degradation, nematicide, *Rotylenchulus reniformis*.

Aldicarb, 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime, is a systemic, broad-spectrum insecticide/nematicide registered for use on multiple crops. In cotton production, aldicarb is applied to manage early-season insects and plant-parasitic nematodes. Aldicarb is applied at planting in a granular form that releases the active ingredient into the soil and degradation begins immediately. Aldicarb is oxidized to aldicarb sulfoxide, which is oxidized more slowly to aldicarb sulfone (Jones et al., 1988; Lightfoot et al., 1987; Smelt et al., 1978). Aldicarb sulfoxide and sulfone are less toxic than aldicarb (Jones et al., 1988). The half lives of aldicarb and its metabolites range from 29 to 78 days (Ou et al., 1986). Coppedge et al. (1967) found aldicarb decomposed more slowly in soils than in cotton plants. Aldicarb degradation occurred most rapidly in a clay soil followed by a silty clay loam soil and a fine sand, although all three soils contained aldicarb metabolites for 12 weeks (Coppedge et al., 1967).

Loss of efficacy of aldicarb has been observed in some mid-South cotton production fields infested with *Rotylenchulus reniformis*. A lack of response to aldicarb was reported by Lorenz et al. (1988) in Arkansas when no differences in cotton yield were observed when aldicarb was applied in-furrow at planting at 0.58, 0.85, and 1.19 kg a.i./ha as compared to a non-treated control. In Alabama, Gazaway et al. (2000) reported aldicarb failed to increase cotton yields for 2 consecutive years in a field where it had previously been effective. In Mississippi, Lawrence and McLean (2000) found no differences in monthly *R. reniformis* populations and subsequent cotton yield between several aldicarb treatments and the non-treated control. In Louisiana, Overstreet (2003) reported a lack of response to aldicarb in 7 of 15 field trials over a 5-year period. Greenhouse trials by McLean and Lawrence (2003) found a loss of efficacy of aldicarb in natural soils but not in the same soils that had been autoclaved, indicating enhanced aldicarb degradation by biologically mediated processes in these soils. In the selected natural soils treated with aldicarb, *R. reniformis* populations were reduced by aldicarb 25% or less as compared to a 96% reduction in autoclaved soils. The use of increasing rates of aldicarb did not increase the efficacy of aldicarb in these soils.

This study examines the degradation of aldicarb, aldicarb sulfoxide, and aldicarb sulfone in cotton field soils. Two soils with documented loss of aldicarb efficacy and one soil where aldicarb was effective were used to determine degradation rates and corresponding effects on soil mycoflora.

Materials and Methods

Tests were established to determine if the loss of efficacy of aldicarb for nematode management in cotton field soils was due to accelerated degradation of aldicarb and its metabolites. Soils were collected from three cotton fields. Aldicarb had been applied in previous years, and a loss of efficacy had been observed in two of the three fields as measured by *R. reniformis* population development and a lack of cotton yield response (McLean and Lawrence, 2003). Soils were collected in Limestone and Colbert Counties, Alabama, and from Washington County, Mississippi. The soil from Washington County (MS) was classified as a silt loam (38% sand, 52% silt, 9.2% clay, pH 6.2), the Limestone County soil (LM) was a loam (36.25% sand, 38.75% silt, 25% clay, pH. 6.5), and the Colbert County soil (CL) was a silt loam (20% sand, 57.5% silt, 22.5% clay, pH 5.5). The loss of efficacy had been observed in the MS

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and LM soils but not in the CL soil; thus, the CL soil was included in these degradation tests as a positive control (McLean and Lawrence, 2003). Soils from each field location were collected in December 2001 and 2002 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 test series 1, treatments were arranged in a 2 × 2 factorial and included (i) Limestone soil or Colbert soil and (ii) aldicarb added at 0.59 kg a.i./ha (0.036 g/pot) or no aldicarb added. In test series 2, the treatments were arranged in a 3×2×2 factorial and included (i) Limestone, Colbert, and Mississippi soils (ii) autoclaved or non-autoclaved soil, and (iii) aldicarb added at 0.59 kg a.i./ha or no aldicarb added.

Tests were planted with PayMaster 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% NaOCl. Seeds were then placed on sheets of 26-cm × 39-cm sterile germination paper for 72 to 96 hours. Two seedlings with radicals of 1 to 2 cm in length were placed in each 10-cm-diam., 950 cm^3 polystyrene pot. Aldicarb was incorporated into the top 5 cm of soil in each pot in the selected treatments at planting.

Plants were grown in the greenhouse for 42 days with a temperature range of 25 °C to 32 °C. Plants 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 four replications. All tests were conducted twice.

One polystyrene pot was removed from each treatment of each replication at 0, 3, 6, 9, 12, 15, 18, 21, 28, 35, and 42 days after application (DAA) of aldicarb for both test series 1 and 2. The entire soil volume from each pot was collected for analysis. Soil weight and moisture content at collection were measured. The soil samples were thoroughly mixed, sealed in plastic bags, and placed at −20 °C. Aldicarb and its two metabolites—aldicarb sulfoxide and aldicarb sulfone—were extracted from the soil samples according to the Standard Operating Procedure 90013 developed by Rhone-Poulenc Ag Company. Briefly, a soil sample (100-g wet weight) was weighed into a 250-ml glass jar to which 100 ml of distilled water was added. The glass jar was tightly capped, vigorously shaken for 30 seconds, and allowed to stand for 30 minutes. This procedure was repeated once. The soil suspension was centrifuged at 6,233, for 15 minutes. The supernatant was filtered through a 0.45-µm-pore membrane and concentrated using an H_2O-Phobic DVB solid phase extraction column (J. T. Baker, Phillipsburg, NJ) according to manufacturer's specifications. HPLC analysis was used to determine aldicarb, aldicarb sulfoxide, and aldicarb sulfone concentrations. Samples were analyzed using a Waters Alliance 2690 system (Waters Corporation, Milford, MA) consisting of a C18 column and a dual wavelength UV detector set at 220 nm and 247 nm. The mobile phase at a flow rate of 1 ml/min was a mixture of component A containing 1/1/18 acetonitrile/methanol/water (v/v/v) and component B containing 2/2/1 acetonitrile/methanol/water (v/v/v). The initial mobile phase composition of 100% A was first brought to 40/60 A/B for 40 minutes, then brought to 100% B by 45 minutes, and held at that composition for 5 minutes. The sample injection volume was 50 µl.

Bacteria were isolated from the soils by serial dilution plating in test series 2. Soil from each pot was collected using 3-mm-diam. × 10-mm-deep cores taken from each pot immediately before soil collection for chemical analysis. One gram of the soil was added to 10 ml of sterile distilled water and agitated. Serial dilutions of 10^{-3} and 10^{-4} were plated with a spiral plater (Spiral Systems, Inc., Bethesda, MD) on four media: aldicarb, aldicarb sulfoxide, aldicarb sulfone amended minimal medias (Stanier et al., 1966), and tryptic soy agar (TSA) (Difco Laboratories, Detroit, MI) for culturable bacteria. Dilution plates were incubated at 22 ± 2 °C for 3 days, and the resulting bacterial colonies were counted. 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).

All data were subjected to analysis of variance with relevant contrasts at each sampling time. Means were compared using Fisher's protected least significant difference test ($P \leq 0.05$). Data from repetitions of each experiment were combined for analysis where data were similar ($P \geq 0.05$). Regression analysis compared aldicarb and its metabolite concentrations (dependent variable) to the aldicarb rate (independent variable) over time. General linear models procedures were used to fit least-squares regression curves to the data sets. Aldicarb and metabolite concentrations and bacterial populations were analyzed using mixed models methodology 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. All differences reported are significant at the $P \leq 0.05$ level.

Results

Test series 1: Aldicarb, aldicarb sulfoxide, and aldicarb sulfone were not detected in either the LM or CL soil prior to the addition of the aldicarb. The quantity of aldicarb present immediately after aldicarb was mixed into the soil (0, days after application [DAA]) averaged 311 ppm and did not differ between the LM and CL soils. At all subsequent sampling dates, less aldicarb was recovered from the LM soil than from the CL soil (Fig. 1A). The aldicarb concentrations declined in the LM soils compared to the CL soil at 6 and 9 DAA. Complete

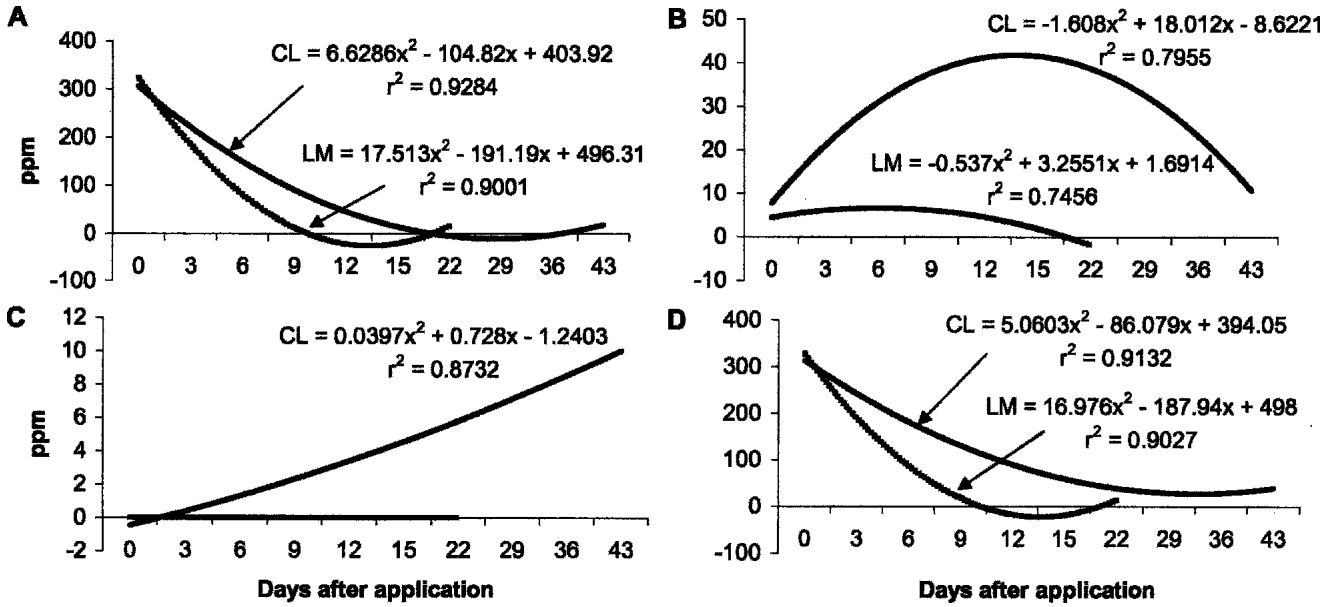

FIG. 1. Concentration of aldicarb (A), aldicarb sulfoxide (B), aldicarb sulfone (C), and total toxic residues (D) in the soil after planting. CL and LM indicate Colbert County and Limestone County soils, respectively.

degradation of aldicarb occurred within 12 DAA in the LM soil as compared to 18 DAA in the CL soil. Negative quadratic regressions best described the concentration reduction curves of aldicarb over time for both soils. However, degradation was faster in the LM soil compared to the CL soil based on the differences in slopes of the regression lines. Aldicarb sulfoxide levels were detected at 0 DAA in both the LM and CL soils (Fig. 1B). In the LM soil, aldicarb sulfoxide was detected from 0 to 15 DAA, with complete degradation occurring in 15 days. In the CL soil, aldicarb sulfoxide was detected through the conclusion of the experiment at 42 DAA, with concentrations increasing through 12 DAA and then gradually decreasing. Concentrations of aldicarb sulfoxide were greater in the CL soil as compared to the LM soil from 3 to 42 DDA. Negative quadratic regressions best describe the concentration reduction curves of aldicarb sulfoxide over time for both soils ($r^2 = 0.9284$ and $r^2 = 0.9001$). As observed with aldicarb, degradation was faster in the LM soil as compared to the CL soil based on the differences in slopes of the regression lines.

Aldicarb sulfone levels were initially detected at 3 and 6 DDA in the LM and CL soils, respectively (Fig. 1C). In the LM soil, aldicarb sulfone was detected from 3 to 15 DDA; however, at all extraction dates concentrations were less than 1.5 ppm. In the CL soil, aldicarb sulfone was detected from 6 to 42 DDA with concentrations gradually increasing over time. Concentrations of aldicarb sulfone were greater ($P \leq 0.05$) in the CL soil as compared to the LM soil from 3 to 42 DDA. A negative quadratic regression curve described the degradation of aldicarb sulfone over time in the CL soil. No relationship was observed between aldicarb sulfone concentration and time for the LM soil. The combined concentrations of aldicarb, aldicarb sulfoxide, and aldicarb sulfone from LM and CL soils were best described by negative quadratic regressions ($r^2 = 0.9132$ and $r^2 = 0.9027$) (Fig. 1D). The concentration of the metabolites was greater ($P \leq 0.05$) in the CL soils as compared to the LM soil based on the differences in slopes of the regression lines. Total degradation of aldicarb and its metabolites occurred within 12 days in the LM soil. Aldicarb sulfoxide and aldicarb sulfone were both present in the CL soil at the conclusion of the test at 42 DAA.

Test series 2: Aldicarb, aldicarb sulfoxide, and aldicarb sulfone were not detected in the MS, LM, or CL soil prior to the addition of the aldicarb. In the MS soil, the quantity of aldicarb present after aldicarb was mixed into the soil (0 DAA) averaged 235 ppm and did not differ between the autoclaved and non-autoclaved soils. At all subsequent sampling dates, less ($P \leq 0.05$) aldicarb was recovered from the MS non-autoclaved soil as compared to the MS autoclaved soil (Fig. 2A). Aldicarb degradation occurred within 9 DAA in the MS natural soil as compared to 15 DAA in the MS autoclaved soil. Negative quadratic regressions best described the concentration reduction curves of aldicarb over time for both autoclaved and non-autoclaved MS soils ($r^2 = 0.8509$ and $r^2 = 0.7945$). Differences in the slopes of the regression lines suggest that degradation was enhanced in the MS non-autoclaved soil as compared to the MS autoclaved soil. Concentrations of aldicarb sulfoxide were lower in the MS non-autoclaved soil as compared to MS autoclaved soil (Fig. 2B). Aldicarb sulfoxide levels were detected at 3 through 15 DAA in the MS autoclaved soil; however, complete degradation occurred in 9 DDA in the MS non-autoclaved soil. Aldicarb sulfone was detected at lower concentrations in the MS

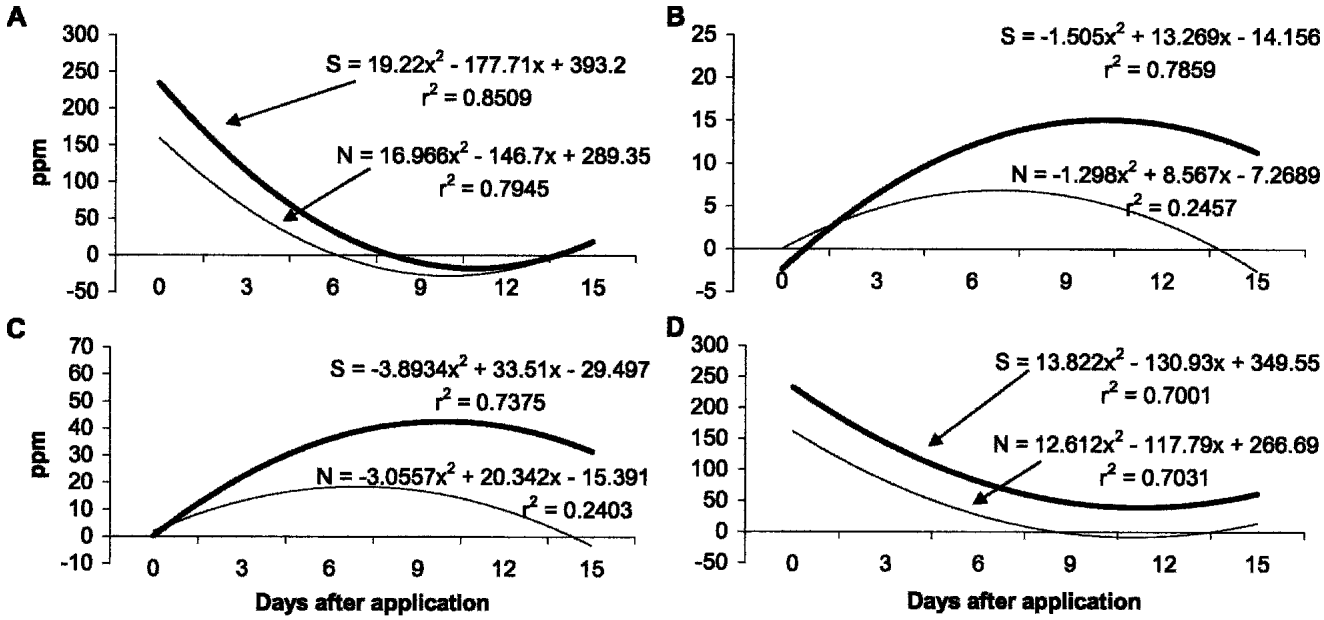

FIG. 2. Concentration of aldicarb (A), aldicarb sulfoxide (B), aldicarb sulfone (C), and total toxic residues (D) in the Mississippi soil.

non-autoclaved soil as compared to the MS autoclaved soils at each sample date of the test (Fig. 2C). The combined concentrations of aldicarb, aldicarb sulfoxide, and aldicarb sulfone were greater ($P \leq 0.05$) in the MS autoclaved soil as compared to the MS non-autoclaved soil. Total degradation of aldicarb and metabolites occurred within 15 days in the MS non-autoclaved soil. Aldicarb sulfoxide and aldicarb sulfone were both present in the MS autoclaved soil at the conclusion of the test (42 DAA). The total concentrations of aldicarb, aldicarb sulfoxide, and aldicarb sulfone from the MS autoclaved and non-autoclaved soils were best described by negative quadratic regressions (r^2 = 0.7001 and r^2 = 0.7031), and degradation was faster in the non-autoclaved soil compared to the autoclaved soil based on the differences in slopes of the regression lines (Fig. 2D).

In the LM soil, the quantity of aldicarb present at 0 DAA averaged 300 ppm in the autoclaved and natural soils. The aldicarb concentrations declined ($P \leq 0.05$) in the LM non-autoclaved soil as compared to the LM autoclaved soil at 3, 6, and 9 DAA (Fig. 3A). Complete aldicarb degradation occurred within 9 DAA in the LM non-autoclaved soil as compared to 12 DAA in the LM autoclaved soil. Negative quadratic regressions best described the concentration reduction curves of aldicarb over time for both autoclaved and non-autoclaved LM soils (r^2 = 0.8711 and r^2 = 0.8615). Based on the differ-

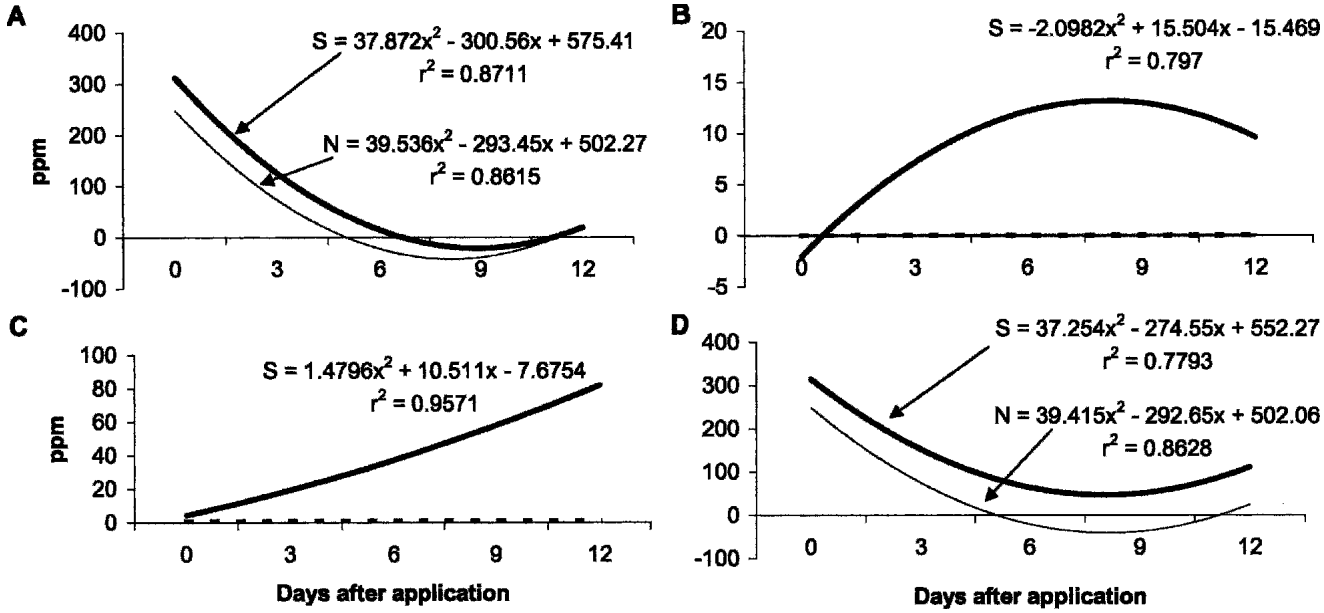

FIG. 3. Concentration of aldicarb (A), aldicarb sulfoxide (B), aldicarb sulfone (C), and total toxic residues (D) in the Limestone soil.

ences in slopes of the regression lines, aldicarb degradation was faster in the LM non-autoclaved soil than in the LM autoclaved soil. Concentrations of aldicarb sulfoxide were lower in the LM non-autoclaved soil than in the LM autoclaved soil (Fig. 3B). Aldicarb sulfoxide levels were detected at 3 through 12 DAA in the LM autoclaved soil; however, aldicarb sulfoxide was not detected at levels > 1 ppm at any sample date in the LM natural soil. A negative quadratic regression best described the degradation of aldicarb over time for the LM autoclaved soil; however, no relationship was observed between the aldicarb sulfoxide rates over time in the LM non-autoclaved soil. Aldicarb sulfone was also detected at lower concentrations in the LM natural soil than in the LM autoclaved soil at each sample date of the test (Fig. 3C). As observed in the aldicarb sulfoxide, no relationship was observed between the aldicarb sulfone rates over time in the LM non-autoclaved soil, whereas a negative quadratic regression best described the reduced concentration of aldicarb sulfone in the LM autoclaved soil ($r^2 = 0.9571$). The combined total concentrations of aldicarb, aldicarb sulfoxide, and aldicarb sulfone were greater ($P \leq 0.05$) in the LM autoclaved soil than in the LM non-autoclaved soil. Total degradation of aldicarb and its metabolites occurred within 15 days in the LM non-autoclaved soil. Aldicarb sulfoxide and aldicarb sulfone were both present in the LM autoclaved soil at the conclusion of the test. The total concentration of aldicarb, aldicarb sulfoxide, and aldicarb sulfone from the LM autoclaved and non-autoclaved soils were best described by negative quadratic regressions ($r^2 = 0.7793$ and $r^2 = 0.8628$), and degradation was faster in the non-autoclaved soil compared to the autoclaved soil based on the increased slope of the non-autoclaved soil regression line (Fig. 3D).

In the CL control soil, negative quadratic regressions best described the concentration reduction curves of aldicarb, aldicarb sulfoxide, aldicarb sulfone, and the total aldicarb metabolites over time for the CL autoclaved and non-autoclaved soils ($r^2 = 0.0917$ and $r^2 = 0.0945$) (Fig. 4A–D). However, the slopes of the regression curves were not different ($P < 0.05$) for aldicarb or any of the metabolites. Aldicarb degradation was not faster in the CL non-autoclaved soil than in the CL autoclaved soil based on the differences in slopes of the regression lines.

Microbial numbers. A total of 43 species of bacteria from 24 genera were identified from all treatments on all media on 2, 3, 6, and 9 DDA (Table 1). Nine species from nine genera utilized aldicarb, 15 species from 11 genera utilized aldicarb sulfoxide, and 10 species from 7 genera utilized aldicarb sulfone as the sole nitrogen and carbon source. Bacterial species that had the capacity to utilize aldicarb and metabolites as their carbon and nitrogen source were isolated from all three soils types including the CL soil where aldicarb was efficacious. Seventy percent of the bacterial species cultured on the bacterial medium TSA were also cultured on one of the aldicarb and(or) aldicarb metabolite media as well. The morphology of the bacterial colonies growing on the aldicarb metabolic media was smaller than on TSA. However, no differences ($P \leq 0.05$) in total bacterial numbers per gram of soil were observed from 0 to 42 DAA in any of the soils or mediums except at 6 DAA. Bacterial numbers were greater in the aldicarb, aldicarb sulfoxide, and aldicarb sulfone media as compared to the TSA control for the MS and LM soils (data not shown). *Arthrobacter oxydans* was isolated from both MS and LM soils and utilized aldicarb. *Pseudomonas putida* utilized aldicarb, aldicarb sulfoxide, and aldicarb sulfone.

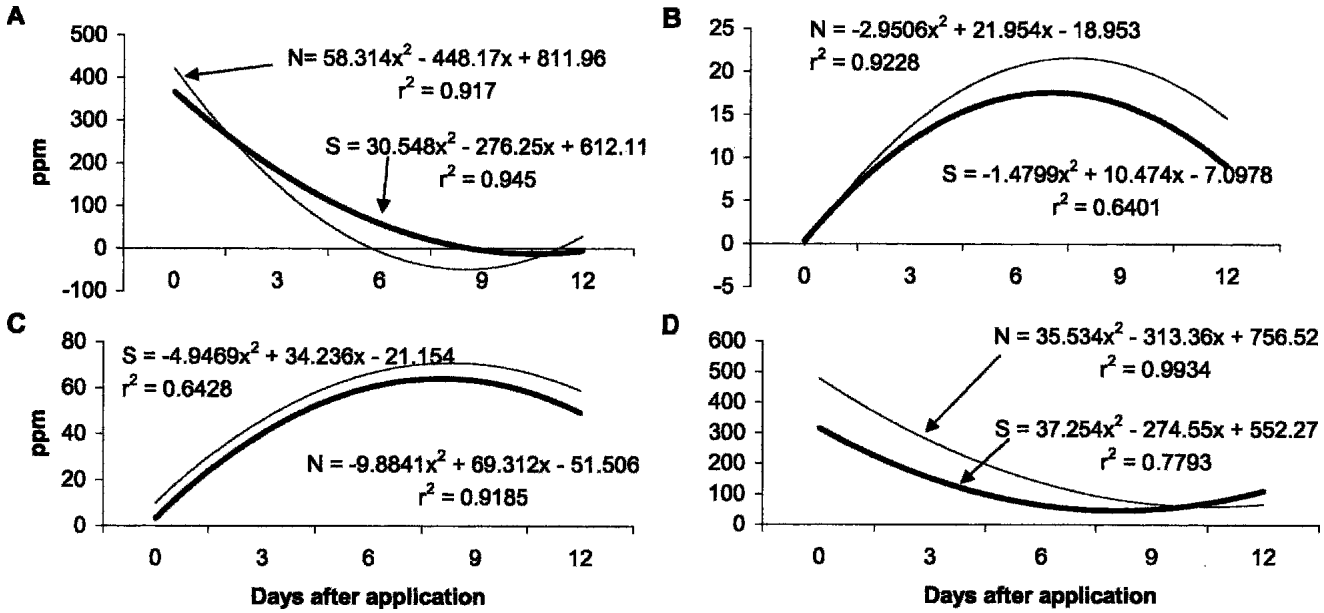

FIG. 4. Concentration of aldicarb (A), aldicarb sulfoxide (B), aldicarb sulfone (C), and total toxic residues (D) in the Colbert soil.

TABLE 1. Bacteria isolated from soils on minimal media with aldicarb, aldicarb sulfoxide, or aldicarb sulfone as the carbon source as well as a tryptic soy agar (TSA) control.

Soil	Medium	Genus	Species	Subspecies
Mississippi	aldicarb	*Acinetobacter*	*radioresistens*	
Limestone	aldicarb	*Arthrobacter*	*globiformis*	
Colbert	aldicarb	*Arthrobacter*	*ilicis*	
Limestone	aldicarb	*Arthrobacter*	*oxydans*	
Mississippi	aldicarb	*Arthrobacter*	*oxydans*	
Mississippi	aldicarb	*Enterobacter*	*cancerogenus*	
Mississippi	aldicarb	*Escherichia*	*coli*	
Limestone	aldicarb	*Kocuria*	*kristinae*	
Colbert	aldicarb	*Nocardia*	*brasiliensis*	
Colbert	aldicarb	*Paenibacillus*	*polymyxa*	
Colbert	aldicarb	*Paenibacillus*	*polymyxa*	
Mississippi	aldicarb	*Pseudomonas*	*putida*	
Mississippi	aldicarb	*Pseudomonas*	*putida*	
Mississippi	aldicarb	*Ralstonia*	*pickettii*	
Mississippi	aldicarb	*Sphingomonas*	*capsulata*	
Limestone	sulfoxide	*Acinetobacter*	*radioresistens*	
Colbert	sulfoxide	*Arthrobacter*	*globiformis*	
Limestone	sulfoxide	*Arthrobacter*	*ilicis*	
Mississippi	sulfoxide	*Arthrobacter*	*oxydans*	
Mississippi	sulfoxide	*Arthrobacter*	*oxydans*	
Mississippi	sulfoxide	*Arthrobacter*	*oxydans*	
Mississippi	sulfoxide	*Arthrobacter*	*oxydans*	
Mississippi	sulfoxide	*Arthrobacter*	*pascens*	
Mississippi	sulfoxide	*Bacillus*	*cereus*	
Limestone	sulfoxide	*Bacillus*	*megaterium*	
Mississippi	sulfoxide	*Bacillus*	*megaterium*	
Colbert	sulfoxide	*Bacillus*	*megaterium*	
Limestone	sulfoxide	*Cellulomonas*	*fimi*	
Mississippi	sulfoxide	*Corynebacterium*	*aquaticum*	
Mississippi	sulfoxide	*Flavobacterium*	*resinovorum*	
Mississippi	sulfoxide	*Flavobacterium*	*resinovorum*	
Colbert	sulfoxide	*Kocuria*	*kristinae*	
Colbert	sulfoxide	*Kocuria*	*varians*	
Mississippi	sulfoxide	*Methylobacterium*	*organophilum*	
Limestone	sulfoxide	*Microbacterium*	*liquefaciens*	
Limestone	sulfoxide	*Paenibacillus*	*polymyxa*	
Limestone	sulfoxide	*Paenibacillus*	*polymyxa*	
Limestone	sulfoxide	*Pantoea*	*agglomerans*	
Colbert	sulfoxide	*Phyllobacterium*	*myrsinacearum*	
Colbert	sulfoxide	*Phyllobacterium*	*myrsinacearum*	
Colbert	sulfoxide	*Pseudomonas*	*aeruginosa*	
Colbert	sulfoxide	*Pseudomonas*	*putida*	
Mississippi	sulfoxide	*Pseudomonas*	*putida*	
Colbert	sulfoxide	*Ralstonia*	*eutropha*	
Colbert	sulfoxide	*Ralstonia*	*eutropha*	
Limestone	sulfoxide	*Ralstonia*	*pickettii*	
Colbert	sulfoxide	*Ralstonia*	*solanacearum*	
Limestone	sulfone	*Arthrobacter*	*globiformis*	
Colbert	sulfone	*Arthrobacter*	*pascens*	
Colbert	sulfone	*Arthrobacter*	*pascens*	
Mississippi	sulfone	*Bacillus*	*sphaericus*	
Mississippi	sulfone	*Bacillus*	*sphaericus*	
Mississippi	sulfone	*Bacillus*	*sphaericus*	
Limestone	sulfone	*Brevibacillus*	*brevis*	
Mississippi	sulfone	*Enterobacter*	*asburiae*	
Colbert	sulfone	*Methylobacterium*	*zatmanii*	
Limestone	sulfone	*Methylobacterium*	*zatmanii*	
Colbert	sulfone	*Nocardia*	*brasiliensis*	
Colbert	sulfone	*Paenibacillus*	*polymyxa*	
Limestone	sulfone	*Paenibacillus*	*polymyxa*	
Colbert	sulfone	*Phyllobacterium*	*myrsinacearum*	
Colbert	sulfone	*Phyllobacterium*	*rubiacearum*	
Limestone	sulfone	*Pseudomonas*	*balearica*	
Limestone	sulfone	*Pseudomonas*	*fluorescens*	
Limestone	sulfone	*Pseudomoonas*	*putida*	
Limestone	sulfone	*Pseudomonas*	*putida*	
Limestone	sulfone	*Pseudomonas*	*syringae*	*syringae*
Colbert	sulfone	*Ralstonia*	*eutropha*	
Colbert	TSA	*Acinetobacter*	*radioresistens*	
Colbert	TSA	*Alcaligenes*	*xylosoxydans*	*denitrificans*
Colbert	TSA	*Arthrobacter*	*globiformis*	
Colbert	TSA	*Arthrobacter*	*pascens*	
Colbert	TSA	*Arthrobacter*	*pascens*	
Limestone	TSA	*Arthrobacter*	*protophormiae/ ramosus*	
Limestone	TSA	*Bacillus*	*cereus*	
Mississippi	TSA	*Bacillus*	*cereus*	
Mississippi	TSA	*Bacillus*	*cereus*	
Colbert	TSA	*Bacillus*	*megaterium*	
Colbert	TSA	*Bacillus*	*megaterium*	
Limestone	TSA	*Bacillus*	*megaterium*	
Mississippi	TSA	*Bacillus*	*megaterium*	
Mississippi	TSA	*Bacillus*	*megaterium*	
Colbert	TSA	*Bacillus*	*mycoides*	
Colbert	TSA	*Bacillus*	*mycoides*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Mississippi	TSA	*Bacillus*	*pumilus*	
Colbert	TSA	*Bacillus*	*sphaericus*	
Colbert	TSA	*Bacillus*	*sphaericus*	
Limestone	TSA	*Cellulomonas*	*fimi*	
Mississippi	TSA	*Flavobacterium*	*resinovorum*	
Mississippi	TSA	*Kluyvera*	*cryocrescens*	
Limestone	TSA	*Microbacterium*	*liquefaciens*	
Colbert	TSA	*Paenibacillus*	*apiarius*	
Colbert	TSA	*Paenibacillus*	*gordonae*	
Colbert	TSA	*Paenibacillus*	*gordonae*	
Colbert	TSA	*Paenibacillus*	*gordonae*	
Mississippi	TSA	*Paenibacillus*	*gordonae*	
Mississippi	TSA	*Paenibacillus*	*gordonae*	
Mississippi	TSA	*Paenibacillus*	*gordonae*	
Mississippi	TSA	*Paenibacillus*	*polymyxa*	
Colbert	TSA	*Phenylobacterium*	*immobile*	
Colbert	TSA	*Phyllobacterium*	*myrsinacearum*	
Mississippi	TSA	*Pseudomonas*	*fluorescens*	
Limestone	TSA	*Pseudomonas*	*putida*	
Limestone	TSA	*Pseudomonas*	*putida*	
Limestone	TSA	*Pseudomonas*	*putida*	
Colbert	TSA	*Ralstonia*	*pickettii*	
Mississippi	TSA	*Rhodococcus*	*erythropolis*	
Mississippi	TSA	*Salmonella*	*choleraesuis*	*choleraesuis*

DISCUSSION

The data presented indicate that enhanced microbial degradation was responsible for the loss of aldicarb efficacy to *R. reniformis* in the MS and LM soils. Loss of efficacy of a nematicide can be the first indication of enhanced degradation. The loss of efficacy of aldicarb to *R. reniformis* in cotton field soil has been documented (McLean and Lawrence, 2003). The HPLC data documented that loss of efficacy was accompanied by the more rapid degradation of aldicarb and its metabolites.

Aldicarb was the predominate compound at the initiation of each test in all three soils. However, aldicarb

rapidly oxidized to aldicarb sulfoxide and then to aldicarb sulfone. Aldicarb, aldicarb sulfoxide, and aldicarb sulfone degradation was faster in natural MS and LM soil than in the autoclaved soils. Aldicarb sulfone was detected simultaneously with aldicarb sulfoxide, indicating the latter began to degrade rapidly. Davis et al. (1993) found accelerated degradation of fenamiphos was due to a rapid degradation of fenamiphos sulfoxide, the nematicidal metabolite of fenamiphos. The aldicarb degradation observed in these soils appears to be similar to the fenamiphos degradation. Coppedge (1967) indicated the insecticidal activity of aldicarb was the result of less toxic but much longer residue of aldicarb sulfoxide. The immediate oxidation of aldicarb sulfoxide to the less toxic aldicarb sulfone is possibly a reason aldicarb has lost its nematicidal activity in these soils.

The degradation of aldicarb and its metabolites in the MS and LM autoclaved soil was not different from the control natural CL soil where aldicarb was an effective nematicide. Levels of aldicarb sulfoxide and aldicarb sulfone were lower in the MS and LM natural soil than in the autoclaved soil, suggesting that aldicarb degradation is biologically mediated. Previous findings by Ou et al. (1988) indicated microbial oxidation was the major route of aldicarb degradation in soil. The half lives of the total toxic residues ranged from 29 to 78 days in the 24 soils tested (Ou et al., 1986). Jones et al. (1988) reported the dissipation rate of aldicarb residues corresponded to a half life of 20 days in Florida citrus groves. In the MS and LM natural soils, the half life of the aldicarb residues occurred before 6 days and total aldicarb degradation occurred within 12 days, which is one fourth the time previously reported by Ou et al. (1986, 1988). In our control CL soil, the half life of the aldicarb metabolites was 15 days and total degradation did not occur within the 42 days of these tests. Thus aldicarb's persistence has been greatly reduced in the MS and LM soils.

Microbial oxidation is the major pathway for aldicarb degradation in soils accounting for 80% of the aldicarb degradation under aerobic conditions (Ou, 1991). Reports of aldicarb increasing the total microflora (bacterial and fungal) numbers in treated soils have been reported (McLean and Lawrence, 2003; 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 on media amended with aldicarb, aldicarb sulfoxide, or aldicarb sulfone. Pathogenic and saprophytic microorganisms have been reported to utilize aldicarb as a carbon source (Jones, 1976). Aldicarb and its metabolites 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 tests, *Pseudomonas putida* was identified as utilizing aldicarb and its metabolites. Enhanced degradation of another carbamate insecticide/nematicide, carbofuran, was related to a *Pseudomonas* sp., which was able to degrade carbofuran in pure culture (Felsot et al., 1981). Davis et al. (1993) indicated accelerated degradation may occur if microorganisms were conditioned by previous exposure to preferentially or more efficiently metabolize fenamiphos and its metabolites.

The more rapid degradation of aldicarb in the MS and LM natural soils indicated that aldicarb is biologically mediated. Aldicarb and its metabolites were degraded more rapidly in the MS and LM natural soils where aldicarb efficacy was reduced. This accelerated degradation appears to be due primarily to an increase in the degradation rate of the nematicidal metabolites of aldicarb, aldicarb sulfoxide, and aldicarb sulfone. The fact that this accelerated degradation was not observed in the MS and LM autoclaved soil indicated that the accelerated degradation is biologically mediated. In conclusion, this study documents that the efficacy of aldicarb as a soil nematicide can be adversely affected by aldicarb-degrading soil microflora. Further research is necessary to further identify microorganisms involved in the accelerated degradation of aldicarb.

Literature Cited

Coppedge, J. R., D. A. Lindquist, D. L. Bull, and H. W. Dorough. 1967. Fate of 2-Methyl-2-(methylthio) propionaldehyde *O*-(Methylcarbamoyl) oxime (Temik) in cotton plants and soil. Journal of Agricultural Food Chemistry 15(5):902–910.

Davis, R. F., A. W. Johnson, and R. D. Wauchope. 1993. Accelerated degradation of fenamiphos and its metabolites in soil previously treated with fenamiphos. Journal of Nematology 25:679–685.

Felsot, A., J. V. Maddox, and W. Bruce. 1981. Enhanced microbial degradation of carbofuran in soils with histories of furadan use. Bulletin of Environmental Contamination Toxicology 26:781–788.

Gazaway, W. S., J. R. Akridge, and K. S. McLean. 2000. Impact of various crop rotations and various winter cover crops on reniform nematode in cotton. Proceedings of the Beltwide Cotton Conference 1:162–163.

Jones, A. S. 1976. Metabolism of aldicarb by five soil fungi. Journal of Agricultural Food Chemistry 24:115–117.

Jones, R. L., A. G. Hornsby, and P. S. C. Rao. 1988. Degradation and movement of aldicarb residues in Florida citrus soils. Pesticide Science 23:307–325.

Lawrence, G. W., and K. S. McLean. 2000. Effect of Telone II on reniform nematode management in Mississippi. Proceedings of the Beltwide Cotton Conference 1:171–173.

Lightfoot, E. N., P. S. Thorne, R. L. Jones, J. L. Hansen, and R. R. Romine. 1987. Laboratory studies of mechanisms for the degradation of aldicarb, aldicarb sulfoxide, and aldicarb sulfone. Environmental Toxicology and Chemistry 6:377–394.

Littell, R. C., G. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. Cary, NC: SAS Inst. Inc.

Lorenz, G. M., T. Kirkpatrick, R. Robbins, K. Rorie, and A. Fisher. 1988. Suppression of reniform and root-knot nematode with Temik and Vydate. Proceedings of the Beltwide Cotton Conference 1:138–139.

McInroy, J. A., and J. W. Kloepper. 1995. Survey of indigenous bacterial endophytes from cotton and sweet corn. Plant and Soil 173: 337–342.

McLean, K. S., and G. W. Lawrence. 2003. Efficacy of aldicarb to *Rotylenchulus reniformis* and biodegradation in cotton field soils. Journal of Nematology 35:65–72.

Nicholson P. S., and P. R. Hirsch. 1998. The effects of pesticides on the diversity of culturable soil bacteria. Journal of Applied Microbiology 84:551–558.

Ou, L. T. 1991. Interactions of microorganisms and soil during fenamiphos degradation. Soil Science Society America Journal 55: 716–722.

Ou, L. T., P. S. C. Rao, K. S. V. Edvardsson, R. E. Jessup, A. G. Hornsby and R. L. Jones. 1988. Aldicarb degradation on sandy soils from different depths. Pesticide Science. 23:1–12.

Ou, L. T., J. E. Thomas, K. S. V. Edvardsson, P. S. C. Rao, and W. B. Wheeler. 1986. Aerobic and anaerobic degradation of aldicarb in ascetically collected soils. Journal of Environmental Quality. 15:356–363.

Overstreet, C. 2003. The use of Telone in cotton production in Louisiana. Proceedings of the Beltwide Cotton Conference 1:277–278.

Read, D. C. 1987. Greatly accelerated microbial degradation of aldicarb in retreated field soil, in flooded soil, and in water. Journal of Economic Entomology 80:156–163.

Smelt, J. H., M. Leistra, N. W. H. Houx, and A. Dekker. 1978. Conversion rates of aldicarb and its oxidation products in soils. III. Aldicarb. Pesticide Science 9:293–300.

Stanier, R. Y., N. J. Palleroni, and M. Doudoroff. 1966. The acerbic pseudomonads: A taxonomic study. Journal of General Microbiology 43:159–271.

Sturz, A. V., and J. Kimpinski. 1999. Effects of fosthiazate and aldicarb on populations of plant-growth-promoting bacteria, root-lesion nematodes and bacteria-feeding nematodes in the root zone of potatoes. Plant Pathology 48:26–32.