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ARTHROPOD MANAGEMENT AND APPLIED ECOLOGY

Frequency of Enhanced Degradation of Aldicarb in Field Soils from the High Plains of Texas.

T A.Wheeler*, J. F. Leser, M. D. Arnold, M. N. Parajulee, B. G. Mullinix Jr.

ABSTRACT

Soil was taken from 23 fields in the High Plains of Texas and tested for potential of enhanced degradation of aldicarb (Temik® 15G, Bayer CropScience, Research Triangle Park, NC) with a greenhouse bioassay using western flower thrips, *Franklinella occidentalis* (Pergande). Soil from each field was split and one-half of the soil was autoclaved while one-half was retained with its natural microbial complement. Aldicarb was applied at 0, 0.005 and 0.008 g ai/pot. Thrips (juveniles) were counted at 3-4 day intervals to measure reproduction until 31-33 days after planting, when leaf area was measured. Rate of aldicarb and days after planting were significant main effects as well as the interaction with aldicarb rate and soil microbes when all soils were combined in one analysis. Plants from pots with no aldicarb had significantly more cumulative juvenile thrips (CJUV) than plants from pots with aldicarb, regardless of the presence or absence of microbes. Average CJUV numbers were similar in autoclaved and natural soil. Enhanced biodegradation of aldicarb was demonstrated to some degree in three fields. Enhanced degradation of aldicarb is not yet a widespread threat for producers using this product for thrips and nematode control in the High Plains of Texas.

Pesticides are naturally degraded by microbes in soil. In "normal" microbial degradation, the rate of degradation typically follows first-order kinetics, assuming the concentration of pesticide is low (Simkins and Alexander, 1984). As the initial concentration of the substrate (pesticide) increases to a high concentration, mineralization kinetics will eventually be fit by a logarithmic model (Simkins and Alexander, 1984). For enhanced microbial degradation where microbes have been selected by previous exposures to utilization of the pesticide as a growth substrate, the rate of degradation is typically sigmoidal (Parkin et al., 1991). With enhanced biodegradation the time that the pesticide has a high enough concentration to be efficacious against the pest is shorter compared to a soil where enhanced degradation is not occurring. Enhanced degradation of soil insecticides/nematicides has been identified in carbofuran (Furadan®, FMC, Philadelphia, PA) (Parkin and Shelton, 1992), fenamiphos (Nemacur®, Bayer CropScience, Research Triangle Park, NC) (Davis et al., 1993), oxamyl (Vydate®, Dupont, Wilmington, DE) (Smelt et al., 1996), aldicarb (Smelt et al., 1996) and ethroprop (Mocap®, Bayer CropScience, Research Triangle Park, NC) (Moens, et al., 2004). McLean and Lawrence (2003) identified several fields where suspected biodegradation of aldicarb led to poor nematode control. Lawrence et al. (2005) documented that biodegradation of aldicarb occurred within 12 days in some soils. In soils where aldicarb was not undergoing enhanced biodegradation, aldicarb metabolites were still present at 42 days (Lawrence et al., 2005).

Aldicarb can be used in cotton production to control nematodes and arthropod pests such as thrips (www.bayercropsouthwest.com/content/MSDS-Label/MSDSLabel635-1623ld600083.pdf). In the Southern High Plains of Texas, approximately 40% of irrigated cotton acreage is infested with the root-knot nematode, *Meloidogyne incognita* ((Kofoid & White) Chitwood) (Robinson et al., 1987; Wheeler et al., 2000). In 2006, thrips were ranked as the number one arthropod pest of cotton in the Texas High Plains, causing an overall reduction in yield of 0.56% and a loss of 41,344 bales (Williams, 2007). There are currently several alternatives to aldicarb to control either nematodes (abamectin as a component of AVICTA® Complete Cotton, Syngenta, Greensboro, NC; and thiodicarb as a component of Aeris™, Bayer CropScience, Research Triangle Park, NC) or thrips (thiamethoxam Cruiser®, Syngenta, Greensboro, NC; andimidacloprid, Gaucho® Grande, Bayer

T A.Wheeler*, J. F. Leser, M. D. Arnold, M. N. Parajulee, B. G. Mullinix Jr., Texas AgriLife Research , 1102 East FM 1294, Lubbock, TX 79403,
*Corresponding author: ta-wheeler@tamu.edu

CropScience, Research Triangle Park, NC) that are labeled for U.S. cotton production. Enhanced biodegradation of aldicarb could influence the chemical choice for nematode and thrips control.

Aldicarb has been in use for over three decades in the Southern High Plains of Texas, primarily for thrips and nematode management in cotton. Soils in this semi-arid environment have a high pH, and often are calcareous. Since aldicarb has been used extensively in some High Plains fields for either thrips or nematode control since the early 1970's, enhanced biodegradation could be present. The primary objective of this project was to evaluate the efficacy of aldicarb in field soils collected from the Southern High Plains of Texas, using a greenhouse bioassay that was designed to identify if soilborne microbes were associated with poorer efficacy of aldicarb.

MATERIALS AND METHODS

A bioassay was developed to determine whether enhanced degradation by microbes in soil was a factor in the efficacy of aldicarb. Soil was collected at five to six locations within a field (from approximately 0.1 ha) from the planted row (beds). Soil was removed from 8 to 25 cm depth at each location and samples were combined to represent the entire field (approximately 50 L was collected). Soil samples from 23 fields were evaluated in this study, following the same protocol of sample collection, processing, and bioassays across all experimental sites. Tests were initiated on 8 Dec. 2005 (fields 1 - 4), 9 Jan. 2006 (fields 5 - 8), 23 Jan. 2006 (fields 9 - 12), 10 Feb. 2006 (fields 13 - 16), 3 March (fields 17 - 20), and 21 March 2006 (fields 21 - 23). All fields chosen for the study had some history of at-planting aldicarb use, though in some cases it was at least three years since aldicarb had been applied. In most cases, aldicarb was used annually. The range in rate of aldicarb applied by producers was 0.42 to 0.84 kg ai aldicarb/ha. Field soils were collected from eight counties in the High Plains, and included both fine textured and coarse textured soils. Field soils were collected within two weeks of use in the bioassays, and were covered and stored in a greenhouse at room temperature during the time between collection and beginning of an individual test. One half of the soil from each field was autoclaved twice at 180°C for 2.5 hours, and the soil was allowed to cool overnight between the autoclave periods to enhance kill of microbes. The autoclaved soil (microbe deficient) and normal soil (microbe natural) were placed into foam drink cups (450-cm^3 of soil). Aldicarb [Temik® 15G (Bayer Crop Sciences, Research Triangle Park, NC, corncob formulation)] was applied at a depth of five cm, at rates of 0, 0.0054, or 0.0077 g ai/cup. Three cotton seeds, cultivar 'Paymaster (PM) 2326RR' (Monsanto; St. Louis, MO), were planted per cup. The seed was not treated with insecticide or nematicide, but did contain the fungicides triademenol [Baytan® 30 (Bayer Cropsciences; Research Triangle Park, NC)] and metalaxyl [Allegiance® FL (Bayer Cropsciences; Research Triangle Park, NC)] for protection against fungi. Plants were thinned to one plant per cup. Bioassay tests for each field soil sample consisted of two factors: [rate of aldicarb (3) and soil microbe treatment (2)] deployed in a 3 x 2 factorial arrangement with five blocks.

Wheat was used to produce populations of thrips, comprised of approximately 90% western flower thrips, *Franklinella occidentalis* (Pergande) and 10% onion thrips, *Thrips tabaci* (Lindeman) as a source of infestation in each bioassay test. When the bioassay test was initiated, potted wheat was killed with glyphosate (18 g ai/L applied to runoff), and placed in close proximity to the cups planted with cotton. This forced the thrips to move to the nearby test cotton. Once the cotton seedlings emerged, the cotyledons and leaves were visually examined at least twice a week for immature (juvenile) and adult thrips. At 31 to 33 days post planting, all leaves were placed in a bottle with 350 ml of water + 2 ml of alcohol, capped and shaken for 30 seconds (Burris et al. 1990). The contents were then poured over two stacked sieves (230-µm over a 74-µm pore size). Water was poured repeatedly over the sieves to wash any thrips to the finer meshed sieve. Thrips were backwashed off the finer mesh sieve, identified as an adult or juvenile at 10X magnification and counted under a microscope. True leaf surface area was measured using a Li-COR 3100 leaf area meter (Li-COR Biosciences, Lincoln, NE).

Juvenile thrips abundance per plant was calculated as cumulative number of thrips from day 20 to the last day of the test. The cumulative number of juvenile thrips (CJUV) at each sampling time was transformed by $\sqrt{(CJUV+0.25)}$. The variable T was created, by subtracting each day of the evaluation from the overall mean for day for each soil, or the combined mean for day for the analysis when all soils were combined. A model was tested for transformed CJUV, with the variables microbe, aldicarb, and time (T) effects and their interactions using PROC

MIXED of SAS version 9.1 (SAS Institute, Cary NC). The fixed variables were microbe (M=0 for autoclaved soil and 1 for natural soil), aldicarb (A=0, 1, and 2 for none, low, and high rates of aldicarb), M x A, T, and the linear and quadratic effects of T for each microbe and aldicarb combination. The measurement of true leaf surface area (cm^2) was added as a covariate to the model statement. The random statement included: set, soil(set), replication x soil(set), set x M, set x A, set x M x A, soil x M(set), soil x A(set), soil x M x A(set), day, set x day, soil x day(set), replication x soil x day(set), and M x A x day. Set was used to describe the set of three or four soils (soils from 3-4 sites) that were run at any given time of the year. For example, four soils were run from Hockley county at the same time (fields 9 -12), on four different greenhouse tables, then the next month, four soils were run from another county (fields 17 - 20) on those same four tables. The Satterthwaite option was used to compute approximate degrees of freedom associated with each estimated standard error. The solution option on the model statement was used to provide the linear and quadratic parameter values. The least squares means statement was used to produce estimates of microbe and aldicarb combinations for √(CJUV+0.25). The outp = option of the model provided estimates of the predicted values. Slopes were compared with a t-test ($P \leq 0.10$) between the autoclaved and natural field soils, for each rate of aldicarb. The t-test formula was based on the assumption of unequal variances (t-value = $(slope_1 - slope_2)/(SE_1^2 + SE_2^2)^{1/2}$, with the degrees of freedom (DF) = $DF_1 + DK_2$. Aldicarb would be considered at risk for enhanced biodegradation if two conditions were met: 1) the slopes or means were similar between natural and autoclaved field soils treated with zero aldicarb; and 2) slopes or means of natural and autoclaved field soils were significantly different at the low and/or high rate of aldicarb.

A repeated measures analysis was run for each individual soil, using a similar model statement to the overall analysis. The random term in the model contained block, day, and microbe x aldicarb x day. If the terms for leaf area or the quadratic function for T were not significant at $P \leq 0.10$, then that term was dropped and the analysis was rerun. Comparisons that were considered indicative of enhanced biodegradation were similar as with the overall analysis, except the mean values of transformed CJUV averaged across all rating periods ≥ day 20 were compared. Means of transformed CJUV had to be different between sterilized soil and natural soil, at the same rate of aldicarb, and similar in the absence of aldicarb for a soil to be considered to demonstrate enhanced degradation.

The effect of the treatments on leaf surface area was analyzed using PROC MIXED. The model statement included M, A, and their interaction. The random statement included the terms: set, soil(set), block x soil(set), set x M, set x A, set x M x A, soil x M(set), soil x A(set), and soil x M x A(set).

RESULTS AND DISCUSSION

The combined analysis (for all field soils) indicated that aldicarb is not presently undergoing a high incidence of enhanced biodegradation in the Texas High Plains. The slopes for the autoclaved (-0.0066) and natural (-0.0072) soils (across other factors) in the absence of aldicarb were similar (Table 1, Fig. 1). Slopes for CJUV tended to be higher in the presence of aldicarb for natural field soils than for autoclaved field soils (Fig. 1), however, the slopes were not significantly different (Table 1).

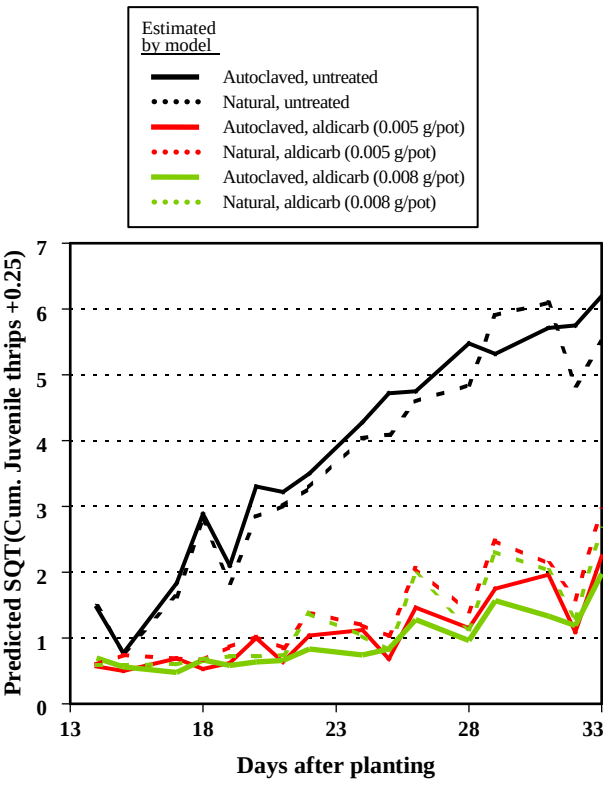

Figure 1. Transformed cumulative juvenile thrips/pot (√CJUV+0.25) for all field soils combined. The points in the figure are fitted from the model including the terms aldicarb (A), microbe (M), their interaction, day after planting – 24 (time), time², and true leaf area (cm^2).

Table 1. Effect of aldicarb and microbes in cotton grown in soils collected in the Texas High Plains during 2005 and 2006, on prediction[x] of cumulative juvenile thrips over time.

Soil	Model[x]	SE[y]	Slope estimates for aldicarb rates (g ai/cup)					
			0		0.005		0.008	
			Sterile	natural	Sterile	natural	Sterile	natural
1	L,M,A	0.033	0.115	0.148	0.046	0.042	0.071	0.053
2	L,A	0.031	0.070	0.049	0.083	0.143	0.057	0.075
3	Q,M,A	0.0076	-0.018	-0.031	0.000	0.002	-0.004	-0.004
4	Q,M,A	0.0082	-0.018	-0.025	0.000	-0.014	0.000	-0.005
5	L,A	0.053	0.245	0.269	0.083	0.134	0.094	0.123
6	Q,M,A	0.012	-0.012	-0.030	-0.007	-0.014	-0.006	-0.023
7	L,A	0.040	0.276	0.237	0.153	0.180	0.198	0.118
8	Q,M,A	0.005	-0.017	-0.023	-0.019*	-0.008	-0.007	-0.010
9	L,A	0.042	0.307***[z]	0.116	0.128	0.136	0.100	0.150
10	Q,A	0.006	-0.026	-0.010	0.011	0.013	0.014	0.025
11	L,A	0.065	0.360***	0.072	0.153	0.120	0.152	0.138
12	L,M,A	0.030	0.276	0.297	0.141	0.188	0.137	0.195
13	L,A	0.026	0.181**	0.077	0.034	0.066	0.026	0.070
14	Q,A	0.005	-0.014	-0.008	0.006	0.007	0.009	0.003
15	L,A	0.028	0.098	0.137	0.021	0.049	0.051	0.058
16	Q,A	0.006	-0.013	-0.006	0.003	0.011	0.009	0.000
17	L,MxA	0.042	0.202**	0.071	0.047	0.038	0.034	0.026
18	Q,A	0.005	-0.018	-0.013	0.006	0.000	0.000	0.006
19	L,MxA	0.058	0.234	0.151	0.068	0.078	0.058	0.112
20	Q,A	0.005	-0.013	-0.013	0.004	0.005	0.009	0.008
21	L,A	0.052	0.274***	0.477	0.057	0.084	0.033	0.058
22	L,A	0.050	0.458	0.509	0.230**	0.075	0.041	0.067
23	L,A	0.049	0.291***	0.564	0.031*	0.153	0.015	0.110
All[w]	Q,MxA	0.0027	-0.0066	-0.0072	0.0043	0.0044	0.0044	0.0036

[w] All was the combined analysis from the 23 soils listed in the Table.

[x] Models fitted included microbe (M), aldicarb (A), their interaction (MxA), and linear (L) or quadratic (Q) functions with the factor termed Mday (day – average days that thrips were counted after planting) with microbe and aldicarb nested within. M, A, and MxA were significant at $P \leq 0.05$ if listed under model. The dependent variable was √(CJUV+0.25), where CUV was the cumulative juvenile thrips, between 20 and 33 days after planting.

[y] SE is the standard error of the six slope estimates. If there were more than one standard error for the six, then the largest standard error is given.

[z] Comparisons between slope of the autoclaved and natural soils at the same rate of aldicarb are significant at 0.01 (***), 0.05 (**), or 0.10 (*).

Examination of individual soils for differences in slopes between natural and autoclaved soils revealed that only two fields (8 and 22, Table 1) fit the criteria listed for enhanced biodegradation. However, since the slope was higher for the microbe deficit soil than the microbe natural soils, biodegradation was not a factor in the slope differences. If enhanced biodegradation occurred, then the microbe natural soil would be expected to have a higher slope than the sterilized soil. There were no soils where slopes were similar in the absence of aldicarb, and higher for the sterilized soil in the presence of aldicarb (Table 1).

The main effect of aldicarb was significant for all soils, where there was significantly fewer tranformed CJUV in the presence of aldicarb than in its absence. In three cases (1, 4, and 13, Table 2), en-

hanced degradation of aldicarb was identified, where transformed CJUV was higher for the natural soils, where aldicarb was present (at one or both rates), than in the microbe deficit soils. In three additional soils (3, 6, 9), there may be enhanced biodegradation, but because there were significant differences in the absence of aldicarb, it can not be determined if the differences in the presence of aldicarb are due to biodegradation.

Table 2. Affect of aldicarb rate and soil microbe treatment (sterilized versus natural microbes) on cumulative juvenile thrips[y] on cotton.

Field	√(Cumulative juvenile thrips+0.25) Rate of Aldicarb applied (g ai/pot)					
	0		0.005		0.008	
	Sterile	Natural	Sterile	Natural	Sterile	Natural
1	4.10	4.71	1.53	2.11	0.97***	2.53
3	3.58**[z]	4.92	0.50**	1.84	0.86*	1.83
4	4.84	4.55	1.59**	3.51	1.48**	3.49
6	3.52*	3.67	1.09*	2.79	1.89	2.58
8	6.12*	5.03	3.24*	2.11	1.48	1.68
9	4.85**	3.70	1.45*	3.70	1.01	1.84
13	4.65	4.58	0.68**	2.13	0.80	1.20

[y] The cumulative juvenile thrips (CUV) was transformed √(CJUV+0.25) before analysis.

[z] Comparisons between slope of the autoclaved and natural soils at the same rate of aldicarb are significant at 0.01 (***), 0.05 (**), or 0.10 (*).

Leaf area was greater in the presence of aldicarb than the absence of aldicarb for both microbe normal and autoclaved field soils ($P < 0.001$). At the low rate of aldicarb (0.005 g ai/pot), leaf area was higher ($P = 0.02$) in autoclaved soil (leaf area = 7.9 cm^2) than in natural soil (leaf area = 5.7 cm^2). Leaf area was also higher ($P = 0.002$) in autoclaved soil at the high rate of aldicarb (leaf area = 9.1 cm^2) than in natural soil (leaf area = 5.7 cm^2). The reduction in leaf area, when aldicarb was present in natural soils compared with autoclaved soils, could be caused by a number of soil factors, including fungal root pathogens (*Thielaviopsis basicola* was present in a number of soils).

Enhanced microbial degradation of soil applied aldicarb does not appear to be a significant factor in the efficacious control of the thrips complex in the Texas High Plains cotton production region. Possible enhanced degradation of aldicarb was identified in soil samples from three field sites. Historical aldicarb use rate and frequency of use was not consistently high for soils that did indicate potential for enhanced degradation. There was a high use rate and consistent aldicarb use in field 1. Aldicarb was only used in field 3 twice in the previous eight years and aldicarb was used consistently, but at low dosages (0.42 – 0.5 kg ai/ha) in field 13. This finding is consistent with a long-term study of aldicarb in Israel (Aharonson and Katan 1993), which is also a semi-arid or arid region. Smelt et al. (1996) found that aldicarb had accelerated degradation at one site (pH 7.3) treated annually for three years, but did not occur at another site (pH 5.6) treated 10 times. Read (1987) found that enhanced degradation of aldicarb by microbes depended on pH, moisture content, amount of product applied per treatment, number of treatments applied, and time period between treatments. The soils in the High Plains are basic, which tends to be more conducive for enhanced degradation of pesticides (Singh et al. 2003; Suett et al. 1996). However, the semi-arid nature of this region, and correspondingly lower microbial population density, may cause a reduced potential for enhanced biodegradation of pesticides.

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