308

EFFECTS OF GRANULAR NEMATICIDES ON NEMATODE POPULATIONS AND CORN YIELDS

by

LEO DUANE LASH

B.S., Kansas State University, 1976

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Plant Pathology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Approved by:

Major Professor

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

TABLE OF CONTENTS

LIST OF TABLES

The association of nematodes with corn, *Zea mays* L., is not new but until recently limited attention was given to the relationship. Taylor and Schleder (15) found, during surveys of nematodes associated with Minnesota crops, large populations of *Helicotylenchus* spp. Steiner and *Pratylenchus* spp. Filipjev in association with corn roots; they suggested that nematodes might be damaging corn in the state, although such damage generally was not recognized. In a greenhouse study, Dickerson, Darling, and Griffin (4) demonstrated that *Pratylenchus penetrans* (Cobb) Filipjev and Stekhoven reduced corn roots, stalks, and stalk diameters. *Tylenchorhynchus maximus* Allen and *Helicotylenchus digonicus* Perry incited stunting of field corn under greenhouse conditions (6), whereas in a field trial a slight increase in grain yields was obtained by reducing nematode populations by fumigation with dichloropropene.

With the recent development and use of granular nematicides, the effects of nematodes on corn can be measured more easily. In South Dakota, Smolik (13) found a negative correlation between the total number of feeding plant parasitic nematodes and yields: using granular nematicides increased grain yields up to 55%. Yield increases of up to 25%, attributed primarily to control of *Hoplolaimus galeatus* (Cobb) Thorne and *Pratylenchus hexincisus* Taylor and Jenkins were determined in Iowa by Norton and Hinz (10). In Indiana, Bergeson (1) found that using carbofuran reduced the number of *Pratylenchus* spp. in the roots by 98.3% and increased average grain yields by 14.4%. Norton et al. (11) later demonstrated that using granular nematicides increased average yields 21% and at the same time resulted in significant negative correlations between yields and populations of *Helicotylenchus pseudorobustus* (Steiner) Golden and *Pratylenchus* spp. in the roots.

Kansas produced 3.9 million metric tons of corn in 1978 (8). Though damage from nematode feeding is rarely visible in the above-ground portions of the plant throughout the state, *Pratylenchus* spp., *Tylenchorhynchus* spp., and *Helicotylenchus* spp. are commonly associated with corn roots. Information is not available, however, to determine their possible role in yield reductions. To elucidate the role of these nematodes in corn production, nematicide trials and correlation studies were performed in various corn producing regions of Kansas.

MATERIALS AND METHODS

Five nematicide experiments at four locations were conducted during 1977, 1978, and 1979. The nematicide treatments were applied to corn grown under two cultural practices: corn grown in rotation with other crops or continuously cropped corn. The first experiment was in a Grundy silty clay loam on the Corn Belt Experiment Field, Powhattan, Northeast Crop Reporting District, where corn had been grown continuously the previous 3 years (Powhattan C-C); the second experiment was conducted at Powhattan but where soybeans, *Glycine max* (L.) Merr., had been grown (in the same soil) the previous year (Powhattan C-S). The third experiment was in a Richfield silt loam at the Garden City Experiment Station, Garden City, Southwest Crop Reporting District, where corn had been grown continuously the previous 5 years. The fourth experiment was in a Keith silt loam at the Colby Experiment Station, Colby, Northwest Crop Reporting District, where grain sorghum, *Sorghum bicolor* (L.) Moench, had been grown the previous year. The fifth experiment was in a Eudora silt loam at the Kansas River Valley Experiment Field, Silver Lake, in the Northeast Crop Reporting District, where corn had been grown continuously the previous 5 years. Powhattan was the only dryland experiment; all others were furrow irrigated.

The hybrids and plant populations for each experiment were as follows: Powhattan C-C and Powhattan C-S, 'O's Gold 5500-A,' 43,500/ha; Garden City, 'Pioneer experimental hybrid,' 59,000/ha; Colby, 'Asgrow RX90,' 59,000/ha; and Silver Lake, 'Pioneer 3183,' 59,800/ha. Tillage practices, fertilizers, and herbicides used were all in accordance with accepted agronomic practices of the areas in which the experiments were conducted.

A randomized, complete-block design replicated four times was used at each location. The number of treatments ranged from eight to 17, including nontreated controls. All plots were four rows wide (76-cm row spacing) and 9.1 to 15.2 m long. All replications were separated by an alley 3 m wide with clear cut areas 0.5 m wide to separate the alley from the replication. To reduce border effects, each experiment was surrounded by at least 3 m of row on the ends and at least four rows of corn on the sides.

Nematicides tested included: aldicarb 15G (Temik); carbofuran 4F and 10G (Furadan); 2-(diethoxyphosphinylimino)-1,3-dithietane 15G, AC 64,475, (Nem-A-Tak); and terbufos 15G and 15GC (Counter). At Powhattan, nematicides were applied, immediately after corn had been planted, in an 18-cm band with a one-row, hand-operated Gandy applicator; they were lightly incorporated into the soil. At the remaining locations, all nematicides were applied at planting with planter-mounter Noble applicators, capable of applying two nematicides simultaneously. Banded treatments (18 cm) were applied in front of the press wheel for slight incorporation. For furrow treatments, nematicides were applied in the seed furrow. Flowable formulations were diluted with approximately 500 ml of water (180 l/ha) and sprayed over the row in an 18 cm band after planting, then lightly incorporated with a garden rake.

Each plot was sampled prior to planting by removing three soil cores (2.3 x 15 cm) from the outside two rows with a field subsampling tool (5).

The soil cores were combined into one composite sample. During the growing season, soil and root samples were taken twice, 30 and 90 days after planting at Silver Lake and 60 and 120 days after planting at the remaining sites, in the following manner: Two plants from each of the outside rows were dug to a depth of approximately 20 cm, the above ground portion of each plant was discarded, and the remaining root ball was quartered with a hatchet. One-half to one-quarter, depending on the size, of the root ball from each of the four plants sampled was combined into one composite sample. Soil samples were processed within 7 days after collection and root samples were processed within 48 hrs; storage, when needed, was at 16°C.

Nematodes were extracted from 100 cc of the composite soil samples by the direct centrifugal-flotation method (3). Nematodes were collected on a 37-µm screen, washed into a 25-ml test tube with approximately 20 ml of water and stored at 4°C until counted. Prior to counting, the volume in each tube was adjusted to 10 ml by aspirating excess water, and the nematodes were suspended by shaking. The number of parasitic nematodes in a 1-ml subsample was counted in a Hawksley counting slide. Final counts were expressed as the number of stunt, *Tylenchorhynchus martini* Feilding and *Quinisulcius acutus* (Allen) Siddiqi; lesion, *Pratylenchus neglectus* (Rensch) Filipjev and Stekhoven, *P. hexincisus*, *P. scribneri* Steiner, and *P. alleni* Ferris; spiral, *Helicotylenchus pseudorobustus*; dagger, *Xiphinema americanum* Cobb; and pin, *Paratylenchus hamatus* Thorne and Allen, nematodes per 100 cc of soil.

The soil about the roots of each composite sample was removed and processed (as described above). After the roots had been washed free of adhering soil with water, blotted dry, and cut into 1- to 2-cm segments, a random subsample of 10 g was placed in a continuous mistchamber for 14 days. Nematodes were collected in a 25 ml test tube at 3- to 4-day intervals and stored at 4°C until counting. After extraction, the nematodes were allowed to concentrate in the bottom of the tube, the volume in each tube was adjusted to 10 ml by aspirating excess water, and a 1-ml subsample was counted in a Hawksley counting slide.

After the nematodes had been extracted from the roots, the roots were dried in a forced-air dryer at 45°C for a minimum of 48 hrs, and the dry weight of each root sample was recorded. Final counts were expressed as the number of lesion nematodes per g of dry root weight.

At all locations, except Silver Lake, the center two rows of each plot were hand harvested. At Silver Lake, the center two rows were harvested by using a two-row harvester. The length of row harvested was 1.5 m less than the total plot length, except at Silver Lake where the entire length was harvested. Percent grain moisture and test weights from all plots were recorded. Grain yields were calculated by correcting weights to 15.5% grain moisture content.

Average yield increases were calculated and analyzed for identical treatments by grouping the experiments as follows: 1) total, using the data from all experiments with identical nematicides, rates, and placements; 2) monoculture, using the data from the experiments established at locations in corn grown continuously for at least 3 years; and 3) rotation, using data from the experiments established where a crop other than corn had been grown the previous year. The Student's t-test was used to compare individual treated means with nontreated means, grouping the replicated data from identical treatments and appropriate controls.

Average nematode control was determined for each nematicide treatment by grouping the data in two cultural practice categories: monoculture and rotation, and then determining the average control across the practices (total). The t-test was used to determine if differences between treatments and controls were significant. Differences between means of the control and of the treated populations were divided by the control mean and multiplied by 100 to determine percent control. All nematode counts for this portion were transformed by $(X)^{0.5} + 1$.

Correlations were calculated between yield, nematode numbers per 100 cc of soil, and number per g of dry root weight for each sampling date, excluding pre-plant. No data transformations were used in the correlation analysis.

For each experiment, multiple regression equations were determined between yields, the dependent variable, and using the number of nematodes in the soil and in the roots for each sampling time, excluding pre-plant, as independent variables. Included as independent variables in the regression analysis were nematode counts transformed by either $(X)^{0.5} + 1$ of $\log_{10}X$.

RESULTS

Analysis of variance showed that the number of nematodes per 100 cc of soil at planting time was not significantly different (P=.05) between replications or treatments at any of the locations. Average nematode populations per 100 cc of soil at planting time were: Powhattan C-C, 219 stunt, 114 lesion, and 131 spiral; Powhattan C-S, 111 stunt, 69 lesion, and 110 spiral; Garden City, 24 stunt and 29 lesion; Colby, 10 stunt and 31 lesion; and Silver Lake, 15 stunt and 119 lesion. In addition, a few pin and dagger nematodes were counted in some samples from all locations, but populations remained low throughout the growing season. Stunt nematodes included *T. martini* and *Q. acutus* at all sites except Colby, where only *T. martini* were found. Lesion nematodes from each site were: Powhattan C-C and Powhattan C-S, *P. hexincisus, P. neglectus,* and *P. scribneri;* Garden City, *P. neglectus, P. scribneri,* and *P. alleni*; Colby, *P. hexincisus* and *P. neglectus*; and Silver Lake, *P. hexincisus, P. neglectus, P. scribneri,* and *P. alleni.*

Feeding sites of corn root worm (*Diabrotica* spp.) on corn roots were observed, and European corn borers (*Ostrinia nubilalis*) were noted at all locations except Colby. Southwestern corn borers (*Diatraea graniosella*) were observed at Garden City. At all locations damage from these insects was negligible and sporadic with no serious grain losses attributable to their feeding. No phytotoxicity, reduced stands, or economically important diseases were noted in any experiment.

A split-plot analysis of variance for yields, using identical nematicide treatments (rate, formulation, and placements) as main plots and years as subplots resulted in significant differences (P=.05) for years and treatments but no significant differences for the treatment-year interaction, indicating the nematicides gave similar results independent of the year.

The average numbers of nematodes from the control plots (for both sampling times during the growing season) at each location are presented in Table 1. These data show the diversity of nematode populations as observed in this study.

As shown in Table 2, mean yield increases for monocultured corn ranged from 29.8% to a loss of 3.3% and 15 of the 30 nematicide treatments resulted in significant (P=.05) yield increases. Only one treatment (oxamyl at 1.12 kg/ha, band, in combination with terbufos 15G at 1.12 kg/ha, furrow) was a yield lower than the control. In general, the 1.68 or 2.24 kg/ha rate of carbofuran (4F or 10G), aldicarb, or oxamyl resulted in the largest increases in yields (6.9% to 29.8%). Oxamyl when combined with either carbofuran 10G or terbufos 15G did not result in significant yield increases, and generally the yield increases were lower than when only oxamyl was applied.

In corn grown in rotation with other crops, yields ranged from a 12.7% increase to a loss of 9.2%. Only terbufos 15G at 1.12 kg/ha, furrow, resulted in a significant yield increase. Three of the 13 treatments resulted in yields equal to or less than the controls. Yield increases for corn grown in rotation were less than those for identical treatments on corn grown in monoculture.

Of the 10 nematicide treatments used in both corn cropping systems, seven showed significant yield increases ranging, from 7.4% to 15.3%; and three were nonsignificant yield increases, ranging from 6.2% to 8.2%. No nematicide treatment used on both cropping systems resulted in a yield loss when compared with the control.

In a continuous corn sequence, only aldicarb (3.36 kg/ha, band) resulted in significant reductions of all nematodes at both sampling time (Table 3). In general, aldicarb and oxamyl most effectively reduced nematode populations, whereas the reductions with carbofuran were intermediate. Terbufos was ineffective in reducing nematode populations. The nematicides used in these experiments did not appear to be selective in controlling any one genera of nematodes.

In corn grown in rotation with other crops, no nematicide treatment significantly reduced the nematode populations at both sampling times (Table 4). Control of stunt nematodes was erratic, due in part to a very low population at Colby (Table 1). Generally, nematode control in corn grown in a rotation system was comparable with that obtained in continuously cropped corn.

Aldicarb (1.68 kg/ha, band; and 3.36 kg/ha, band) and oxamyl (2.24 kg/ha, band) significantly reduced all nematode populations monitored, at both sampling times, regardless of cropping history (Table 5). Other rates and placements of nematicides generally reduced the populations, but the reductions were not as consistent. Furrow-applied nematicides were not as effective as those applied in a band. There was a slight reduction of nematode control at the 120-day sampling time, compared with the 60-day sampling time. Resurgence of lesion nematodes in the roots at the 120-day sampling time was noted for carbofuran 10G at the 0.84 kg/ha, band, rate. Terbufos and AC 64,475 were least effective in controlling nematodes in soil and roots.

At Silver Lake, where samples were taken at 30 and at 90 days after planting (Table 6), the actions of the nematicides were comparable to the averages of the other sites. All treatments except carbofuran 10G (1.68 kg/ha, band) significantly lowered root populations, compared with the control at 30 days.

Correlation coefficients between yields and the various nematodes were determined for all locations and growing season sampling times (Table 7). No correlations between sampling times or between nematode genera at the same or different sampling times were calculated because of the effect of the nematicides on the nematode populations. Yields, for the most part, were inversely related to nematode populations, both in the soil and in the roots. Except for stunt nematodes at Silver Lake, no single nematode population at either samping time was consistently correlated with yields.

Multiple regression coefficients for predicting yields were significant at Powhattan C-C and at Silver Lake. For Powhattan, the best equation was:

$$\text{Yield (kg/ha)} = 6{,}232.2 - 61.02(a) - 110.24(b) + 12.08(c) + 18.59(d)$$

($P=.02$ and $R^2=.214$), where a, b, c, are the number of stunt, lesion, and spiral nematodes per 100 cc of soil, respectively; and d is the number of lesion nematodes per g dry root wt, at 60 days after planting. Individual correlation coefficients for lesion nematodes in the soil and lesion nematodes in the roots were significant ($P=.05$). For Silver Lake, the best equation was:

$$\text{Yield (kg/ha)} = 9{,}839.7 - 81.87(a) + 119.39(b) - 20.35(c)$$

($P=.001$ and $R^2=.387$), where a and b are the number of stunt and lesion nematodes per 100 cc of soil, respectively; and c is the number of lesion nematodes per g dry root wt, at 90 days after planting. All individual correlation coefficients were significant. Nematode counts used in determining both equations were transformed by $(X)^{0.5} + 1$.

DISCUSSION

Results of this study showed that: 1) granular nematicides can effectively reduce the number of nematodes in and about the roots of corn; 2) yields generally increase with the use of these materials; and 3) there is a general negative correlation between the yield of corn and the number of nematodes in the soil and in the corn roots. These results basically agree with published results of others working with corn in the Midwest (1, 10, 11, 14, 15).

Negative correlations are not conclusive proof that nematodes are causing yield losses, but they are highly suggestive of a cause-and-effect relationship. A study by Sasser, Barker, and Nelson (12) determined that by using nematicides to alter the natural population of nematodes and by measuring crop responses (yields), correlations could be used to determine the effect of diverse nematode populations on yields. Because nematodes continuously interact with corn plants from emergence until maturity and are acted upon by the environment, it is difficult to determine the precise effect of nematodes on yields by sampling populations only twice during the growing season.

The effect of *T. martini* and *Q. acutus* on corn yields has not been investigated. Hollis et al. (7) reported that *T. martini* did not significantly affect the growth of rice. Birchfield and Martin (2) found that *T. martini* did not reproduce on 'White Tuxpan' field corn in the greenhouse. The effects of *Q. actus* on corn has not been investigated. The correlation coefficients between stunt nematodes and yields (Table 7) suggested that stunt nematodes at Silver Lake were a factor in yield losses. At Colby, the stunt nematodes were probably not responsible for yield losses because of the low populations measured in the soil.

Yield reductions by various species of lesion nematodes have been reported by various workers (1, 10, 11, 14, 15). Spiral nematodes have been described as moderate pathogens by themselves, but in combination with other nematodes they may contribute to greater yield reductions (9). Correlations between nematodes and yields appear to be variable, however; mostly negative correlations were found. These correlations were not of the same magnitude as reported by others (11, 13), but they do indicate the importance of nematode in yield reductions. The effect of pin and dagger nematodes on yields could not be determined because of the low nematode populations at all locations tested.

Differences in yield response of corn to nematode control does exist when comparing corn grown in rotation to corn grown in a continuous corn sequence. Although nematode control was generally less for corn grown in a rotation sequence, some nematicide treatments reduced nematodes about the same as did those in the continuous corn sequence; however, yield increases were not at large (e.g. 1.68 kg/ha aldicarb, band), suggesting that chemical control of nematodes on corn following a crop other than corn might not be profitable.

Corn rootworms did not appear to be a significant factor in any of the experiments. Though oxamyl and aldicarb are not effective against corn rootworm larva, these nematicides resulted in some of the largest yield increases of corn, suggesting that the yield response to nematicide treatments was a result of nematode control. The largest yield increase (12.6%, average of 3 years) for corn grown continuously and in rotation with other crops, from a nematicde that had no effect on corn rootworm, was aldicarb at 1.68 kg/ha, band (Table 2). Assuming that nematodes are responsible for only a 10% reduction of yields, then a loss of 34.4 million dollars (based on the total production and average price) occurred in Kansas in 1978..

The y-intercept value of the multiple regression may be used to approximate the theoretical yield in the absence of nematodes. These theoretical yields represent an increase of 14.4% and 35.1% over the average yield of the nontreated plots for Silver Lake and Powhattan C-C, respectively. The yield increases actually obtained from the highest yielding treatments over the nontreated plots were 20.1% and 43.9% for Silver Lake and Powhattan C-C, respectively. The closeness of the actual increases to the theoretical yields shows that nematodes caused significantly reduced yields at these two locations.

In Kansas, symptoms of nematode feeding are not normally visible in above-ground plant portions, which decreases the awareness of nematode-related yield losses. If above-ground symptoms (such as stunting, unexplained nutrient and water deficiencies, uneven height) are apparent they are usually attributed to maladies other than nematodes. The data presented indicate that nematodes are responsible for yield losses in corn grown under cultural practices normally used in Kansas. Even with the high variance normally associated with small field plots, significant reductions in nematode populations and significant yield increases were obtained with many of the nematicides tested. Chemical control of nematodes is not warranted in all corn fields in Kansas, but in certain fields and locations the control of nematodes with nematicides may increase yields substantially.

ACKNOWLEDGMENTS

Appreciation is expressed to E. Banbury, M. Claassen, G. Herron, and L. Maddux for their assistance with the field plots. This study was supported in part by grants from American Cyanamid Co., E. I. du Pont de Nemours & Co., FMC, and Union Carbide Corp.

LITERATURE CITED

1. Bergeson, G. B. 1978. Control of the lesion nematode (Pratylenchus spp.) in corn with carbofuran. Plant Dis. Reptr. 62:295-297.

2. Birchfield, W., and W. J. Martin. 1956. Pathogenicity on sugarcane and host plant studies of a species of Tylenchorhynchus. Phytopathology 46:277-280.

3. Dickerson, O. J. 1977. An evaluation of the direct centrifugal-flotation method of recovering nematodes from soil. Plant Dis. Reptr. 61:1054-1057.

4. Dickerson, O. J., H. M. Darling, and G. D. Griffin. 1964. Pathogenicity and population trends of Pratylenchus penetrans on potato and corn. Phytopathology 54:317-322.

5. Esser, R. P., J. B. MacGowan, and H. M. Van Pelt. 1965. Two new nematode subsampling tools. Plant Dis. Reptr. 49:265-267.

6. Griffin, G. D. 1964. Association of nematodes with corn in Wisconsin. Plant Dis. Reptr. 48:458-459.

7. Hollis, J. P., L. S. Whittock, J. G. Atkins, and M. J. Fielding. 1959. Relations between nematodes, fumigation and fertilization in rice culture. Plant Dise. Reptr. 43:33-40.

8. Kansas State Board of Agriculture. 1978. 62nd annual report and farm facts. Topeka, Kansas. 258 pp.

9. Norton, D. C. 1977. Helicotylenchus pseudorobustus as a pathogen on corn, and its densities on corn and soybean. Iowa State J. Res. 51:279-285.

10. Norton, D. C., and P. Hinz. 1976. Relationship of Hoplolaimus galeatus and Pratylenchus hexincisus to reduction of corn yields in sandy soils in Iowa. Plant Dis. Reptr. 60:197-200.

11. Norton, D. C., J. Tollefson, P. Hinz, and S. H. Thomas. 1978. Corn yield increases relative to nonfumigant chemical control of nematodes. J. Nematol. 10:160-166.

12. Sasser, J. N., K. R. Barker, and L. A. Nelson. 1975. Correlation of field populations of nematodes with crop growth responses for determining relative involvement of species. J. Nematol. 7:193-198.

13. Smolik, J. D. 1975. Nemas. S. D. Farm Home Res. 26:5-9.

14. Smolik, J. D. 1978. Influence of previous insecticidal use of ability of carbofuran to control nematode populations in corn and effect on corn yield. Plant Dis. Reptr. 62:95-99.

15. Taylor, D. P., and E. G. Schleder. 1959. Nematodes associated with Minnesota crops II. Nematodes associated with corn, barley, oats, rye, and wheat. Plant Dis. Reptr. 43:329-333.

Table 1. Average number of nematodes, extracted *from* the soil and *from* corn roots in the non-treated experimental plots at each location

	Nematodes per 100 cc of soil								Lesion nematodes/g dry wt	
	Stunt		Lesion		Spiral		Total[a]			
Location	60[b]	120[b]	60	120	60	120	60	120	60	120
Powhattan C-C[c]	208	200	298	520	178	475	683	1198	8,816	5,236
Powhattan C-S[c]	60	153	113	438	183	1128	370	1743	5,990	4,663
Garden City	12	101	5	133	--	--	17	234	1,602	1,559
Colby	0	5	20	33	--	--	23	48	450	806
Silver Lake[d]	24	31	39	117	--	--	74	154	11,408	6,738

[a] Includes a few spiral, dagger, and pin nematodes.

[b] Days after planting.

[c] C-C and C-S indicate corn grown in continuous culture and corn grown in a rotation system, respectively.

[d] Samples taken 30 and 90 days after planting.

Table 2. Average corn yields and percent yield increases for corn treated with various nematicides and produced in a monoculture or a crop rotation sequence.

Treatment			Monocultured			Rotated			Total		
Nematicide	Rate (a.i.) kg/ha	Placement	n[a]	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase
Carbofuran 4F	2.24	band	2	7,784.4	29.8**[b]	-	--	--	2	7,784.4	29.8**
Aldicarb	0.84	furrow	2	7,232.5	19.2**	-	--	--	2	7,232.5	19.2**
Oxamyl	0.56	band	1	5,486.0	18.9*	-	--	--	1	5,486.0	18.9*
Aldicarb	2.24	band	1	8,856.8	17.8**		--	--	1	8,856.8	17.8**
Carbofuran 10G	2.24	band	2	8,114.4	23.0**	1	7,364.4	1.4	3	7,723.2	15.3**
Carbofuran 10G	1.68	band	3	8,214.3	19.0**	1	10,156.0	2.6	4	8,699.8	13.7**
Terbufos 15GC	1.12	furrow	1	9,679.0	12.8	-	--	--	1	9,679.0	12.8
Aldicarb	3.36	band	1	5,203.5	12.8	-	--	--	1	5,203.5	12.8
Aldicarb	1.68	band	2	7,810.8	18.4	1	7,409.0	2.0	3	7,677.2	12.6**
Oxamyl	1.12	band	2	7,420.8	12.5	-	--	--	2	7,420.8	12.5
Carbofuran 4F	1.68	band	1	8,426.7	12.1	-	--	--	1	8,426.7	12.1
Terbufos 15G	1.12	furrow	1	9,305.5	8.5**	1	11,145.0	12.7*	2	10,229.8	10.7**
Carbofuran 10G	0.84	band	2	9,069.3	12.7**	1	10,280.0	3.9	3	9,472.9	9.3**

Table 2. (cont'd.)

Treatment			Monocultured			Rotated			Total		
Nematicide	Rate (a.i.) kg/ha	Placement	n[a]	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase
AC 64,475	1.68	band	1	8,677.8	15.4*	1	10,334.9	4.5	2	9,506.3	9.2*
Oxamyl	1.68	band	-	--	--	1	10,800.9	9.2	1	10,800.9	9.2
Oxamyl	2.24	band +									
Carbofuran 10G	0.84	furrow	1	8,845.7	9.2	1	--	--	1	8,845.7	9.2
Aldicarb	0.84	band	2	7,192.5	9.0	-	--	--	2	7,192.5	9.0
Aldicarb	1.12	furrow	1	9,344.7	8.9	-	--	--	1	9,344.7	8.9
Oxamyl	2.24	band	3	7,892.1	14.3**	1	6,598.6	-9.2	4	7,568.7	8.2
Terbufos 15GC	1.12	band	1	9,242.7	7.7*	-	--	--	1	9,242.7	7.7*
AC 64,475	1.12	band	-	--	--	1	10,642.5	7.6	1	10,642.5	7.6
Terbufos 15G	1.12	band	3	7,707.0	11.6**	2	8,782.1	2.4	5	8,137.0	7.4**
Aldicarb	1.68	furrow	2	6,736.7	11.0*	1	7,263.9	0.0	3	6,912.4	6.9
Aldicarb	1.12	band	1	8,003.0	6.4**	-	--	--	1	8,003.0	6.4**
Carbofuran 10G	1.12	furrow	1	7,907.3	5.2	1	7,791.2	7.3	2	7,849.2	6.2

Table 2. (concluded)

Treatment			Monocultured			Rotated			Total		
Nematicide	Rate (a.i.) kg/ha	Place-ment	n[a]	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase	n	Yield kg/ha	Percent increase
Aldicarb	0.56	furrow	1	9,115.6	6.2	-	--	--	1	9,115.6	6.2
Oxamyl	1.12	furrow +									
Carbofuran 10G	0.84	band	1	7,945.0	5.7	-	--	--	1	7,945.0	5.7
Oxamyl	1.12	band +									
Carbofuran 10G	0.84	furrow	1	8,845.7	3.1	-	--	--	1	8,845.7	3.1
Carbofuran 10G	1.68	furrow	1	7,728.4	2.8	-	--	--	1	7,728.4	2.8
Oxamyl	2.24	furrow	1	7,602.9	1.1	-	--	--	1	7,602.9	1.1
Oxamyl	1.12	band +									
Carbofuran 10G	0.84	band	1	7,541.7	0.2	-	--	--	1	7,451.7	0.2
Oxamyl	1.12	band +									
Terbufos 15G	1.12	furrow	1	8,293.3	-3.3	-	--	--	1	8,293.3	-3.3
Oxamyl	1.12	furrow	-	--	--	1	6.780.6	-6.7	1	6,780.6	-6.7

[a]Number of experiments with the identical nematicide treatment.

[b]*,** indicates a significant difference from control plots at the P=.05, P=.01 level, respectively.

Table 3. Average percent control of nematodes at two sampling times for continuously cropped corn[a]

Treatment			Nematodes per 100 cc of soil									Lesion nematodes per g dry wt		
	Rate (a.i.)	Place-	Stunt			Lesion			Spiral					
Nematicide	kg/ha	ment	n[b]	60[c]	120[c]	n	60	120	n	60	120	n	60	120
AC 64,475	1.68	band	1	32	66**[d]	1	+31	53	-	--	--	1	55	41
Aldicarb	0.84	band	1	60*	33	1	64**	55*	1	64*	54*	1	67	69*
Aldicarb	0.84	furrow	2	39	57**	2	40	31*	1	33	11	2	55*	40**
Aldicarb	1.12	band	1	50	48	1	31	54	-	--	--	1	76**	36
Aldicarb	1.68	band	1	71**	63*	1	90**	74**	1	37	63	1	80*	66**
Aldicarb	1.68	furrow	2	47*	37**	2	62*	49**	1	49*	29	2	69**	41**
Aldicarb	2.24	band	1	13	55	1	61	65	-	--	--	1	79	49
Aldicarb	3.36	band	1	60*	93**	1	78*	83**	1	63*	95*	1	89*	90**
Carbofuran 10G	0.84	band	1	26	41	1	31	32	-	--	--	1	44	+ 7
Carbofuran 10G	1.12	furrow	1	13	27	1	+13	39	-	--	--	1	17	17
Carbofuran 10G	1.68	band	2	40*	28*	2	42*	32*	1	42*	+10	2	45**	32
Carbofuran 10G	1.68	furrow	1	5	47*	1	18	53	-	--	--	1	30	21
Carbofuran 10G	2.24	band	1	62**	57	1	42	42**	1	80*	55	1	50	47
Carbofuran 4F	1.68	band	1	+ 2	13	1	31	28	-	--	--	1	56*	23
Carbofuran 4F	2.24	band	2	45*	35*	2	61	49**	1	44	38	2	69**	44*

Table 3. (concluded)

Treatment			Nematodes per 100 cc of soil									Lesion nematodes per g dry wt		
	Rate (a.i.)	Place-	Stunt			Lesion			Spiral					
Nematicide	kg/ha	ment	n[b]	60[c]	120[c]	n	60	120	n	60	120	n	60	120
Oxamyl	0.56	band	1	53*	37	1	77**	53**	1	59	35*	1	63*	55**
Oxamyl	1.12	band	1	69**	56	1	72	51*	1	53	16	1	81*	74**
Oxamyl	2.24	band	2	57	38*	2	65*	57**	1	68*	58	2	70*	34*
Oxamyl	2.24	furrow	1	+ 5	6	1	+13	39	-	--	--	1	59	+ 9
Oxamyl	1.12	band +												
Corbofuran 10G	0.84	band	1	+ 1	27	1	+62	55	-	--	--	1	50*	48
Oxamyl	1.12	furrow +												
Carbofuran	0.84	band	1	58	52	1	31	36	-	--	--	1	56	10
Terbufos 15G	1.12	band	2	38*	17	2	3	21	1	30	26	2	2	23

[a] Data from Silver Lake were not included because of differences in sampling times.

[b] Number of experiments using identical nematicide treatments.

[c] Days after planting.

[d] *,** indicates a significant difference from control plots at the P=.05, P=.01 level, respectively.

Table 4. Average percent control of nematodes at two sampling times for corn grown in a rotation system

Treatment			Nematodes per 100 cc of soil									Lesion nematodes per g dry wt		
			Stunt			Lesion			Spiral					
Nematicide	Rate (a.i.) kg/ha	Placement	n[a]	60[b]	120[b]	n	60	120	n	60	120	n	60	120
AC 64,475	1.12	band	1	+191	53	1	+10	+38	-	--	--	1	+14	+72
AC 64,475	1.68	band	1	+ 79	16	1	19	+57	-	--	--	1	+35	+41
Aldicarb	1.68	band	1	59	33	1	73*[c]	47*	1	43*	56	1	77**	35
Aldicarb	1.68	furrow	1	52	21	1	53	9	1	37*	36	1	55**	8
Carbofuran 10G	0.84	band	1	+209	+146	1	30	+74	-	--	--	1	+ 9	+34
Carbofuran 10G	1.12	furrow	1	+ 10	+ 23	1	+14	+17	1	22	7	1	34	+14
Carbofuran 10G	1.68	band	1	+137	+ 22	1	11	+ 5	-	--	--	1	+30	+43
Carbofuran 10G	2.24	band	1	61*	59	1	58	57*	1	26*	37	1	82**	28
Oxamyl	1.12	furrow	1	17	+ 2	1	44	19	1	39*	13	1	12	18
Oxamyl	1.68	band	1	+224	+ 59	1	18	+ 1	-	--	--	1	+18	+34
Oxamyl	2.24	band	1	38	34	1	80*	65*	1	56*	56	1	78**	40
Terbufos 15G	1.12	band	2	3	11	2	21	+18	1	42	16	2	20	+16
Terbufos 15G	1.12	furrow	1	+112	+54	1	45	+26	-	--	--	1	25	+ 9

Table 4. (concluded)

[a]Number of experiments using identical nematicide treatments.

[b]Days after planting.

[c]*,** indicates a significant difference from control plots at the P=.05, P=.01 level, respectively.

Table 5. Average percent control of nematodes at two sampling times for all locations[a]

Treatment			Nematodes per 100 cc of soil									Lesion nematodes per g dry wt		
	Rate (a.i.)	Place-	Stunt			Lesion			Spiral					
Nematicide	kg/ha	ment	n[b]	60[c]	120[c]	n	60	120	n	60	120	n	60	120
AC 64,475	1.12	band	1	+191	53	1	+10	+38	-	--	--	1	+14	+72
AC 64,475	1.68	band	2	32	58*[d]	2	3	16	-	--	--	2	22	6
Aldicarb	0.84	band	1	60*	33	1	64*	55*	1	65*	54*	1	67	69*
Aldicarb	0.84	furrow	2	39	57**	2	40	31*	1	33	11	1	55*	40**
Aldicarb	1.12	band	1	50	48	1	31	53	-	--	--	1	76**	36
Aldicarb	1.68	band	2	67**	50*	2	84**	61**	2	40**	59*	2	79**	51**
Aldicarb	1.68	furrow	3	48**	32	2	57*	35**	2	43**	33	3	64**	29*
Aldicarb	2.24	band	1	13	55	1	61	65	-	--	--	1	79*	49
Aldicarb	3.36	band	1	60**	93**	1	78*	83**	1	63*	95*	1	89*	90**
Carbofuran 10G	0.84	band	2	+19	10	2	30	+ 3	-	--	--	2	25	+19**
Carbofuran 10G	1.12	furrow	2	+ 1	2	2	+13	3	1	22	7	2	28	+ 3
Carbofuran 10G	1.68	band	3	31	24	3	35	27*	1	42	+10	3	34*	16
Carbofuran 10G	1.68	furrow	1	5	47*	1	18	53	-	--	--	1	30	21
Carbofuran 10G	2.24	band	2	62**	58*	2	48**	49**	2	52**	42**	2	65**	38

Table 5. (cont'd.)

Treatment			Nematodes per 100 cc of soil									Lesion nematodes per g dry wt		
			Stunt			Lesion			Spiral					
Nematicide	Rate (a.i.) kg/ha	Placement	n[b]	60[c]	120[c]	n	60	120	n	60	120	n	60	120
Carbofuran 4F	1.68	band	1	+ 2	13	1	31	28	-	--	--	1	56*	23
Carbofuran 4F	2.24	band	2	45*	35*	2	61	49**	1	44	38	2	69**	44*
Oxamyl	0.56	band	1	53*	37	1	77**	53**	1	59	35*	1	63*	55*
Oxamyl	1.12	band	1	69**	56	1	72	51*	1	53	16	1	81*	74**
Oxamyl	1.12	furrow	1	17	+ 2	1	44	19	1	39*	13	1	12	18
Oxamyl	1.68	band	1	+224	+59	1	18	+ 1	-	--	--	1	+18	+35
Oxamyl	2.24	band	3	52*	37*	3	70**	60**	2	62**	57*	3	73**	53**
Oxamyl	2.24	furrow	1	+ 5	6	1	+13	39	-	--	--	1	59	+ 9
Oxamyl	1.12	band +												
Carbofuran 10G	0.84	band	1	+ 1	27	1	+62	55	-	-	--	1	50*	48
Oxamyl	1.12	furrow +												
Carbofuran	0.84	band	1	58	52	1	31	36	-	--	--	1	56	10
Terbufos 15G	1.12	band	4	27	15	4	11	4	2	36*	20	4	8	5
Terbufos 15G	1.12	furrow	1	+112	+54	1	45	+26	-	--	--	1	25	+ 9

Table 5. (concluded)

[a]Data from Silver Lake were not included, due to differences in sampling times.

[b]Number of experiments using identical nematicide treatments.

[c]Days after planting.

[d]*,** indicates a significant difference from control plots at the P=.05, P=.01 level, respectively.

Table 6. Average percent control of nematodes at two sampling times for various nematicide treatments at Silver Lake

Treatment			Nematodes per 100 cc of soil				Lesion nematodes per g dry wt	
	Rate (a.i.)	Place-	Stunt		Lesion			
Nematicide	kg/ha	ment	30[a]	90[a]	30	90	30	90
Aldicarb	0.56	furrow	44	+15	6	44**[b]	77**	34
Aldicarb	0.84	band	50	4	14	36	68**	36
Aldicarb	1.12	furrow	65	+32	21**	47**	66**	44
Aldicarb	1.68	band	44	39	41	51**	78**	66**
Carbofuran 10G	0.84	band	29	+55	46	22	36*	16
Carbofuran 10G	1.68	band	38	13	15	2	37	+ 4
Carbofuran 10G	2.24	band	50	2	8	9	32	37*
Oxamyl	1.12	band	39	+15	19	24	61**	21
Oxamyl	2.24	band	50	13	25	44**	62*	55*
Oxamyl	1.12	band +						
Carbofuran 10G	0.84	furrow	44	17	38	55*	60**	31
Oxamyl	2.24	band +						
Carbofuran 10G	0.84	furrow	31	+11	25	35**	66**	41

Table 6. (concluded)

Treatment			Nematodes per 100 cc of soil				Lesion nematodes per g dry wt	
			Stunt		Lesion			
Nematicide	Rate (a.i.) kg/ha	Placement	30[a]	90[a]	30	90	30	90
Oxamyl	1.12	band +						
Terbufos 15G	1.12	furrow	47	0	16	32*	70**	19
Terbufos 15G	1.12	band	13	4	+21	45*	35**	7
Terbufos 15G	1.12	furrow	29	3	5	32*	34*	24
Terbufos 15GC	1.12	band	35	19	2	6	19	28
Terbufos 15GC	1.12	furrow	50	29	30*	20	54**	26

[a]Days after planting.

[b]*,**indicates a significant difference from control plots at the P=.05, P=.01 level, respectively.

Table 7. Correlation coefficients between yields and nematode counts during the growing season for each location.

	Nematodes per 100 cc of soil						Lesion nematodes/g dry wt	
	Stunt		Lesion		Spiral			
Location	60[a]	120[a]	60	120	60	120	60	120
Powhattan C-C[b]	-.26*[c]	-.02	-.25	+.17	-.10	+.20	-.02	-.17
Powhattan C-S[b]	+.44*	-.06	+.30	-.01	-.05	-.08	-.25	-.02
Garden City	-.05	-.01	-.10	-.02	--	--	-.09	+.13
Colby	+.14	+.15	-.15	-.37*	--	--	-.13	-.15
Silver Lake	-.41**	-.31**	-.09	-.07	--	--	-.06	-.36**

[a] Days after planting.

[b] C-C and C-S indicate corn grown in continuous culture and corn grown in a rotation system, respectively.

[c] *,** indicates significance at the P=.05, P=.01 level, respectively.

[d] Samples taken at 30 and 90 days after planting.

EFFECTS OF GRANULAR NEMATICIDES ON NEMATODE POPULATIONS AND CORN YIELDS

by

LEO DUANE LASH

B.S., Kansas State University, 1976

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Plant Pathology

KANSAS STATE UNIVERISTY
Manhattan, Kansas

1980

ABSTRACT

Five experiments for evaluating nematicide efficacy in corn were conducted in silt loam soils at four Kansas locations during 1977, 1978, and 1979. Nematode populations were determined at planting and twice during the growing season. Yield response to the application of nematicides was greater in continuous corn culture than in corn grown in a rotation system with either grain sorghum or soybeans. The maximum yield increase was 29.8% for continuously cropped corn and 12.7% for corn grown in rotation. Nematicides controlled the nematodes to varying degrees. In most instances, band applications of nematicides resulted in greater control of nematodes than did furrow applications. Populations of stunt, lesions, and spiral nematodes were inversely correlated with yields at all but one location. The best correlation obtained between yields and nematode populations for one location was r = -.41 (P=.02) for stunt nematodes, *Tylenchorhynchus martini* and *Quinisulcius acutus*, 30 days after planting.