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Responses of Vegetables to Repeated Yearly Applications of Nematocides to Muck Soil

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Responses of Vegetables to Repeated Yearly Applications of Nematocides to Muck Soil

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INTRODUCTION

After several years of growing a series of vegetable crops at the Muck Crops Branch at Celeryville, Ohio, the area available for experimentation had become heavily infested with parasitic nematodes in an irregular pattern of distribution (6). It was impossible to obtain any reliable yield data, even in replicated plots, in variety trials or experiments dealing with the use of insecticides, fungicides, herbicides, and fertilizers.

In an effort to locate the areas of maximum and minimum nematode infestation, all experimental work was suspended in 1956. Then the whole area was divided into plots 24 feet wide and these plots in turn were divided into secondary plots 55 feet long. This provided a total of about 400 plots 24 by 55 feet. Figure 1 illustrates both the manner in which these plots were arranged and the distribution pattern of root-knot infestation on carrot.

Each 24-foot plot was planted to carrot, onion, celery, and potato in bands 6 feet wide. Stand counts, growth measurements, and yield data were then taken in an effort to determine the influence of variations in the nematode populations on plant growth and crop yields.

Since it was impractical to examine the roots of all plants for nematode damage, it was decided to accept the percentage of visibly deformed carrot roots (Figure 2) as an index of the density of populations of the root-knot nematode (*Meloidogyne hapla*) This was the species most damaging to carrots and celery in the muck soil at Celeryville.

Damage to the carrot roots was found to vary from 0 to 100%, the amount apparently being regulated to a considerable extent by the crop previously grown in a specific plot in 1955 (8). The most interesting, as well as the most significant, feature of the data obtained was the wide variation in nematode damage which occurred within distances of 24 by 55 feet (the dimensions of the plots from which the data were taken).

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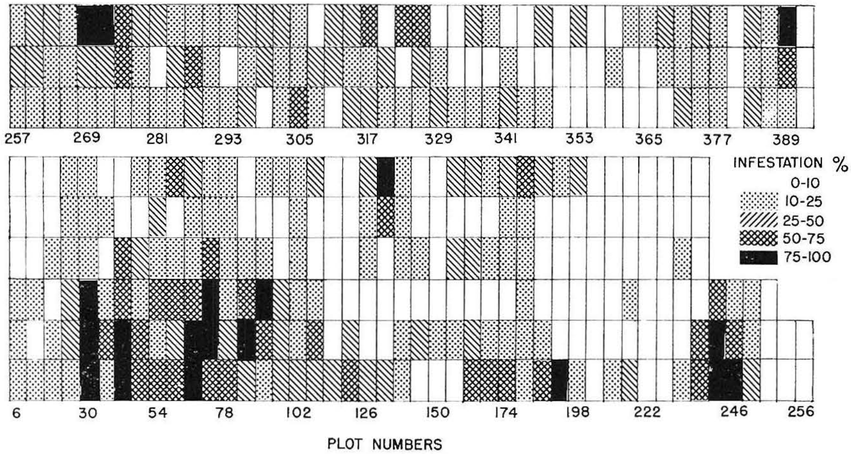

Fig. 1.—Plot layout of Muck Crops Branch, Celeryville, Ohio, and pattern of carrot infestation by root-knot nematodes in 1956.

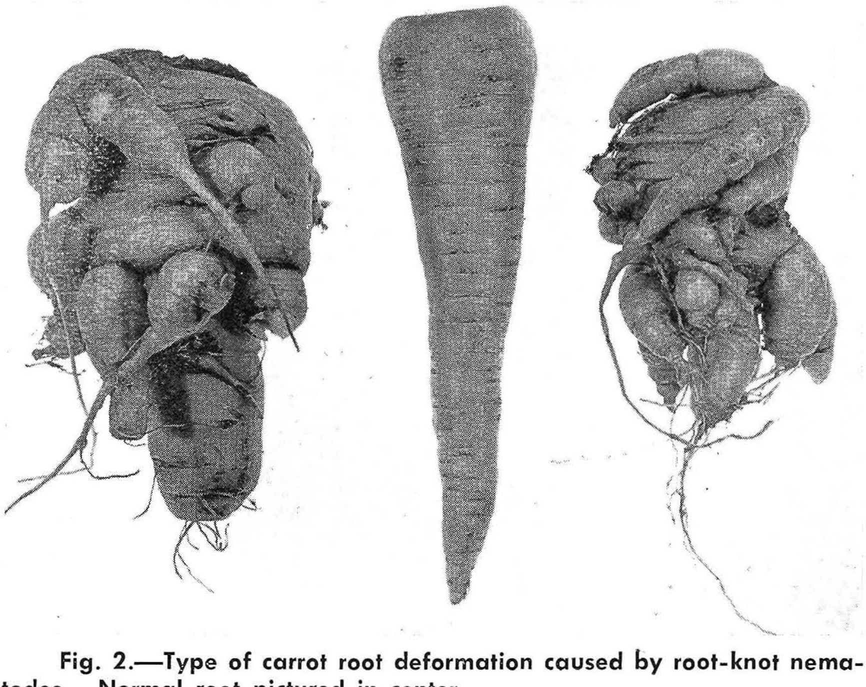

Fig. 2.—Type of carrot root deformation caused by root-knot nematodes. Normal root pictured in center.

In one instance, plots located end to end showed a percentage variation in nematode damage of 2.2 to 87.0%. In two other plots located side by side (a distance of only 24 feet) the variation was from 16.7% in one plot to 73.8% in the adjacent one (Figure 1). The average yields of carrots in the plots with 76 to 100% of the roots deformed were approximately half of those yields where the percentage of infestation was from 0 to 10% (6).

PROCEDURE

In the early fall of 1956, the entire farm of approximately 15 acres was treated with D-D at the rate of 40 gallons per acre. It was assumed that this would eliminate most of the nematodes present and thus make it possible to again obtain data acceptable for use in evaluating the performance of various pesticides, fertilizers, crop varieties, etc. (1, 3, 7).

The plot boundaries established in 1956 (24 by 55 feet) were preserved. Conforming with these, an isolated area 48 by 330 feet at one end of the farm was set aside for an experiment on the effects of repeated yearly applications of a specific nematocide on crop growth and nematode populations (11, 12, 14). This provided a series of six plots each 48 by 55 feet. Five of these plots received a different nematocide and the sixth was left as an untreated check (12).

Beginning in the spring of 1957, these plots received the same nematocidal compounds each year for 9 years. Those used were Dowfume W-85 (EDB), Vapam (SMDC), Nemagon EC-2 (DBCP), Picfume (chloropicrin), and either D-D or Telone (dichloropropenes) (7).[3]

The applications were made each year, at a depth of about 8 inches, between May 12 and 18, whenever the soil temperature reached 55° F. The soil in all plots, including the untreated check, was prepared with a rotary tiller similar to the one shown in Figure 3. SMDC and DBCP were applied during the tilling operation (2). EDB and the dichloropropenes were applied at a depth of 8 inches with the equipment shown in Figure 4, with the applicator blades spaced 10 inches apart. Equipment similar to that in Figure 5 was used to apply chloropicrin (13).

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[3]Mention of a proprietary product in this publication does not constitute a guarantee or warranty by the Ohio Agricultural Research and Development Center or the U. S. Department of Agriculture and does not imply approval by the Research Center or the Department to the exclusion of other products which may also be suitable. No discrimination is intended against any company not mentioned nor is any guarantee implied for the products of the companies listed. The information in this publication shall not be used in sales promotion or in advertising which expresses or implies endorsement of any product by the Research Center or the Department. (See Table 1 for chemical composition and rate of use. These nematocides are referred to below by their generic designations.)

Fig. 3.—Type of rotary tiller used to apply SMDC and DBCP to muck soil and to prepare the soil in the untreated check and before the application of the other nematocides.

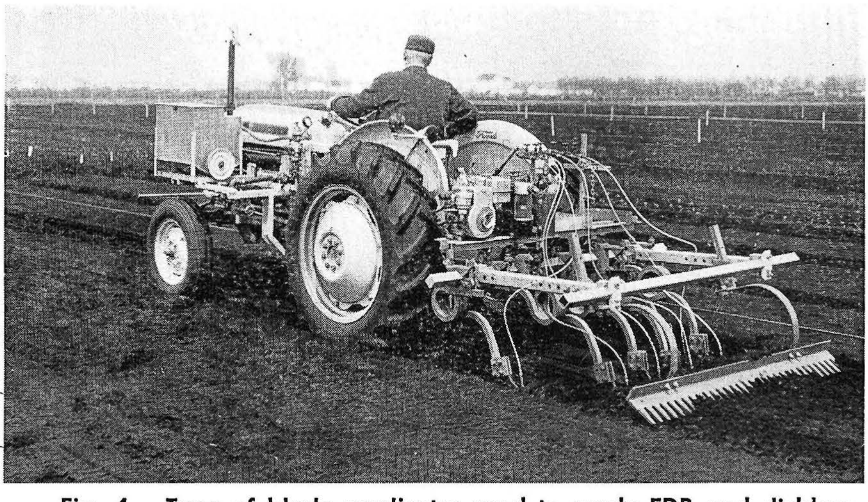

Fig. 4.—Type of blade applicator used to apply EDB and dichloropropenes to soil prepared previously by rotary tilling.

Fig. 5.—Type of specially designed applicator used to apply chloropicrin to the soil for nematode control.

After an interval of 12 to 14 days, chosen to allow the more phytotoxic chemicals to escape from the soil, eight different vegetable crops were planted in 6-foot bands across each plot. These were radish, lettuce, onion, spinach, red beet, carrot, potato, and celery. The first six were planted with a seeder and the potato tubers with a planter; the celery was transplanted. Radish, lettuce, and spinach were planted more than once during the growing season.

Seedling stand and weed counts were made in some instances. The weed counts were made in the band planted to onions. The carrots were always examined at harvest to determine the percentage of roots deformed by the attack of the root-knot nematode (Figure 2). The degree of root-knot infestation was scored on 10 celery plants from each differently treated plot (see Figures 6A and 6B). The potatoes were examined at harvest to check on the degree of scab infection, since that disease was apparently controlled to some extent by some nematocides (10). Comparative plant growth in the differently treated plots was also noted for certain vegetables.

The numbers of nematodes of three different plant parasitic genera (*Meloidogyne, Pratylenchus, and Paratylenchus*) were determined at monthly intervals and in some instances on a bi-weekly basis throughout the growing season (4).

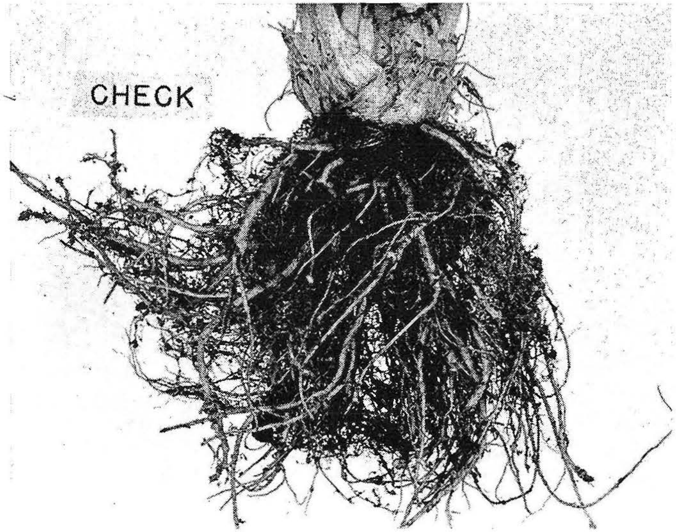

Fig. 6A.—Effect of infestation by root-knot nematodes on the character of the root system of celery growing in muck soil. Specimen taken from untreated check plot in 1962.

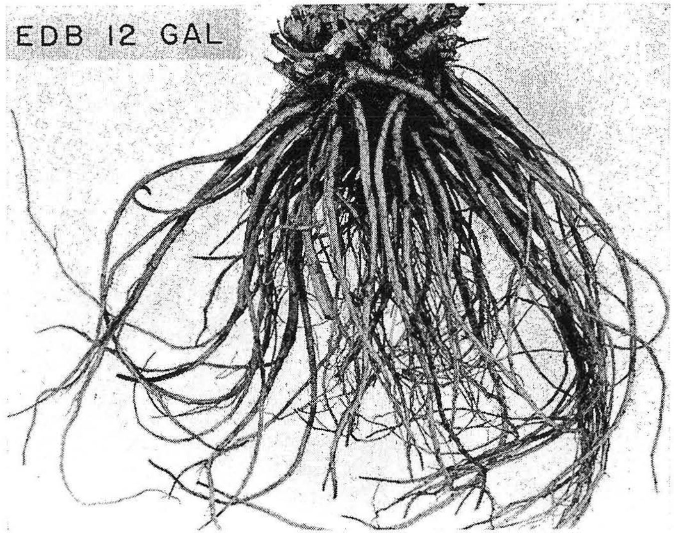

Fig. 6B.—Normal root system of celery. Specimen taken from plot treated with EDB in 1962.

RESULTS

Data for Duration (9 Years) of the Experiment

Yield data were collected each year during the 9-year duration of the experiment (1957-1965) and the averages are given in Table 1. The data include notes on severity of potato scab (*Streptomyces scabies*), the percentage of carrot roots deformed by the root-knot nematode (*Meloidogyne hapla*), the severity of root-knot attack on the roots of celery plants, the average number of nematodes of three genera (*Meloidogyne, Pratylenchus, Paratylenchus*) per pint of soil (4), and the average number of weeds of all species in 20 feet of row in the onion plots in a band 6 inches wide. From these data, it is possible to select which of the six treatments were associated with the highest yields of each vegetable, which gave the best control of the three genera of plant parasitic nematodes most commonly present, and the possible effect of each treatment on a reduction in the severity of potato scab and in weed populations.

Spinach, radish, carrot, and celery gave approximately the same yields with all chemical treatments. However, potato, onion, lettuce, and beet showed varying degrees of yield reduction below that in the untreated checks and in those plots treated with EDB and DBCP, the two compounds containing bromine. Most of this decrease occurred during the last 3 years of the experiment, when the bromine level in the soil had apparently become high enough to exhibit a phytotoxic effect on those crops which proved to be susceptible to injury at the concentration present.

Damage to the roots of celery and carrot by the root-knot nematode was greatest in the check plots (see Figures 6A, 6B, 7A, B, C, D, E, F). However, the yields of these two vegetables were not greatly affected.

The average number of root-knot nematodes was highest in the plot treated with chloropicrin, closely followed by those in the check and SMDC-treated plots. The lowest numbers were in the soil treated each year with DBCP, EDB, and the dichloropropenes. DBCP, which gave excellent control of *Meloidogyne hapla,* gave much less control of *Pratylenchus.* Dichloropropene was most effective against the latter. Dichloropropene and SMDC showed the best average control of *Paratylenchus,* with EDB being comparatively ineffective.

SMDC was the only compound which gave any worthwhile control of weeds, although chloropicrin, dichloropropenes, and EDB gave some reduction.

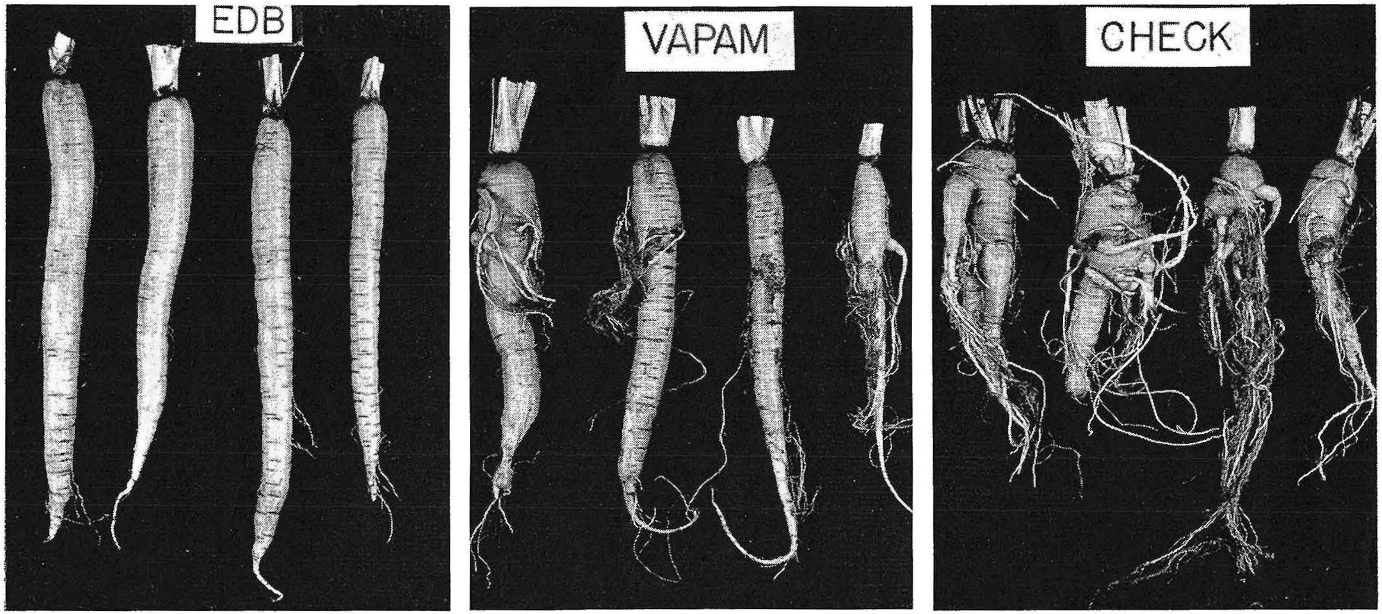

Fig. 7.—Average general appearance of carrot roots grown in muck soil treated with different nematocides.

A.—EDB (Dowfume W-85) at 12 gallon per acre

B.—SMDC (Vapam) at 50 gallons per acre

C.—Untreated check

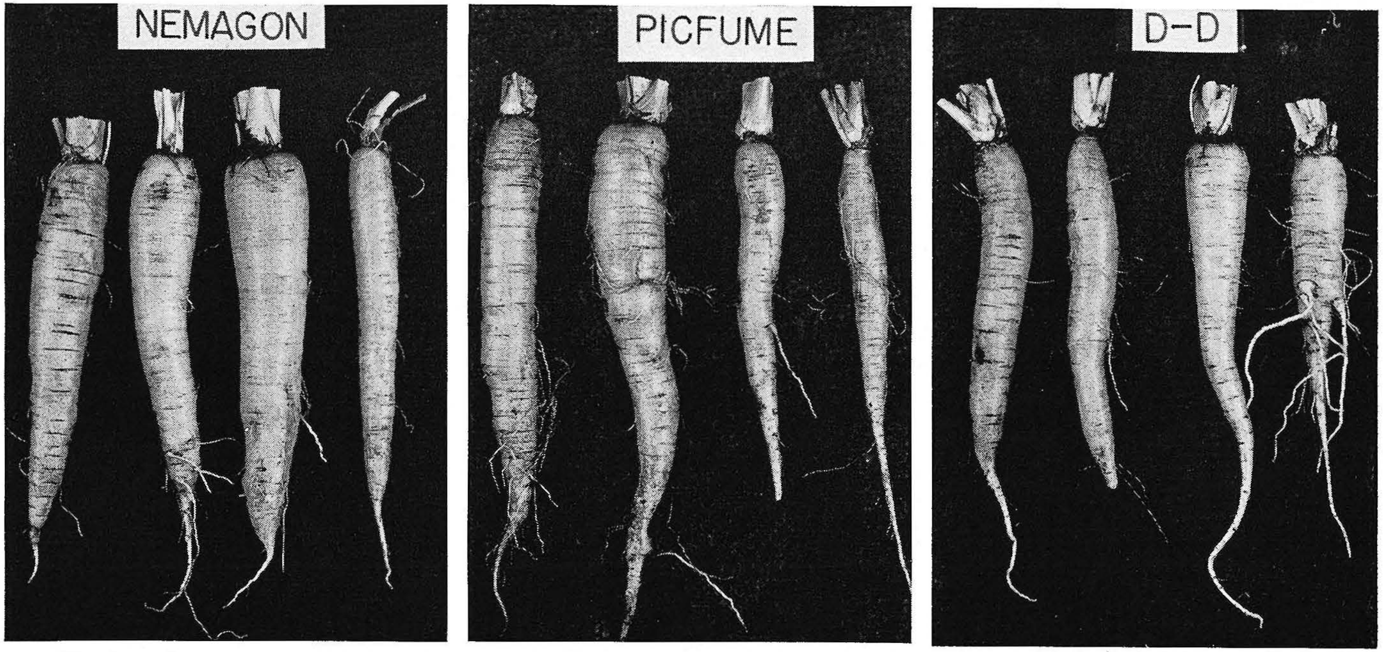

Fig. 7.—Average general appearance of carrot roots grown in muck soil treated with different nematocides.

D.—DBCP (Nemagon EC-2) at 10 gallons per acre

E.—Chloropicrin (Picfume) at 35 gallons per acre

F.—Dichloropropenes (D-D or Telone) at 40 gallons per acre

TABLE 1.—Average Yields Over 9-Year Period of Eight Vegetables Planted in Plots of Muck Soil Treated Each Year with Five Different Nematocides and in an Untreated Check Plot.

Treatment*	Gallons Applied per Acre†	Spinach	Lettuce	Radish	Beet	Onion	
		Tons/A.	Tons/A.	Tons/A.	Tons/A.	Bu./A.	Weeds per 100 Ft. of Row
None (Check)	—	5.88	9.31	13.4	17.6	597	276
Dowfume W-85 (EDB)	12	6.61	7.82	15.1	18.0	445	165
Vapam (SMDC)	50	6.52	9.38	14.0	16.8	644	71
Nemagon EC-2 (DBCP)	10	4.94	7.27	16.4	17.0	0	243
Picfume (chloropicrin)	35-40	5.38	10.00	13.7	20.9	541	104
D-D or Telone (dichloropropenes)‡	40-50	4.67	7.86	14.1	17.1	617	152

Treatment	Gallons Applied per Acre	Potato		Carrot		Celery	
		Bu./A.	Scab Severity 0 = None 4 = Max.	Tons/A.	Percent Deformed by Root-knot	Tons/A.	Root-knot Severity 0 = None 4 = Max.
None (Check)	—	499	1.7	21.0	47.6	17.1	2.69
Dowfume W-85 (EDB)	12	344	3.0	22.0	8.6	18.4	0.07
Vapam (SMDC)	50	509	2.4	22.2	38.0	18.5	2.08
Nemagon EC-2 (DBCP)	10	386	1.0	22.6	9.6	19.0	0.27
Picfume (chloropicrin)	35-40	454	0.7	20.5	19.1	17.2	0.74
D-D or Telone (dichloropropenes)	40-50	449	1.7	20.1	14.0	17.6	0.77

*Dowfume W-85 (EDB)—ethylene dibromide (83%); Vapam (SMDC)—sodium N-methyldithiacarbonmate; Nemagon EC-2 (DBCP)—An emulsifiable formulation of 1,2-dibromo-3-chloropropane (50%); Picfume (chloropicrin)—trichloro nitromethane; D-D—1 to 1 mixture of 1,3-dichloropropene and 1,2-dichloropropane; Telone—1,3-dichloropropene and related chlorinated C_3 hydrocarbons.

†Variations in rate of use represent an increase made in later years of the experiment when it seemed evident that initial rates chosen were not high enough to give a satisfactory degree of nematode control in muck soil.

‡D-D was used during the first 3 years of the experiment and Telone was substituted for it during the last 6 years.

Yields for Last 3 Years

The comparative effects of the various factors in this experiment on yields of the different vegetables are shown more clearly in data for the last 3 years of its duration. These data are presented in Table 2.

It is apparent that neither the number of nematodes in the soil nor the presence of bromine in the nematocides had any marked effect on the yield of carrots. The quality of the crop was greatly reduced, however, by the amount of root-knot damage in the check and SMDC-treated plots.

The yield of celery was reduced somewhat by high nematode populations and the accompanying high incidence of root-knot nematodes on the roots of the plants. The high yield from the DBCP plot indicates that the plants responded to the comparative absence of *Meloidogyne* but were less affected by a high population of *Pratylenchus*.

Potatoes and onions showed definite decreases in yields in the EDB and DBCP plots, indicating an unfavorable growth response to the presence of bromine in the soil. On the other hand, both crops showed yield increases over the untreated check in plots treated with the other three compounds.

Lettuce and beets yielded less with EDB and DBCP than in the untreated check; spinach yields were also slightly depressed in those plots. Radish apparently responded to treatment of the soil with the bromine-containing compounds, EDB and DBCP, with increased yields over the untreated check and larger yields than in the plots treated with SMDC, chloropicrin, or dichloropropene.

Bromine Level and Yields[4]

To further illustrate the relationship which apparently existed between the bromine content of the soil and the yields of the different vegetable crops in this experiment, data obtained in 1964 and 1965 are presented in Table 3 (14). It is evident that the yields of carrot, celery, and radish were not depressed by the levels of bromine in the plots treated with EDB and DBCP. However, potato, onion, beet, and to a lesser extent lettuce and spinach yielded considerably less than the untreated check. The depressing effect of bromine, even though the levels were lower in 1965 than in 1964, was much more marked on beet and spinach in 1965 than in 1964. Carrot yields in the EDB and DBCP plots were actually lower than in the check plot. The depressant effect on lettuce was similar for the 2 years.

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[4]The data on bromine content of the soil and plant tissues was furnished by the Dow Chemical Company.

TABLE 2.—Average Yields of Eight Vegetables During Last 3 Years (1963-65) of 9-Year Interval of Experiment on Plots of Muck Soil Treated Each Year with Same Nematocide.

Treatment	Gallons per Acre	Carrot Tons/A.	Celery Tons/A.	Potato Bu./A.	Onion Bu./A.	Lettuce Tons/A.	Spinach Tons/A.	Beet Tons/A.	Radish Tons/A.
Check (None)	—	29.8	20.2	468	757	7.23	6.39	18.4	14.3
EDB	12	30.4	21.5	280	488	5.66	5.91	15.2	16.2
SMDC	50	29.2	22.1	497	686	8.79	6.83	18.8	14.8
DBCP	10	30.0	22.9	339	0	6.70	5.37	17.6	16.5
Chloropicrin	40	28.8	20.7	499	820	9.97	5.31	20.1	14.6
Dichloropropene	50	32.2	21.2	485	872	9.84	5.68	16.3	14.3

TABLE 3.—Yield Response of Various Vegetable Crops to Comparative Bromine Contents of Soil in Differently Treated Plots of Muck Soil.

Treatment	Gallons Applied per Acre	Bromine Content of Soil (p.p.m.)	Carrot Tons/A.	Celery Tons/A.	Potato Bu./A.	Onion Bu./A.	Lettuce Tons/A.	Beet Tons/A.	Spinach Tons/A.	Radish Tons/A.
1964										
None (Check)	—	32.0	34.6	25.8	570	1085	5.25	7.1	5.7	12.8
EDB	12	56.0	41.1	27.9	415	555	3.90	5.5	5.3	15.0
DBCP	10	68.0	41.6	34.0	365	0	3.96	5.6	3.8	15.8
1965										
None (Check)	—	10.0	30.8	14.1	415	753	12.60	22.6	10.1	11.0
EDB	12	27.0	27.3	15.1	155	463	10.05	12.4	7.4	12.2
DBCP	10	19.5	29.6	15.8	168	0	10.95	19.5	8.0	13.3

The comparatively high bromine content of the untreated check plot can be explained by the possibility that soil was moved by cultivation, as well as wind and water erosion, from an adjacent plot treated with DBCP. However, the 1964 bromine content of a soil sample taken at least 200 feet from the experimental area (and across a roadway) which had never been treated with a bromine-containing nematocide was 24 p.p.m. It was approximately 15 p.p.m. several hundred feet away in a turf area.

Increasing Effect of Bromine on Yields

To demonstrate the manner and degree of change in comparative crop yields during the progress of this experiment, the data on yields have been divided into three 3-year portions. These are then stated as percentages of the total yields for the entire 9-year interval. These percentages are listed in Table 4 for the four vegetables most affected by the gradual addition of bromine to the soil.

The data with respect to EDB and DBCP must be examined in contrast to those of the check plot to determine what took place in the way of a reduction in yields during the last 3-year interval in plots

TABLE 4.—Percent of 9-Year Total Yields of Four Crops Most Susceptible to Bromine Toxicity Which Occurred During Each of Three 3-Year Intervals for Each Treatment. Note Low Percentages for Last 3 Years for Each Group in Plots Treated with EDB and DBCP.

Crop and Year Interval	Check	EDB	SMDC	DBCP	Chloro-picrin	Dichloro-propenes
Potato						
1957-59	31.0	33.8	30.9	31.4	30.4	29.1
1960-62	36.3	39.1	36.6	41.1	32.5	34.9
1963-65	32.7	27.1	32.5	27.5	37.1	36.0
Onion						
1957-59	27.9	30.1	27.6	0.0	24.7	24.2
1960-62	29.4	32.8	27.6	0.0	26.1	27.9
1963-65	42.7	37.1	44.8	0.0	49.2	47.9
Beet						
1957-59	38.0	42.9	32.8	46.4	40.0	38.0
1960-62	28.6	28.4	30.2	25.0	25.8	27.0
1963-65	33.4	28.7	37.0	28.6	34.2	35.0
Lettuce						
1957-59	34.7	30.8	40.0	39.0	30.6	28.8
1960-62	28.6	45.0	28.5	34.3	35.8	31.8
1963-65	36.7	24.2	31.5	26.7	33.6	39.4

TABLE 5.—Comparative Effectiveness of Various Nematocides Against Three Plant Parasitic Nematodes and Resultant Effects on Yields of Five Different Vegetables. Data Are Averages for 6-Year Interval, 1960-65.

Treatment	Gallons Applied per Acre	Average Number of Nematodes per Pint of Soil for Months of July, August, Sept., and Oct. (1960-65)			Radish	Onion	Potato	Carrot		Celery	
		Root-knot*	Lesion	Pin	Tons/A.	Bu./A.	Bu./A.	Yield Tons/A.	Percent Deformed	Yield Tons/A.	Root-Knot Severity 0 = None 4 = Max.
None	—	4010	618	2837	11.7	646	517	23.6	66.7	19.6	3.07
EDB (83%)	12	186	207	2326	13.4	463	342	24.7	9.0	21.7	0.02
DBCP (50%)	10	79	974	249	13.4	0	397	23.9	11.2	22.7	0.25
SMDC	50	2771	213	92	12.4	700	528	24.0	51.8	21.8	2.53
Chloropicrin	35-40	3419	505	305	12.1	621	471	22.8	22.8	19.8	0.48
Dichloropropene	40-50	654	161	107	11.9	694	491	23.8	17.3	21.3	0.47

*Recovered as root-knot nematode larvae.

treated with these bromine-containing compounds. For instance, only 27.1% of the average of the total potato production in the plot treated with EDB occurred during the last 3 years, whereas the corresponding value was 32.7% in the untreated check. The results were similar for the plot treated with DBCP but the percentages for chloropicrin and dichloropropene were actually greater than that of the check plot.

No onions matured in the plot treated with DBCP but 37.1% of the 9-year total production occurred during the last 3-year interval in the EDB plot. However, this was 5 percent below that for the check plot and the other three treatments all exceeded the check during the last 3 years. The data for beets and lettuce were similar, with lettuce showing a considerable percentage drop below the check in the last 3-year interval in the plots treated with EDB and DBCP.

Nematode Populations and Yields

The nematode populations in the differently treated plots affected yields of certain vegetables being grown (9, 11, 12), although this was apparently a minor factor. Since density of these populations was definitely affected by the different nematocides used in the experiment, data relative to the relationships between these population differences and crop growth are presented in Table 5. The yield data of Table 5 represent averages of only the last 6 years of the experiment, since data on nematode populations were collected only during that interval. The yield data presented in Table 1 cover the averages for the entire 9 years of the experiment.

One portion of Table 5 gives the 6-year averages of the three plant parasitic nematodes most commonly present in the muck soil of the Celeryville Branch as they were affected by the five different nematocides. DBCP and EDB gave the best control of the root-knot nematode, with SMDC and chloropicrin giving comparatively poor control. The dichloropropenes (represented by D-D and Telone) gave good control and are most commonly recommended in Ohio for the control of the root-knot and lesion nematode complex whenever it is not advisable to use bromine-containing compounds.

DBCP and chloropicrin gave comparatively little control of lesion nematodes, with fewest in the plot treated with the dichloropropenes. The latter and SMDC gave the best control of lesion nematodes. EDB, which gave good control of root-knot and lesion nematodes, gave very little reduction in the population of the pin form below the number present in the untreated check plot.

Any relationship or correlation which may exist between nematode populations and yields of the five vegetables listed in Table 5 are obscured somewhat by the phytotoxic effects of the various nematocides. These in turn had a definite effect on yields with such crops as onion and potato.

Radish yields were highest with EDB and DBCP and these compounds also gave the best control of root-knot nematodes. However, it is doubtful whether this nematode has any appreciable effect in regulating radish yields (5, 11, 12). Furthermore, the yield of radishes was lowest with the dichloropropenes where the control of root-knot nematodes was comparatively good, both in terms of population and visible infestation of celery and carrot. It appears that the population density of lesion nematodes had little effect on radish yields, since crop production was similar in plots as widely separated in nematode numbers as EDB and DBCP. There was little or no apparent correlation between numbers of pin nematodes and radish yields.

The yields of onion and potato were obviously affected unfavorably by EDB and DBCP and any yield effects of nematode populations in those plots were negligible. SMDC gave the highest yields of these two crops in the experiment, in spite of comparatively high numbers of root-knot nematodes. The yields in the untreated check plot were also high.

Dichloropropene gave higher yields of both crops than chloropicrin, with lower populations of all three nematodes. However, this may have been partially due to poorer average stands of plants in two or

TABLE 6.—Percent of Potato Tubers Free of Scab in Plots Treated Each Year for 9 Years with Same Nematocidal Compound. Data Are for Last 7 Years of Experiment in Percentage Free of Scab and for Last 4 Years Where Severity of Infection Was Estimated.

Treatment	1959	1960	1961	1962	1963	1964	1965	Average
None	52.1	76.2	29.1	50.8	18.6	6.7	2.0	33.6
EDB	25.8	56.4	12.0	14.3	0.0	0.0	0.0	15.5
SMDC	31.4	70.0	27.3	26.0	1.4	1.5	0.0	22.5
DBCP	56.4	71.5	40.7	65.3	50.0	30.9	34.0	49.8
Chloropicrin	68.4	78.9	61.3	83.8	58.0	38.1	43.0	63.0
Dichloropropenes	58.2	59.6	48.0	38.3	27.3	7.4	7.0	35.1
Treatment*								
None				0.70	1.20	1.44	2.47	1.45
EDB				2.87	3.23	2.90	3.07	3.02
SMDC				1.04	2.80	1.91	3.05	2.20
DBCP				0.39	0.83	0.78	0.81	0.70
Chloropicrin				0.25	0.38	0.81	0.78	0.56
Dichloropropenes				0.62	1.07	1.45	1.89	1.26

*In this section of Table 6, the severity or degree of scab infection is shown by a value varying from 0 for no scab lesions present to 4 for a maximum number of lesions.

three instances in which chloropicrin had not completely escaped from the soil at the time the crops were planted.

Carrot and celery yields were usually higher in the plots treated with EDB and DBCP where the root-knot populations were low. There were obviously some depressing effects on yields of these two crops by the large numbers of all three nematodes in the untreated check plot. However, the yields of both carrot and celery were also high in the plot treated with SMDC, in spite of a comparatively high degree of root-knot infestation on the roots of both crops.

Thus, although certain plots treated with the different nematocides usually gave higher yields of the five crops listed in Table 5 than the untreated check, these were not always the plots in which population of any specific nematode was lowest.

Nematocides and Potato Scab

Since there seemed to be some difference in the development of potato scab in the differently treated plots, it was decided in the fall of 1959 (the third year of the experiment) to determine the percentage of tubers free of scab lesions. The counts were continued each year until the end of the experiment and the data are presented in Table 6.

From the beginning, a smaller percentage of tubers from the plot treated with EDB was free of scab than in any other plot and there were more clean tubers among those from the chloropicrin-treated plot than from any other. These conditions persisted, with the result that the average percentage of tubers free of infection in the plot treated with chloropicrin was four times as great at the end of the experiment as in the plot which received EDB. Scab was twice as prevalent with EDB as in the untreated check plot. The plot treated with SMDC also produced more scabby tubers than the check.

The severity of scab infection varied widely. The tubers were graded on a scale in which tubers with no lesions were rated as 0 and those with 12 or more lesions were given a 4 rating, with lower numbers of lesions rated at 1, 2, or 3. The ratings were then multiplied by the number of tubers in the sample which bore a given rating and an average rating was obtained. These data were collected for the last 4 years of the experiment and the results are shown in the lower portion of Table 6.

Chloropicrin again gave the lowest average value, which represents the fewest lesions, and the EDB plot showed the most infection. SMDC was higher than the check, dichloropropene slightly lower, and the DBCP and chloropicrin plots considerably lower. These data suggest that injury to the potato seed pieces and the young plants by EDB may

TABLE 7.—Comparative Number of *Fusarium* **Propagules on Agar Plates per Gram of Soil Cultured from Differently Treated Plots of Muck Soil in 1959 After 3 Years of Successive Treatments. Data Are in Thousands of Propagules per Gram of Soil.**

Treatment	April	May	June	July	August	Sept.	Oct.	Average
None	17	18	21	26	26	27	21	22.3
EDB	10	16	23	21	14	14	26	17.7
SMDC	22	10	18	11	11	19	36	18.1
DBCP	9	10	15	14	16	22	27	16.1
Chloropicrin	7	6	5	8	8	15	7	8.0
D-D	18	13	19	20	27	37	37	23.0
Monthly Average	12	12	17	17	17	21	22	

have made the newly developing tubers more susceptible to infection by scab. It also is possible that chloropicrin reduced the infectivity of the causal organism *Streptomyces scabies.*

Effect of Nematocides on Fusaria

During the summer of 1959, soil samples were taken from the treated plots and cultured for the presence of the fungus genus *Fusarium.* Species of this fungus are common in the muck soil of the area, where they cause radish and celery "yellows" (5). The number of *Fusarium* propagules per gram of soil are shown in Table 7. All but one treatment (D-D) showed some reduction below the check in the number of propagules present on the agar plate cultures. Chloropicrin showed a 64% reduction below the untreated check plot.

In other experiments conducted by the authors, Picfume and Trizone, two nematocidal preparations containing chloropicrin, have proven to be two treatments most likely to give a reduction in the *Fusarium* and *Verticillium* wilts of vegetables in Ohio. However, neither of these diseases caused any appreciable losses in the different plots of this experiment. Neither radish nor celery yellows were believed responsible for the retarded growth or death of any plants. The concentration of the fungus tended to increase as the season advanced, with the maximum occurring in October, the final month in which samples were taken.

SUMMARY

Five different nematocides, including two which contained bromine, were added each year for 9 years to the same muck soil plots, with a check plot left untreated. The experiment was designed to study the influence of cumulative residues of the nematocides on the growth of eight different vegetables and on nematode control. Bromine residue determinations were made during the last 2 years of the experiment.

The treatments used were Dowfume W-85 (EDB), Vapam (SMDC), Nemagon EC-2 (DBCP), Picfume (chloropicrin), and D-D or Telone (dichloropropenes). The vegetables were radish, lettuce, onion, carrot, spinach, beet, celery, and potato. The plant parasitic nematodes considered were *Meloidogyne hapla, Pratylenchus* spp. and *Paratylenchus* spp.

Data were taken on yields, infestation by root-knot on celery and carrot, numbers of nematodes, scab infection on potatoes, and in some instances counts of stand and weed populations. The nematocides were applied about mid-May and the vegetables were planted about 2 weeks later, after the nematocides had an opportunity to escape from the soil.

Radish, carrot, and celery gave approximately the same yields in all six differently treated plots. Onion, potato, and to a lesser extent lettuce, beet, and spinach showed reductions in yields below the untreated check in plots treated with the bromine-containing compounds (EDB and DBCP). Most of the decrease in the presence of bromine occurred in the last 3 years of the experiment.

The onion seedlings never lived more than 3 weeks after emergence in the DBCP plot. They matured progressively later each year in the plot treated with EDB, with some plants failing to form bulbs during the last 3 or 4 years.

Potato seed pieces formed fewer and less vigorous plants in the plots which received bromine than in the other four plots. Potato yields fell further behind those of the check plot each year the experiment was continued.

Beet and onion were showing a gradual decrease in yields in the bromine-treated plots during the last 2 or 3 years of the experiment. This also was partially true of spinach. Radish actually yielded better in the 8th and 9th years in the plots treated with EDB and DBCP than in the untreated check.

Potato scab was most severe in the plot treated with EDB and least prevalent in the one treated with chloropicrin. Weeds were least numerous in the plot treated with SMDC, followed by chloropicrin. Damage to the roots of celery and carrot by the root-knot nematode

(*Meloidogyne hapla*) was greatest in the untreated check plot, with nearly as much damage in the plot treated with SMDC. However, the yields of both crops were not decreased greatly in either plot, although the quality of the carrots was very poor due to root deformation.

DBCP and EDB gave the greatest reduction in *Meloidogyne* populations. SMDC and chloropicrin gave comparatively poor control. DBCP and chloropicrin gave rather poor control of *Pratylenchus*. SMDC and the dichloropropenes gave the best results with both lesion and pin nematodes. EDB, which gave good control of root-knot and lesion nematodes, gave little reduction in the populations of *Paratylenchus*.

Bromine residues remained low in the plots treated with EDB and DBCP until September and October, even though the treatments had been applied in May. Bromine was found in areas some distance from the site of the experiment, indicating a natural bromine content of 10 to 20 p.p.m. in the soil in October. This suggests that these levels of bromine are not phytotoxic. This was in contrast to 56 and 68 p.p.m. in plots treated with EDB and DBCP, respectively. These amounts were definitely injurious to certain vegetables. All vegetables tested accumulated more bromine in their tissues than was present in the soil in which they were growing. More bromine accumulated in the tops of beets and radishes than in the roots.

Potato scab became progressively more prevalent each year with all treatments. The increase was most rapid in the plot treated with EDB, followed in a progressively slower trend by SMDC, the untreated check, the dichloropropenes, DBCP, and chloropicrin. By 1965, all tubers in the plots treated with EDB and SMDC showed some lesions, only 2% were free of lesions in the check plot, and 43% were free of lesions in the plot treated with chloropicrin. There were more lesions per tuber in the plot treated with EDB than with any of the other treatments. Lesions were fewest in the plot which received chloropicrin.

The potential for infection by *Fusarium* diseases was highest in the plot treated with D-D in 1959, 3 years after the experiment was initiated. It was closely followed by the untreated check, with the least potential for infection in soil samples taken from the plot treated with chloropicrin.

LITERATURE CITED

1. Good, J. M. and A. L. Taylor. 1965. Chemical control of plant parasitic nematodes. Agri. Res. Serv., U. S. Dept. Agr., Agri. Handbook 286:1-28.
2. Hedden, O. K., J. D. Wilson, and J. P. Sleesman. 1966. Equipment for applying soil pesticides. Agri. Res. Serv., U. S. Dept. Agr., Agri. Handbook 297:1-36.
3. Hollis, J. P. and M. J. Fielding. 1958. Population behavior of plant parasitic nematodes in soil fumigation experiments. La. Agri. Exp. Sta., Bull. 515:1-30.
4. Walker, J. T. and J. D. Wilson. 1960. The separation of nematodes from soil by a modified Baermann funnel technique. Plant Dis. Reptr. 44:94-97.
5. Wilson, J. D. 1956. Seek method to control radish disease caused by a soil fungus. Ohio Agri. Exp. Sta., Ohio Farm and Home Res. 41(301):52-54.
6. Wilson, J. D. 1957. A distribution pattern of root-knot nematode infestation on muck-grown carrots. Down-to-Earth 13(1):4-7.
7. Wilson, J. D. 1961. Comparative effectiveness of various nematocides in the control of root knot in muck soils. Plant Dis. Reptr. 45 (7):534-538.
8. Wilson, J. D. 1964. Influence of preceding vegetable crop on nematode populations the previous year. Plant Dis. Reptr. 48(6):500-501.
9. Wilson, J. D. 1964. Nematode populations that accompany vegetables grown in monoculture. Ohio Agri. Exp. Sta., Ohio Farm and Home Res. 49(3):45-47.
10. Wilson, J. D. 1965. Response of potatoes to the repeated use of nematocides. Abstr., Amer. Potato J. 42(10):300.
11. Wilson, J. D. and Orve Hedden. 1961. Nematode populations in muck soil treated each year with the same fumigant. Down-to-Earth 17(1):6-10.
12. Wilson, J. D. and Orve Hedden. 1964. Effect of repeated applications of nematocides on vegetable yields and nematode populations in muck soils. Plant Dis. Reptr. 48(9):698-702.
13. Wilson, J. D., Orve Hedden, and C. A. Reimer. 1958. Field application of chloropicrin for the control of soil-inhabiting nematodes, fungi, bacteria, and insects affecting vegetable crops. Down-to-Earth 13(4):13-16.
14. Wilson, J. D. and M. G. Norris. 1966. Effect of bromine residues in muck soils on vegetable yields. Down-to-Earth 22:15-18.

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