Soil Property Influences on *Xiphinema americanum* Populations as Related to Maturity of Loess-Derived Soils[1]

D. P. SCHMITT[2]

Abstract: Field populations of *Xiphinema americanum* around roots of *Syringa vulgaris* 'President Lincoln' were larger in Marshall silty clay loam, a medially developed loess soil, than in Monona silt loam, a minimally developed loess soil. Most *X. americanum* occurred in the top 15 cm of soil, with few below 30 cm. Maximum numbers occurred in August of both years in the Marshall soil, and in August 1969 and June 1970 in the Monona soil. Population fluctuations during the growing season were coincident with changes in soil moisture content. Although the population fluctuation pattern was the same at each depth tested, the adult-to-juvenile ratio increased in one soil while it decreased in the other. Numbers of *X. americanum* decreased as root weights decreased within a soil profile, but they were not correlated with root weights over all soils and depths. More *X. americanum* were recovered from the Marshall than from the Monona soil, but fibrous root weights were greater in the Monona soil. Survival of *X. americanum* in soil columns in growth chamber experiments was better in the Marshall than in the Monona soil. Movement and survival were different in identically textured Monona A and B horizon soils. Factors related to the ion exchange sites may affect *X. americanum. Key Words:* cation exchange capacity, ions, movement.

Received for publication 6 November 1972.

[1] Journal Paper No. J-7430 of the Iowa Agriculture and Home Economics Experiment Station, Ames 50010. Project No. 1851.

[2] Department of Botany and Plant Pathology, Iowa State University, Ames 50010. Present address: Division of Plant Industries, Tennessee Department of Agriculture, P.O. Box 40627, Melrose Station, Nashville 37204.

Little is known about the biology of *Xiphinema americanum* Cobb. Soil type (12) and climatic factors (7, 12) are suggested as being important in relative population size. Soil moisture (6, 10, 15) and soil temperature (6, 10) influenced *X. americanum* populations under laboratory conditions. These factors may

account for the similar population trends of *X. americanum* in different geographical areas (4, 5, 7, 11, 12).

The importance of different edaphic factors in determining population magnitudes and fluctuations are difficult to measure because of variation in soils, soil profiles, and climate regimes in most previous studies (4, 5, 7, 11, 12). The purpose of this research was to study the activities of *X. americanum* on common lilac, *Syringa vulgaris* L. 'President Lincoln', at different depths in Monona silt loam, a minimally developed loess soil; i.e., one in which the soil profile has differentiated only slightly from the homogenous parent material, and Marshall silty clay loam, a medially developed loess soil; i.e., one that has differentiated moderately from the parent material. Investigation of soil factors that might be governing nematode populations was included. Loess soils were selected because they were derived from homogenous parent material and any differences are due primarily to weathering.

MATERIALS AND METHODS

FIELD EXPERIMENT: Population and vertical distribution patterns of *Xiphinema americanum* were investigated in Monona silt loam near Hamburg, Iowa, and in Marshall silty clay loam near Shenandoah, Iowa. The soils at these two sites about 30 miles apart were originally prairie but have been planted with nursery crops and lilacs in particular for at least 8 years. *Xiphinema americanum* was the dominant nematode at both locations. Small numbers of *Helicotylenchus pseudorobustus* (Steiner) Golden, *Meloidogyne hapla* Chitwood, *Pratylenchus vulnus* Allen and Jensen, and *Tylenchorhynchus acutus* Allen were found occasionally.

A 15-m row of lilacs at each site was subdivided into four replicates. Samples were collected with a 7.6-cm diam soil bucket auger and placed in polyethylene bags at monthly intervals from August 1969 through September 1970, excluding January and February 1970. Two samples were composited from each replicate at depths of 0-8, 8-15, 15-23, 23-31, 31-38, 38-46 and 46-61 cm. Sample holes were filled with soil and staked, and each successive sample was taken 30-46 cm from the previous one. Nematodes were extracted from 250 cc of soil within 2 days of sampling by a modification of the Christie and Perry (2) method.

Roots from each sample were oven-dried and weighed. Soil moisture of each sample was determined and calculated as a percentage of field capacity (14). Soil thermographs were used to record temperatures at 8, 19, 31 and 43 cm depths in the Marshall soil, and 8 and 31 cm in the Monona soil.

Each replicate for one sampling period was analyzed for soil texture, field capacity (FC) (14), cation exchange capacity (CEC), organic matter (OM), total nitrogen (N), ammonium nitrogen (NH_4^+), nitrate nitrogen (NO_3^-), phosphorus (P), potassium (K), pH (13) and electrical conductivity (EC) (1) as a measure of soluble salts (Table 1).

GROWTH CHAMBER EXPERIMENTS: Three experiments were designed to test the effects of A and B horizon soils of Monona silt loam and Marshall silty clay loam on survival and distribution of *X. americanum* in a controlled environment using growth chambers. The A horizon in both soils was 30 cm deep, and the B horizon soil was collected from the next 30 cm of the profile. An apparatus was designed and constructed to control moisture and temperature in the nematode's environment (Fig. 1). A water tank was attached to soil columns, each consisting of a series of either six 2.5 cm or three 5.1 cm long × 2.2 cm inside diam glass cylinders. The glass cylinders were taped together, waterproofed on the outside with paraffin and placed in a water bath. Blotter paper was placed at the bottom of the column to prevent the irrigation tube from becoming blocked with soil. Autoclaved soil was added to half-fill the column. *X. americanum*, collected at the field plots, was added with a pipette, and the column was filled with soil. The soil was kept as near FC as possible by adjusting the water level in the tank. Water in the water bath prevented rapid temperature fluctuations.

The photoperiod for each experiment was 14 hr. In Experiment 1, half of the treatments were placed in a growth chamber at 27 C and the remainder in a growth chamber at daily fluctuating temperatures of 13-24 C. In Experiment 2, half of the treatments were placed in a growth chamber at 24 C and the remainder in a growth chamber with daily fluctuating temperatures of 18-32 C. Daily fluctuating temperatures of 18-27 C were used in Experiment 3. The soil columns were not planted in Experiment 1 and in half of the replicates of Experiment 3. Lilac seedlings (one/column) were planted in all columns of

TABLE 1. Soil analysis of Monona silt loam and Marshall silty clay loam.

Depth	Soil fraction and particle size (μm)			CEC[a,c]	Field capacity[c]	Organic matter	N	NH_4^+	NO_3^-[c]	P[c]	K[c]	pH[c]	Electrical[b,c] conductivity
	Sand[c] (50-2000)	Silt (2-50)	Clay[c] (<2)										
(cm)	(%)	(%)	(%)	(meq/100g)	(%)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)		(mmho/cm)
						Monona							
0-8	18	55	27	7.5	23	2.8	0.14	88	21	193	280	5.9	1.49
8-15	18	55	27	8.1	23	2.8	0.14	95	21	134	188	5.8	1.41
15-23	19	54	27	9.1	24	3.3	0.17	130	17	118	184	5.6	1.69
23-31	19	54	27	10.0	26	3.4	0.17	102	26	134	189	5.5	1.19
31-38	19	54	27	10.4	25	3.1	0.16	48	30	91	207	5.6	1.37
38-46	19	54	27	9.5	24	2.6	0.13	96	34	100	180	5.5	1.47
46-61	19	54	27	10.3	26	2.3	0.12	73	24	100	195	5.5	0.99
						Marshall							
0-8	16	54	30	11.2	27	3.1	0.16	112	36	556	345	5.4	0.63
8-15	16	54	30	11.9	25	3.3	0.14	108	33	426	272	5.0	0.50
15-23	16	52	32	13.3	27	2.8	0.14	121	34	358	231	4.8	0.69
23-31	16	49	35	14.7	28	3.1	0.16	108	46	187	185	4.6	0.45
31-38	16	51	33	17.0	30	3.0	0.15	140	51	179	201	4.6	0.47
38-46	16	50	34	17.8	30	2.8	0.14	71	29	109	206	4.8	0.45
46-61	16	48	36	19.0	29	2.4	0.12	74	21	164	200	4.8	0.30

[a]Cation exchange capacity; expressed as meq/100 g.
[b]Measure of soluble salts expressed as mmho/cm.
[c]Significant ($P = 0.05$) between Monona and Marshall soils.

Experiment 2 and in the remaining columns of Experiment 3. Inocula of 600, 320 and 530 *X. americanum* were added to columns of Experiments 1, 2 and 3, and the tests were terminated after 15, 28 and 34 days, respectively.

RESULTS

Soil analyses are presented in Table 1. The two soils were dissimilar (P = 0.05) for all factors measured except OM, N and NH_4^+. CEC, NO_3^- and P were the only measured soil factors that were significantly different between the Monona A and B horizon soils (P = 0.05), whereas the composition of each layer in the Marshall silty clay loam was different (P = 0.05).

FIELD STUDY: Fewer *X. americanum* were extracted from the Monona silt loam than from the Marshall silty clay loam profiles (P = 0.01), although the former contained more roots (P = 0.05) (Table 2). Numbers of nematodes decreased with increasing depth, and few were recovered below 30 cm. Numbers also decreased as the root weight decreased within a profile, but there was no correlation between numbers of nematodes and weight of fibrous roots over all sample dates and depths (r = 0.24 for adults, r = 0.19 for juveniles).

Population fluctuations in Fig. 2 are for the 0 to 8-cm depth; data from other depths reflect similar trends and are not given. Greatest numbers occurred in August, except when soil moisture was less than 30% of field capacity in the Monona soil. Small peaks were observed in November, March and June. Most gravid females were found in June in the Monona soil and August in the Marshall soil. Gravid females were found as deep as 15 cm in the Monona soil and 38 cm in the Marshall soil.

Population fluctuations of adults and juveniles were similar at all depths for a given soil and often followed similar trends in the two soils (Fig. 2). The adult-to-juvenile ratios, however, were opposite; i.e., when the adult-to-juvenile ratio was increasing in one soil, it was decreasing in the other until late in the experiment when water tensions (Fig. 2) were most dissimilar in the two soils.

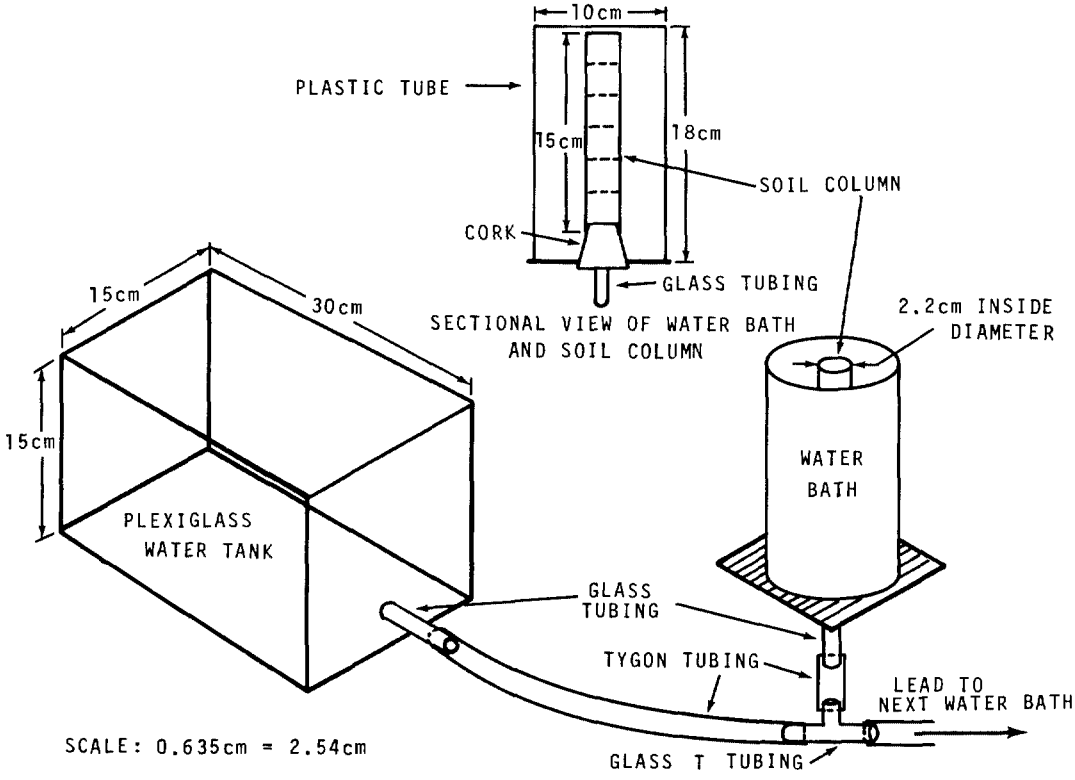

FIG. 1. Apparatus used to study influence of the A and B horizon soils of Monona silt loam and Marshall silty clay loam on the survival and movement of *Xiphinema americanum*. See text for explanation.

TABLE 2. Average weights of lilac roots and numbers of *Xiphinema americanum* adults and juveniles over all sampling periods and depths in the Monona silt loam and Marshall silty clay loam, August 1969 - September 1970.

Soil	Depth (cm)	Root wt[a] (g)	*Xiphinema americanum*[b] Adults	*Xiphinema americanum*[b] Juveniles
Monona	0-8	2.42	54	40
	8-15	1.59	50	52
	15-23	0.77	16	19
	23-31	0.46	9	7
	31-38	0.38	6	6
	38-46	0.38	3	5
	46-61	0.24	1	3
Marshall	0-8	1.19	101	123
	8-15	0.65	91	120
	15-23	0.39	36	33
	23-31	0.23	12	13
	31-38	0.17	5	10
	38-46	0.10	3	2
	46-61	0.11	2	2

[a]Oven-dry root weights were significant (P = 0.01) between soils. Each figure is the average of four replicates.

[b]Numbers of *Xiphinema americanum* adults and juveniles were significantly different (P = 0.01) between soils and depths within a soil.

Numbers of *X. americanum* did not follow changes in soil temperature, but were greater when average minimums were above 15 C. Population fluctuations followed soil moisture changes during the growing season (Fig. 2).

GROWTH CHAMBER EXPERIMENTS: Survival of *X. americanum* was greater in the A horizon of Marshall soil than in the A horizon of Monona soil (P = 0.01, Experiments 1 and 2, Fig. 3-A). Survival was greater in the B horizon of Marshall soil than in the B horizon of Monona soil, but only significantly so in Experiment 1 (Fig. 3-A). *X. americanum* survived better in the B horizon of both soils than in the A horizon (Fig. 3-A). This contradicts the results of the field experiment, but in the field, the A horizon contained the greater food source for the nematodes whereas experiments in the columns were designed to avoid effects of root distribution.

Survival in the Marshall soil was enhanced by alternating temperatures. *X. americanum* extracted from columns containing lilac seedlings were active, and their intestines were full of food; whereas intestines of nematodes from unplanted columns were vacuolated and most were dead at the end of the experiment.

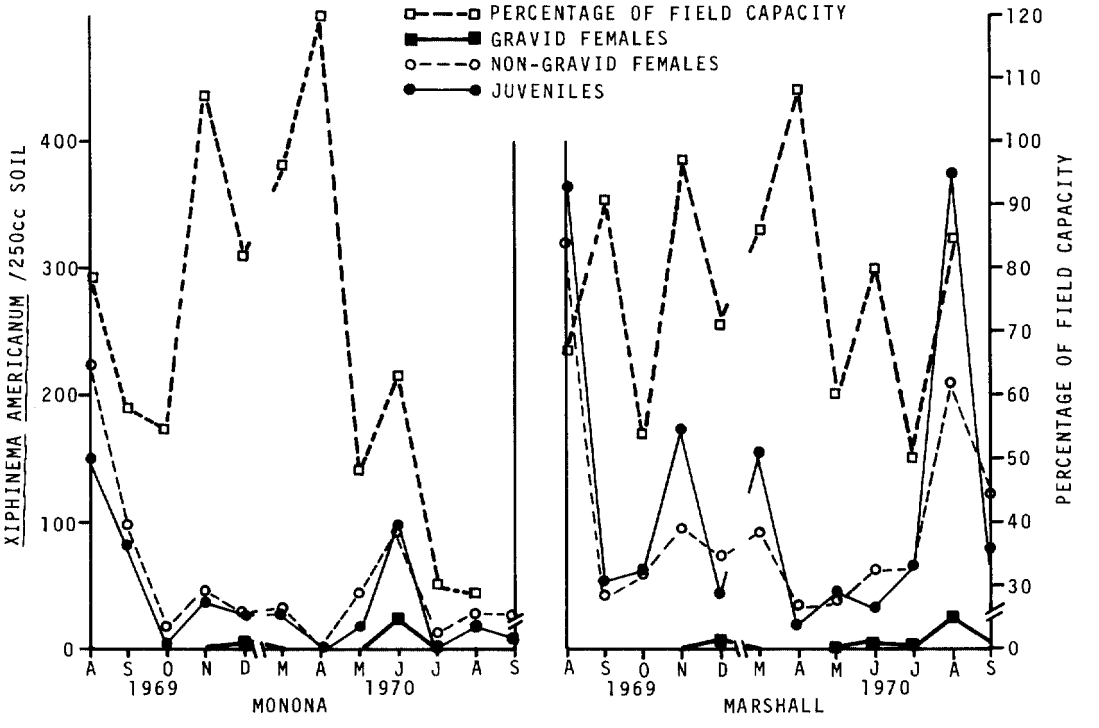

FIG. 2. Population fluctuation of *Xiphinema americanum* around lilac 'President Lincoln' roots in Monona silt loam and Marshall silty clay loam soil from August 1969 through September 1970. 0-8 cm.

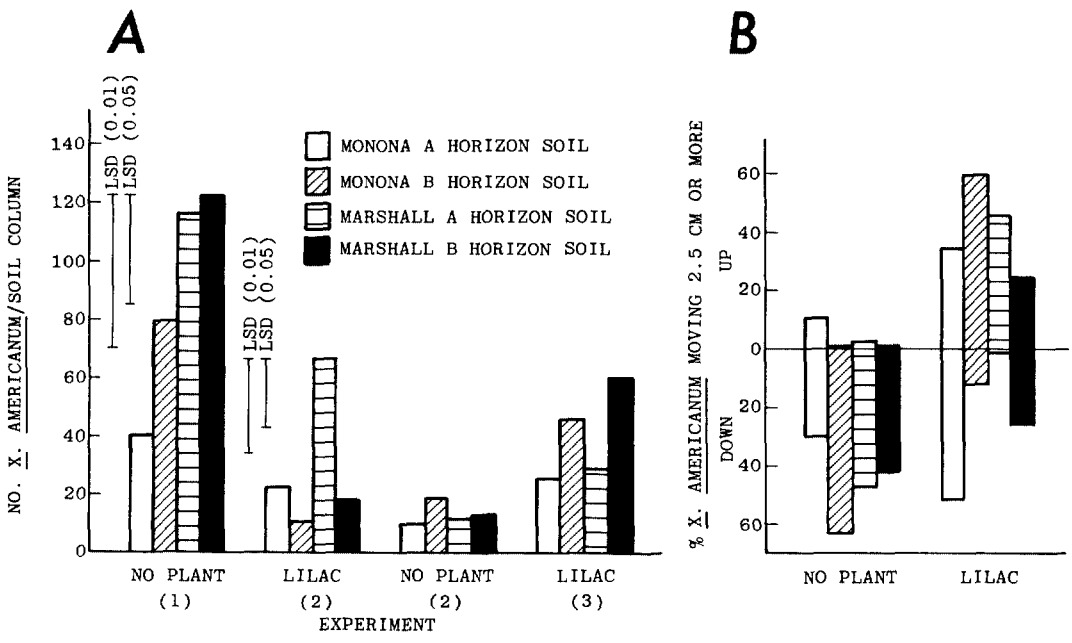

FIG. 3. **A.** Survival of *Xiphinema americanum* in 15-cm soil columns containing Monona silt loam and Marshall silty clay loam from A and B horizons. **B.** Percentage of *Xiphinema americanum* moving vertically at least 2.5 cm in 15-cm soil columns containing Monona silt loam and Marshall silty clay loam from A and B horizons. 1970.

When *X. americanum* were placed 8 cm deep in the unplanted columns, most were extracted below the point of infestation, but some moved upward in the Monona A horizon soil (Fig. 3-B). In columns planted with lilac seedlings, most nematodes moved upward in the Monona B and Marshall A horizon soils, but in both directions in Monona A and Marshall B horizon soils (Fig. 3-B). The same pattern of movement occurred in the columns planted with lilac in Experiment 3, but few survived the 34 days in unplanted columns so that a comparison with Experiment 1 could not be made. Some nematodes were extracted at least 5 cm from the point of infestation by the end of the experiments.

DISCUSSION

The silty clay loam was more suitable than the silty loam for *X. americanum* in both the soil columns and field plots. Soil texture and structure are physical factors important to nematode distribution (3, 8, 9, 17). These factors relate to moisture and space that affect the nematode's ability to survive. My research indicates that other factors are important based upon evidence in movement and survival in the A and B horizons of the Monona soil. CEC, NO_3^- and P were the only three of 10 factors that differed significantly ($P = 0.05$) in the identically textured horizons.

Although not determined, structure was probably not important in the growth chamber experiments because these soils have a moderately developed granular structure which was destroyed in handling and processing. Thus, ions such as P or NO_3^- could be factors in differences in survival and movement of *X. americanum* in the A and B horizons of the Monona soil. NO_3^- has been shown to affect numbers of *Pratylenchus penetrans* (16).

The threefold greater EC in the Monona than in the Marshall soils was not at a concentration that affects salt-sensitive plants, but it may be important to the development of *X. americanum*. This aspect of nematode ecology needs to be elucidated. NO_3^-, P and CEC influence plant growth, which could then affect *X. americanum*, possibly by greater plant resistance or susceptibility of seedlings. Since the lilac seeds were collected from a single source, one or more soil properties were probably the important factors in this study. Furthermore, in the absence of plants, the survival of *X. americanum* was significantly greater in the Marshall than in the Monona soils

(Fig. 3-B). Probably NO_3^-, P or CEC alone or in combination, or other factors not measured, affected the behavior and survival of *X. americanum.*

LITERATURE CITED

1. BOWER, C. A. and L. V. WILCOX. 1965. Soluble salts. p 933-951. *In* C. A. Black [ed.]. Methods of soil analysis. Part 2. Chemical and microbiological properties. Agron. Monogr. No. 9.
2. CHRISTIE, J. R. and V. G. PERRY. 1951. Removing nematodes from soil. Proc. Helminthol. Soc. Wash. 18:106-108.
3. COHN, E. 1969. The occurrence and distribution of species of *Xiphinema* and *Longidorus* in Israel. Nematologica 15:179-192.
4. DI SANZO, C. P. and R. A. ROHDE. 1969. *Xiphinema americanum* associated with maple decline in Massachusetts. Phytopathology 59:279-284.
5. FLORES, H. and R. A. CHAPMAN. 1968. Population development of *Xiphinema americanum* in relation to its role as a vector of tobacco ringspot virus. Phytopathology 58:814-817.
6. GRIFFIN, G. D. and K. R. BARKER. 1966. Effects of soil temperature and moisture on the survival and activity of *Xiphinema americanum*. Proc. Helminthol. Soc. Wash. 33:126-130.
7. GRIFFIN, G. D. and H. M. DARLING. 1964. An ecological study of *Xiphinema americanum* Cobb in an ornamental spruce nursery. Nematologica 10:471-479.
8. HARRISON, B. D. and R. D. WINSLOW. 1961. Laboratory and field studies on the relation of arabis mosaic virus to its nematode vector *Xiphinema diversicaudatum* (Micoletzky). Ann. Appl. Biol. 49:621-633.
9. JONES, F. G. W., D. W. LARBEY and D. M. PARROTT. 1969. The influence of soil structure and moisture on nematodes, especially *Xiphinema, Longidorus, Trichodorus* and *Heterodera* spp. Soil Biol. Biochem. 1: 153-165.
10. LOWNSBERY, B. F. and A. R. MAGGENTI. 1963. Some effects of soil temperature and soil moisture on population levels of *Xiphinema americanum*. Phytopathology 53:667-668.
11. MALEK, R. B. 1969. Population fluctuations and observations of the life cycle of *Xiphinema americanum* associated with cottonwood (*Populus deltoides*) in South Dakota. Proc. Helminthol. Soc. Wash. 36:270-274.
12. NORTON, D. C. 1963. Population fluctuations of *Xiphinema americanum* in Iowa. Phytopathology 53:66-68.
13. RUSSEL, D. A. 1965. Laboratory manual for soil fertility students; modifications by L. R. FREDERICK and J. R. MURPHY. Agron. Dept., Iowa State University, Ames. 46 p.
14. TROEH, F. R. and R. G. PALMER. 1966. Introductory soil science laboratory manual. Iowa State Univ. Press, Ames, Iowa. 95 p.
15. VAN GUNDY, S. D., L. H. STOLZY, T. E. SZUSZKIEWICZ and R. L. RACKHAM. 1962. Influence of oxygen supply on survival of plant parasitic nematodes in soil. Phytopathology 52:628-632.
16. WALKER, J. T. 1971. Populations of *Pratylenchus penetrans* relative to decomposing nitrogenous soil amendments. J. Nematol. 3:43-49.
17. WARD, C. H. 1960. Dagger nematodes associated with forage crops in New York. Phytopathology 50:658 (Abstr.).