Plant-parasitic Nematodes in Loess Toposequences Planted with Corn[1]

D. C. Norton and M. Oard[2]

Abstract: Populations of plant-parasitic nematodes in an Iowa cornfield were studied along north- and west-facing toposequences. Samples were collected monthly during the growing season. The greatest biomass for *Xiphinema americanum* occurred at the footslope on the north face. *Paratylenchus microdorus* had its greatest biomass at the summit position, generally more in the west- than in the north-facing slope. *Pratylenchus* spp. in the roots peaked at the toeslope in the north-facing slope, but at the footslope in the west-facing slope. *Helicotylenchus pseudorobustus* peaked at the backslope and the toeslope along the north- and west-facing slopes, respectively. Diversity, as computed for each plot by the Shannon-Weiner diversity index, was highest at the backslope in both toposequences. *Key words: Helicotylenchus pseudorobustus, Paratylenchus microdorus. Pratylenchus* spp., *Xiphinema americanum.*

Large populations of nematodes often are correlated negatively with poor yields in the hilly loess region of western Iowa as revealed by samples submitted for nematode analysis. The association between a soil sample and its field situation often is unknown, however. Apart from a study of nematodes in Clarion-Webster toposequences planted with soybeans in central Iowa (5), little is known about nematode distribution with topographic gradients in agroecosystems in the midwestern United States. An examination of the occurrences of plant-parasitic nematodes along topographic gradients is desirable both for diagnostic and predictive purposes. The present study examined the distribution of plant-parasitic nematodes in the highly dissected loess farmland of western Iowa.

MATERIALS AND METHODS

Description of study area: The study was located in section 11, R 43 W, T 76 N of Pottawattamie County, Iowa, in the hilly thick loess topography of the Monona-Ida-Hamburg Soil Association (6). This association comprises 7,500 km². Relief between ridge crest and valley floor often exceeds 60 m. Soils are largely silty loams with good internal drainage and high moisture-holding capacity. They require fertilizer inasmuch as they tend to be deficient in nitrogen and phosphorus. Most of the area is cultivated, but the steep, highly erosive slopes necessitate conservation measures such as terracing and contour listing.

The field used was planted on the contour with corn (*Zea mays* L. cv. Trojan TX119) in 1978 and 1979 at 47,000 seeds/ha. Spacing between rows was 97 cm. Phorate at 1.06 kg/ha was used as an insecticide. Field work began in May 1979 during the first week of planting. Transects along the north- and west-facing slopes of the same field were surveyed by using an Abney level and stadia rod. The transects were at right angles to each other, with five stations located in each transect (Fig. 1). The summit position was common to both toposequences. A series of four subplots of each station were staked along the center of each slope. Each subplot was 1.5 m wide and three rows deep. The subplots were parallel to one another and served to replicate the effects of slope position. Station positions, distances, and percentage slopes are given

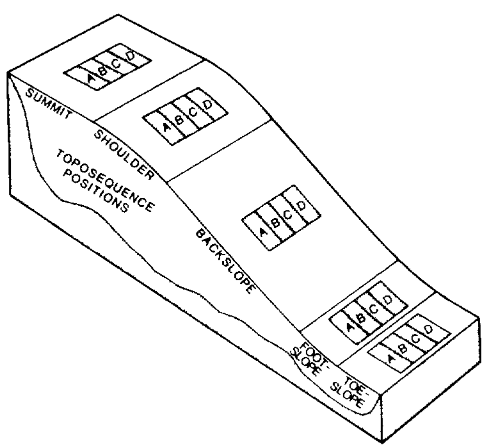

Fig. 1. Diagram of toposequence positions, Underwood, Iowa, 1979.

Received for publication 17 November 1980.

[1]Journal Paper No. J-10013 of the Iowa Agriculture and Home Economics Experiment Station, Project 2382. Sponsored, in part, by a grant from the FMC Corporation.

[2]Department of Plant Pathology, Seed and Weed Science, Iowa State University, Ames, IA 50011.

in Table 1. Soil analyses were made from composite samples collected from each station at the beginning of the season (Table 2). Soil moisture determinations were taken from each replication at each slope position after May but only data for 17 July and 18 September are shown. Temperatures at the 5- and 15-cm depths were recorded at each station in June, July, and September.

Seven species of plant-parasitic nematodes occurred at the site. They, with their fresh-weight adult female biomasses calculated from 25–30 nematodes for each species in August by the method of Andrássy (1), were: *Helicotylenchus pseudorobustus* (Steiner) Golden (0.238 μg), *Hoplolaimus galeatus* (Cobb) Filipjev & Schuurmans-Stekhoven (2.570 μg), *Paratylenchus microdorus* Andrássy (0.061 μg), *Pratylenchus* spp. (0.180 μg), *Quinisulcius acutus* (Allen) Siddiqi (0.154 μg), *Tylenchorhynchus nudus* Allen (0.125 μg), and *Xiphinema americanum* Cobb (1.200 μg). *Pratylenchus* spp. consisted of *P. hexincisus* Taylor and Jenkins and *P. scribneri* Steiner, but data for these were combined in the analysis. *Quinisulcius acutus* and *T. nudus* were found in such low numbers and in only 3% of the samplings that, except for the diversity indices, they were not included in the statistical analyses.

Collection and extraction of nematodes: Soil samples were collected to a depth of 20 cm monthly from May through September 1979 with a 2.5-cm diameter soil probe.

Table 1. Distances and percentage slope in toposequences, Underwood, Iowa, 1979.

Position	Distance		Slope
	Vertical (m)	Horizontal (m)	(%)
	North-facing slope		
Summit	20.4	0.0	0
Shoulder	18.6	5.5	29
Backslope	12.5	42.1	26
Footslope	1.8	118.6	11
Toeslope	0.0	147.5	0
	West-facing slope		
Summit	17.1	0.0	0
Shoulder	15.2	9.8	21
Backslope	9.4	10.9	24
Footslope	1.8	92.4	9
Toeslope	0.0	124.4	0

Ten cores were collected from each subplot and composited into one sample. Processing was within 48 h of sampling.

In the laboratory, each sample was mixed thoroughly, and 100-cm³ aliquots were processed by centrifugal flotation (3). Beginning with the June sample, the roots were separated from the soil, and 1–2 g of fresh roots, cut into 2-cm pieces, were mixed thoroughly, washed, and placed in a 125-ml flask for nematode extraction (2). After nematode extraction, the roots were dried at 90 C. Counts were calculated as nematodes per gram of dry root.

Statistical analyses: The test was analyzed as a multiple regression of individual species numbers on slope aspect (i.e., north or west facing), position along the slope, and sampling time. In addition, correlations between nematode species biomass and soil and environmental parameters for August and September samples were examined by using Pearson product moment coefficients. The Shannon-Weiner diversity index $H' = -\Sigma p_i \log p_i$ to the base e where p_i equals the proportion of species i in the sample, was calculated for all samples (7).

Yields: All corn in all plots was harvested at maturity for yield.

RESULTS

Moisture levels were greater along the backslope and lower positions than at the summit and shoulder. In addition, the north-transect plots were consistently wetter than the west-facing plots at each sampling period. Correlations between nematode species biomass and various soil and environmental parameters are summarized in Tables 3 and 4.

Yields: Total corn yields in kg/ha for the summit, shoulder, backslope, footslope, and toeslope along the north-facing slope were 4,739, 7,643, 10,241, 11,617, and 12,534, respectively. Yields for the same positions on the west-facing slope were 4,739, 4,433, 6,114, 10,394, and 10,547, respectively.

Nematode biomass at different sites: Statistical tests performed on the data yielded similar results regardless whether the figures used were nematode numbers or biomass. In general, a species tended to have a marked affinity for a particular slope po-

Table 2. Soil analyses in May and soil moisture in July and September along toposequences planted to corn, Underwood, Iowa, 1979.

Slope position	pH	% sand	% silt	% clay	% organic matter	Cation exchange capacity (MEQ/100g soil)	% soil moisture		Field capacity	% saturation
							July	September		
	North-facing slope									
Summit	7.9	1.9	83.5	14.6	1.4	17	19	18	26.5	39
Shoulder	7.9	6.6	76.5	16.9	1.6	18	22	18	27.0	41
Backslope	6.7	5.5	71.8	22.7	3.5	19	25	22	29.5	42
Footslope	5.5	6.1	67.0	26.9	4.1	20	23	23	28.0	39
Toeslope	5.5	9.6	67.9	22.5	4.6	25	25	22	27.5	44
	West-facing slope									
Summit	7.9	1.9	83.5	14.6	1.4	17	19	18	26.5	39
Shoulder	8.1	6.6	77.8	15.6	2.1	18	20	16	27.5	42
Backslope	7.8	10.8	70.2	19.0	2.9	17	23	20	27.5	43
Footslope	6.6	13.6	60.2	26.2	3.5	28	23	18	28.5	39
Toeslope	7.1	15.0	62.8	22.2	4.4	21	24	18	27.0	42

Table 3. Pearson Product moment correlations (r) between nematode biomass and slope and soil parameters in toposequences, Underwood, Iowa, 1979.†

Soil or environmental parameter	Nematode				
	Helicotylenchus pseudorobustus	*Paratylenchus microdorus*	*Pratylenchus* spp.		*Xiphinema americanum*
			Soil	Root	
Slope aspect	–0.27	0.10	–0.11	0.10	–0.41
Slope position (summit to toeslope)	0.37	–0.91**	0.82**	0.61	0.25
Cation exchange capacity	0.07	–0.46	0.83**	0.84**	0.06
Percent saturation	0.25	–0.56	0.06	–0.30	–0.27
Field capacity	0.79**	–0.50	0.58	0.51	0.21
Percent organic matter	0.51	–0.93**	0.85**	0.57	0.37
Percent clay	0.52	–0.79**	0.92**	0.85**	0.50
Percent silt	–0.37	0.82**	–0.80**	–0.78**	–0.16
Percent sand	0.21	–0.57	0.30	0.07	0.03
pH	–0.42	0.74**	–0.92**	–0.65*	–0.64*

*Significant at $P = 0.05$.
**Significant at $P = 0.01$.
†Nematode biomass from August samples was utilized for the analysis.

sition. Also, peak nematode biomass generally coincided with the peak standing crop of the host, which occurred in early September. Most *Helicotylenchus pseudorobustus* occurred at the backslope, except in the west face where they increased to the greatest biomass in the toeslope in September (Fig. 2A). *Paratylenchus microdorus* had its greatest biomass at the summit and shoulder positions in both transects. A secondary peak occurred at the footslope of the west slope, but no such peak occurred in the north slope (Fig. 2B). *Xiphinema americanum* biomass was greatest at the footslope in the north face in August and September but small at all other times and places (Fig. 2C). Biomass of *Pratylenchus* spp. both in the soil (Fig. 3A) and roots (Fig. 3B) was always greater at the footslope or toeslope than at the other positions, with the greatest biomass usually occurring at the footslope.

Table 4. Pearson Product moment correlations (r) between soil, yield, and slope parameters in toposequences, Underwood, Iowa, 1979.

Soil parameter	Environmental parameter	
	Slope aspect	Slope position
Yield	–0.36**	0.89**
Percent organic matter	–0.09	0.97**
Percent saturation	0.00	0.44**
pH	0.44**	–0.78**
Field capacity	–0.24	0.39**
Percent clay	–0.15	0.83**
Percent silt	–0.15	–0.92**
Percent sand	–0.45**	0.51**
Soil moisture	–0.31**	0.50**

*Significant at $P = 0.05$.
**Significant at $P = 0.01$.

Differences in biomass of nematodes among the three main effects of slope, position, and time of sampling, plus the interactions between slope face and position and between slope position and sampling time, were significant at $P = 0.01$ for all species except *H. galeatus*. The interaction between slope face and sampling time was significant at $P = 0.01$ for *Pratylenchus* spp. and *X. americanum*. Trends in significance were similar for all soil parameters and nematode biomass across both sample times (Table 3). Correlations of nematode biomass with slope aspect were not significant for any species. On the other hand, nematode dis-

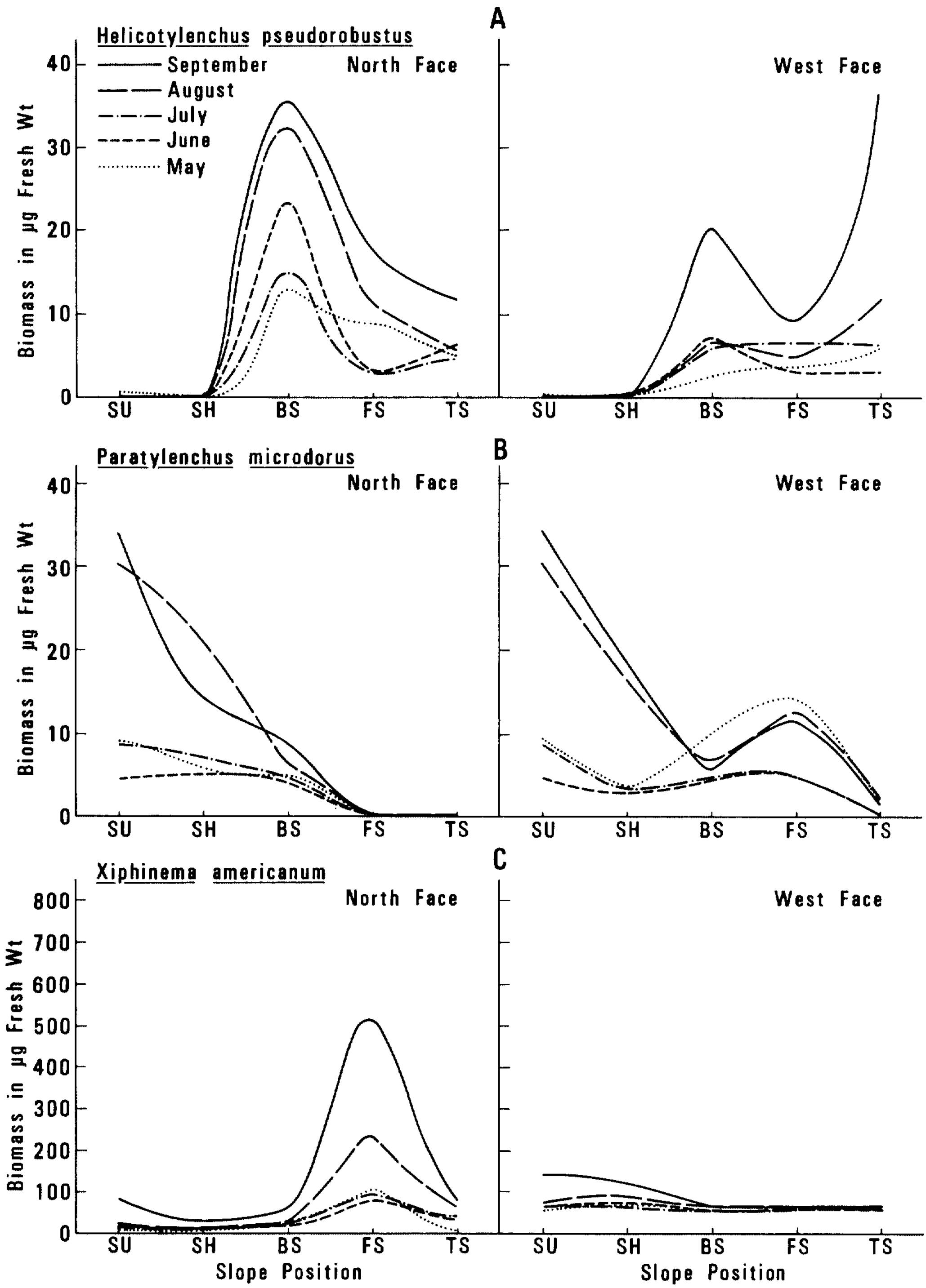

Fig. 2. Biomass of nematodes along topsequences, Underwood, Iowa, 1979. A) *Helicotylenchus pseudorobustus,* B) *Paratylenchus microdorus,* C) *Xiphinema americanum.* SU = summit, SH = shoulder, BS = backslope, FS = footslope, TS = toeslope.

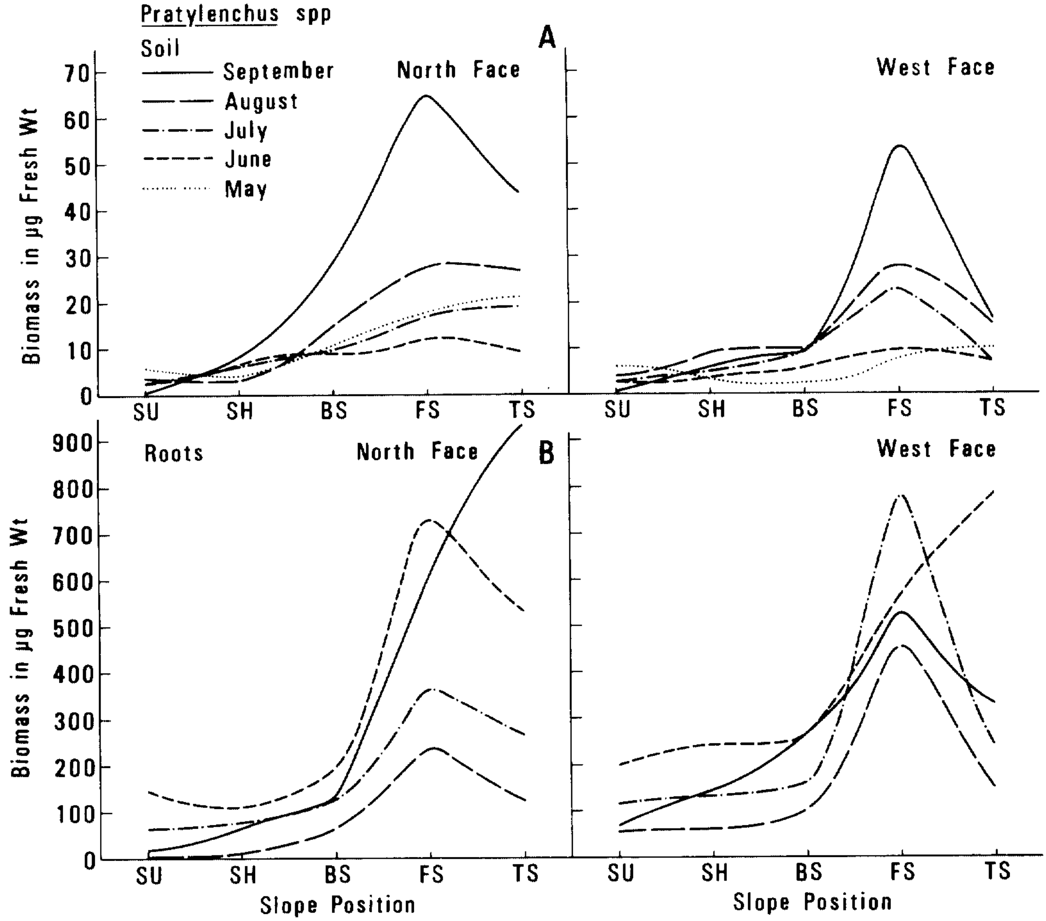

Fig. 3. Biomass of *Pratylenchus* spp. along toposequences, Underwood, Iowa, 1979. A) soil, B) roots. SU = summit, SH = shoulder, BS = backslope, FS = footslope, TS = toeslope.

tribution is strongly correlated with position along the slope for *P. microdorus* and *Pratylenchus* spp. Increase in biomass for *H. pseudorobustus* and *Pratylenchus* spp. is positively correlated with a position downslope, while there is an inverse relation with slope position with *P. microdorus*. The soil parameters most consistently and significantly correlated with distribution of plant-parasitic nematodes were pH and percentage of organic matter, clay, and silt.

In addition, correlations were calculated between the environmental parameters (slope aspect and position) and the time of sample with a variety of soil parameters and yield. Correlation with slope aspect was significant for yield, soil moisture, pH, and percentage sand. Highly significant correlations with slope position were found for all variables (Table 4) except with the temperature at 15 cm.

Diversity of plant-parasitic nematodes: There was an increase in amplitude in the diversity curve from the shoulder to the backslope for both transects, but it was more pronounced in the north-facing slope (Fig. 4). The analysis of variance showed that the differences in diversity indices attributed to differences in slope position are highly significant, $P = 0.01$. Peak diversities at the different sampling times are greater for the north than for the west face, but the difference due to the slope aspect was not significant. Generally speaking, the overall trend is one of greater diversity at the backslope for both transects.

DISCUSSION

Biologically, diversity (H′) is the interaction between species richness (i.e., the number of species per given area) and evenness of their distribution. Most plant-

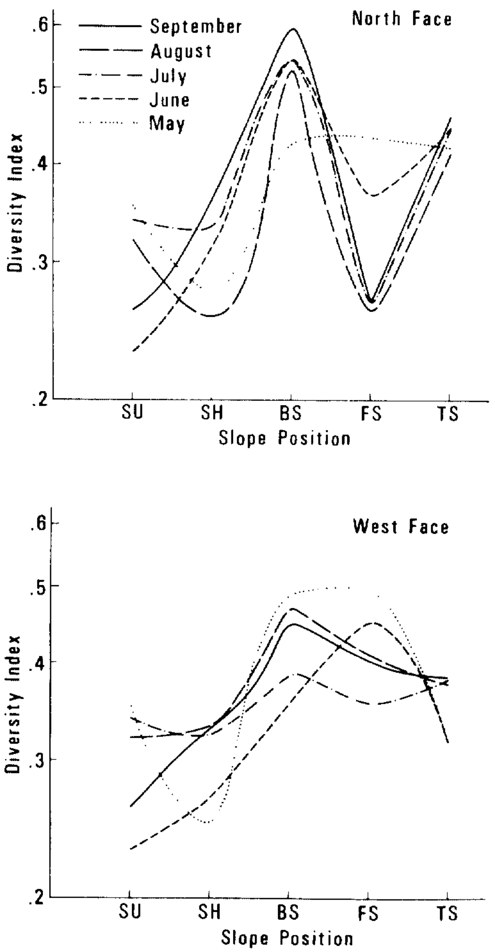

Fig. 4. Diversity indices based on nematode biomass along topsequences, Underwood, Iowa, 1979. SU = summit, SH = shoulder, BS = backslope, FS = footslope, TS = toeslope.

parasitic nematodes are obligate herbivores and therefore feed only in one trophic level. At the individual species level, an increase in nematode community diversity would mean a shift from generalized to more specialized forms and reduction in the realized niche breadth for most species. In a monocropped agroecosystem the vegetation is uniform, which eliminates the variable of germplasm and makes the system naturally less stable than noncultivated areas. Usually, increase in diversity correlates with increased stability and favorableness of habitat. Applying the axiom to the study area, one would predict that the diversity would be less at the summit and shoulder positions because of the greater extremes of temperature and droughtiness. By a similar argument, the amelioration of temperature and moisture fluctuations afforded by a north face should mean a greater nematode diversity for the north vs. the west slope. Both these predictions are borne out by the plots of slope position vs. diversity for the north and west faces in Fig. 4 and also by the analysis of variance.

From a practical point of view, low diversity often correlates with unstablized conditions that favor a single species or a relatively few species at the expense of the normal species complement. Monocrop situations are examples of such truncated species complements where a few species predominate. Such strongly dominated communities, stripped of much of their organismal and organizational complexities, have fewer internal controls and are thus more vulnerable to the pathological buildup of a single species than are more diverse communities.

The relevance, then, of the present study to crop and disease problems is that it demonstrates that diversity for a known parasitic, and therefore potentially pathological, group of species varies markedly and somewhat predictably within a field relative to such environmental parameters as slope position and aspect. The potential for disease outbreaks in the form of parasitic nematode buildup is similarly variable and, within broad limits, predicatable within a given field. Thus, increased understanding of the environmental factors controlling nematode distribution and buildup would allow the farmer to apply control measures with more selectivity and greater cost effectiveness.

Little is known about the factors favoring *P. microdorus*. The nematode occurred most frequently at the summit and shoulder positions, which drained the best and were the driest. In this study, the nematode was significantly negatively correlated with the position downslope, percentage organic matter, and percentage clay and significantly positively correlated with percentage silt and pH (Table 3). Its greatest occurrence at the driest sites agrees with data for *P. projectus*, which can survive dry conditions well (8). The negative correlation of *X. americanum* with pH agrees with data from 40 Iowa soybean fields having little or no slope (4). The finding of Nyhan et al. (5) that *Helicotylenchus pseudorobustus* had the largest population at the summit position on a Clarion-Webster toposequence, in contrast to its greater occurrence in the toeslope or backslope positions in the present study, could indicate edaphic changes. These differences indicate that further work is needed. In the present study, a toposequence survey (unpublished) in adjacent land sections to the main test had patterns close to those in the main study, indicating that similar toposequences have similar patterns of nematode distribution.

LITERATURE CITED

1. Andrássy, I. 1956. The determination of volume and weight of nematodes. Acta Zool. Acad. Sci. Hung. 2(1-3):1-15. Pp. 73-84 *in* B. M. Zuckermann, M. W. Brzeski, and K. H. Deubert, eds. English translation of selected East European papers in nematology. University of Massachusetts, 1967.

2. Bird, G. W. 1971. Influence of incubation solution on the rate of recovery of Pratylenchus brachyurus from cotton roots. J. Nematol. 3:378-385.

3. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.

4. Norton, D. C., L. R. Frederick, P. E. Ponchillia, and J. W. Nyhan. 1971. Correlations of nematodes and soil properties in soybean fields. J. Nematol. 3:154-163.

5. Nyhan, J. W., L. R. Frederick, and D. C. Norton. 1972. Ecology of nematodes in Clarion-Webster toposequences associated with Glycine max (L.) Merrill. Proc. Soil Sci. Soc. Am. 36:74-78.

6. Oschwald, W. R., F. F. Riecken, R. I. Dideriksen, W. H. Scholtes, and F. W. Schaller. 1965. Principal soils of Iowa. Iowa Coop. Ext. Serv. Spec. Rep. 42.

7. Pielou, E. C. 1975. Ecological diversity. Wiley-Interscience. New York.

8. Rhoades, H. L., and M. B. Linford. 1961. Biological studies on some members of the genus Paratylenchus. Proc. Helminthol. Soc. Wash. 28: 51-59.