Correlations of Nematodes and Soil Properties in Soybean Fields[1]

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Abstract: Soil samples from 40 soybean fields were collected in 1967 and 1968 and analyzed for nematodes and soil properties. Correlations of total nematodes, non-stylet nematodes, Dorylaimoidea (excluding *Xiphinema americanum*), *X. americanum*, *Helicotylenchus pseudorobustus*, *Tylenchus* spp., *Aphelenchus avenae*, and other groupings of nematodes were made with *p*H; percentage sand, silt, and clay; percentage organic matter; cation exchange capacity; saturation percentage, and percentage saturation. Organic matter, *p*H, and cation exchange capacity were most consistently highly correlated with the nematodes. *H. pseudorobustus* had the most consistently significant correlations with the soil factors. Correlations of nematodes were with more soil factors and were stronger in a wet than in a dry year. The highest numbers of nematodes were usually found in the lighter soils, except in the loamy sand where moisture probably was limiting. In general, soil moisture levels below 20% saturation were probably limiting for most nematodes studied, except for the dorylaims which survived in large numbers in soils with less than 20% saturation. *Key Words:* Ecology, Soil.

The physical characteristics of soil are important relative to occurrence and population dynamics of nematodes (22). Some of these are *p*H (9, 17, 21), soil texture and type (6, 10, 18), and organic matter (8, 13). The interrelations are complex, and many soil factors do not work independently. Highly controlled laboratory experiments may yield some insight into the ecological amplitude of certain nematodes, but field application of such data sometimes is not reliable because of the complex environment of natural habitats or the artificial conditions of the laboratory. Although laboratory experiments may help explain field phenomena, in the field one ultimately faces the complexities of nematode occurrence, and must make the basic interpretations relative to nematode ecology.

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Although the host plant is of primary importance in nematode ecology, edaphic factors may also be limiting. For example, *Meloidogyne* spp. and *Belonolaimus* spp. are usually not damaging in certain soil textures. Also, numbers of nematode species will differ in different soils even though the same plant cultivar is grown. Nyhan *et al.* (11) found that larger populations of nematodes generally existed around soybeans at the summit position of two toposequence studies in Iowa and that populations generally became less as one proceeded to the toeslope. In agricultural soils, there is an ecological amplitude, which will be governed greatly by edaphic factors. The work reported here is the result of a 2-year field study in which soil factors were correlated with numbers of selected nematode species under an annual cropping system.

MATERIALS AND METHODS

Correlations of soil properties with nematode populations were calculated using data from 40 Iowa soybean fields sampled in 1967 or 1968. Soil properties included *p*H, cation exchange capacity (CEC), organic matter (OM), pore space, percentage sand-silt-clay, textural class, saturation percentage (moisture content when soil is prepared for saturation extract), percentage saturation, total rainfall, and total soluble cations. Cropping history and the slope of the land also were considered. The sampled fields, which were widely distributed in the state, were chosen on the basis of known cropping and fertility history for the past 15 years and for diversity of soil factors. Soybeans were planted in all fields in the sampling year and all except two were in corn the previous year. All samples in a field during a season were taken from the top 25.4 cm (10 inches) at two locations in a 9.14 × 9.14 m (30 × 30 ft) plot selected for uniformity of soil properties.

Soil samples were collected from each of the 40 fields three times during the growing season in order to reduce the effects of population fluctuations. An average of the three sampling dates were used in the calculations. Two composites of three 1-quart samples representing six sampling locations were taken from the top 10 inches of soil around the roots of soybeans from each field at each sampling period. Samplings were made at about the 4th, 10th, and 15th weeks of soybean growth. The soil was screened through a 4-mm sieve and analyses were made by using the standard procedures for *p*H (14), organic matter (14), cation exchange capacity (14), saturation percentage (1), percentage saturation (1), soluble salts (1), soil particle size (19), and total pore space (the latter only in 1968). Five-hundred-cc aliquants of the composite sample were processed for nematodes essentially by the Christie and Perry (3) method of extraction within 1 day of sampling. Data were analyzed only for nematodes or nematode groups found in most fields and in sufficient quantity to provide a large enough volume of data for analysis. The nematode species or groups counted were total nematodes, all stylet nematodes, non-stylet nematodes, dorylaims (Dorylaimoidea minus *Xiphinema americanum* Cobb), Tylenchinae-Psilenchinae Tylenchoidea, *Tylenchorhynchus nudus* Allen, *Helicotylenchus pseudorobustus* (Steiner) Golden, *Hoplolaimus galeatus* (Cobb) Thorne, and *X. americanum*. The data were analyzed by a stepwise regression using logarithmic transformations of the actual nematode numbers based upon the equation:

$$y = B_0 \pm B_1 (a) \pm B_2 (b) \pm B_3 (c) \pm B_4 (d) \ \ldots \ \pm B_{10} (j)$$

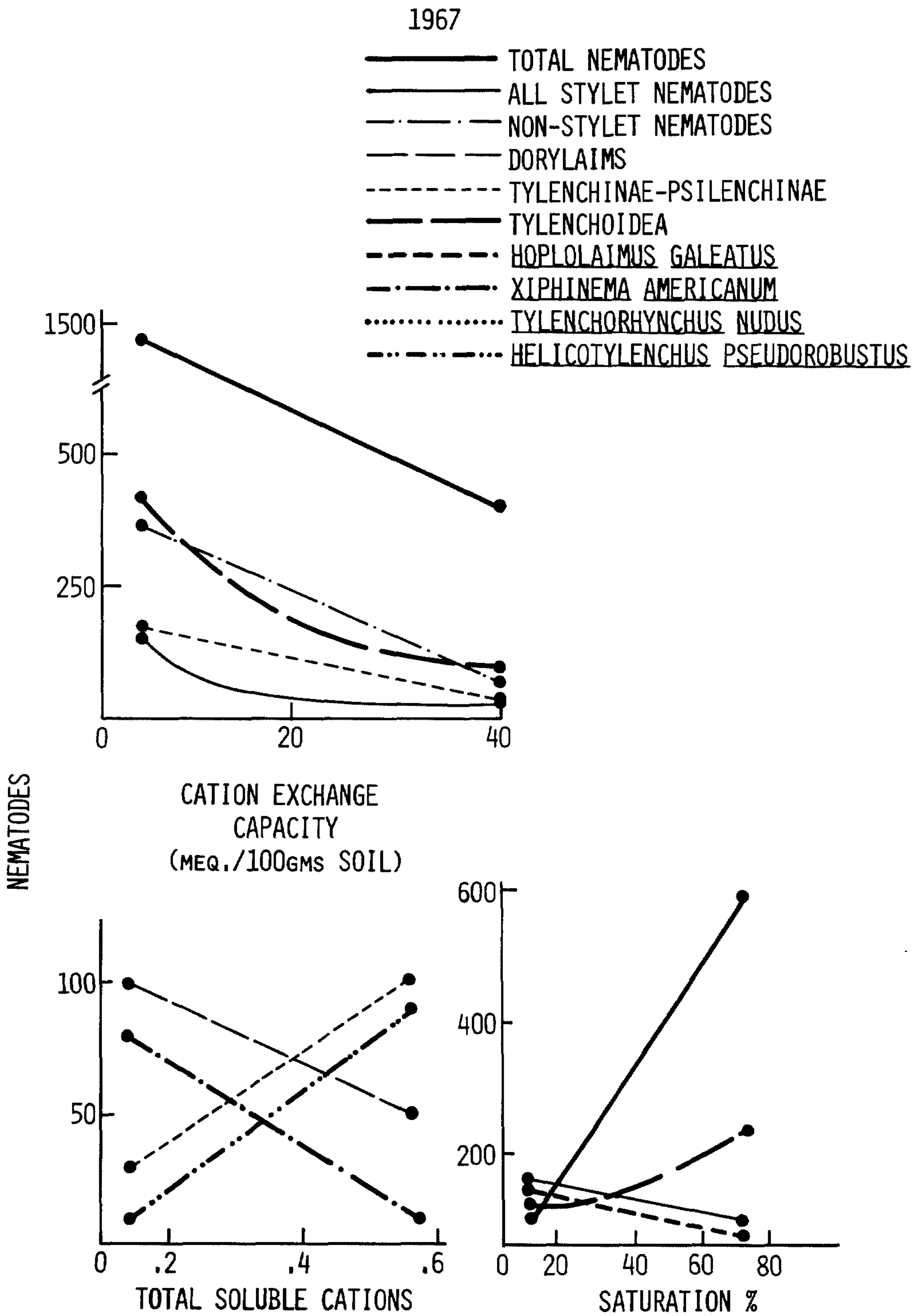
where the coefficients (B) are multiplied by the corresponding variable soil factors; (y) is the dependent variable and (a) . . . (j) are the independent variables. The prediction equation, which verifies the relationships between nematodes and soil factors, was calculated from each individual regression coefficient. Therefore, the nematode figures on the y-axis in Fig. 1–4 are relative trends of particular nematode(s) and are not actual numbers of nematodes recovered.

RESULTS

Rainfall in Iowa in 1967 and 1968 presented two contrasting situations. Soil moisture in 1967 was normal and adequate, with little or no moisture stress occurring in the crops. Drought prevailed in many parts of Iowa in 1968, and farmers in some areas plowed under corn and soybeans in late summer with no attempt at harvest.

The significant correlations of soil factors and nematode numbers are presented in Fig. 1–4. Since precipitation differed greatly between 1967 and 1968, the results are presented separately.

1967 SEASON: Twenty-seven significant correlations were found in 1967, with percentage saturation and total rainfall not being



1967
TOTAL NEMATODES
ALL STYLET NEMATODES
NON-STYLET NEMATODES
DORYLAIMS
TYLENCHINAE-PSILENCHINAE
TYLENCHOIDEA
HOPLOLAIMUS GALEATUS
XIPHINEMA AMERICANUM
TYLENCHORHYNCHUS NUDUS
HELICOTYLENCHUS PSEUDOROBUSTUS
1500
500
250
0
20
40
NEMATODES
CATION EXCHANGE CAPACITY (MEQ./100GMS SOIL)
100
50
0
.2
.4
.6
TOTAL SOLUBLE CATIONS
600
400
200
0
20
40
60
80
SATURATION %

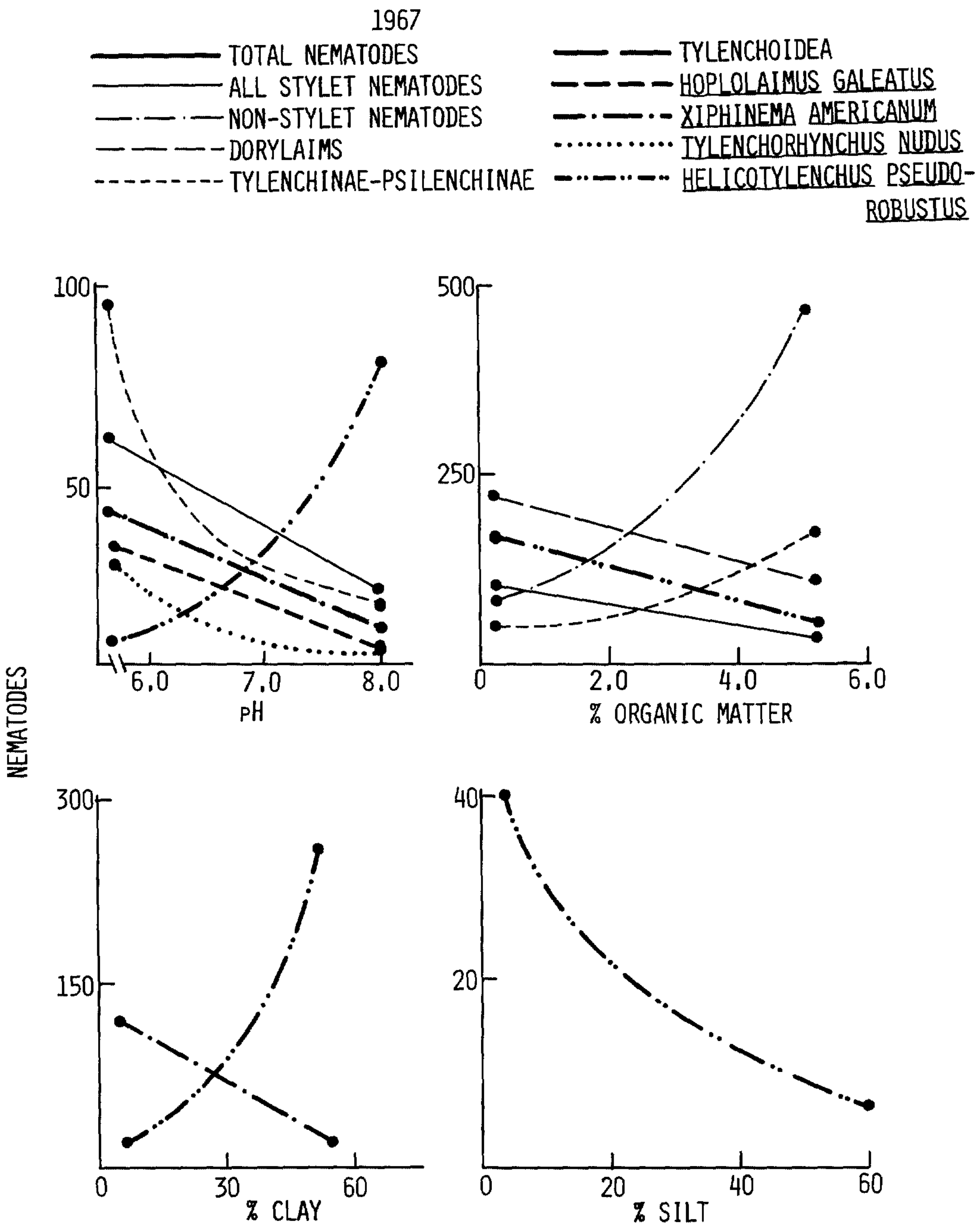


FIG. 2. Significant correlations of nematodes with *p*H, percentage organic matter, percentage clay, and percentage silt in Iowa soybean fields, 1967.

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FIG. 1. Significant correlations of nematodes with cation exchange capacity, total soluble cations, and saturation percentage in Iowa soybean fields, 1967.

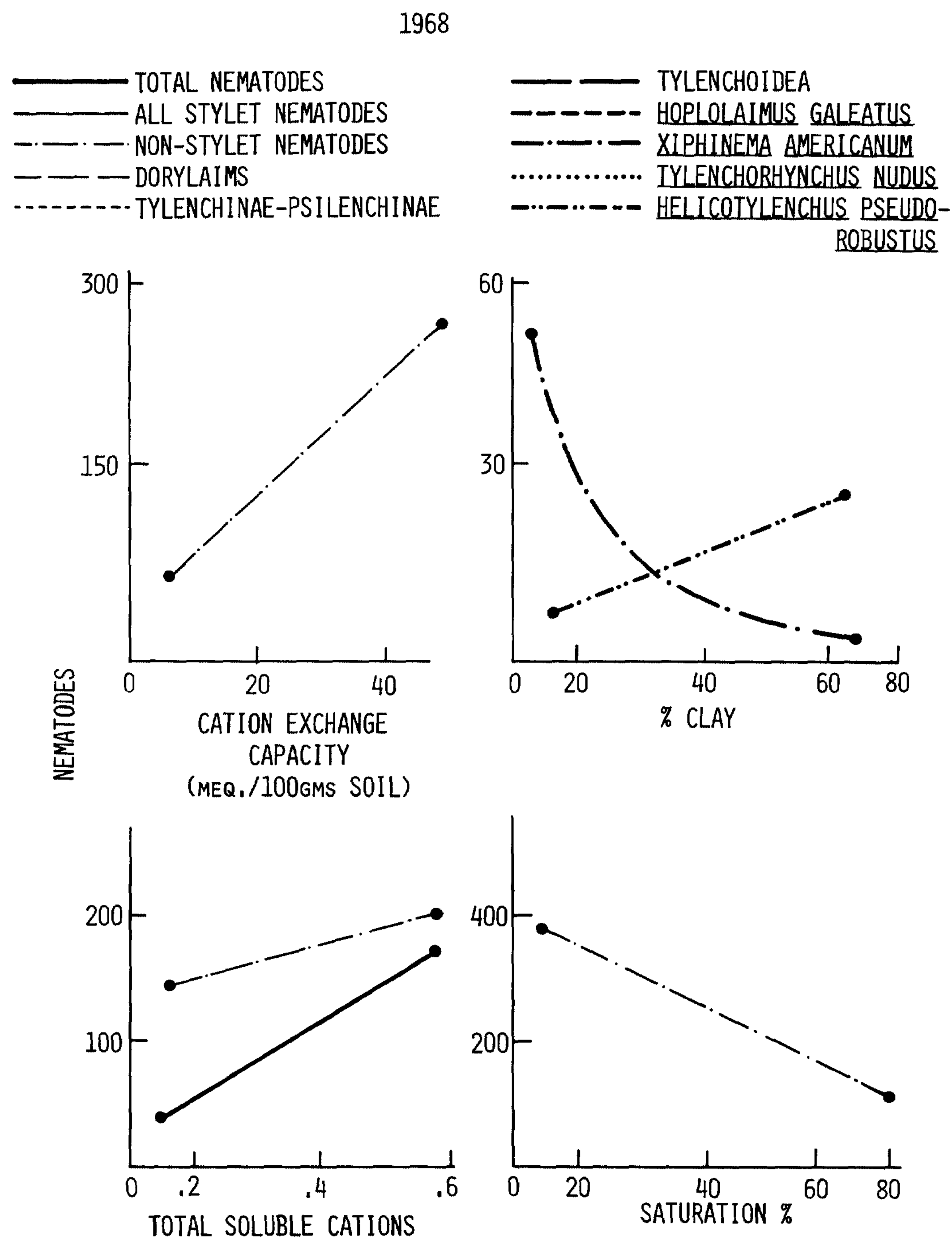


FIG. 3. Significant correlations of nematodes with cation exchange capacity, percentage clay, total soluble cations, and saturation percentage in Iowa soybean fields, 1968.

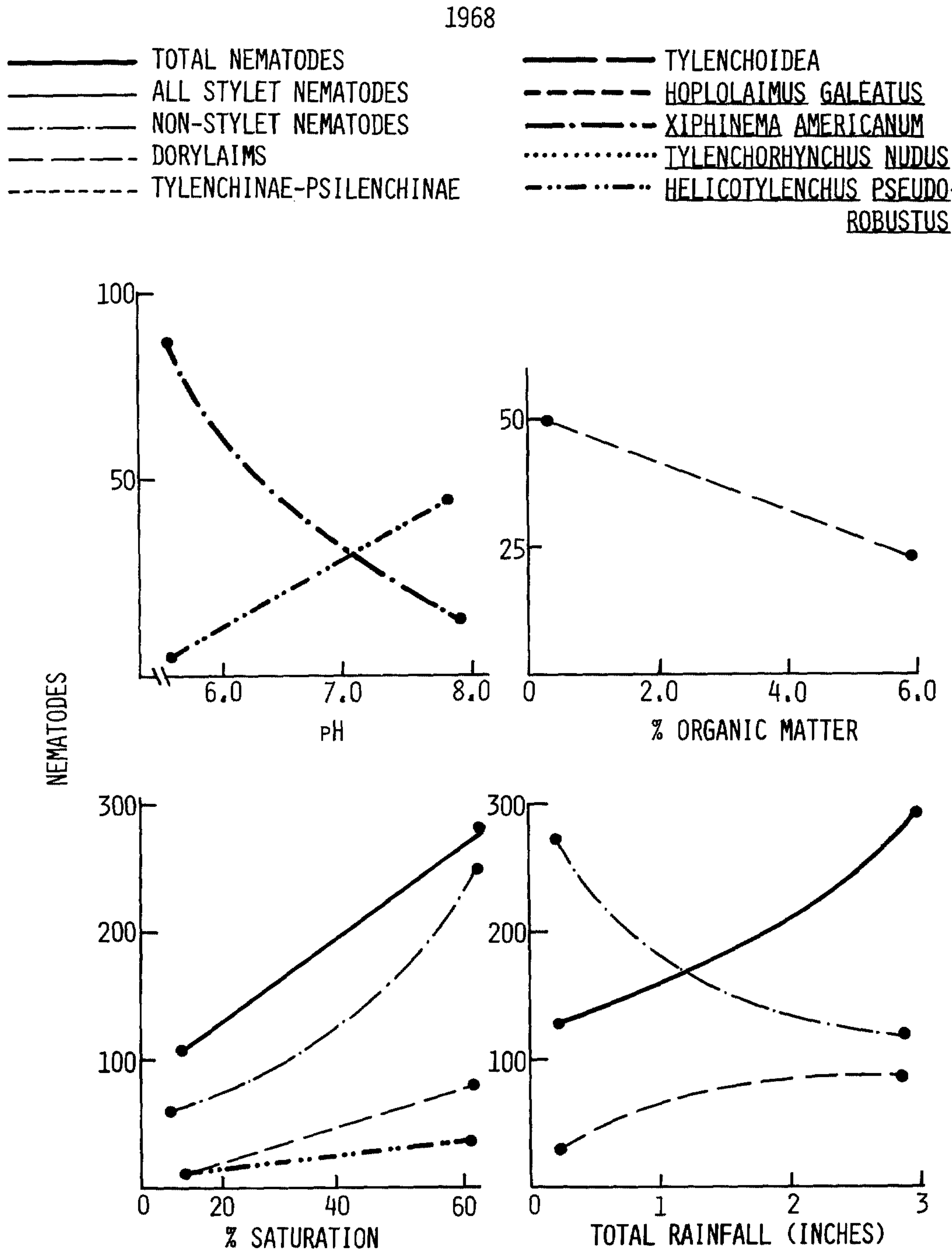


FIG. 4. Significant correlations of nematodes with *p*H, percentage organic matter, percentage saturation, and total rainfall in Iowa soybean fields, 1968.

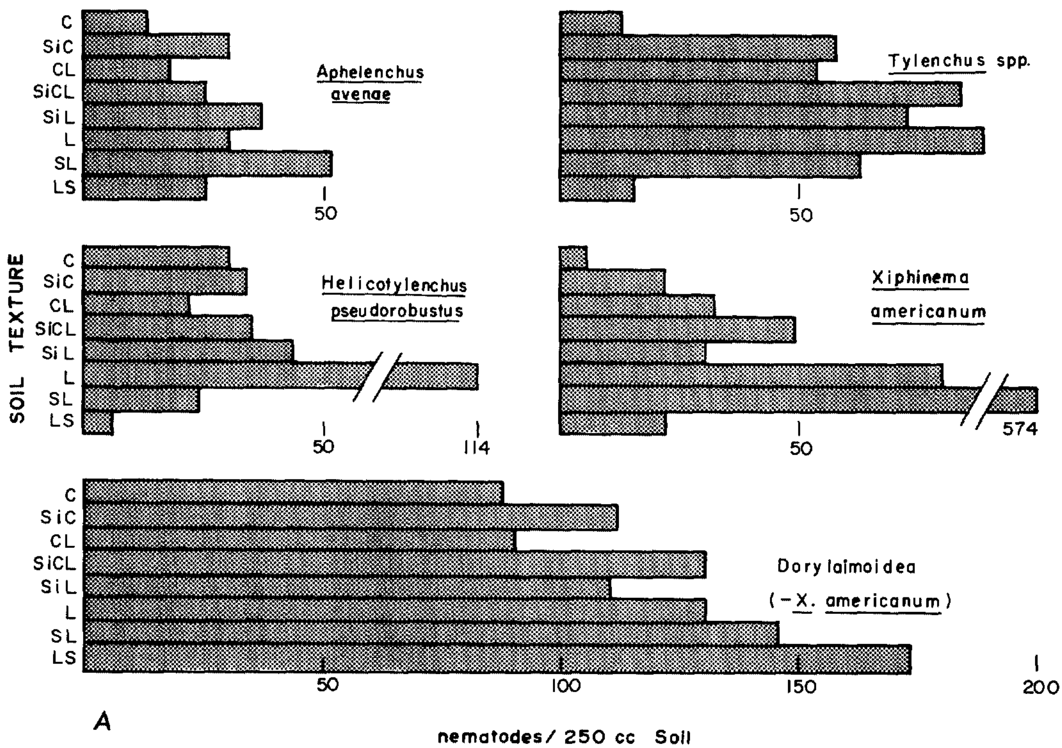
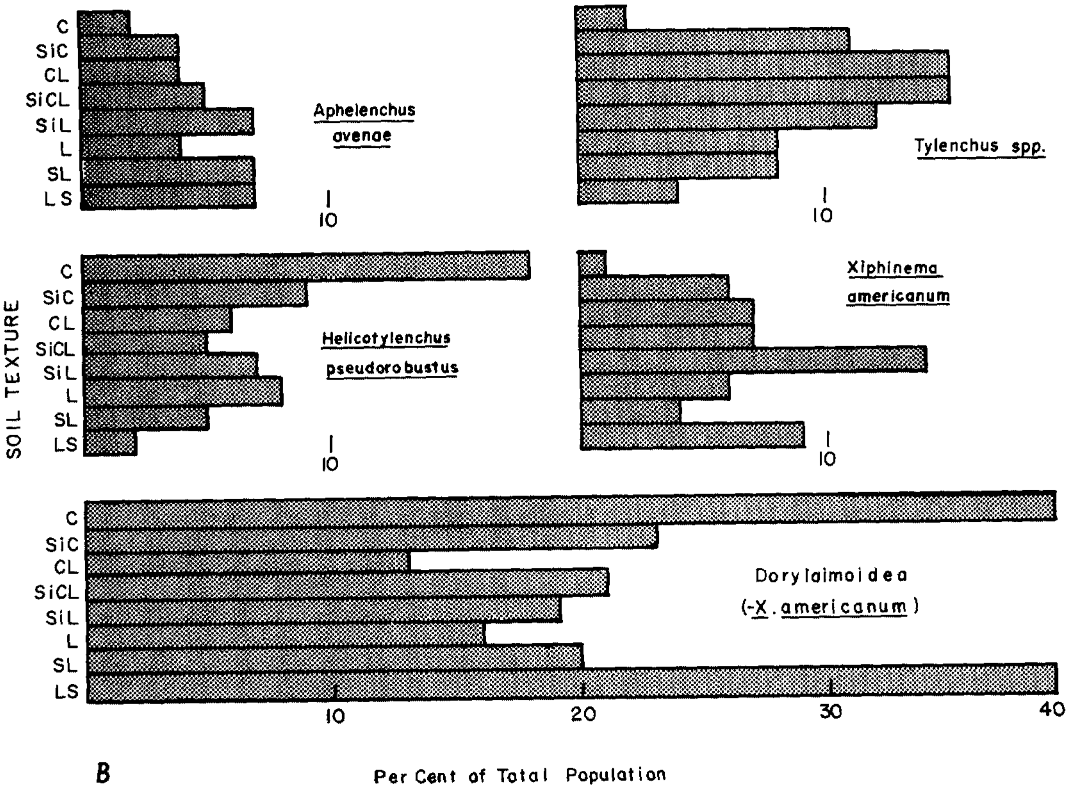


FIG. 5. Soil texture effects on selected plant-parasitic nematode populations (larvae and adults). **A.** Numbers per 250 cc soil (based on two replicated 3-quart samples from each 30′ × 30′ plot); **B.** Percentage composition of total nematode population observed; C = clay, Si C = silty clay, CL = clay loam, Si CL = silty clay loam, Si L = silty loam, L = loam, SL = sandy loam, LS = loamy sand.

measured. Of the 27 significant correlations, 19 were negative, and eight were positive. Most significant correlations were found with CEC, *p*H, and OM. All significant correlations with *X. americanum* (*p*H, total soluble cations, clay), *H. galeatus* (saturation percentage, *p*H) and *T. nudus* (*p*H) were negative, while three (*p*H, soluble cations, clay) of five significant correlations with *H. pseudorobustus* were positive. The percentage of sand, silt, or clay was significant only three times (*X. americanum*, clay-negative; *H. pseudorobustus*, clay-positive, silt-negative).

1968 SEASON: Even though percentage saturation and rainfall were included in 1968, there were only 16 significant correlations, and seven of these involved the two added factors. The significant correlations of the dorylaims and OM, and *X. americanum* and *H. pseudorobustus* with *p*H and clay content were consistently significant in both years. Most other factors that were significant in 1967 (wet year) were not significant in 1968 (a dry year).

Although the percentage of sand, silt, and clay were individually of little significance, the effects of the interrelationships probably are meaningful. The association of soil texture and nematodes for all fields in 1967 and 1968 are presented in Fig. 5A. With the exception of the Dorylaimoidea, the fewest nematodes were frequently found at the extreme soil texture ranges; i.e., clay and loamy sand. The highest numbers of nematodes



were usually found in lighter soils, except in the loamy sands where moisture probably became limiting. Similar trends were found for nematodes associated with soybeans in the southeastern United States (15). There was an irregular but general increase of total numbers of dorylaims with decreased clay content and increased sand content.

When the percentage of total populations is considered, a smaller percentage of *Tylenchus* spp., *H. pseudorobustus*, and *X. americanum* was found in loams or sandy loams compared with the total nematode population (Fig. 5B). The greatest percentages of the total nematode population of *H. pseudorobustus* were found in clays and silty clays. Because smaller numbers of all nematodes were found in clay soil, this nematode is apparently better adapted to heavier soils. The highest average percentage of the dorylaims, by far, was at the soil texture extremes, i.e., in the clays and loamy sands. The numbers and percentage of dorylaims contrasted especially sharply (Figs. 5A, B).

A. avenae, *H. pseudorobustus*, and *X. americanum* were present in fewer numbers in 1968 than in 1967, presumably due to the drier soils in 1968. Lower numbers generally prevailed in all soil textures and thus did not appreciably affect the relative ratios among soil textures. Some of the largest numbers of the dorylaims were found in lighter and drier soils, which indicates that this group may generally thrive, or at least survive, under drier conditions than other nematodes. In general, soils of 20% saturation or below seem limiting for most nematodes, except the dorylaims.

Discussion

No consistent correlations of nematode population and cropping history were found. It would be surprising if such correlations did not exist, but in our study, the diversity of physical habitats, coupled with diverse cropping systems, all of which included annual plowing, probably masks effects that might occur under more uniform conditions.

The effect of CEC may be real or imaginary relative to the occurrence of soil nematodes. It is reasonable to expect that CEC might have a direct effect on nematodes. The amphids of nematodes are assumed to be chemoreceptors (5, 7). Thus, it is conceivable that differences in exchangeable cations, either by soil characteristics or by plant absorption could be detected by the amphids or other chemoreceptors. Because CEC is closely linked to soil texture, *p*H, and organic matter, it is possible that these other factors also might be involved. Even though members of the Tylenchinae-Psilenchinae and the Tylenchoidea as a group were negatively correlated with CEC, none of the plant parasitic nematodes was significantly correlated with CEC. This indicates that (i) these nematodes (*X. americanum*, *H. pseudorobustus*, *T. nudus*, *H. galeatus*) are not influenced by CEC, or (ii) any influence of CEC on these nematodes is overshadowed by the influence of the host plant or by other soil factors. This suggests that significant correlations of CEC may be largely with the non-plant parasitic forms. It is possible that CEC *per se* has no influence on nematodes and that the correlations found are summations or interrelationships of other factors. If this is so, one might expect by chance alone that at least one plant-parasitic nematode would have been significantly correlated with CEC, be it real or accidental. Correlations do not prove causation, but they may be an indicator of trends in nematode populations. Whether a given correlation proves to reflect causality or interrelationships of several factors may be secondary in a pragmatic sense. The positive correlation of the Tylenchinae-Psilenchinae and the non-stylet nematodes with organic matter in 1967, while others were correlated negatively, is logical since nematodes belonging to the Rhabditidae, Cephalobidae, and the Tylenchinae-Psilenchinae are known to feed on either bacteria or fungi. Thus, habitats with high organic matter are well suited to these organisms.

In our work all significant correlations of nematode numbers and *p*H were negative, except with *H. pseudorobustus*, which were positive. Others found a positive correlation of *p*H with *Tylenchorhynchus maximus* and *T. nudus* in the *p*H range 5.0–6.5 (16) and with *Criconemoides xenoplax* and *Tylenchulus semipenetrans* up to *p*H 7.5 (17, 20, 21). Brzeski and Dowe (2), however, reported a negative correlation of *p*H and *T. dubius* in cabbage fields in Poland.

Geraert (4) reported that *H. pseudorobustus* had no preference for moisture or soil type. We found that this nematode was significantly correlated with *p*H, OM, clay, silt, total soluble cations, and percentage saturation in one or both years. *H. pseudorobustus* is one of the most common plant-parasitic nematodes in Iowa, a state with predominantly medium to heavy-textured soils in cultivated areas. The positive correlation of this nematode with percentage clay in both years and percentage of occurrence when compared with other textures (Fig. 5) is consistent with these observations.

H. pseudorobustus behaved significantly differently from *X. americanum* with respect to *p*H, percentage clay, and total soluble cations. In no instance was any significant correlation of the two nematodes with soil factors similar. Likewise, Oteifa *et al.* (12) noted that the Dorylaimoidea behaved differently from the Tylenchoidea relative to soil properties. These observations suggest that further ecological differences among taxonomic groups may be revealed.

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