Effect of Soil Type on Population Densities of Nematodes in Soybean Rotation Fields[1]

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Abstract: The effect of soil type on population densities of plant parasitic nematode species in 17 field blocks of four different soil types rotated to corn, soybeans, wheat, and forage mixtures was investigated during a generally droughty 5-year period. High densities of *Helicotylenchus pseudorobustus* were found in dark silty clay loams. Highest densities of *Tylenchorhynchus acutus* were also in one of the dark-colored silty clay loams. Light-colored silt loams favored development of *Paratylenchus projectus*, which developed poorly in the darker soils. Comparable densities of *Xiphinema americanum* were found in all soils and on all crops, regardless of soil type. *Tylenchorhynchus martini*, although present, did not build up in any of the soils. Populations of *Pratylenchus* species were generally low in the rotated blocks of all soil types. *Key Words:* Corn, Wheat, Forage, *Helicotylenchus pseudorobustus*, *Tylenchorhynchus acutus*, *Tylenchorhynchus martini*, *Paratylenchus projectus*, *Xiphinema americanum*, *Pratylenchus* spp.

This study, carried out 1963–1967, was designed to investigate the effect of soil type on nematode population densities in fields under soybean rotations. It is part of a 10-year study of factors influencing field population densities of plant parasitic nematodes present in North-Central USA (1, 2, 3, 4).

MATERIALS AND METHODS

Two areas with light-colored silt loams and two areas with dark silty clay loams were selected. One of the light-colored soils, a Proctor silt loam on the Agronomy Farm at Urbana, is a coarse soil, well-drained, and moderately permeable. The other light-colored soil was a Cisne silt loam at the Toledo Soil Experiment Field in Cumberland County, Illinois. The latter characteristically has a hard pan and can be very dry or very wet, depending on the weather conditions. One of the dark-colored soils, an area of Drummer silty clay loam at Urbana, has a moderately sticky black clay loam to silty clay loam surface and a heavy silty clay loam subsoil. The second dark soil, an Illiopolis silty clay loam at the Hartsburg Soil Experiment Farm in Logan County, Illinois, is a very dark, heavy soil with a moderately permeable subsoil.

Eight, 1-hectare blocks in Urbana (four of Proctor soil and four of Drummer) and four at Toledo were planted to a 4-year rotation of corn (*Zea mays* L.), soybeans (*Glycine max* (L.) Merr.), wheat (*Triticum aestivum* L.) and forage, consisting of alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.) and bromegrass (*Bromus inermis* Leyss). Each block in a 4-block series was planted to a different crop. Three, 1-hectare Illiopolis blocks at Hartsburg were planted to a 3-year rotation of corn, soybeans, and wheat; another block was planted to continuous corn; and another to continuous soybeans.

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term study. Following the completion of a rotation cycle in a block, a new, identical cycle was begun. Each stage in a given rotation on a given soil was represented by one block in a given year.

Nematodes in each block were sampled each year between mid-July and mid-August, and processed by standarized techniques given previously (1, 3, 4). Two additional Urbana soybean blocks of an intermediate soil type were also sampled each year at monthly intervals from May to October to provide data on normal fluctuations within a season. Tests of reproducibility of sampling results and of consistency of laboratory methods have been detailed elsewhere (1, 3, 4). The Kruskal-Wallis H Test (7) and Festinger's d Test (5) were used in the analyses of the present study, with the repeated observations from different years and different blocks forming the basis for the statistical comparisons.

RESULTS

Data are for species of plant parasitic nematodes which occurred naturally in the areas studied. These included the ectoparasitic species *Helicotylenchus pseudorobustus* (Steiner) Golden, *Paratylenchus projectus* Jenkins, *Tylenchorhynchus martini* Fielding, *Tylenchorhynchus acutus* Allen, and *Xiphinema americanum* Cobb. Several species of *Pratylenchus* occur together in these fields as a complex (3), including *P. hexincisus* Taylor and Jenkins, *P. scribneri* Steiner, *P. penetrans* Cobb, *P. neglectus* Rensch, and *P. crenatus* Loof.

Nematode densities in the Urbana blocks sampled at monthly intervals were in accord with previous observations (2, 3, 4) that in these fields soil populations of the *Pratylenchus* species tended to decline during the early part of the growing season, reaching a low point near mid-season. Ectoparasitic species, however, tend to increase in total numbers throughout the growing season, although the increase may not be a smooth curve (V. R. Ferris, unpublished data).

In the blocks of contrasting soil types sampled once each season, there were marked differences in the densities of *H. pseudorobustus*. Small numbers were found in the silt loam soils (Urbana-Proctor and Toledo-Cisne), but much larger numbers in the silty clay loams (Urbana-Drummer and Hartsburg-Illiopolis). Figs. 1 and 2 show, by means of relative abundance polygons, densities in individual blocks of the Urbana-Proctor and Hartsburg series respectively, selected because they are typical. This species was not detected at all in some of the years in two of the Urbana-Proctor blocks (Fig. 1). Means for densities from all blocks in each crop in a given soil type are in Table 1. Significantly lower numbers of *H. pseudorobustus* were found in blocks of the two silt loams than in the silty clay loams for corn, soybeans and wheat ($P < 1\%$), and also for forage ($P < 5\%$).

Densities of *P. projectus* were also markedly different in the blocks of different soil types, but the effect on this species was opposite that for *H. pseudorobustus* (Table 1). Means of *P. projectus* in the combined silt-loam soils (Urbana-Proctor and Toledo-Cisne) were significantly higher ($P < 1\%$) than in the silty clay loams (Urbana-Drummer and Hartsburg-Illiopolis) with all four crops. Figs. 3 and 4 are typical of the densities observed in these blocks.

Although *T. martini* was found at all locations, densities remained low at mid-season in all blocks during the 5 years of the study. *T. acutus* did not build up on the silt loam soils at either location, and was not even found at Toledo. Nor did this species develop on the Urbana-Drummer silty clay loam. However, in the Illiopolis silty clay loam at Hartsburg, mean densities of 100 per 473 cc soil or more were found on

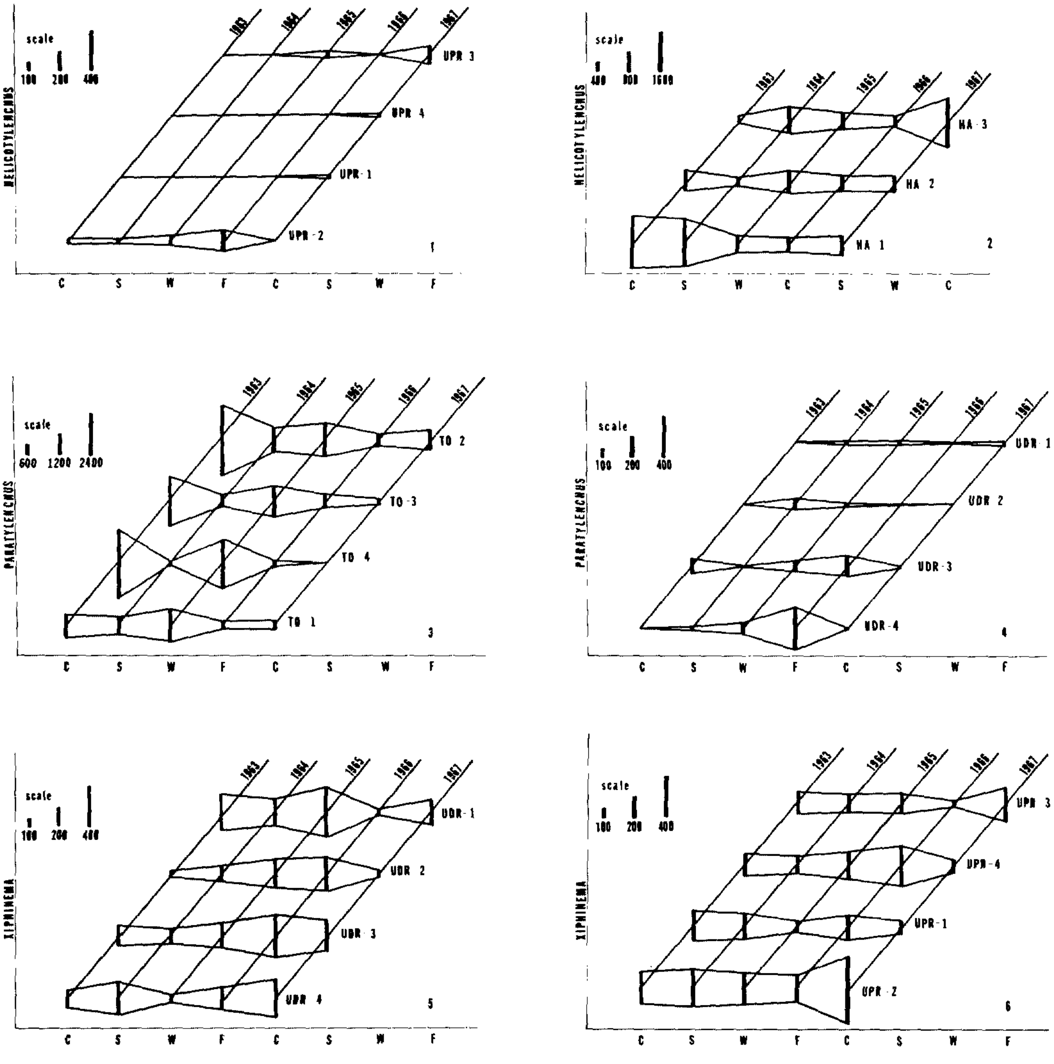

FIG. 1–6. Relative abundance polygons showing nematodes recovered per 473 cc (1 pint) of soil in individual blocks of different soils. Letters on horizontal axes show crop sequence (C, corn; S, soybeans; W, wheat; F, forage). Blocks in a given crop may be compared by reading vertically. Numbers of nematodes for each block in a given year may be compared by reading along the diagonals. **1.** *Helicotylenchus pseudorobustus* in Urbana-Proctor silt loam blocks designated UPR-1, UPR-2, UPR-3, and UPR-4; **2.** *H. pseudorobustus* in Hartsburg-Illiopolis silty clay loam blocks designated HA-1, HA-2, and HA-3; **3.** *Paratylenchus projectus* in Toledo silt loam blocks designated TO-1, TO-2, TO-3, and TO-4; **4.** *P. projectus* in Urbana-Drummer silty clay loam blocks designated UDR-1, UDR-2, UDR-3, and UDR-4; **5.** *Xiphinema americanum* in Urbana-Drummer silty clay loam blocks designated UDR-1, UDR-2, UDR-3, and UDR-4; **6.** *X. americanum* in Urbana-Proctor silt loam blocks designated UPR-1, UPR-2, UPR-3, and UPR-4.

TABLE 1. Means of numbers of six nematode species found in four different soils in blocks grouped according to the crop growing at time of sampling.

Soil Type Code and crop	Mean numbers of nematodes per 473 cc (1 pint) soil					
	H. pseudorobustus	*P. projectus*	*T. martini*	*T. acutus*	*X. americanum*	*Pratylenchus* spp.
Urbana-Proctor silt loam						
A corn	6	608	0	0	326	115
B soybeans	15	530	0	0	276	37
C wheat	11	385	0	0	196	9
D forage	35	1987	0	0	217	20
Toledo-Cisne silt loam						
E corn	6	1085	4	0	197	238
F soybeans	8	1513	0	0	82	91
G wheat	0	1200	8	0	47	66
H forage	20	1757	0	0	159	178
Urbana-Drummer silty clay loam						
I corn	531	14	14	0	302	112
J soybeans	1068	47	16	6	334	103
K wheat	393	20	8	0	85	31
L forage	157	53	8	0	248	52
Hartsburg-Illiopolis silty clay loam						
M corn	1339	120	0	101	147	240
N soybeans	906	49	0	133	104	108
O wheat	486	19	8	166	69	59
P corn (cont.)[a]	805	15	0	0	53	561
Q soybean (cont.)[a]	840	47	0	175	115	42

Comparison	df	Values for H ($=\chi^2$)					
A,E vs. I,M	19	14.28**	12.12**	—	—	—	—
B,F vs. J,N	19	14.28**	9.60**	—	—	—	—
C,G vs. K,O	19	14.28**	14.28**	—	—	—	—
D,H vs. L	14	6.00*	9.36**	—	—	—	—

[a] The designated crop was planted continuously in these fields.
* Significant at the $p = 0.05$ level.
** Significant at the $p = 0.01$ level.

all three crops in the rotation, with the differences in buildup among crops not significant. There was no buildup in continuous corn, but good buildup in continuous soybeans (Table 1).

Xiphinema americanum was present in all blocks, and in contrast to the other species discussed, densities of this species in the blocks of different soil types were similar. Fig. 5 and 6 show rather consistent recoveries for all crops in eight of these blocks over the 5-year period in both Urbana-Drummer silty clay loam and Urbana-Proctor silt loam respectively. Means for each crop based on data from all blocks sampled are given on Table 1.

The recoveries of *Pratylenchus* species were low in the Urbana-Proctor silt loam, which is the best-drained soil of the group. Most other recoveries (Table 1) were low compared with observations reported previously (3) and with no further effect of the soil type apparent. It should be noted that small numbers of *P. crenatus* Loof were present at the Toledo location. These, together with the other four species, comprised the *Pratylenchus* "complex" found in the blocks.

DISCUSSION

Explanations for findings in field experiments necessarily involve much speculation. However, some interpretation of field results in terms of information from controlled laboratory experiments is desirable and essential. The conclusions of Kable and Mai (6) from their laboratory studies on the influence of soil moisture on *Pratylenchus penetrans*, are relevant to the present study. The former authors feel that nematode population growth in the field is controlled by an interaction of soil moisture with soil type. They point out that clay loam soils need to dry to higher moisture tensions after rain or irrigation than do sandy soils before conditions favor nematode activity, and that under the same climatic influences, clay loam soils dry out less rapidly than sandy soils. Further, they suggest that at high moisture tensions, nematodes may better obtain their metabolic water requirements from the abundant water-filled fine capillaries of clay loam soils than from sandy loams.

If it can be generalized that the growing seasons for the 5-year period, 1963–1967, tended to be droughty, then it can be postulated that the light soils did not provide sufficient soil moisture for *H. pseudorobustus*, whereas the conditions in the heavier soils were more suitable. The information of Table 2 regarding precipitation on the Agronomy Farm in Urbana would seem to substantiate the hypothesis, except perhaps for the year 1965, although even in that year, the soil was fairly dry for 2 weeks prior to the July 23 date of sampling (V. R. Ferris, unpublished data). If this general line of

TABLE 2. Departures from normal precipitation (cm) at Urbana, Illinois, during growing seasons 1963–1967.

Year	May	June	July	August
1963	−8.26	−4.04	+3.12	+0.48
1964	−9.07	+3.43	−1.73	−1.96
1965	−1.24	−2.03	+5.16	+8.97
1966	−2.95	−2.11	−4.45	−0.99
1967	+1.30	−5.84	−1.09	−2.29

reasoning is pursued, it must be postulated that all of the soils were too dry during this period (1963–1967) for much mid-season development of *T. martini*, although earlier investigations showed that this species developed on all crops in the rotation (4).

The fact that *X. americanum* differed from all other species in the relatively high densities in blocks of all soil types indicates that this species is less sensitive to soil moisture differences, at least within the range provided by these fields, than the other species. Lownsbery and Maggenti (8) reported equal buildup of *X. americanum* at three different moisture levels in a controlled laboratory study. We obtained higher counts in all blocks during the fairly dry period of this study than in an earlier study on crop effect (4). This might indicate that *X. americanum* develops better in somewhat drier soils. However, none of the blocks of the soil-type study had a double cropping of corn which might also tend to keep populations higher, inasmuch as a second year of corn may have a depressant effect on *X. americanum* (4).

The *Pratylenchus* species in these blocks may have been limited by dry conditions and absence of a double cropping of corn (an excellent host for several of the *Pratylenchus* species occurring here). Kable and Mai (6) suggest that in the Northeast United States, population peaks of *P. penetrans* in the spring and the autumn coincide with periods of moderate moisture tensions in field soils.

The present authors are in agreement that overall buildups of *Pratylenchus* species in soil and roots probably coincide with favorable soil moisture conditions. However, the relatively low counts from soil at mid-season when most individuals are inside the roots, reflect the endoparasitic nature of the genus and contrast with findings for the ectoparasitic species.

The buildup of *T. acutus* in soybean fields is erratic (1). The nematode is present throughout the soybean-growing area of the North-Central region, and occasionally builds up to extremely high numbers. The higher counts of *T. acutus* in the heavy Hartsburg-Illiopolis soil may indicate that this species is relatively susceptible to drying.

Although *P. projectus* may build up to high numbers on soybeans and forage (4), low densities were found even on these crops in the two heavier soils. This was in marked contrast to the large densities in all crops on the two light-colored soils. The fact that *Paratylenchus* species are able to molt to the resistant pre-adult stage, and to survive extended periods of adverse conditions (1, 9), may account in part for the adaptability of this species to the drier soils.

The nematode species considered in this study did not all behave similarly relative to soil type. Winslow's (10) generalization, that soil type may be more important than the crop in determining presence or absence of certain migratory root nematodes, might apply here. Within each soil type, as Winslow noted, the crop affects the prevalence of the various species. We observed that species which appear to develop better with higher soil moisture (*H. pseudorobustus* and the *Pratylenchus* species), also develop very well on corn (3, 4); and corn is a crop that grows best with high soil moisture. In contrast, *P. projectus* and *X. americanum*, which reproduce better on soybeans and legume-containing forages (4) thrive in the drier soils.

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