Influence of Selected Maize Hybrids on Nematode Populations Under Differing Edaphic Conditions

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ABSTRACT

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Commercial maize hybrids were grown at locations throughout east central Iowa to test their effects on plant-parasitic nematode populations in various soil types. Hybrids differed ($P = 0.05$) mainly with respect to population increase for *Pratylenchus* spp. Numbers of *Helicotylenchus pseudorobustus*, Tylenchorhynchinae, and *Xiphinema americanum* were not affected by differences in maize germ plasm. Relative hybrid suitability for *Pratylenchus* spp. reproduction remained essentially constant among locations despite differences in soil type and *Pratylenchus* species composition. For some hybrids, nematode reproduction was significantly influenced ($P = 0.05$) by age of host plant.

Additional key words: interactions, lesion nematode

Many species of plant-parasitic nematodes have been associated with maize (*Zea mays* L.) in the midwestern United States (4,7,10,17). Relationships between nematode numbers and maize yield have been suggested through simple correlations (16) and use of nematicides to reduce field populations (2,5,9,14). Information is lacking, however, on the combined interaction of maize hybrids, edaphic factors, and nematode populations under field conditions in the upper Midwest. Earlier reports of nematode resistance in maize mainly consider *Meloidogyne* spp. affecting hybrids grown in the southeastern United States (1,11,12). More recently, significant differences in reproduction of *Helicotylenchus pseudorobustus* (Steiner) Golden were observed among 10 maize lines under greenhouse conditions (13), but none were judged highly resistant. In field and greenhouse tests of maize inbred lines, Georgi et al (6) and Waudo and Norton (18) found differences in the host suitability to *Pratylenchus* spp., which are perhaps the most important nematodes affecting maize in the upper Midwest.

The objectives of this study were to determine if differences exist in the ability of selected maize hybrids to support plant-parasitic nematode populations and to ascertain whether host suitability for population development is influenced by varying soil characteristics among locations.

MATERIALS AND METHODS

The results reported are from a test at Dayton, IA, in 1976 and experiments at seven locations throughout east central Iowa during 1977 and 1978. An additional site at Chariton in southern Iowa was added during 1978. These locations represent six principal Iowa soil associations and eight soil types with percentages of sand-silt-clay as follows: Webster clay loam (23-49-28) at Adel and Dayton, Haig silty clay loam (2-70-28) at Chariton, Sawmill silt loam (15-59-26) at Dewitt, Waukegan loam (over sand) (11-59-30) at Johnston, Garwin silty clay loam (2-64-34) at Kellogg, Otley silty clay loam (1-68-31) at Marengo, Tama silty clay loam (9-59-32) at Reinbeck, and Nicollet loam (53-27-20) at Roland.

Maize was preceded by soybeans, alfalfa, or red clover at all sites except Chariton, where maize was cropped

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continuously for 6 yr. Plots were planted to Pioneer maize hybrids 3780, 3728, 3541, 3591, and Mo17 × B73 at seeding rates of 361, 426, and 492 kernels per 100 m of row in 1977 and at 426 kernels per 100 m of row in 1978. Seven additional DeKalb maize hybrids (XL-16, XL-25, XL-35, XL-43, XL-44, XL-55, and XL-72B) were included at Dayton and Chariton. Fertilizer was applied as needed at each location. Herbicide application included alachlor (7.01 L/ha) at Adel, Chariton, and Roland and none at other locations. Insecticide applications were limited to heptachlor (1.68 kg/ha) at Reinbeck in 1977–1978 and to ethoprop (1.34 kg/ha) and fonofos (1.12 kg/ha) at Kellogg and Roland, respectively, in 1978. An experimental unit consisted of two adjacent 6.1-m rows of the same hybrid. Row spacings were 96 cm at Reinbeck, 91 cm at Kellogg, and 76 cm at the remaining sites. DeKalb hybrids were arranged in 7 × 7 latin squares at Dayton in 1976 and at Chariton in 1978. Other hybrids were arranged in randomized blocks replicated three times in 1977, seven times at Chariton in 1978, and twice at all other locations in 1978. A composite soil sample from each experimental unit consisted of 10 cores (2 × 15 cm) from within the paired rows. Samples were taken at midseason and maturity in 1976 and 1977 and at monthly intervals from May through September in 1978.

Nematodes were recovered from a 100-cm^3 subsample of soil within 48 hr of sampling by the centrifugal-flotation method (8). Beginning in July, fibrous roots were collected from soil samples and processed for migratory endoparasites by Bird's shaker method (3). Roots were dried and weighed after nematode extraction, and numbers of endoparasites per gram of dry root were determined. Before statistical analysis, nematode data were transformed as follows: natural log $(X + 1)$, where X is the original nematode count. This facilitated statistical analysis of treatments with unequal initial nematode densities as well as partly compensating for skewdness resulting from population increases during the growing seasons.

RESULTS

Conditions for maize growth during 1977 varied greatly among locations because of combined effects of drought stress, hail injury, and insect damage. These problems did not occur in 1976 or 1978, when maize growth was nearly ideal at all sites.

In a preliminary test of seven maize hybrids at Dayton in 1976, significant differences in nematode population increase occurred at the end of the growing season for root-extracted *Pratylenchus* spp. (Table 1) and *Helicotylenchus pseudorobustus*, Tylenchorhynchinae, and nonstylet nematodes from soil. No such differences occurred at midseason.

Mean numbers of nematodes associated with five maize hybrids were greater in 1977 than in 1978 (Table 2). No significant differences in susceptibility occurred among hybrids during 1977, though trends were similar to those in 1978. Root populations of migratory endoparasitic *Pratylenchus* spp. and *Hoplolaimus galeatus* responded differently ($P = 0.05$) to the various maize hybrids in 1978 (Table 2). No differences were detected in responses of ectoparasites *H. pseudorobustus* or *Xiphinema americanum* to hybrids. Significantly greater ($P = 0.05$) recovery of *Pratylenchus* spp. occurred from roots of hybrids 3780 and 3541 during 1978. Populations were also influenced ($P = 0.05$) by maize development, as evidenced by the significant interaction ($P = 0.05$) between hybrids and age of plants in 1978.

Mean population size for *Pratylenchus* spp. from maize roots of hybrids Mo17 × B73, 3780, 3728, 3541, and 3591 at Chariton (Table 3) followed the identical ranking of the combined means from the seven locations discussed previously (Table 2). Significantly lower ($P = 0.05$) lesion nematode populations were recovered from hybrid 3728, whereas populations from hybrid 3780 exceeded those from the remaining four hybrids

Table 1. Mean numbers of *Pratylenchus* spp. associated with DeKalb maize hybrids at Dayton, IA, in 1976

	No./g dry root	
Hybrid	8 September[z]	Seasonal average
XL-72B	43 a	69
XL-16	49 ab	108
XL-55	125 ab	142
XL-35	190 ab	213
XL-44	335 b	324
XL-25	367 b	348
XL-43	383 b	402

[z]Means are antilogs calculated from transformed data. Those followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 2. Mean numbers of nematodes associated with Pioneer maize hybrids and a station line hybrid at seven Iowa locations in 1977 and 1978 (Chariton site not included)[y]

	Hybrid[z]				
Nematode	Mo17 × B73	3780	3728	3541	3591
			No./100 cm^3 soil		
Helicotylenchus pseudorobustus					
1977	64	53	51	75	69
1978	42	61	40	46	39
Pratylenchus spp.					
1977	37	33	18	47	23
1978	15	16	17	16	16
Xiphinema americanum					
1977	25	29	17	24	20
1978	6	8	5	8	5
			No./g dry root		
Hoplolaimus galeatus					
1977	3	4	9	3	9
1978	1 b	2 b	9 a	2 b	1 b
Pratylenchus spp.					
1977	531	754	462	827	797
1978	277	404	236	382	268
July 1978	149 b	651 a	201 b	351 ab	182 b
August 1978	334	275	244	305	336
September 1978	427 b	369 b	269 b	684 a	314 b

[y]Numbers represent seasonal means unless otherwise noted.
[z]Means are antilogs calculated from transformed data. Those followed by the same letter or no letter are not significantly different ($P = 0.05$) from hybrid to hybrid across columns according to Duncan's multiple range test.

Table 3. Mean population size for nematodes associated with Pioneer maize hybrids and a station line hybrid tested in a randomized block design at Chariton, IA, in 1978[z]

	No./100 cm^3 soil			
Hybrid	*Helicotylenchus pseudorobustus*	*Pratylenchus* spp.	Total nematodes	*Pratylenchus* spp. (no./g dry root)
Mo17 × B73	178	73 bc	594	701 b
3780	188	124 a	619	1,448 a
3728	150	52 c	551	567 d
3541	205	96 ab	704	871 ab
3591	150	61 c	562	695 c

[z]Means are antilogs calculated from transformed data. Those followed by the same letter or no letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

(Table 3). At Chariton, soil populations of *Pratylenchus* spp. also varied significantly among hybrids, paralleling the response of root populations. Neither total numbers of soil nematodes nor populations of *Helicotylenchus pseudorobustus* varied among maize hybrids. In a duplicate experiment at Chariton, incorporating the same seven hybrids and experimental design used in the preliminary test at Dayton, significant differences in population increase again occurred only among the soil and root populations of *Pratylenchus* spp., with XL-72B supporting the lowest populations and XL-25 the highest (Table 4).

Table 4. Mean population size for nematodes associated with DeKalb maize hybrids tested in a latin square design at Chariton, IA, in 1978[z]

	No./100 cm³ soil			
Hybrid	***Helicotylenchus pseudorobustus***	***Pratylenchus* spp.**	**Total nematodes**	***Pratylenchus* spp. (no./g dry root)**
XL-25	163	120 a	630	2,812 a
XL-35	187	121 a	672	2,151 ab
XL-44	137	77 b	596	1,767 bc
XL-55	164	140 a	730	1,703 bc
XL-43	166	101 ab	631	1,585 bc
XL-16	138	100 ab	604	1,315 c
XL-72B	163	100 ab	685	697 d

[z] Means are antilogs calculated from transformed data. Those followed by the same letter or no letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 5. Species composition of *Pratylenchus* spp. populations at eight Iowa locations in 1978[a]

Location	***P. agilis* Thorne & Malek (%)**	***P. alleni* Ferris (%)**	***P. flakkensis* (%)**	***P. hexincisus* (%)**	***P. scribneri* (%)**
Adel					
28 July	0	0	86	14	0
29 September	0	0	88	12	0
Chariton					
18 July	0	0	0	67	33
15 September	0	0	0	67	33
DeWitt					
25 July	42	30	0	14	14
30 September	38	38	0	15	9
Johnston					
28 July	0	0	0	47	53
29 September	0	0	0	47	53
Kellogg					
25 July	10	33	0	14	43
29 September	4	28	0	17	50
Marengo					
25 July	0	0	100	0	0
30 September	0	0	100	0	0
Reinbeck					
25 July	33	0	67	0	0
30 September	33	0	67	0	0
Roland					
28 July	0	0	0	22	78
29 September	0	0	0	32	68

[a] Based on identification of 30 randomly selected adult nematodes.

Table 6. Mean numbers of *Pratylenchus* spp. per gram of dry root associated with Pioneer maize hybrids and a station line hybrid at eight Iowa locations in 1978

	Location							
Hybrid	**Adel**	**Chariton**	**DeWitt**	**Johnston**	**Kellogg**	**Marengo**	**Reinbeck**	**Roland**
Mo17×B73	851	93	788	555	62	861	31	1,076
3780	936	135	1,143	1,161	96	2,167	31	808
3728	604	60	492	427	43	1,519	22	563
3541	1,268	107	868	1,659	56	1,571	47	508
3591	681	64	1,247	857	90	833	22	288
Location av.[x]	966 ab	92[y]	1,025 ab	988 ab	83[z]	1,557 a	40 c	764 b

[x] Means are antilogs calculated from transformed data. Those followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.
[y] Excluded from analysis owing to increased number of replicates and difference in experimental design at Chariton.
[z] Excluded from analysis because of preseason application of ethoprop for corn rootworm control.

Species composition of the *Pratylenchus* population at each location in 1978 is presented in Table 5. *Pratylenchus hexincisus* Taylor & Jenkins was the most commonly encountered species and was found in conjunction with *P. scribneri* Steiner at all but one of the six sites from which it was recovered. Populations at all sites represented a mixture of two to four species of *Pratylenchus* except for Marengo, which consisted entirely of *P. flakkensis* Seinhorse. No shift in species composition was observed at any location between the July and September samplings.

In addition to significant differences among maize hybrids, numbers of *Pratylenchus* spp. also differed ($P = 0.05$) among locations (Table 6). Although 20-fold differences in mean population size for nematodes occurred among several hybrids, most maintained similar host suitability despite differences in soil type and the previously mentioned *Pratylenchus* species compositions among locations. For example, hybrid 3780 supported either highest or second highest numbers of *Pratylenchus* spp. at all locations, whereas hybrid 3728 supported the lowest nematode populations at six of the eight locations. No significant interactions occurred between locations and hybrids, further supporting these observations.

Comparisons of nematode populations and soil properties (pH, organic matter content, cation-exchange capacity, field capacity, and percentages of sand, silt, and clay) during the droughty year of 1977 showed nematode numbers were most significantly ($P \leqslant 0.05$) affected by soil properties related to moisture retention. For instance, numbers of *Helicotylenchus pseudorobustus* ($r = 0.49$, $P = 0.02$), *Hoplolaimus galeatus* ($r = 0.44$, $P = 0.04$), *Pratylenchus* spp. ($r = -0.44$, $P = 0.04$), and Tylenchorhynchinae ($r = -0.52$, $P = 0.01$) were correlated with silt content. Similar correlations occurred with sand and clay content and field capacity for various nematode genera. In 1978, when moisture was adequate, nematode population development was most closely related to soil chemical properties. Cation exchange capacity and pH were the most frequently correlated factors, with the latter being related to population development among dorylaimids ($r = 0.76$, $P = 0.002$), *H. galeatus* ($r = -0.77$, $P = 0.002$), *Paratylenchus projectus* ($r = -0.65$, $P = 0.01$), *Pratylenchus* spp. ($r = 0.66$, $P = 0.01$), and Tylenchorhynchinae ($r = 0.80$, $P = 0.01$).

DISCUSSION

The hybrids in this study differed with regard to reproduction of *Pratylenchus* spp. Ectoparasitic nematodes did not respond to variations in host germ plasm.

Despite changes in seasonal populations, *Pratylenchus* species, and soil type among locations, relative hybrid suitability for *Pratylenchus* spp. reproduction did not change. This suggests that lesion nematode resistance in maize may result from numerous mechanisms under polygenic control, because monogenic resistance mechanisms rarely affect different pathogen species and frequently vary among pathotypes within a species (15). Among maize inbreds, 63-fold (18) and 44-fold (6) differences in susceptibility to *Pratylenchus* spp. have been reported. Although only 12 hybrids were examined in this study, the fivefold difference among hybrids at Chariton indicates that the potential for differences in nematode reproduction within commercial hybrids may be less than that among inbred lines.

Relative suitability for *Pratylenchus* spp. reproduction changed significantly among hybrids from July to September 1978, perhaps reflecting differences in midseason damage to the host root system or seasonal changes in the reproduction rate of the nematode. The importance of differential reproduction was recognized by Georgi et al (6) in studies of maize inbred susceptibility to *P. hexincisus*. In our study, hybrid 3780 was most susceptible before flowering but showed decreasing susceptibility thereafter, whereas hybrids 3591 and Mo17 × B73 changed little throughout the season. Breeders need to be aware of these seasonal dynamics when evaluating lesion nematode resistance in maize, because selections based on late-season nematode recovery may not accurately represent midseason host suitability. Similarly, correlations among nematode populations and soil properties changed with variation in the type of environmental stress affecting host plant development in this study. These limitations should be acknowledged when attempting to use soil factors to predict potential nematode problems.

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