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Maize Nematode Problems

Maize, rice, and wheat are the three most important food crops in the world. Until recently, the relationships of nematodes to maize production losses have received little attention. Maize nematology has developed slowly because in most parts of the world the crop is planted for local food by subsistence farmers and often in semiarid climates. Where grown for profit, maize is considered a "low cash crop," compared with such "high cash crops" as citrus and many vegetables. The lack of trained personnel also impeded progress. Nematodes are recognized now as major pests of maize in most areas of the world where they have been investigated (3,4,6,8,10,11).

Probably all the maize plants grown on the 100 million hectares devoted to this crop in the world are parasitized by nematodes. This is not as startling as it may seem. Plant-parasitic nematodes are ubiquitous, and we can expect universal parasitism of maize roots. The real problems are: 1) determining which species of nematodes are pathogenic to maize, 2) correlating population densities with yield loss, 3) determining environmental effects on nematode activity, and 4) determining how to control them.

The maize root system is largely fibrous. Many nematodes feed on or are confined to the cortical tissues of the fibrous roots. Because cortical tissues are intermediary for translocation of raw materials between the epidermis and vascular tissues, destruction of cortical cells seriously impairs this vital function. Maize often seems tolerant to large numbers of nematodes, eg, 3,000 lesion (*Pratylenchus* spp.) nematodes per gram of dry root. Frequently, enormous populations, ie, 10,000–40,000 *Pratylenchus* spp. per gram of dry root, are found and nearly always are associated with poor plant growth.

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Symptoms and Occurrence

Damage caused by nematodes sometimes is obvious (Fig. 1), but the farmer may not associate the cause with nematode feeding. Symptoms often are similar to those caused by other organisms or by local weather or adverse agronomic practices. The field appearance may be one of stunted plants locally (Fig. 2) or generally, often resulting in an undulating or "roller coaster" effect (Fig. 3). Individual plants may lose vigor, be off-color, lack response to fertilizer, have poor pollination, have small ears, or be lodged. More often than not, the main indication of nematode damage is that the farmer does not obtain the yields he thinks he should. These losses are insidious and are often more widespread than striking damage. Such insidious losses are accepted because the cause frequently is unknown.

The maize root is the primary organ attacked by nematodes, although the stem nematode (*Ditylenchus* spp.) is damaging stalks in Europe. Root symptoms vary widely but may consist of slight general discoloration to few or many distinct lesions (Fig. 4), stubby roots (Fig. 5), a proliferation of fibrous roots, or just a general unthrifty root system. Sometimes there is no discoloration but just a small root system. The impaired root system usually is responsible for the poor appearance of the foliage.

At least 120 species of plant-parasitic nematodes are known to be associated with maize throughout the world. Of these, over 60 are associated with maize in North America. Because of environmental differences, only three to seven species of plant-parasitic nematodes are usually found in a field at one time. In spite of the large number of nematodes associated with maize, pathogenicity studies have been attempted with only a few. Sometimes the circumstantial evidence is so overwhelming that a certain species is assumed to be pathogenic in the absence of experimental proof. These assumptions can be misleading.

One aspect has become very clear. We can no longer refer simply to nematodes and maize but must refer to which nematode species are associated with which cultivar and under what environments.

Evaluation of losses is difficult because nematodes usually occur in polyspecific communities. One or two species frequently dominate, however, and seemingly are the major cause of reduced yields. Yield losses sometimes correlate better with total nematode biomass in the roots than with biomasses of separate species (Fig. 6).

Thresholds

A common question is, "How many nematodes are needed for significant

Fig. 1. Field of maize (Lee County, Iowa) heavily infested with the needle nematode (*Longidorus breviannulatus*).

Fig. 2. A spot of stunted plants in a 12-ha maize field heavily infested with *Pratylenchus scribneri*. Such spots were common in the field, and yield in the spots was reduced by 80%.

Fig. 3. The undulating "roller coaster" effect on plant height in a maize field (Woodbury County, Iowa) heavily infested with *Pratylenchus scribneri* and *P. hexincisus*.

damage?" Of course, no value or range of values that covers most situations can be quoted with authority. This is because different nematode species differ in their life cycles, host-parasite relationships, rates of increase, and ecological niches (Fig. 7). In addition, the environment under which the plant is growing has a tremendous influence on the amount of damage caused by nematodes. Such poor agronomic conditions as moisture stress, soils unsuitable for maize growth, low fertility, and inadequate weed control, with increased competition for the maize roots, all bear on the amount of damage that results from nematode feeding. Thus, threshold values must be determined for each local situation.

Evidence that we have obtained in Iowa generally indicates that numbers of *P. hexincisus* below 1,000 per gram of dry root at midseason will not cause measurable yield losses. Numbers between 1,000 and 4,000 are considered marginal for causing loss. As numbers increase above 5,000 per gram of dry fibrous root, the probability increases

Fig. 4. Lesions caused by *Pratylenchus hexincisus* in maize roots. (From Zirakparvar [12])

Fig. 5. Root of maize from an area heavily infested with *Longidorus breviannulatus*. The root-pruning or stubby-root effect can be mistaken for herbicide damage.

that significant damage is occurring or will occur. Local conditions can modify these figures either way. For example, in years with moderately excess rainfall on loam or clay-loam soils, nematode numbers often decrease. Nematode damage is often slight in these situations, not only because of fewer nematodes, but also because of the good plant growth that compensates for damage by nematodes feeding. The same number of nematodes in a moderately dry year can cause significant damage because nematode populations often increase under these conditions and the plant is under a moisture stress.

Use of Chemicals

Until we know more about the usefulness of cropping systems for nematode control and until resistant cultivars are more available, nematicides are and will be a principal short-term control method.

The efficacy of most nematicides will vary, depending on the properties of the chemicals themselves; time, depth, and method of application; possible buildup of nematode resistance to a given chemical (something we know little about); soil type; rainfall; and other climatic and edaphic factors. In any test of candidate nematicides, there is usually a wide spectrum of nematode control among the chemicals. Control of *Pratylenchus* spp. by granular nematicides is depicted in Figure 8 for maize growing in a silty loam soil. Treatments that combine different chemicals or apply them at different times, such as a lay-by, often give better control than a single application of one nematicide. Nematicides have been a helpful tool in delineating losses caused by nematodes, but their use should be only in conjunction with other methods of evaluation.

Resistance

It is often said that resistance to the browsing type of nematode, such as *Pratylenchus* spp., is more difficult to find and incorporate than resistance to nematodes such as *Meloidogyne* spp., the cause of root-knot, where host-parasite relationships are more intricate. It is becoming evident, however, that maize genotypes react differently to individual species of *Pratylenchus*. Table 1 shows the ability of nematode species to increase on several commercial hybrids in the same field. These data are based on nematode numbers and do not imply knowledge on pathogenicity, tolerance, or regrowth ability of the root. If large differences in susceptibilities of hybrids occur, their parentage must also vary considerably in reaction to nematodes. Although we need to learn much about resistance, tolerance, and the ability of the roots to recover, any plant that supports large numbers of nematodes increases the chances that the subsequent crop will be damaged.

In the northern corn belt of the United States, most of the common nematodes that parasitize maize also parasitize soybeans, a crop commonly rotated with maize. We are becoming more cognizant that nematodes parasitizing cultivars of either maize or soybeans do so to different degrees. We need many more data before we can make sound and useful recommendations, however.

Species of *Pratylenchus* probably are the most common and most important nematodes attacking maize in the corn belt. Nematodes of other genera can be more damaging in certain localities but usually are not so widely distributed as species of *Pratylenchus*. The ubiquitous-

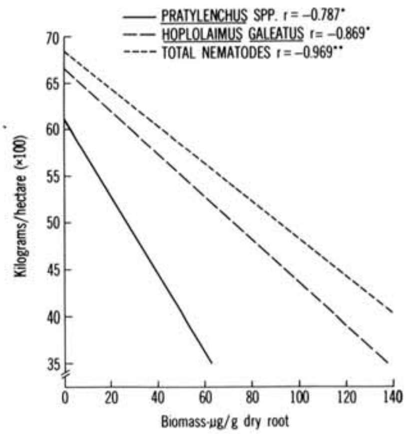

Fig. 6. Correlations of the biomass of *Pratylenchus* spp. and *Hoplolaimus galeatus*, alone and together, with maize yields in Story County, Iowa. (Calculated from Norton et al [8])

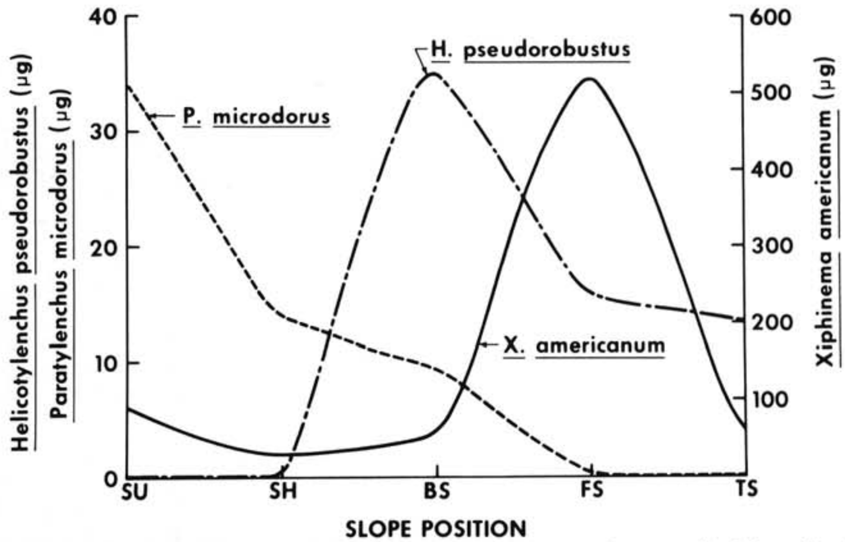

Fig. 7. Differences in biomass of three nematodes along a slope gradient in maize in Pottawattamie County, Iowa, 1978. SU = summit, SH = shoulder, BS = backslope, FS = footslope, TS = toeslope. (Redrawn from Norton and Oard [7])

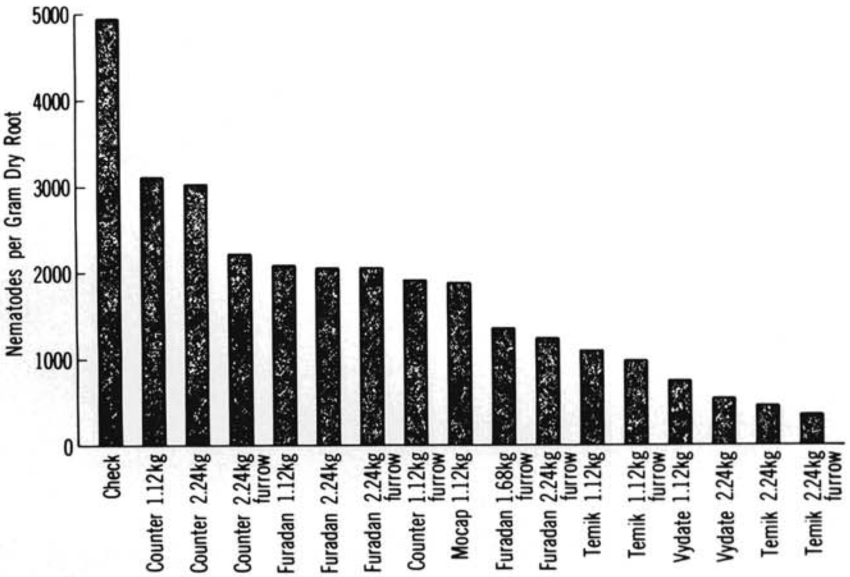

Fig. 8. Effectiveness of chemicals in controlling *Pratylenchus* spp.; rates are in kilogram per hectare.

Table 1. Seasonal mean numbers of *Pratylenchus* spp. associated with commercial maize hybrids in Iowa, 1978[a]

Commercial hybrid	Nematodes per 100 cm³ soil[b]	Nematodes per gram dry root[b]
1[c]	152	3,778
2	162	2,982
3	111	2,409
4	176	2,314
5	120	2,080
6	117	1,821
7	113	1,290
8	152	135
9	112	107
B73 × Mo17	90	93
10	79	64
11	66	60

[a] From the Ph.D. dissertation of S. H. Thomas, Iowa State University, 1980.
[b] Average of seven replications sampled monthly from mid-June through October.
[c] Closed-pedigree hybrids are listed anonymously to avoid a misrepresentation of any company's product line, since surveying the many hundreds of commercial hybrids produced was impossible.

ness of *Pratylenchus* spp. attacking maize should not imply that every maize crop will sustain losses due to these pests. But every year, conditions in some fields will allow an increase of lesion nematodes that results in economic loss. If we can find good resistance in maize to certain lesion nematode species, we could discount these species as potential threats over wide areas.

Eight species of lesion nematodes are known to attack maize in Iowa, with the most widespread being *P. hexincisus* and *P. scribneri*. We know that maize genotypes differ in their susceptibilities to a given species of *Pratylenchus*, but do all lesion nematode species react the same? This remains to be seen.

There are no released varieties resistant to lesion nematodes in the United States. Before plant breeders can incorporate resistance into commercially acceptable hybrids, we must first find resistance. We are taking two approaches. One is to test open-pedigree inbreds and hybrids commonly used in the north central region of the United States. The second approach is to search for resistance in a wide variety of germ plasm, including flint, dent, pop, pod, and sweet corns from around the world. We are also testing collections of teosinte (*Zea mexicana*), commonly believed to be a forerunner of modern maize, and *Z. diploperennis*, a perennial species related to maize. Preliminary results indicate that teosinte is as susceptible to *P. hexincisus* as many accessions of dent and flint types. If teosinte is a primitive corn, susceptibility to *P. hexincisus* might have been carried along by natural evolution. Several workers in the north central region of the United States are finding inbreds susceptible to *Pratylenchus* spp. It is possible that breeders are unknowingly carrying this susceptibility along.

Future

In a way, it is easier to discuss the present and future problems than past accomplishments. Nematology must be incorporated into integrated pest management systems. Yet, baseline data for IPM decisions are often lacking. Many hurdles are procedural. Sampling techniques (1) are not standardized and must be adapted to each situation. The distribution of various plant-parasitic nematodes in a field is rarely uniform or random (2). Ferris and McKenry (5) have shown that different nematodes differ in distribution in and between the rows. Qualitative and quantitative differences in the nematode population also vary along a toposequence (Fig. 7).

Many commercial hybrids in which large numbers of *Pratylenchus* spp. have been found are root-rot susceptible. This association deserves more attention than it has received. Root rots of maize have been studied for decades, but nematodes attacking maize have received concentrated effort only in the past few years. Do we really understand the etiology of the root disease complex? I doubt it.

Because of the complex nature of the soil ecosystem, one or two experiments do not give an overview. Taking the narrow, often short-term approach is not enough. As one scientist (9) put it, ". . . those at too great a distance may, I am well aware, mistake ignorance for perspective."

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Dr. Norton is professor of plant pathology at Iowa State University, Ames. After receiving his Ph.D. in plant pathology from Ohio State University in 1950, he was on the staff of Texas A&M University for 8 years. In 1959 he moved to Iowa State, where he teaches plant nematology and specializes in research with nematodes attacking maize.

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