A New Corn Disease Caused by *Longidorus breviannulatus* in the Midwest

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ABSTRACT
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Longidorus breviannulatus can cause severe stunting, chlorosis, and occasional mortality of corn in irregular patches in sandy soils during the first 6-8 wk after planting. Later, damaged plants may become as tall as unaffected ones, but stalks remain slender, and if formed, ears are much reduced in size. Root symptoms include yellow discoloration, slightly swollen root tips, stubby-root, pruning of laterals, and scarcity of small feeder roots. When soil moisture is high, seminal roots are destroyed and brushlike crown roots proliferate near the soil surface. The prop root system is unaffected. The disease has been found in Illinois, Iowa, and Indiana and is most severe on soils containing more than 90% sand.

Additional key words: ecology, pathogenicity, *Zea mays*

Needle nematodes (*Longidorus* spp.) were not reported as parasites of agronomic crops in the midwestern United States until 1975 when *Longidorus breviannulatus* Norton and Hoffman was associated with stunted corn (*Zea mays* L.) in Iowa (3). In June 1975, up to 400 *L. breviannulatus* per 100 cm^3 of soil were recovered from the rhizosphere of severely stunted dent corn at the Illinois River Valley Sand Field, a research farm in Mason County, IL. Numerous seedlings had died 2–3 wk earlier, and the second planting had the same symptoms as the first planting. All life stages of the nematode were present, but first- and second-stage juveniles predominated. This paper describes the disease in Illinois and Iowa and results of a pathogenicity test in the greenhouse.

DISTRIBUTION

L. breviannulatus has been found on dent corn in seven counties in central and northern Illinois, dent corn in four counties in southeastern Iowa, and sweet corn in one county in northwestern Indiana (J. M. Ferris, *personal communication*). It also has been associated with field corn in Delaware (3) and sorghum (*Sorghum bicolor* Pers.) in Illinois. In the Midwest, *L. breviannulatus* has been found only in soils containing 49% or more sand. Populations are highest and damage is greatest in soils containing more than 90% sand. Males (undescribed and extremely rare) have been found in field and greenhouse populations in Illinois.

When soil moisture is high, *L. breviannulatus* often occurs in abundance in the upper 10 cm of the soil around seminal and young crown roots early in the growing season. Populations appear to become concentrated at progressively lower depths as the season advances, however, and the nematode may not be detected in the top 15 cm of soil by the end of the season or before spring planting. In nonirrigated corn during drought, the nematode also may be rare or absent in the upper 15 cm of the soil but abundant below the normal 20-cm depth of sampling for advisory purposes during the early season period of maximum symptom expression. Thus, in drier sands, abiotically induced drought and nutrient stress symptoms above ground mask those induced by the nematode.

FIELD SYMPTOMS

Damage by *L. breviannulatus* often becomes evident within 2 wk after seedlings emerge. Symptoms are most pronounced in late May and June (Figs. 1 and 2). Oval to oblong patches, up to 2 ha, of stunted and chlorotic plants occur

Fig. 1. Severe stunting of irrigated dent corn in an experimental area heavily infested with *Longidorus breviannulatus* (center) in contrast to healthy plants (left background) in a lightly infested area, 7 wk after planting, Illinois River Valley Sand Field, Mason County, Illinois.

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in the field. The most severely affected plants in the center of the patches frequently have purple discoloration, characteristic of phosphorus deficiency. This symptom may be ephemeral, however. Stunted plants appear to be under drought stress, particularly when the moisture level of the upper 10 cm of the soil profile drops below field capacity.

Belowground symptoms are typically most obvious on the seminal and first crown roots of seedlings (Figs. 3 and 4). The radicle is abbreviated, and terminals of the primary seminal and crown roots may be slightly swollen. Stubby-root and root pruning of laterals can be severe. Scarcity of small feeder roots give the reduced root system a coarse appearance. Roots have a pronounced yellow discoloration. Symptoms in the top 5–10 cm of the soil are progressively less severe on successively produced upper crown node roots, which penetrate to greater depths. The devitalization and yellowing of these roots usually are most obvious at 10–15 cm depths. Injury to a primary root tip at this depth often results in proliferation of enlarged, stubby lateral roots just behind the terminus. Irrigation or frequent rainfall in late spring tends to enhance symptom expression. Under these conditions, abnormal, brushlike crown roots may proliferate just beneath the soil surface, with little or no penetration of roots below 10 cm (Fig. 5). These plants can be pulled easily from the soil. Although there are no distinct root lesions, older components of the crown root system become tan to brown, and the seminal roots may be destroyed.

The severity of symptom expression is closely related to numbers of *L. breviannulatus* recovered from the rhizosphere in May and June. Stunting of shoots and symptoms on roots have been observed with as few as 10 nematodes per 100 cm^3 of soil. Seedlings often die when numbers of nematodes exceed 100/100 cm^3.

After June, as *L. breviannulatus* becomes less abundant in the top 15 cm of soil, surviving plants begin to overcome earlier damage. Discolored, initially damaged roots contrast sharply with the normal white crown roots that formed later and appear to have circumvented concentrations of needle nematodes and to have remained unaffected. There is no evidence of injury to the prop root system. Although plants may attain normal height by the end of the season, stalks remain slender, and ears, if formed, are greatly reduced in size. Yields in severely affected areas have been reduced by as much as 62%, compared with those in lightly or uninfested areas.

GREENHOUSE TEST

Pathogenicity of *L. breviannulatus* was tested in the greenhouse in an attempt to duplicate field symptoms on roots.

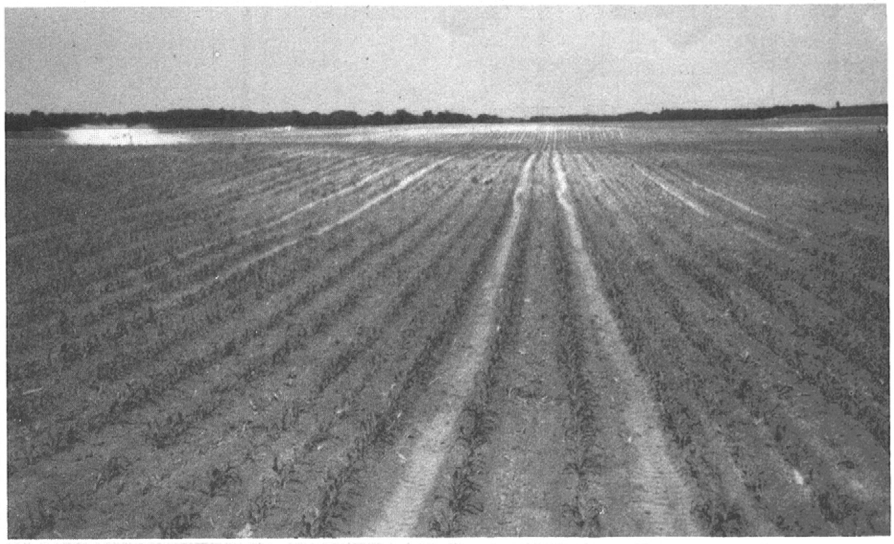

Fig. 2. Area of severe stunting (background) caused by *Longidorus breviannulatus* in an irrigated hybrid seed corn production field, 5 wk after planting, Mason County, Illinois. (Courtesy of M. T. Turner, Funk Seeds International).

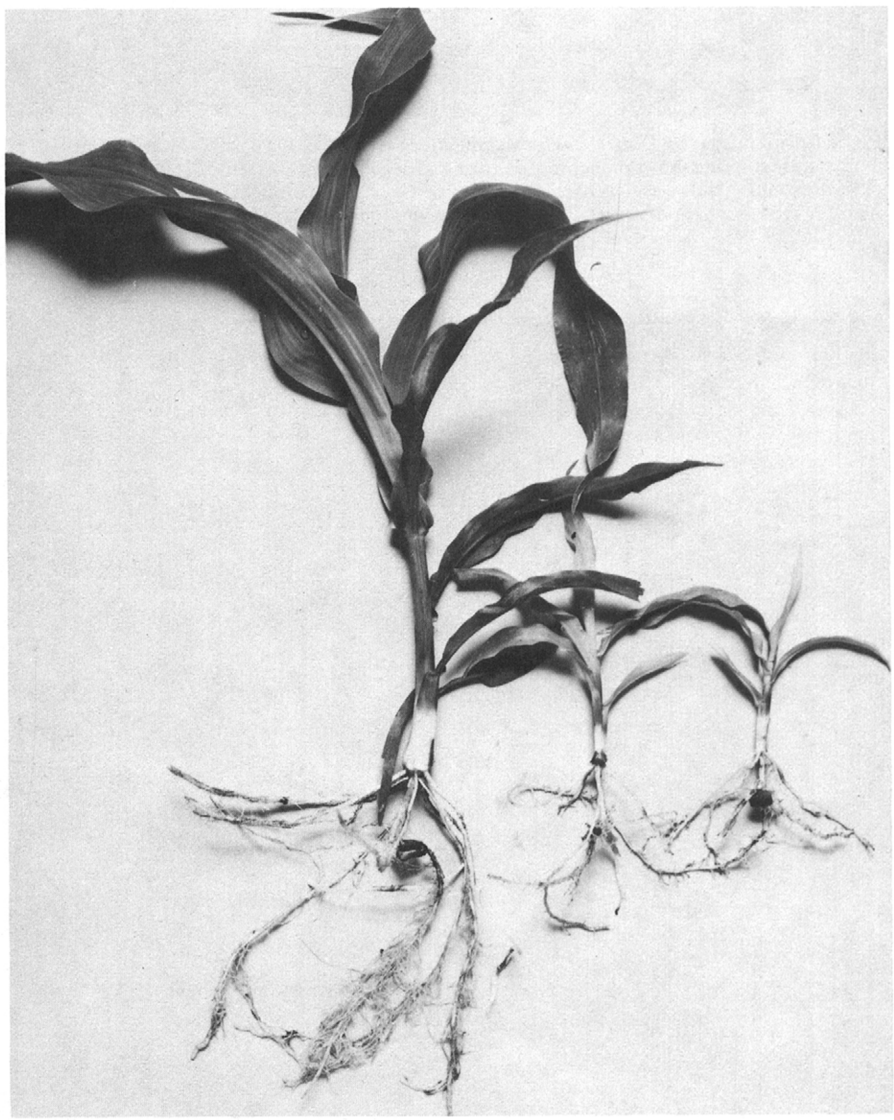

Fig. 3. Healthy corn plant (left) from an uninfested area of an unirrigated production field and two stunted plants from an area infested with *Longidorus breviannulatus*, 7 wk after planting, Lee County, Iowa.

Naturally infested Plainfield sand was obtained from an area of severe stunting at the Illinois River Valley Sand Field (Fig. 1) 1 wk after first recovery of the nematode. Equal amounts of the soil were steam-sterilized, fumigated with 1,3-D at 120 L/ha, or left untreated.

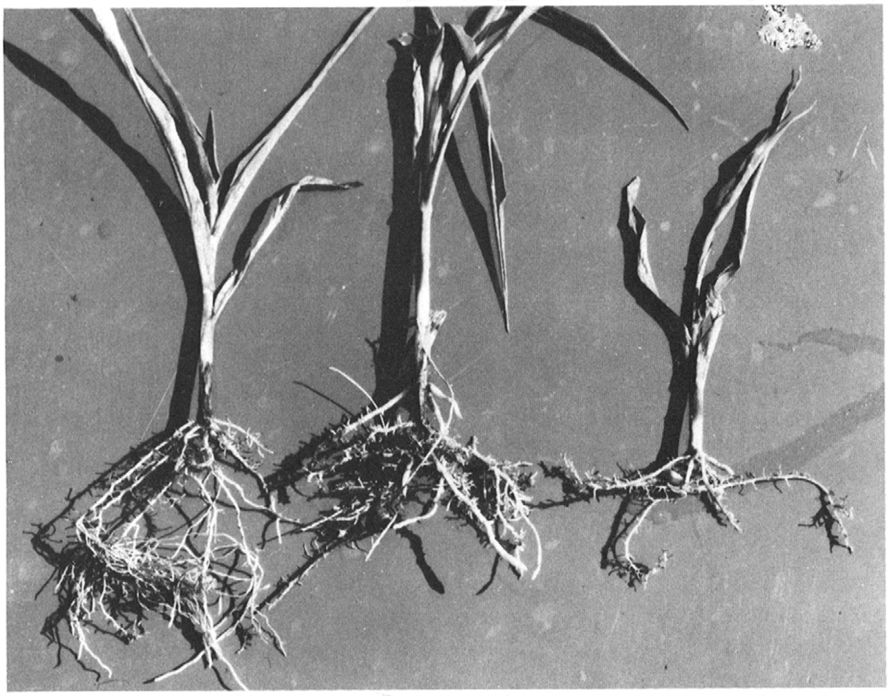

Fig. 4. Corn damaged by *Longidorus breviannulatus:* Seven-week-old corn plant (left) from an area of moderate stunting shows milder root damage and deeper root penetration, (center) from an area of severe stunting shows heavily damaged root system and severe drought stress, and (right) second planting from the area of severe stunting shows symptoms similar to those of the first planting, Illinois River Valley Sand Field.

Fig. 5. Root system of a severely stunted, 7-wk-old corn plant with proliferated and stubby crown roots, swelling of primary root tips, dark discoloration of older roots, and premature deterioration of the radicle (lower left) caused by *Longidorus breviannulatus*, Illinois River Valley Sand Field.

Corn seeds, cv. PAG SX29, were surface-sterilized with 0.5% NaOCl, germinated for 2 days on filter paper, and planted singly in 12.5-cm clay pots containing 700 cm^3 of soil. Pots with untreated soil each contained about 2,500 *L. breviannulatus* in all life stages. Half of the pots containing steamed soil each were infested with 1,600 hand-picked J_3 to adult nematodes. The soil in the remainder of the pots received wash water from the extraction process. A similar number of pots of fumigated soil were inoculated with 1,000 nematodes each or no nematodes.

Three replications for each of the five treatments were randomized on a greenhouse bench where ambient temperatures averaged 27 C. No fertilizer was applied and pots were watered when the soil surface became dry. One month after planting, shoots were removed from all plants. Roots in one pot from each treatment were washed free of soil and examined. Nematodes were extracted from the soil by a modification of the method of Christie and Perry (1). Each remaining pot was replanted with a surface-sterilized, germinated seed and similarly analyzed 1 mo later.

One month after planting, the root system from untreated, naturally infested soil had a yellowish-brown discoloration and was drastically reduced in size. Primary roots were greatly abbreviated, and lateral roots were scarce, short, stubby, and devoid of fine feeder roots. Tips of some of the larger lateral roots were slightly swollen. Average shoot weight was reduced 70% from that of the steamed-soil, noninoculated treatment. Although the obvious enlargement of primary root tips and overproduction of laterals near the soil surface did not occur, the symptoms closely approximated those on young plants in heavily infested soil in the field.

Root systems from steamed and fumigated soils that had been inoculated were similar in appearance. Although root growth was not affected as severely as that in naturally infested soil, volumes and weights of roots were approximately half those from noninoculated pots because of fewer laterals and feeder roots. Primary root length was not noticeably affected. Root systems exhibited the characteristic yellow discoloration. Shoot weights were reduced 10% from those of controls.

Root systems from naturally infested soil 1 mo after replanting were reduced more than those from the first planting (Fig. 6). Primary roots did not exceed 5 cm in length. Second-planting root systems from steamed, inoculated soil were almost identical with those from the first planting, naturally infested soil, in which nematodes initially were more numerous. Roots from fumigated, inoculated soil were less affected. Shoot

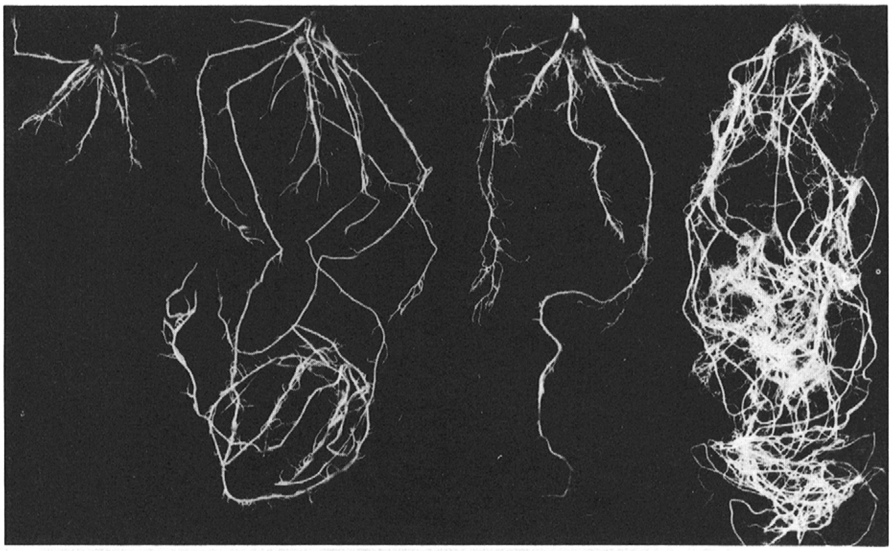

Fig. 6. Corn root systems from a greenhouse pathogenicity test, 2 mo after inoculation with *Longidorus breviannulatus* and 1 mo after replanting. Soil was (left to right) naturally infested with 2,500 nematodes per pot, fumigated with 1,3-D and inoculated with 1,000 nematodes, steam-sterilized and inoculated with 1,600 nematodes, and steam-sterilized but not inoculated.

weight from naturally infested soil was reduced 40%, but that from steamed, inoculated soil was reduced 60%, compared with the steamed-soil, noninoculated treatment.

First- and second-stage juveniles of *L. breviannulatus* were recovered in substantial numbers from both naturally infested and inoculated soils 1 mo after planting, confirming that the nematode reproduces on corn. Nematodes were most abundant in steamed, inoculated soil at 1 mo and in the naturally infested soil at 2 mo. Total numbers did not, however, exceed initial levels in any treatment, apparently as a result of extraction loss of this large nematode. Settling time in the wet sieving portion of Christie and Perry's method (1), which is superior to Jenkins' centrifugal flotation method (2) for extraction of *L. breviannulatus*, must be brief for maximum recovery of advanced life stages, and incubation temperature during the Baermann portion of extraction is critical (25–30 C) for efficient recovery of all stages.

DISCUSSION

The reduced root systems, stubby-root, root pruning, swollen lateral root tips, and yellow root discoloration in the greenhouse test and in corn growing in heavily infested fields were similar enough to confirm that *L. breviannulatus* is the primary cause of the disease. The absence of obvious swelling of primary root tips and overproduction of roots near the soil surface in the test were attributed to the lower fertility level and other differences in growing conditions between greenhouse and field. The root injury closely resembles that caused by *Belonolaimus* spp., *Paratrichodorus* spp. (5), and *L. africanus* on lettuce (4). We did not find these nematodes. The severe injury encountered under high soil moisture conditions also can be mistaken for that caused by the dinitroaniline herbicides, which cause more distinct clubbing of roots and which were not used on fields where the disease has occurred.

Although large populations of *L. breviannulatus* apparently are limited to highly sandy soils, the nematode causes the most serious localized nematode disease of corn in the upper Midwest. Growers noticed the characteristic early stunting and mineral deficiency symptoms several years before the nematode was discovered. The symptoms usually were attributed to temporary mineral deficiency or other abiotic problems, because affected plants eventually attained normal color and often became as tall as unaffected plants by late summer.

There are indications in Illinois that the increased irrigation of sandy soils in recent years has rendered the needle nematode problem more conspicuous by increasing growth of nonparasitized plants in dry seasons but having little effect on plants heavily parasitized. Irrigation also seems to stimulate population development of *L. breviannulatus* in these otherwise droughty soils, because populations are consistently higher in irrigated than in unirrigated sands.

The infestation at the Illinois River Valley Sand Field was on first-year corn that had followed a grass cover. In other areas, *L. breviannulatus* has been recovered in substantial numbers only from fields of continuous corn. Although the nematode has been found in a few fields of soybean that were rotated with corn, there is no evidence that soybean is a host. The nematode was rare or absent in soil samples from soybean and several dicotyledonous vegetable crops at the Sand Field but present in low numbers on corn and other graminaceous crops that had been rotated with those crops. The host range of *L. breviannulatus* may, therefore, be relatively restricted and is being investigated.

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