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Effects of *Pratylenchus zeae* and *Quinisulcius acutus* Alone and in Combination on Sorghum[1]

J. A. Cuarezma-Terán and L. E. Trevathan[2]

Abstract: Host–parasite relationships of *Pratylenchus zeae* and *Quinisulcius acutus,* alone or in combination, were studied on sorghum in the greenhouse and laboratory. *Q. acutus* at 1,000 or 5,000 nematodes per 15-cm-d pot and *P. zeae* at 500 nematodes per pot significantly suppressed plant height and fresh and oven dry shoot and root weights. A mixture of 1,000 *Q. acutus* and 500 *P. zeae* per pot resulted in greatest suppression of growth. Roots of plants inoculated with *Q. acutus* alone were reduced in number and size and showed lesions and discoloration. Reproduction of this nematode 42 days after inoculation was much greater in treatments of 100 or 1,000 than 5,000 nematodes. The population density of the two species at 6 weeks after inoculation was significantly less when combined than for each species alone. When the two species were combined, reproduction of *P. zeae* was greater than that of *Q. acutus,* but the final populations per gram of root weight were the same. *Q. acutus* fed ectoparasitically on epidermal cells of sorghum roots in the zone of elongation and differentiation when observed under in vitro conditions.

Key words: reproduction, pathogenicity, population dynamics, nematode feeding, *Sorghum bicolor.*

Investigators have reported the pathogenicity of several nematode species to sorghum (*Sorghum bicolor* [L.] Moench) (24,25). Host–parasite relations of *Quinisulcius acutus* have been studied on few plants (10,17,20,27). This nematode was found in association with some crop plants apparently causing no measurable root injury.

Nematode–nematode interactions have received attention (1,11,12,15,19,22), but little information is available on interactions on sorghum. Smolik (26) reported that both *Tylenchorhynchus nudus* and *Trichodorus allius* significantly reduced sorghum growth. Chevres-Román et al. (7) demonstrated that *Trichodorus porosus, Tylenchorhynchus claytoni,* and *Pratylenchus zeae* are pathogenic to corn and sorghum.

Nine genera of phytoparasitic nematodes were found associated with sorghum in Mississippi (9). *P. zeae* and *Q. acutus* were most common and are considered partially responsible for sorghum root rot and decline. The objective of this study was to determine the relative effects of *P. zeae, Q. acutus,* and both in combination on sorghum growth in the greenhouse. Additionally, host–parasite relationships of *Q. acutus* on sorghum were studied in the laboratory.

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[1] Mississippi Agricultural and Forestry Experiment Station Journal Series No. 5885.

[2] Graduate Research Assistant and Associate Professor, Department of Plant Pathology and Weed Science, P.O. Drawer PG, Mississippi State University, Mississippi State, MS 39762.

Materials and Methods

Growth, maintenance, and extraction of organisms: Cultures of *P. zeae* and *Q. acutus* were established in the greenhouse on 'Dekalb 59' sorghum with nematodes isolated from the rhizosphere of sorghum in the field. Nematodes were extracted from soil by a modified Baerman funnel technique (8). The nematode suspension was sieved, and the filtrate was used as a nematode-free treatment.

Infectivity of Q. acutus: Four-day-old DeKalb 59 sorghum seedlings germinated in peat pots were transplanted into 15-cm-d clay pots, one plant per pot, containing a methyl bromide-fumigated mixture of sand and soil (1:1, v:v) with a pH of 5.4 and 14:14:14 (N-P_2O_5-K_2O) slow release fertilizer at the rate of 85 g per 2×10^{-2} m^3 soil mixture. After transplanting, *Q. acutus* in water suspension was pipetted into depressions in the soil around the base of plants. Treatments included no nematodes, nematode-free filtrate (2.5 ml/pot), 100, 1,000, and 5,000 nematodes per pot. Six replicates of each treatment were arranged in a randomized block design on a greenhouse bench, and the experiment was repeated. Air temperature averaged 31 C and soil temperature 29 C during plant growth.

Six weeks after inoculation, plant height was measured, and above-ground plant parts were removed at the soil surface and weighed. Roots were washed free of soil, blotted to remove excess water, and weighed. Tops and roots were then dried for 48 hours at 100 C and weighed. Nematodes were extracted from 250 cm^3 mixed

TABLE 1. *Quinisulcius acutus* recovered from the rhizosphere and roots of inoculated sorghum grown in 15-cm-d pots in a greenhouse.

Treatment	Soil	Root
No nematodes	0*	0
Nematode-free filtrate	0	0
100 nematodes	748	0
1,000 nematodes	7,900	0
5,000 nematodes	9,720	0

* Final populations per pot with 12 replicates were based on extraction of 250 cm^3 soil or 4 g roots after 6 weeks.

soil as described earlier and from 4 g of fresh roots using a shaker incubation method (4).

Two-day-old sorghum seedlings growing on 1.5% water agar in transparent plastic petri dishes were inoculated with *Q. acutus* and incubated at 28 C. Nematode feeding activity was observed periodically with a dissecting microscope.

Interaction of P. zeae and Q. acutus: Experiments were established as outlined earlier to determine interactive effects of *P. zeae* and *Q. acutus* on sorghum. Treatments consisted of no nematodes, nematode-free filtrate (2.5 ml/pot), 1,000 *Q. acutus* (Qa), 500 *P. zeae* (Pz), and 1,000 *Q. acutus* plus 500 *P. zeae* (Qa + Pz) per pot. Inoculum levels were based on results of field assays reported for Mississippi (9). Treatments were replicated five times in the greenhouse, and the experiment was repeated. All measurements described above were made on sorghum exposed to both nematode species in this experiment. Nematode extraction from roots was accomplished as described for the experiment with *Q. acutus* alone, but a modified centrifugal-flotation technique was used for recovery from soil (14). All data were subjected to analysis of variance, and means were separated by Duncan's multiple-range test.

RESULTS

Infectivity of Q. acutus: Final nematode populations were similar in both experiments, and the combined data are presented in Table 1. At inoculum levels of 100 and 1,000 nematodes per pot, the final nematode population was almost eight times the number inoculated. However, at the inoculum level of 5,000 nematodes per pot, the final population was less than double the inoculum. No nematodes were recovered from roots.

Nematodes affected plant growth similarly in the two experiments, and the combined data are presented in Table 2. Plant height, top fresh and dry weights, and root fresh and dry weights were suppressed significantly by initial treatments with 1,000 or 5,000 nematodes, as compared to the nontreated control. There were no other differences between treatments.

Abundant sorghum roots developed on plants growing in nematode-free soil (Fig. 1A), soil to which nematode-free filtrate was added (Fig. 1B), or soil to which 100 *Q. acutus* were added (Fig. 1C). Total root system and root number were all reduced when plants were grown in the presence of 1,000 (Fig. 1D) or 5,000 (Fig. 1E) nematodes; these roots had lesions and were discolored.

Nematodes were observed attached to seedling roots of sorghum, feeding specifically on epidermal cells in the zone of differentiation and elongation and on root hairs. Feeding periods lasted no longer than 6 minutes. Nematodes were not observed inside root tissues. Root lesions and discoloration occurred at feeding sites.

Interaction of P. zeae and Q. acutus: Be-

TABLE 2. Effect of different initial levels of *Quinisulcius acutus* on growth of sorghum in 15-cm-d pots replicated 12 times in a greenhouse.

Treatment	Plant height (cm)	Top weight (g)		Root weight (g)	
		Fresh	Dry	Fresh	Dry
No nematodes	55.9 a	25.4 a	3.4 a	8.3 a	2.5 a
Nematode-free filtrate	53.9 a	24.4 ab	2.9 ab	8.0 a	2.3 a
100 nematodes	55.0 a	24.2 ab	3.0 ab	9.0 a	2.4 a
1,000 nematodes	38.4 b	17.9 bc	2.3 b	3.8 b	0.8 b
5,000 nematodes	37.3 b	17.3 c	2.3 b	3.8 b	1.0 b

Numbers followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple-range test.

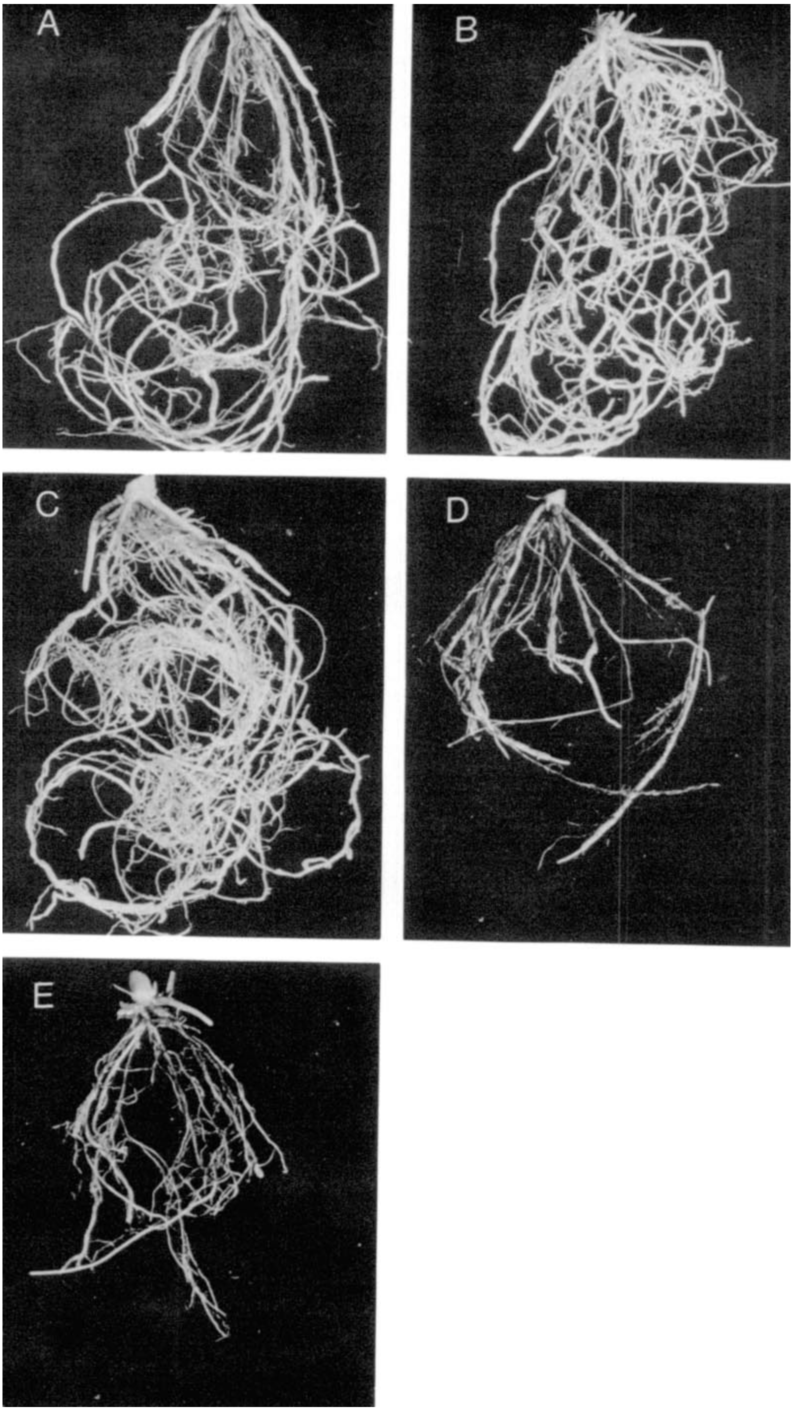

FIG. 1. Root systems of sorghum plants grown in a greenhouse for 6 weeks in fumigated soil to which was added A) no nematodes; B) nematode-free filtrate (2.5 ml/pot); C) 100, D) 1,000, and E) 5,000 *Quinisulcius acutus* nematodes per pot.

cause results of the two experiments were similar, the data were combined and analyzed as a split-plot design. Differences were evident in growth of plants in soil with and without nematodes after 6 weeks (Fig. 2). Root systems were small with few feeder roots and were generally deteriorated with many lesions in the presence of nematodes.

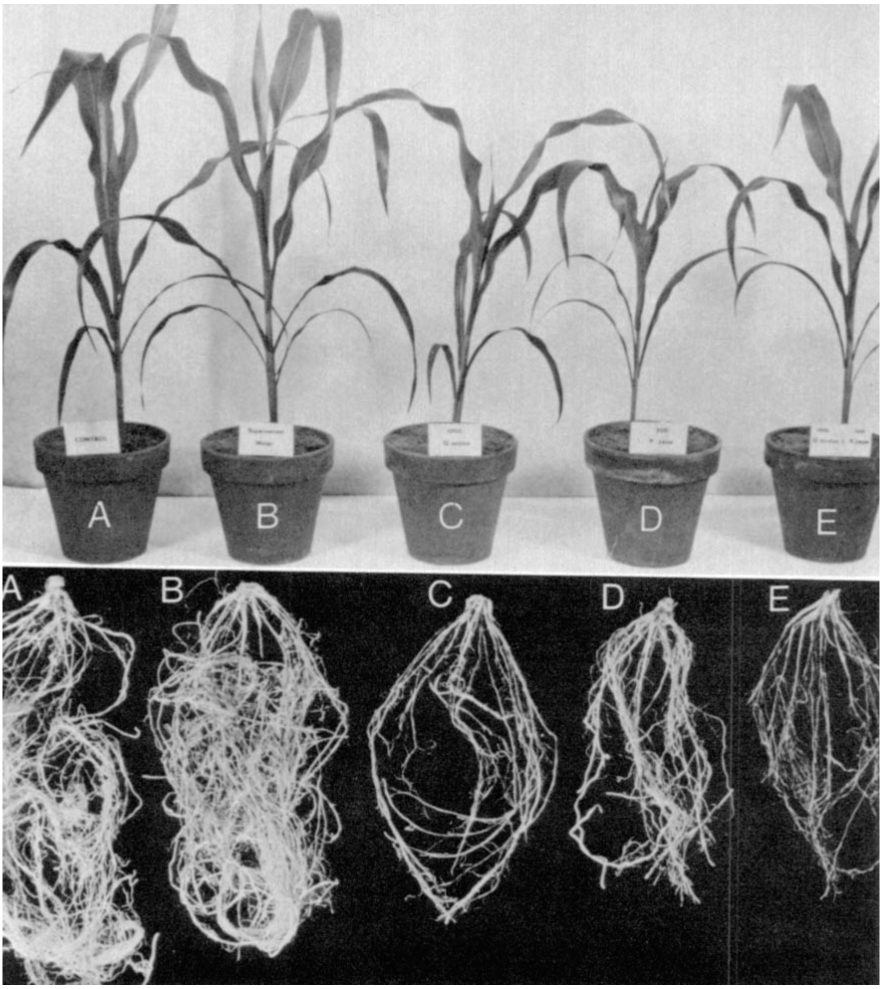

FIG. 2. Shoot and root growth of sorghum plants in a greenhouse after 6 weeks in various soil treatments. A) No nematodes. B) Nematode-free filtrate (2.5 ml/pot). C) 1,000 *Quinisulcius acutus* per pot. D) 500 *Pratylenchus zeae* per pot. E) 1,000 *Q. acutus* plus 500 *P. zeae* per pot.

Plant height and fresh and dry top and root weights were suppressed ($P = 0.05$) by all nematode treatments (Table 3). There were no differences in plant growth responses between inoculations of 1,000 *Q. acutus* and 500 *P. zeae*. Plant height was reduced significantly by the mixed nematode population compared with either nematode alone.

Populations of both *P. zeae* and *Q. acutus*

TABLE 3. Effects of *Pratylenchus zeae* and *Quinisulcius acutus* singly and in combination on growth of sorghum in 15-cm-d pots replicated 10 times in a greenhouse.

Treatment	Plant height (cm)	Top weight (g)		Root weight (g)	
		Fresh	Dry	Fresh	Dry
No nematodes	56.8 a	13.1 a	5.9 b	13.1 b	9.9 a
Nematode-free filtrate	57.9 a	15.8 a	7.9 a	17.3 a	12.2 a
1,000 *Q. acutus*	48.1 b	8.9 b	2.3 c	8.4 c	5.1 b
500 *P. zeae*	43.5 b	6.5 bc	1.7 c	5.9 cd	3.6 bc
1,000 + 500 Qa + Pz	34.1 c	4.8 c	0.9 c	4.2 d	2.0 c

Numbers followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple-range test.

TABLE 4. Recovery of *Pratylenchus zeae* and *Quinisulcius acutus* from the rhizosphere and roots of sorghum growing in 15-cm-d pots in a greenhouse.

Treatment	*Q. acutus**				*P. zeae**			
	Per pot			Per g dry root wt	Per pot			Per g dry root wt
	Soil	Roots	Total		Soil	Roots	Total	
No nematodes	0	0	0	0	0	0	0	0
Nematode-free filtrate	0	0	0	0	0	0	0	0
1,000 *Q. acutus*	7,505 a	0	7,505 a	5,604 a	0	0	0	0
500 *P. zea*	0	0	0	0	5,400 a	2,846 a	8,246 a	2,011 a
1,000 + 500 Qa + Pz	3,057 b	0	3,057 b	7,812 a	3,920 b	2,064 b	5,984 b	3,989 a

Numbers within each column followed by the same letter were not statistically different ($P = 0.05$) based on Student's *t*-test.
* Nematodes extracted from 250 cm^3 soil and 4 g root tissue.

increased when added individually to sorghum (Table 4). The total population of each species was lower when the two species were combined than when they were separate. However, on a unit root dry weight basis, the final populations of both species, either combined or individually, were similar. The reproduction factor (final population/initial population) of 12.0 for *P. zeae* was significantly greater ($P = 0.05$) than the 3.1 for *Q. acutus.*

DISCUSSION

Both *P. zeae* and *Q. acutus,* alone or in combination, were pathogenic to DeKalb 59 sorghum in greenhouse tests. Because *Q. acutus* feeds on sorghum roots and suppresses both root and shoot growth, this nematode is said to be a pathogen of sorghum in the greenhouse. The rapid increase in nematode populations also suggests that sorghum is a good host for *Q. acutus.* The related genus *Tylenchorhynchus* has been associated with sorghum (2), and certain species have been determined as pathogenic on many crops (3,13,16,18,23). Application of nematicides to fields infested with *T. martini* has resulted in increased grain sorghum yields (28).

The absence of nematodes inside root tissues and the observed feeding activity showed that *Q. acutus* is an ectoparasitic nematode. The feeding activity of *Q. acutus* was similar to that reported for several *Tylenchorhynchus* spp. (5,18,23), although some have been reported to feed as endoparasites (20,23).

It is not known whether the larger reproduction factor for *P. zeae* is the result of a lower initial inoculum level or if it is actually dominant reproductively over *Q. acutus.* Since inoculum levels used reflect those found in the field (9), it is possible that this same phenomenon occurs in sorghum under production conditions. On a unit root weight basis, the final population of each nematode species was similar when the two species were combined. The lower total population of each species when the two were combined was apparently because of smaller root systems and competition for infection sites.

No reports exist of pathogenicity to sorghum of *Q. acutus* combined with other nematodes, although our results are similar to those of a report for *Tylenchorhynchus claytoni,* alone and combined with *Pratylenchus penetrans* (21). *T. vulgaris* was reported to suppress growth of maize, and when combined, *P. zeae* dominated *T. vulgaris* (29). *P. penetrans* was reported to adversely affect *T. martini* populations on both alfalfa and red clover (6). Field studies are in progress to determine the impact of *P. zeae* and *Q. acutus* on sorghum yield.

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