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Effects of Irrigation, Nitrogen, and a Nematicide on Pearl Millet[1]

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Abstract: Pearl millet is used mainly as a temporary forage crop in the southern United States. A new pearl millet hybrid has potential as a major grain crop in the United States. The effects of nematodes, irrigation, a nematicide, and nitrogen rates on a new pearl millet grain hybrid, HGM-100, and nematode population changes were determined in a 2-year study. Root-knot nematodes (*Meloidogyne incognita* race 1) entered the roots of pearl millet and caused minimal galling, but produced large numbers of eggs that hatched into second-stage juveniles. Root-gall indices ranged from 1.00 to 1.07 on a 1–5 scale and were not affected by irrigation or rates of nitrogen. Yield of pearl millet was up to 31% higher under no supplemental irrigation than under irrigation, 16% higher in fenamiphos-treated plots than untreated plots, and 56% higher in plots treated with 38 kg nitrogen/ha than plots treated with 85 kg nitrogen/ha. In southern Georgia, pearl millet appears to be resistant to ring nematode (*Criconemella ornata*) but favors development and reproduction of *M. incognita.*

Key words: chemical control, *Criconemella ornata,* irrigation, *Meloidogyne incognita,* millet, nematode, nitrogen, *Pennisetum glaucum,* ring nematode, root-knot nematode

Pearl millet (*Pennisetum glaucum*) is used mainly as a temporary forage crop in the southern United States. Over 20 million hectares of pearl millet are grown annually for grain in India and Africa (9), and it has potential as a major grain crop in the United States. The pearl millet plant is drought tolerant, has a low nitrogen requirement, and produces a large, fibrous root system that can extract and utilize nutrients from the subsoil (9). In addition, it is high in protein and has a good balance of amino acids (9).

The extended period during which pearl millet can be planted in southern Georgia makes is especially adapted to double-cropping systems with spring or winter crops. Pearl millet follows most crops in rotation without serious cultural and disease problems (7), but many plant-parasitic nematodes that parasitize other crops also attack pearl millet. *Criconemella ornata, Paratrichodorus minor, Pratylenchus brachyurus, P. zeae,* and *Belonolaimus longicaudatus* caused poor stands, stunting, and reduced yield of pearl millet cultivars (2,4, 5). Good (1) reported that field corn yield was low following millet, which was a good host for *B. longicaudatus.* He also showed that numbers of *B. longicaudatus* were greatest in millet-cotton cropping sequences. Johnson and Burton (5) reported that forage yields of pearl millet cultivars were increased from 40 to 73% when nematicides were used to control nematodes.

McGlohon et al. (8) reported that millet cv. Starr did not support growth and reproduction of the root-knot nematodes *Meloidogyne incognita* and *M. javanica.* In field studies, Johnson and Burton (5) reported that population densities of *M. incognita* did not increase in plots of pearl millet not treated with a nematicide during the growing season. From greenhouse studies, Johnson et al. (6) reported that pearl millet cultivars varied in response to *Meloidogyne incognita, M. javanica,* and *M. arenaria,* and root-gall indices ranged from 1.0 to 2.5 on a 1–5 scale.

Management of important nematodes on pearl millet should be improved through information on nematode population changes as influenced by nematicides, irrigation, and nitrogen. The objective of this 2-year study was to determine

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the effects of nematodes, irrigation, nitrogen, and a nematicide on yield of a new pearl millet grain hybrid, HGM-100, and nematode population densities.

Materials and Methods

Plots for the 2-year (1987–1988) study were established in June 1987 on Bonifay sand (siliceous thermic, grossarenic, Plinthic Paleudult) containing 93% sand, 3% silt, and 4% clay; <1% organic matter; pH 6.0–6.8. The soil was naturally infested with root-knot nematodes, *Meloidogyne incognita,* and ring nematodes, *Criconemella ornata.* The soil was disk 10 cm deep, turned 20–25 cm deep with a moldboard plow, and beds were established. Each plot contained three 1.8 × 12.2-m beds.

The experimental design was a split-split plot randomized complete block with irrigation regimes as whole plots, nematicide treatments as subplots, and nitrogen treatments as sub-sub-plots. During the tests, all plots received 23.1 cm rainfall and irrigated plots received an additional 17.2 cm water in 1987. In 1988, all plots received 38.1 cm rainfall and irrigated plots received an additional 19.5 cm water. The preplant treatments were an untreated control and fenamiphos 15G applied at 6.72 kg a.i./ha broadcast and incorporated 15 cm deep with a tractor-mounted rototiller. Each year the nitrogen (N) treatments were low, medium, and high rates. In 1987, the low rate was 38 kg N/ha (560 kg/ha 5-10-15, N-P_2O_5-K_2O preplant + 28 kg/ha ammonium nitrate (34% N) sidedress 25 days postplant), the medium rate was 57 kg N/ha (560 kg/ha 5-10-15, N-P_2O_5-K_2O preplant + 84 kg/ha ammonium nitrate sidedress 2 weeks postplant), and the high rate was 85 kg N/ha (560 kg/ha 5-10-15, N-P_2O_5-K_2O preplant + 168 kg/ha ammonium nitrate sidedress 2 weeks postplant). In 1988, the low rate was 0 kg N/ha (670 kg/ha 0-10-20, N-P_2O_5-K_2O), medium rate was 38 kg N/ha (670 kg/ha 0-10-20, N-P_2O_5-K_2O + 112 kg/ha ammonium nitrate), and the high rate was 76 kg N/ha (670 kg/ha 0-10-20, N-P_2O_5-K_2O + 224 kg/ha ammonium nitrate) broadcast over the beds and incorporated 15 cm deep with a tractor-mounted rototiller before planting. Pearl millet grain hybrid HGM-100 was seeded 17 July 1987 and 28 June 1988 at 3.36 kg seeds/ha in two rows 0.91 m apart on beds. Propazine 4L was sprayed broadcast at 1.12 kg a.i./ha 17 July 1987 and 29 June 1988 for weed control.

Twenty soil cores (2.5 × 15 cm) were collected from each plot on 16 July, 20 August, 18 September, and 29 October 1987 and 23 June, 19 July, 17 August, 19 September, and 3 November 1988 and assayed for nematodes. The samples from each plot were mixed and a 150-cm^3 subsample was processed by centrifugal-flotation (3). Ten plants from each plot were dug 20 August 1987 and 2 November 1988 and rated for percentage galling on a 1–5 scale: 1 = no galls; 2 = 1–25; 3 = 26–50; 4 = 51–75; and 5 = 76–100% roots galled.

Seed heads from plants in 3 m of each row in the center bed (total 6 m) were collected, dried to 10% moisture, threshed, and weighed. All data were subjected to analysis of variance by least-squares (10). Correlation analysis was used to inspect the relationships between yield and the nematode population densities in the soil and root-gall indices. Only significant ($P \leq 0.05$) effects are discussed unless stated otherwise.

Results and Discussion

There were no significant interactions among irrigation, nematicide, and nitrogen treatments; therefore, means across all treatments are presented (Tables 1, 2). Numbers of *C. ornata* were less than 30/150 cm^3 soil on most sampling dates in both years and were not affected by treatments (data not included). Although *C. ornata* population densities increased to high levels on selected cultivars of pearl millet (4), apparently pearl millet hybrid HGM-100 is not a good host for *C. ornata.*

In 1987, population densities of *M. incognita* second-stage juveniles (J2) in the

TABLE 1. Nematode population densities, root-gall indices, and yield of pearl millet as influenced by irrigation, fenamiphos, and nitrogen treatments in field plots in Tifton, Georgia, in 1987.

Treatment	Number *Meloidogyne incognita*/150 cm^3 soil				Root-gall index	Yield
	16 July	20 August	18 September	29 October	20 August	(kg/ha)
Irrigation						
Yes	7a	6b	140a	36a	1.05a	1,965b
No	6a	19a	38b	27a	1.03a	2,565a
Nematicide						
Fenamiphos	5a	7b	34b	2b	1.00b	2,431a
Untreated						
Nitrogen (kg/ha)	8a	18a	144a	61a	1.07a	2,099b
Preplant 11 August						
28 10	4a	5b	39b	26a	1.02a	2,609a
28 29	4a	14ab	87ab	23a	1.02a	2,516a
28 57	12a	19a	141a	45a	1.07a	1,669b

Data are means of four replications. Means in columns within treatments followed by the same letter are not different according to the Waller-Duncan k-ratio *t*-test (k = 100).

soil increased from July to September and declined in October (Table 1). Numbers of J2 were lower in irrigated plots than nonirrigated plots in August but were higher in irrigated plots than in nonirrigated plots in September. Numbers of J2 were lower in fenamiphos-treated plots than untreated plots from August through October. Similar results have been reported for fenamiphos on other nematodes and other pearl millet cultivars (4). Generally, the numbers of J2 in the soil increased as the rates of nitrogen increased and were lower in plots treated with the lowest rate of nitrogen than in plots treated with the highest rate of nitrogen in August and September. This is the first report demonstrating this nematode-nitrogen-host relationship on pearl millet.

In 1988, numbers of *M. incognita* J2 in the soil declined from June to August and increased to higher levels in November (Table 2). Numbers of J2 were not different among treatments on most sampling dates. Numbers of J2 in the soil in November were lower in irrigated plots than nonirrigated plots and lower in fenamiphos-treated plots than untreated plots.

Root-gall indices, visual ratings of percentage root galling caused by *M. incognita*, ranged from 1.00 to 1.07 in 1987 and were not affected by irrigation or rates of nitro-

TABLE 2. Nematode population densities and yield of pearl millet as influenced by irrigation, fenamiphos, and nitrogen treatments in field plots in Tifton, Georgia, in 1988.

Treatment	Number *Meloidogyne incognita*/150 cm^3 soil					Yield
	23 June	19 July	17 August	19 September	3 November	(kg/ha)
Irrigation						
Yes	118a	11a	7a	104a	604a	1,240a
No	81a	11a	1b	82a	850b	1,175a
Nematicide						
Fenamiphos	98a	13a	2a	70a	406b	1,204a
Untreated						
Nitrogen (kg/ha)	101a	9a	6a	117a	1,048a	1,211a
Preplant						
0	133a	11a	7a	132a	848a	1,182a
38	93ab	13a	2a	79a	694a	1,294a
76	72b	9a	2a	69a	639a	1,145a

Data are means of four replications. Means in columns within treatments followed by the same letter are not different according to the Waller-Duncan k-ratio *t*-test (k = 100).

gen (Table 1). Roots of plants in fenamiphos-treated plots were free of galls in August but roots of plants in untreated plots were slightly galled. Roots of all plants were free of detectable galls on 3 November 1988. Based on our results, we conclude that *M. incognita* enters the roots of HGM-100 pearl millet, causes minimal galling, but produces large numbers of eggs that hatch into J2 in the soil from August to November. These results support earlier reports (6). We interpret this to mean that HGM-100 pearl millet is resistant to injury by *M. incognita.*

Yield of grain from nonirrigated plants was greater than yield from irrigated plants in 1987 (Table 1). Yield from plants in untreated plots was lower than yield from plants in fenamiphos-treated plots. In 1987, yield from plants in plots treated with the highest rate of nitrogen was lower than those treated with medium or low rates of nitrogen. In 1988, yield was not affected by irrigation, fenamiphos, or nitrogen treatments (Table 2). Yield of pearl millet was up to 31% higher under no supplemental irrigation than under irrigation, 16% higher in fenamiphos-treated plots than untreated plots, and 56% higher in plots treated with 38 kg N/ha than plots treated with 85 kg N/ha (Table 1). Our data indicate that farmers in southern Georgia can inadvertently reduce grain yields of pearl millet by applying too much nitrogen fertilizer and being too optimistic about applying supplemental irrigation, other than during severe droughts. Preliminary data (W. W. Hanna, unpubl.) indicate that certain genotypes of pearl millet may use an abundant nitrogen supply for vegetative growth instead of grain production.

In southern Georgia, pearl millet appears to be resistant to *C. ornata,* but favors development of *M. incognita* (4). This information is especially important for development of cropping systems with millet that include vegetable crops or other crops that are susceptible to *M. incognita.* Additional research is needed to determine the host-parasite relationships between pearl millet hybrid HGM-100 and other plant-parasitic nematodes.

Literature Cited

1. Good, J. M. 1968. Relation of plant-parasitic nematodes to soil management practices. Pp. 113–138 *in* G. C. Smart, Jr., and V. G. Perry, eds. Tropical nematology. Gainesville: University of Florida Press.
2. Good, J. M., N. A. Minton, and C. A. Jaworski. 1965. Relative susceptibility of selected cover crops and coastal bermudagrass to plant nematodes. Phytopathology 55:1026–1030.
3. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.
4. Johnson, A. W., and G. W. Burton. 1973. Comparison of millet and sorghum-sudangrass hybrids grown in untreated soil and soil treated with two nematicides. Journal of Nematology 5:54–59.
5. Johnson, A. W., and G. W. Burton. 1977. Influence of nematicides on nematodes and yield of sorghum-sudangrass hybrids and millets. Plant Disease Reporter 61:1013–1017.
6. Johnson, A. W., G. W. Burton, and W. C. Wright. 1977. Reactions of sorghum-sudangrass hybrids and pearl millet to three species of *Meloidogyne.* Journal of Nematology 9:352–353.
7. Kramer, N. W., and W. M. Ross. 1970. Cultivation of grain sorghum in the United States. Pp. 167–199 *in* J. S. Wall and W. M. Ross, eds. Sorghum production and utilization. Westport, Connecticut: The Avi Publishing Company.
8. McGlohon, N. E., J. N. Sasser, and R. T. Sherwood. 1961. Investigation of plant-parasitic nematodes associated with forage crops in North Carolina. North Carolina Agricultural Experiment Station Technical Bulletin 148. North Carolina State University, Raleigh.
9. Rachie, K. O., and J. V. Majmudar. 1980. Pearl Millet. University Park, Penn State University Press.
10. Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. New York: McGraw-Hill.