Control of Meloidogyne javanica and M. arenaria on kenaf and roselle with genetic resistance and nematicides[1]

N. A. MINTON and W. C. ADAMSON[2]

Abstract: Kenaf (*Hibiscus cannabinus*) and roselle (*H. sabdariffa*) were evaluated in nematicide-treated and untreated field soil naturally infested with either *Meloidogyne javanica* or *M. arenaria.* Root-knot indices indicated that the kenaf breeding line j-1-113 had moderate resistance to *M. javanica* and low resistance to *M. arenaria.* Kenaf cv Everglades 71 was highly susceptible to both *M. javanica* and *M. arenaria,* and roselle breeding line A59-56 was highly resistant. Both nematode species reproduced on all plant entries, but more larvae were recovered from the soil in plots planted to Everglades 71 than in plots planted to j-1-113 or A59-56. In untreated soil infested with *M. javanica,* dry-matter yields were greater ($P = 0.05$) for j-1-113 and A59-56 than for Everglades 71. The percentages of live plants at harvest were: j-1-113, 88; A59-56, 93; and Everglades 71, 9. Ethylene dibromide (1,2-dibromoethane) at 73.9 kg a.i./ha and DBCP (1,2-dibromo-3-chloropropane) at 17.6 kg a.i./ha increased dry-matter yields significantly for all entries planted in soil infested with *M. arenaria.* Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) at 5.9 kg a.i./ha did not increase the dry-matter yields of any entry. None of the nematicides increased the growth of any entry significantly in soil infested with *M. javanica. Key Words: Hibiscus cannabinus, Hibiscus sabdariffa,* ethylene dibromide, DBCP, carbofuran.

Kenaf (*Hibiscus cannabinus* L.) and roselle (*H. sabdariffa* L.), two fiber crops, are potential sources of pulp for making paper. In the southeastern United States, however, root-knot nematodes (*Meloidogyne* spp.) could limit production of both crops unless resistant cultivars are grown or means are found to reduce nematode damage. Wilson and Summers (6) reported resistance in kenaf to *M. incognita* in field experiments. Minton et al. (4) and Adamson et al. (1, 2) found resistance to *M. incognita acrita, M. javanica,* and *M. arenaria* in kenaf, and to *M. incognita acrita* and *M. javanica* in roselle.

This paper reports the reaction to *M. javanica* of breeding lines of kenaf and roselle grown in field plots, and the responses of these plants grown in soil infested with *M. javanica* or *M. arenaria* and treated with nematicides.

MATERIALS AND METHODS

Three experiments were conducted at Savannah, Georgia, on Ocilla loamy sand (86% sand, 11% silt, and 3% clay) naturally infested with *Meloidogyne javanica* (Treub) Chitwood or *M. arenaria* (Neal) Chitwood. The soil was turned ca 25 cm deep, and seed beds 10-15 cm high were formed. The soil received 1.12 metric tons/ha of 5-10-15 fertilizer before planting, and 0.11 metric tons/ha of N were applied as a side dressing each year. Rows were 6 m long, spaced 91 cm apart.

Entries in each experiment were Everglades 71 (nematode-susceptible kenaf), j-1-113 (nematode-resistant kenaf), and A59-56 (nematode-resistant roselle).

Nematode population levels in the soil were assayed with Jenkins' rapid centrifugal-flotation technique (3). Roots of 10 plants from the two outside rows of each four-row plot or subplot were dug and rated for root galls.

Yields, plant heights, and stem diameters at the base of the plant were obtained from plants on the two center rows of each plot or subplot. Yields were based on a 5-m^2 area, and 10 plants per plot were measured to determine heights and basal diameters. Ten plants per plot or subplot were oven-dried to obtain dry weights.

Data for the 2-year study were combined for statistical analysis (5).

Experiment 1: This experiment was designed to study the reaction of field-grown kenaf and roselle to *M. javanica* and their effects on nematode populations in the soil.

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[2] Research Nematologist, Federal Research, Science and Education Administration U.S. Department of Agriculture, Georgia Coastal Plain Experiment Station, Tifton, Georgia 31794; and Research Plant Geneticist, Federal Research, Science and Education Administration, U.S. Department of Agriculture, U.S. Plant Introduction Station, Savannah, Georgia 31405. We thank B. G. Mullinix, Jr., for assistance with statistical analysis.

Kenaf and roselle were planted in four-row plots, replicated four times in a randomized complete block design. Seeds were planted 15 April 1974 and 8 April 1975. Stands were adjusted to ca 64 plants per plot.

Numbers of live plants were recorded from a 5-m^2 area per plot biweekly between 15 July and 30 November each year. Root-knot gall ratings were recorded 21 November 1974 and 9 December 1975. Gall ratings were based on a 1–5 scale: 1 = no galling, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of root systems galled. Yields, plant heights, and stem diameters were obtained on 2 February 1975 for the 1974 planting, and on 9 January 1976 for the 1975 planting. Nematode population levels in the soil were determined biweekly.

Experiments 2 and 3: Control of *M. javanica* in Experiment 2 and *M. arenaria* in Experiment 3 with nematicides and resistant kenaf and roselle was studied. The nematicides and rates used were: ethylene dibromide (1,2-dibromoethane) at 73.9 kg/ha; DBCP (1,2-dibromo-3-chloropropane) at 17.6 kg/ha; and carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) at 5.9 kg/ha. A split-plot design was used with nematicides as main plots and plant entries as subplots. Each subplot contained four rows.

Ethylene dibromide was injected 20 cm deep with a single chisel in the row ca two weeks before planting. DBCP was injected in the same manner at planting, and carbofuran was applied in a 38-cm band over the row and incorporated 10 cm deep with a power-driven rototiller.

The plots were planted with Everglades 71 and j-1-113 kenaf and A59-56 roselle on 17 April 1975 and 15 April 1976. Nematodes in the soil were assayed on 11 August 1975 and 13 August 1976. Yields, plant heights, and stem diameters for the 1975 and 1976 plantings were recorded 12 January 1976 and 27 December 1976, respectively.

RESULTS

Experiment 1: Resistance to *M. javanica* in field plots was indicated for A59-56 and j-1-113 as shown by root-knot indices (Table 1) and root-knot larval populations in the soil (Fig. 1). Everglades 71 was highly susceptible. A59-56 had a significantly lower root-knot index rating than j-1-113, although the numbers of larvae in the soil were not different. Numbers of root-knot larvae were much greater in plots planted to Everglades 71 than in plots planted to A59-56 and j-1-113. Numbers of nematodes in all entries were maximum in August. Under the resistant entries, numbers of nematodes remained relatively constant from 19 August to 30 September, whereas under the susceptible Everglades 71 they decreased rapidly after 19 August. The

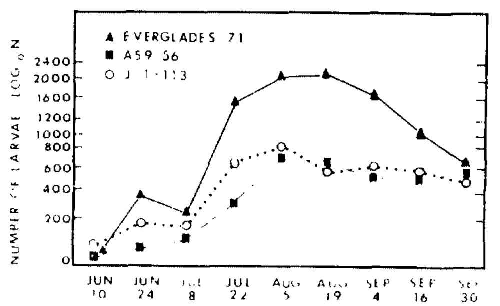

FIG. 1. Influence of kenaf and roselle on *Meloidogyne javanica* larvae in the soil.

TABLE 1. Comparison of root-knot indices, yields, plant heights, and stem diameters of kenaf and roselle grown in soil infested with *Meloidogyne javanica*.[a]

Entry	Root-knot index	Yield (metric tons/ha)	Height (m)	Stem diameter (cm)
Kenaf				
Everglades 71	5.0 a	3.8 a	2.3 a	1.9 a
j-1-113	3.6 b	8.8 b	3.2 b	2.0 a
Roselle				
A59-56	2.5 c	9.4 b	3.4 b	2.0 a

[a]Means in the same column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple-range test.

decline was related to death of plants (Fig. 2). Percent live plants for Everglades 71 declined rapidly beginning in July and continued to 30 October, when only 9% were still living. Conversely, respectively 93% and 88% of A59-56 and j-1-113 were alive on 30 October.

The level of root-knot nematode resistance was reflected in yield differences. The correlation coefficient between root-knot index and yield was –0.87 ($P = 0.01$). Yields were respectively 147% and 132% greater for A59-56 and j-1-113 than for Everglades 71. Yield of A59-56 and j-1-113 did not differ. A59-56 and j-1-113 were taller than Everglades 71, although stem diameters did not differ.

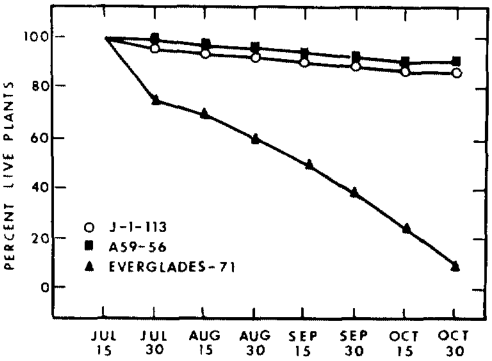

FIG. 2. Survival of kenaf and roselle plants growing in soil infested with *Meloidogyne javanica*.

Experiment 2, M. javanica: Roots of A59-56 and j-1-113 were relatively free of galls in all plots (Table 2). Roots of Everglades 71 were severely galled in the control and carbofuran plots. Ethylene dibromide and, to a lesser extent, DBCP reduced galling of Everglades 71 roots. Average root-knot indices for all treatments were greatest for Everglades 71 and least for A59-56. Population levels of *M. javanica* larvae in the soil were greatest for Everglades 71 and least for A59-56 ($P = 0.05$).

Yields did not differ significantly among *Hibiscus* entries or among nematicide treatments, although numerical differences were relatively large (Table 3). Average yields for all treatments, however, were 18% greater for j-1-113 than for Everglades 71.

Plant heights did not differ among entries or among treatments ($P = 0.05$). Chemical treatments had no significant effect on stem diameters ($P = 0.05$). Average stem diameters for all treaments were greatest for Everglades 71, intermediate for j-1-113, and least for A59-56 ($P = 0.05$).

Experiment 3, M. arenaria: Root-knot indices in the control plots indicated a very high level of resistance to *M. arenaria* for A59-56 and a lower level for j-1-113 compared with Everglades 71, which is susceptible (Table 2). Ethylene dibromide reduced the root-knot index for all entries,

TABLE 2. Root-knot indices of kenaf and roselle plants grown in soil infested with two *Meloidogyne* species and treated with nematicides.

Species and treatment	Index[a]			
	Kenaf		Roselle	
	Everglades 71	j-1-113	A59-56	Av
M. javanica				
Control	3.6 a	1.7 a	1.2 a	2.2 a
Ethylene dibromide	1.3 c	1.1 a	1.0 a	1.1 b
DBCP	2.5 b	1.3 a	1.1 a	1.6 a
Carbofuran	3.5 a	1.6 a	1.1 a	2.1 a
Av	2.8	1.4	1.1	
M. arenaria				
Control	5.0 a	4.2 a	1.6 a	3.6 a
Ethylene dibromide	1.4 c	1.3 c	1.0 b	1.2 c
DBCP	3.3 b	3.0 b	1.2 ab	2.5 b
Carbofuran	5.0 a	4.4 a	1.6 a	3.7 a
Av	3.7	3.2	1.4	

[a]Data underscored by the same line in rows or followed by the same letter in columns within a nematode species are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.

TABLE 3. Influence of nematicides on yields of kenaf and roselle plants grown in soil infested with two *Meloidogyne* species.

Species and treatment	Yield (metric tons/ha) Kenaf Everglades 71	Kenaf j-1-113	Roselle A59-56	Av
M. javanica				
Control	5.8	6.9	8.7	7.1
Ethylene dibromide	9.8	10.0	8.7	9.5
DBCP	7.7	8.6	7.6	8.0
Carbofuran	6.1	9.2	7.8	7.7
Av[y]	7.4	8.7	8.2	
M. arenaria[z]				
Control	1.5 c	3.0 b	10.0 b	4.8 c
Ethylene dibromide	11.7 a	10.6 a	12.5 a	11.6 a
DBCP	6.9 b	8.6 a	12.4 a	9.3 b
Carbofuran	2.2 c	4.0 b	11.2 ab	5.8 c
Av	5.6	6.6	11.5	

[y]Average yield was significantly greater for j-1-113 than for Everglades 71.
[z]Data underscored by the same line in rows or followed by the same letter in columns are not significantly different (P = 0.05) according to Duncan's multiple-range test.

and DBCP reduced the index for Everglades 71 and j-1-113. Carbofuran had no effect on galling. Ethylene dibromide and DBCP reduced nematode populations under Everglades 71 and j-1-113 (P = 0.05).

Two-year average yields in untreated plots were greater for A59-56 than for Everglades 71 and j-1-113 (Table 3). A59-56 produced much greater yields than did Everglades 71 and j-1-113. DBCP and ethylene dibromide increased yields of all entries. A59-56 yields were greater than j-1-113 yields in all treatments, and greater than Everglades 71 yields in all treatments except ethylene dibromide. The correlation coefficients between yield and root-knot index and number of root-knot larvae in the soil were respectively −0.92 (P = 0.01) and −0.56 (P = 0.01).

Plant heights in untreated plots were greater for A59-56 than for Everglades 71 and j-1-113 (P = 0.05). Ethylene dibromide and DBCP increased heights of all entries (P = 0.05). A59-56 was taller than j-1-113 in all treatments, and taller than Everglades 71 in all except the ethylene dibromide treatment (P = 0.05). J-1-113 was taller than Everglades 71 in the carbofuran treatment but shorter than Everglades 71 in the ethylene dibromide treatment (P = 0.05).

Basal diameters in the untreated plots were greater for A59-56 than for Everglades 71 and j-1-113 (P = 0.05). Nematicides did not increase the basal diameter of A59-56, but all nematicides increased it for Everglades 71, and ethylene dibromide and DBCP increased it for j-1-113 (P = 0.05).

Yields of j-1-113 and A59-56 were greater than yields of Everglades 71 in soil infested with *M. javanica* in Test 1 (Table 1) but not in test 2 (Table 3). Yield trends, however, were the same in both tests. The two tests were on different sites.

Yield increases due to nematicides were greater in test 3 in plots infested with *M. arenaria* than in test 2 in plots infested with *M. javanica* (Table 3). In the control plots, root-knot indices were greater for *M. arenaria* than for *M. javanica,* suggesting a difference in nematode damage (Table 2). Therefore, the differences in yield response may have been due to differences in pathogenicity of the two nematode species or differences in nematode infestation levels in the two fields. Also, differences in inherent productivity of the two fields or a combination of these and other factors could have affected yields.

CONCLUSIONS

Root-knot indices indicated that the kenaf breeding line j-1-113 had moderate resistance to *M. javanica* and low resistance to *M. arenaria*. Everglades 71 was susceptible to both *M. javanica* and *M. arenaria*, and roselle breeding line A59-56 was highly resistant. Both nematode species reproduced on all plant entries, but more larvae were recovered from soil in plots planted to Everglades 71 than in plots planted to j-1-113 and A59-56. The level of resistance in j-1-113 and A59-56 provides plants with yield potentials superior to that of the susceptible commercial cultivar, Everglades 71, when planted on nematode-infested soil. Even though yields of j-1-113 and A59-56 were increased significantly over that of Everglades 71 in only one test with *M. javanica*, the level of resistance to this nematode appears to have practical value.

Soil population levels of *Meloidogyne* larvae and root-knot indices were good indicators of nematode resistance. With highly susceptible plants, however, there is a relatively short period during the growing season when larval populations in the soil are maximum. Sampling of field soil to evaluate resistance must be timed to correspond with peak population levels. Also, a measure of resistance was the percent live plants remaining at the end of the season. Nematodes appeared to be the major pathogen, although other microorganisms may have contributed to death of plants.

Kenaf and roselle are long-season plants and require maximum nematode protection over a long period. Ethylene dibromide controlled both nematode species more effectively and for a longer period than did DBCP or carbofuran.

The results indicate that resistant lines and nematicides can complement one another in increasing *Hibiscus* yields on soils heavily infested with *M. javanica* and *M. arenaria*. When soils have less severe nematode infestations than those in the experimental plots, however, either resistant cultivars or a nematicide used on a susceptible cultivar might provide adequate control.

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