of tomato have been based primarily on the use of certified seed and transplants (11,17). However, because of a long incubation period and lack of adequate methods to detect low populations of *C. m. michiganensis* from infested seed and symptomless transplants, the disease continues to be a threat. Hence, host resistance seems to be the most promising approach for disease management if resistance can be incorporated into high-yielding, adapted cultivars. Partial resistance (i.e., tolerance) to *C. m. michiganensis* has been expressed as reduced severity of symptoms, which probably is associated with a lower level of systemic infection by *C. m. michiganensis*, and corresponds to lower reductions in yield (6,19).

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Possible Root Transmission of the Red Ring Nematode (*Rhadinaphelenchus cocophilus*) to Coconut Palms

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ABSTRACT

Warwick, D. R. N., and Bezerra, A. P. T. 1992. Possible root transmission of the red ring nematode (*Rhadinaphelenchus cocophilus*) to coconut palms. Plant Dis. 76:809-811.

The significance of root transmission of the red ring nematode (*Rhadinaphelenchus cocophilus*) to coconut palms (*Cocos nucifera*) was investigated in a screen-house experiment. Transmission by root contact occurred in seven of 15 plants growing around five inoculated plants. In another experiment, each plant became infected when a nematode suspension was placed on the mechanically damaged roots. Young seedlings planted in a hole where previously diseased palms were growing did not develop the typical symptoms of red ring disease. Red ring nematodes could not successfully colonize the husk tissue or the bole area. Seedlings were also artificially infected with red ring nematodes and observed for 30 wk. Nematodes could be extracted from the seed of only one plant. At the end of the 30-wk period, no nematodes could be detected. Thus, seedling tissue may not be suitable for development of red ring nematodes.

Red ring disease of coconuts, caused by *Rhadinaphelenchus cocophilus* (Cobb) Goodey, leads to severe losses in coconut (*Cocos nucifera* L.) plantations throughout tropical America (4,14,15,19). Coconut trees of 3–10 yr are most affected (17). Typical internal symptoms of the disease include a brown-orange (red) and yellow ring in cross section; this ring is the main characteristic of the disease. Young leaves are also discolored, and the whole plant collapses in the course of disease development. No shedding of nuts occurs in any stage. The red ring is 2–4 cm wide and is located about 5 cm from the edge of the stem. The discolored area is largely infested and contains a high number of active nematodes.

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The transmission of the red ring nematode by the palm weevil *Rhynchophorus palmarum* L. (Coleoptera, Curculionidae) is well-documented (3,11,12). The first evidence that the palm weevil was a vector of red ring disease was supplied by Cobb (3). Hagley (11) examined 157 palms and found that 95% of the palms with red ring disease were also infested with weevils. He also examined 213 field-collected weevils and found that 38.5% of the field population was externally contaminated with living nematodes. Later, Hagley (12) reported that the incidence of red ring disease was highly correlated with the seasonal abundance of the palm weevil. Gerber and Giblin-Davis (8) reported that more than 90% of newly emerged weevil adults in Trinidad are infested with red ring nematodes. Griffith (10) concluded that the control of the disease could be best achieved by sanitation measures and vector control.

Studies on direct transmission of the nematode through the palm roots in the field are difficult, because there is always the chance of nematode transmission by

the palm weevil. Blair (1) conducted inoculation experiments and found that roots became infested when inoculated with a water suspension of the nematode. Goberdhan (9) also demonstrated that artificial infection is possible through the introduction of fragments of nematode-infected tissue. Kastelein (13) indicated that the red ring nematode might also occur in soil. Franco (7) found that the nematode is transmitted through root contact in cases in which the red ring develops from the bottom to the top of the palm.

The purpose of this study was to determine if direct transmission of the red ring nematode occurs through root contact and cultivation practices. The possibility of transmission to young seedlings and seedling susceptibility were also investigated. The experiments were done in a screen house, where the presence of *R. palmarum* was never observed.

MATERIALS AND METHODS

Root transmission test. Twenty healthy coconut seedlings of cultivar Brazil Tall were obtained from an area free of red ring disease and were transplanted in a screen house in 1987. The experiments were done 3 yr later, when plants began to form boles and were susceptible to the nematode (17). Red ring nematodes were obtained from infected tissue (4). A suspension (5 ml) containing approximately 6,000 nematodes was introduced into the base of the stem of five plants; a drill and a hypodermic syringe were used. To determine if the leaves showed external symptoms of yellowing, we observed the remaining 15 plants, which grew around the infected ones (Fig. 1). When any symptoms were observed, the plant was uprooted and sampled. The remaining nonsymptomatic plants were removed 30 wk later, at the end of the experiment.

Cultivation test. In another trial, 12 coconut plants of the same cultivar and age as those used in the root transmission test were cultivated with a hoe. A suspension of active nematodes (3,000 nematodes per liter of water) was poured over the damaged roots. The soil in the surrounding area was watered and kept moist for 2 days. This work was also done in the screen house, where *R. palmarum* was not present.

Seedling susceptibility. We conducted the experiment to determine if seedlings planted into sites where infected plants had been removed would become infected with red ring. Immediately after the infected plant was taken out, 10 seedlings of the coconut cultivar Cameroon Red Dwarf, each 7 mo old, were planted in the same hole without chemical treatment. After 1 or 2 mo, the plants were removed and examined for the presence of red ring nematodes. This experiment was also done in the screen house, free from the presence of *R. palmarum*. Seedling susceptibility was further investigated by mechanical inoculation of 20 palms. A suspension (5 ml) containing 3,000 nematodes was introduced into a hole made by a drill at the base and into the stem. In every test, the planting density was 294 trees per hectare.

Sampling and processing. Pieces of root tissue (2 cm long) and pieces of stem tissue (50 g) were taken at stem heights of 5, 30, 60, and 90 cm, starting at the soil line, and the number of nematodes per gram of tissue was determined. In all cases, the plants were observed for external symptoms and then removed. In the laboratory, we examined samples for nematodes following the standard procedure (5).

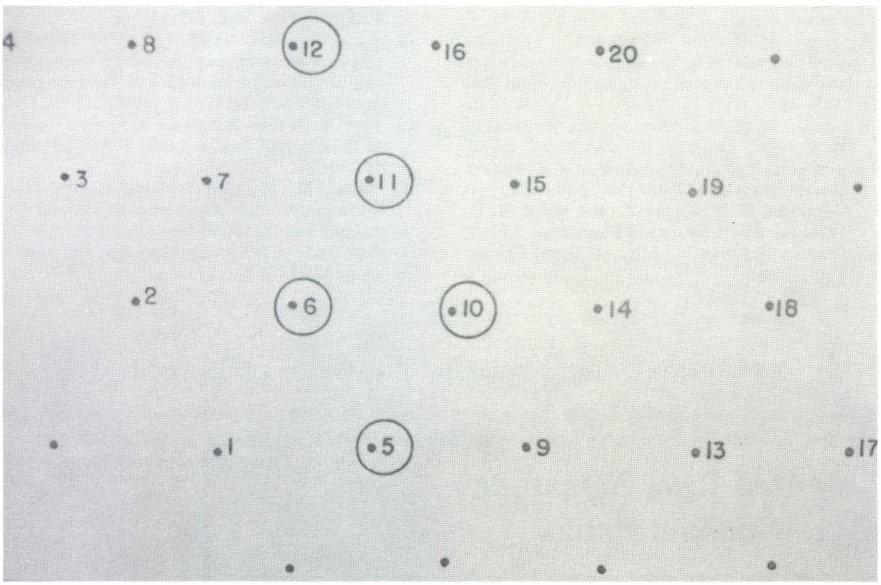

Fig. 1. Map of the locations (in the screen house) of the 20 coconut palms used in the root transmission experiment. Plants 5, 6, 10, 11, and 12 were mechanically inoculated in the stem with *Rhadinaphelenchus cocophilus*.

Table 1. Number of active red ring nematodes (*Rhadinaphelenchus cocophilus*) found in coconut tissue

Plant number[a]	Weeks after inoculation	Number of nematodes per gram of tissue				
			Stem (cm above soil line)			
		Roots	5	30	60	90
1	30	...[b]	...	...	...	...
2	17	5	34	...	...	...
3	30	...	...	...	...	...
4	30	...	...	...	...	...
5**	7	156	376	136	7	...
6**	7	20	189	...	...	...
7	13	8	52	17	...	...
8	30	...	...	...	...	...
9	21	108	381	97	15	6
10**	7	18	71	183	97	...
11**	7	...	152	178	...	...
12**	7	23	189	...	...	...
13	30	51	78	41	23	65
14	12	23	12	...	...	...
15	30	...	4	4	4	80
16	12	...	...	...	...	...
17	30	...	...	...	...	...
18	30	...	...	...	...	...
19	30	...	...	...	...	...
20	30	19	82	19	47	75

[a] **, Plants artificially inoculated with nematode suspension.
[b] No nematodes found.

RESULTS

Root transmission. The five trees subjected to basal mechanical inoculation developed symptoms of leaf yellowing within 7 wk. Nematodes were found in the bole area of all inoculated plants (Table 1). Nematodes were detected in seven of the 15 plants surrounding the five mechanically inoculated plants (Table 1). Nematodes were detected in the uninoculated plants 12 wk after the first mechanical inoculation (plant 14). Again, nematodes were found in the roots, bole area, and 30 cm above the soil line. At week 17, the nematode

was found only in the bottom part of plant 2. In plant 9, cut 21 wk after the first inoculation, nematodes had invaded the whole stem (Table 1). After 30 wk, clearly visible leaf symptoms indicated that the plants were succumbing to red ring disease. When plants 13, 15, and 20 were examined, nematodes had invaded the stems and the roots (Table 1). The number of nematodes per gram of plant tissue ranged from 4 to 381. More nematodes were found in the mechanically inoculated plants than in the plants in which the nematodes were presumably acquired through root contact.

Cultivation test. All 12 plants that were subjected to root damage and watered with a nematode suspension developed symptoms at between 80 and 92 days. By this time, red ring infection was well advanced. The oldest and lowest three leaves had died, and the other leaves were yellowing progressively. When these plants were cut apart and examined, nematodes were found throughout the stems. Leaf yellowing was not observed in two plants, although nematodes were extracted from the roots and the stem tissue from up to 30 cm.

Seedling susceptibility. Seedlings that were replanted after diseased plants were removed remained healthy. No nematodes were detected in the roots, stem region, or in the old seed. Twenty young seedlings that were inoculated mechanically did not develop the disease either; however, six red ring nematodes were extracted from one seedling.

DISCUSSION

The recommended density of 143 tall coconuts per hectare posed problems for doing transmission experiments. In our experiment, a spacing of 3 m between plants and a density of 294 trees per hectare was used, and nematode transmission by root contact with infected plants to healthy ones occurred in the experiment. However, in a coconut plantation, root contact occurs constantly. Menon and Pandalai (16) measured a length of 22 m for a single root. In addition, when trees are replanted, the common practice is to plant the new trees between the old rows with a 4-m space between plants.

Schuiling and Van Dinther (18) showed that a nematode population was found almost exclusively in the necrotic area of the ring. The number of nematodes extracted ranged from 0 to 4,833 per gram of tissue; the average was 300 per gram of tissue. In our trial, the number of nematodes was lower and ranged from 0 to 381. This may be explained by the young age of the plants used in the experiment. The number of active nematodes varied enormously in the samples and among the plants. However, on the average, mechanically infected plants showed symptoms first and had more nematodes than the plants that became infected through root contact. This was expected, because the number of nematodes in inoculated plants is probably higher (6,000) than in plants to which nematodes migrated from diseased plants.

Results similar to those in previous experiments with red ring disease were obtained with seedlings (6). We suggest that seedling tissues are not suitable for the development of nematodes. According to Blair (1,2), green nuts can support nematode populations when the nuts are inoculated artificially, but nematodes cannot pass through the fruit stalk when the nuts are inoculated on a bearing tree. In our study, the seedlings were not successfully colonized, and no nematodes were recovered from them, except in one case after mechanical inoculation.

In conclusion, red ring nematodes can be transmitted by means other than the insect vector. Infected plants should be removed immediately if by doing so further root contact can be avoided. Wounding of roots during cultivation practices should also be avoided.

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