Factors Affecting the Control of Rotylenchulus reniformis with UHF Electromagnetic Energy

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Abstract: The reniform nematode *Rotylenchulus reniformis* was reduced in the upper 10 cm of soil with application of UHF electromagnetic energy. Bioassay of treated soil indicated no delayed effect on the population from the treatment. The population was significantly reduced by hot water treatments at 40 C for 10 min, and at 45 C for 5 and 10 min, 50 C and above killed all nematodes. Data were inconclusive as to whether the effect of UHF electromagnetic energy was thermal or nonthermal. *Key Words:* reniform nematode, hot water treatment.

Radio waves have been investigated as a method for controlling soil pests (2, 3, 6, 7). However, most of these investigations use frequencies in the low to high range. Recently, Davis et al. (1) showed that ultra-high frequency (UHF) electromagnetic energy is lethal to plants and seeds of several species. Menges and Wayland (5) demonstrated the effectiveness of weed control with UHF electromagnetic energy from an experimental field unit. O'Bannon and Good (6) found that *Meloidogyne incognita* Kofoid and White in soil exposed in a commercial microwave oven operating at 2,450 (± 20) MHz was reduced at 15 sec and eliminated at 30 sec. In a preliminary field test, Heald et al. (4) found that UHF energy significantly reduced

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populations of *Rotylenchulus reniformis* Linford & Oliveira, and increased cantaloupe plant size. Presently, there is some question as to whether the effect of UHF energy is thermal or nonthermal.

The objectives of these investigations were: (i) to determine depth of control of *R. reniformis* by UHF energy (2,450 MHz) under field conditions, (ii) to record soil temperature as affected by UHF energy treatments, (iii) to determine lethal temperature for *R. reniformis* in hot water baths, and compare with lethal soil temperatures from UHF energy.

MATERIALS AND METHODS

Field experiment: A field (Hidalgo sandy clay loam) infested with *R. reniformis* was disked. Rows 101 cm apart were made with a rotary tiller and flattened to a smooth surface with bed shapers, so that the top of the bed was 25 cm wide. UHF energy was applied at 0, 183, 366, and 732 J/cm^2 with a field applicator as described by Wayland et al. (8). Each treatment was replicated five times. Glass thermometers were inserted into the soil 30 sec after the machine emitting UHF waves passed over a plot. Soil temperatures were recorded at depths of 5, 10, and 15 cm, 1, 10, 20, 30, and 60 min after treatment. Soil samples for nematode analysis were taken one day later at 5-, 10-, and 15-cm depths from a 15 × 15 × 20-cm cube taken in the middle of each row. Each sample included soil approximately 1.25 cm above and below the specified depth. Nematodes were extracted from 100 g of each sample by the Baermann funnel technique. After 48 h, 40 ml of water with the nematodes in suspension were drawn from funnels and counted.

Bioassay: A soil core was removed from each replication by pushing a metal cylinder (15 cm diam) into the soil in the middle of each row to a depth of 20 cm. This cylinder and its soil were placed on a greenhouse bench to serve as a plant pot. Two pea seeds [*Vigna cylindrica* (L.) Skeets 'Black-eye'] were planted in each pot and grown for 73 days. Soil was removed from the cylinders at 5-, 10-, and 15-cm levels and nematodes extracted as described above.

Lethal temperature determination: To determine the lethal temperature for *R. reniformis,* test tubes (24 × 2.2 cm) containing 70 ml of water were placed in a constant-temperature bath and stabilized at temperatures of 23, 35, 40, 45, 50, or 55 C. Room temperature, ~ 23 C, was used as the untreated control. One milliliter of water containing about 10,000 reniform nematodes was added to each test tube at each temperature and the tube left in the bath for 5 or 10 min. Each treatment was replicated five times. After heat treatment, tubes were emptied into plastic pots filled with 450 g of a steam sterilized Hidalgo sandy clay loam. Two cantaloupe seeds were planted in each pot and pots were placed in a growth chamber at 27 C. After 73 days, plants were removed from the soil. Roots were washed and stained with acid fuchsin in lactophenol, cleared in lactophenol, and examined for female nematodes. Soil from each pot was mixed, and from 100 g, *R. reniformis* were extracted and counted as described above.

RESULTS AND DISCUSSION

The effects of UHF energy on field populations of reniform nematodes at three soil depths are shown in Table 1. High (732 J/cm^2) and medium (366 J/cm^2) energy levels gave excellent nematode reduction to depths of 10 cm. Although mean numbers recovered at the 10-cm depth for the high and medium

TABLE 1. Effect of UHF energy on *Rotylenchulus reniformis* at three soil depths immediately after treatment and by bioassay 73 days after treatment.

	Soil depth (cm)					
	5		10		15	
Treatment joules/cm^2	Field[a]	Bioassay	F	B	F	B
732	0	0	40	56	655	461
366	0	54	38	361	400	1,130
183	3	105	276	168	262	479
Untreated control	464	1,159	252	338	640	161

[a]Average mean nematode count per five replications.

level are about the same, only one replication of the high-energy 10-cm level contained nematodes, whereas three replications of the medium-energy 10-cm depth sustained populations. Low energy levels controlled nematodes at the 5-cm level only. No effect was seen on populations at 15 cm at either of the three energy levels.

Soil temperatures (Fig. 1) at the three depths varied according to energy levels. Highest mean soil temperature (95 C) was recorded at 5 cm, 1 min after emission of the high-energy level. Generally, populations were eliminated in soil at depths where the soil temperature exceeded 50 C. The exceptions were at 5 cm in the low-energy treatment, where 12 larvae were recovered in one replication, and at 10 cm in the high-energy treatment, where 200 larvae were recovered in one replication. No larvae were recovered in any of the other replications at these depths or treatments. Temperatures at the medium-energy level at 10 cm were very similar to temperatures at the 15-cm, high-energy level; however, there was a difference in populations recovered. At the 10-cm, medium-energy level, the temperature rose to 45 C after 10 min and remained there through the one-hour period, resulting in reduced nematode numbers from three replications. At the high-energy level, 15-cm depth, temperature rose to 45 C after 30 min and remained there for the rest of the hour, with nematode numbers averaging 655 per 100 g soil, equal to that in

TABLE 2. Effect of hot water treatments on *Rotylenchulus reniformis* 73 days after an initial inoculation (10,000/pot) to southern peas.

Time (min)	Water temperature (C)					
	23	35	40	45	50	55
5	2,140[a]	1,818	1,695	1,326*	0	0
10	1,964	2,209	1,284*	1,477*	0	0

[a]Mean nematode count per five replications.
*Significantly different from untreated control $P = 0.01$.

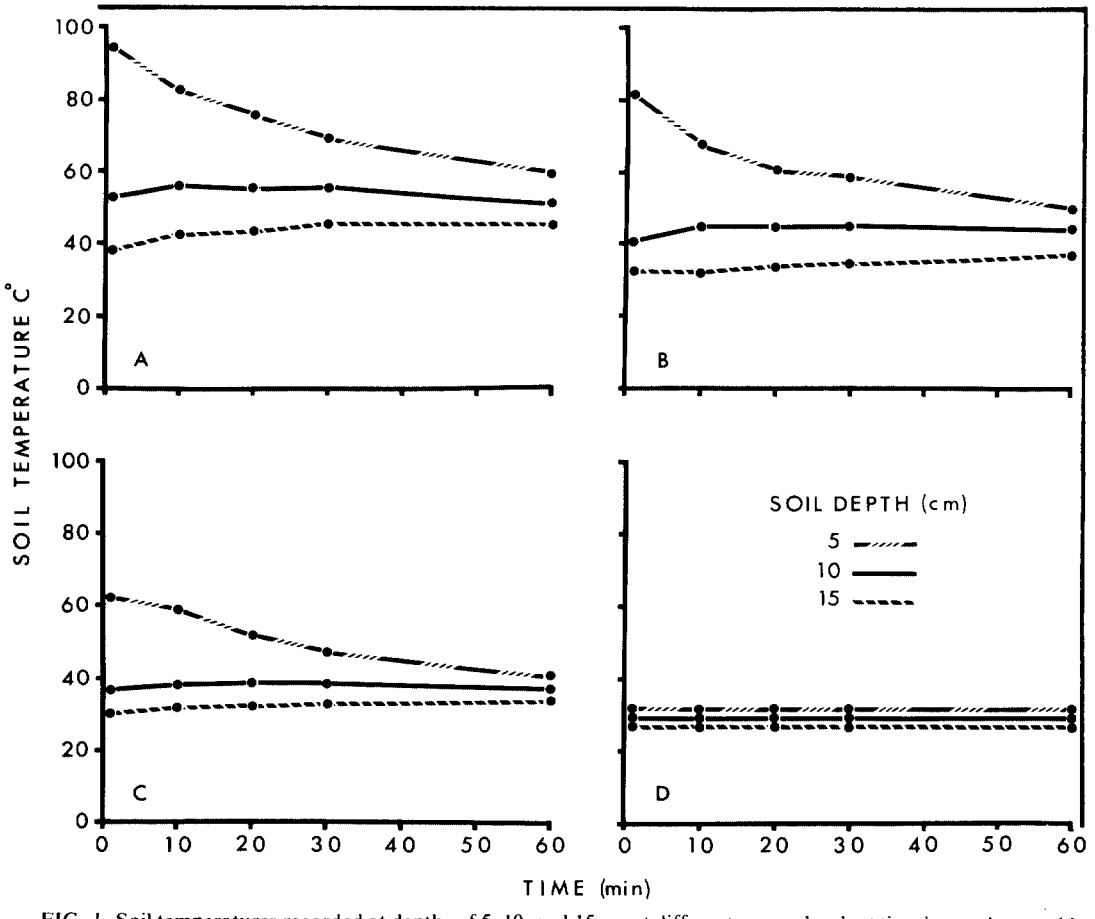

FIG. 1. Soil temperatures recorded at depths of 5, 10, and 15 cm at different energy levels at time intervals up to 1 h. A. 732 joules cm^2, B. 366 joules/cm^2, and D. untreated control.

untreated controls. The bioassay data (Table 1) indicate that there was no delayed effect from UHF on the nematode population, as nematodes persisted in all treated soils and had reinfested all depths except the 5-cm depth of the high-energy treatment.

Hot-water treatments (Table 2) significantly reduced nematode populations at 40 C after 10 min, and 45 C after 5 min. Temperatures of 50 C and above killed all nematodes. O'Bannon and Good (6), working with a commercial microwave oven, made similar conclusions but assumed that temperature was the lethal factor because of the extreme temperature recorded. Eglitis and Johnson (2), controlled damping-off fungi in greenhouse soils by radio frequency energy, and concluded that the soil temperature might account for the effect on the soil microflora, but did not rule out the possibility of nonthermal effects. Wayland et al. (9) found that microwaves decreased germination of bean seed at temperatures that had no effect on germination in hot-water baths. They concluded that the phytotoxic effect was from differential local heating or from nonthermal effects. Attempts in this laboratory to determine lethal and nonlethal energy levels on nematodes with a commercial instrument have not been conclusive, because of uneven heat distribution in the oven and lack of energy control. The differences in dielectric properties make it probable that nematodes adsorb more microwave energy than does soil. This could cause internal damage that might be toxic to the nematode.

LITERATURE CITED

1. DAVIS, F. S., J. R. WAYLAND, and M. G. MERKLE. 1971. Ultrahigh-frequency electromagnetic fields for weed control: phytotoxicity and selectivity. Science 173:535-537.
2. EGLITIS, M., and F. JOHNSON. 1970. Control of seedling damping-off in greenhouse soils by radio frequency energy. Plant Dis. Rep. 54:268-271.
3. EGLITIS, M., F. JOHNSON, and E. P. BREAKEY, JR. 1956. Soil pasteurization with high frequency energy. Phytopathology 46:635 (Abstr.).
4. HEALD, C. M., R. M. MENGES, and J. R. WAYLAND. 1973. Effect of ultrahigh frequency electromagnetic energy on Rotylenchulus reniformis. Proc. South. Agric. Workers 70:200 (Abstr.).
5. MENGES, R. M., and J. R. WAYLAND. 1973. Effect of soil moisture on preemergence weed control with ultrahigh frequency (UHF) electromagnetic energy in cantaloupe. Proc. West. Soc. Weed Sci. 26:37 (Abstr.).
6. O'BANNON, J. H., and J. M. GOOD. 1971. Applications of microwave energy to control nematodes in soil. J. Nematol. 3:93-94.
7. SELMAN, W. L., and V. R. WALLEN. 1967. Effect of exposure to radio frequency electric fields on seed-borne microorganisms. Can. J. Plant Sci. 47:39-49.
8. WAYLAND, J. R., F. S. DAVIS, and M. G. MERKLE. 1973. Toxicity of an UHF device to plant seeds in soil. Weed Sci. 21:161-162.
9. WAYLAND, J. R., F. S. DAVIS, L. W. YOUNG, and M. G. MERKLE. 1972. Effect of UHF fields on plants and seeds of mesquite and bean. J. Microwave Power 7:385-388.