Nematode Electrocution

FIELDS E. CAVENESS AND CLARENCE E. CAVENESS[1]

Abstract: The effects of electric shock on *Panagrellus redivivus* adults and larvae and *Meloidogyne incognita acrita* larvae were studied. The nematodes were placed in tap water between two stainless steel electrodes, spaced 2 mm apart and cemented to a glass slide. Electric potentials of 1, 5, 10, 15, 20, 30, and 60 vdc/mm and vac/mm were applied for periods of 1 sec to 5 min at 0.05 to 77 ma. The results demonstrated that ac or dc electric shocks as low as 5 v/mm for larvae and 10 v/mm for adults can be lethal. Some larvae and eggs within the body of *P. redivivus* females were not affected at 600 v/mm. Potentials of 20 and 60 vdc/mm for 2-sec stimulated hatch of *Meloidogyne* eggs. *Key Words:* Nematode, Electrocution, *Panagrellus redivivus, Meloidogyne incognita acrita, Hatch.*

Electrocution of nematodes was first demonstrated by Daulton and Stokes (1). They reported a pulsating direct current (200 to 700 Hz) was lethal to *Meloidogyne* spp. in water. However, no data were given on potential, milliamperes, time of exposure, or substrate temperature increase. Lear and Jacob (3) reported unsuccessful attempts to kill *Meloidogyne incognita acrita* larvae and eggs in 102 cc of soil using 13-kv dc with a maximum final nonlethal soil temperature of 24 C. Stokes and Martin (4) reported electric shock had no effect on *Meloidogyne javanica* in small blocks of soil but that larvae were killed in water at about 31.5 vdc/mm (= 800 v/in.). Larvae were stunned between 15.7 vdc/mm and 23.6 vdc/mm) (= 400 and 600 v/in.) but were unaffected by 12.6 vdc/mm (= 320 v/in.). The electrocution trials of *Panagrellus redivivus* and *M. incognita acrita* larvae and eggs described in this paper include exposure times from nearly instantaneous death to a maximum of 5 min.

MATERIALS AND METHODS

A variable full-wave rectifier for direct current and a variable transformer for alternating current connected to the power mains provided selection of specific electrical potentials. Milliammeter-monitored adjustable potentiometers were used for fine amperage adjustment. Temperature changes were measured by a temperature potentiometer. (See Figs. 1 and 2).

Nematodes were placed in tap water between two stainless steel electrodes affixed to a glass slide with silicone rubber cement dams at each end to form a well 2-mm wide, 1-mm deep, and 30-mm long between the electrodes. Potential was maintained until all nematode movement ceased or up to 5 min. Each test was replicated five times, and each replicate consisted of ten nematodes except for 10 *M. incognita acrita* egg masses. Controls were included in each of 12 tests. Physical test parameters are given in Table 1 with individual test modifications listed below.

Test 1: Ten *P. redivivus* adults were individually exposed to treatments 1 through 14 (Table 1). Treated nematodes were placed in oatmeal and yeast culture to test for reproduction of survivors.

Test 2: *P. redivivus* adults were treated as in Test 1, and larvae within the female body were further exposed to 1200 v (= 600 v/mm) potential between electrodes 2 mm apart.

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[1] Senior Electrical Engineer, Space Division of North American Rockwell Corporation, 12214 Lakewood Boulevard, Downey, California 90241, and Nematologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Shafter, California 92363. Present address: International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Western State, Nigeria.

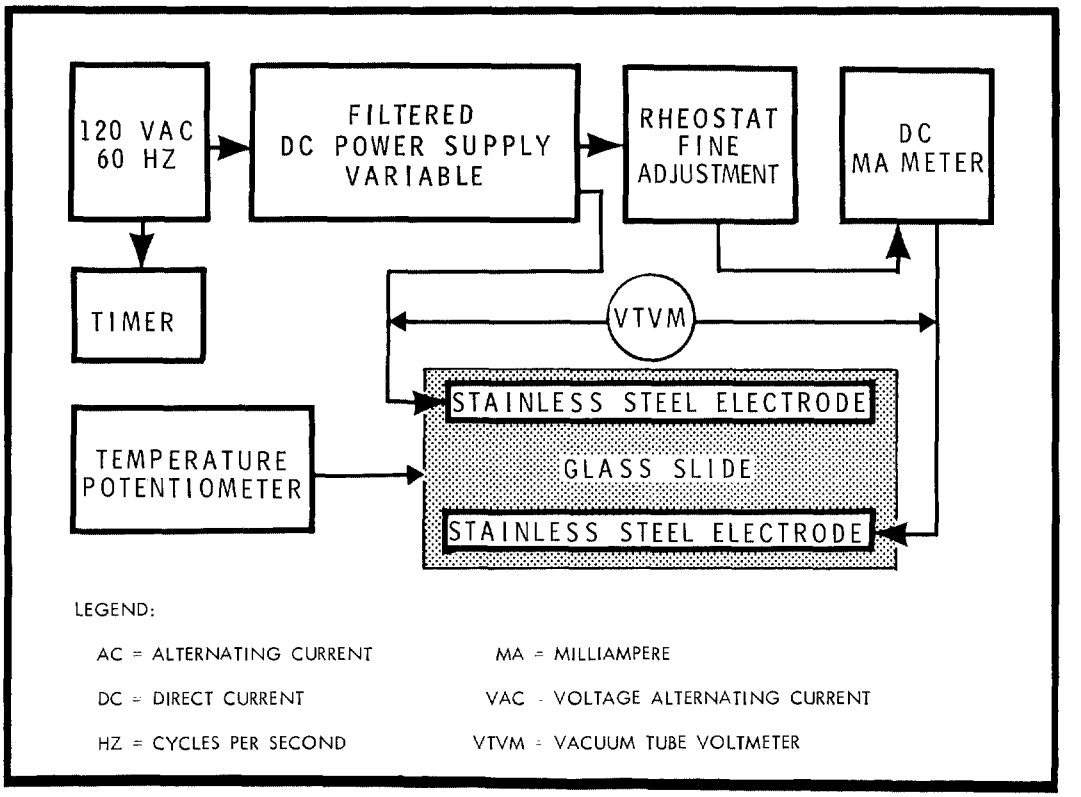

FIG. 1. Electrical block diagram, dc mode.

Test 3: *P. redivivus* larvae were treated as in Test 1. The larvae were placed in an oatmeal and yeast culture for reproduction of survivors.

Test 4: *P. redivivus* adults were treated as in Test 1, then Baermann-extracted for 20 hr on a Scottie® (Scott Paper Co., Chester, Pa.) filter, hereafter called "Baermann extraction," to check for revived nematodes.

Test 5: *P. redivivus* adults were treated as in Test 2, then Baermann-extracted for 20 hr for the recovery of revived nematodes.

Test 6: *P. redivivus* larvae were treated as in Test 1, then Baermann-extracted for 20 hr for the recovery of revived nematodes.

Test 7: *P. redivivus* adults were exposed to 30 vdc/mm and 30 vac/mm for 1 sec out of each 10 sec over a period of 150 sec (15 sec total exposure).

Test 8: *P. redivivus* adults were exposed to 60 vdc/mm and 60 vac/mm for 1 sec out of each 15 sec over a period of 45 sec (3 sec total exposure).

Test 9: *P. redivivus* adults were exposed to 30 vdc/mm and 30 vac/mm for 1 sec out of each 60 sec over a period of 27 min (28 sec total exposure).

Test 10: *P. redivivus* adults were exposed to 60 vdc/mm and 60 vac/mm for 1 sec out of each 60 sec over a period of 10 min (11 sec total exposure).

Test 11: *M. incognita acrita* larvae were exposed to treatments 1 through 14

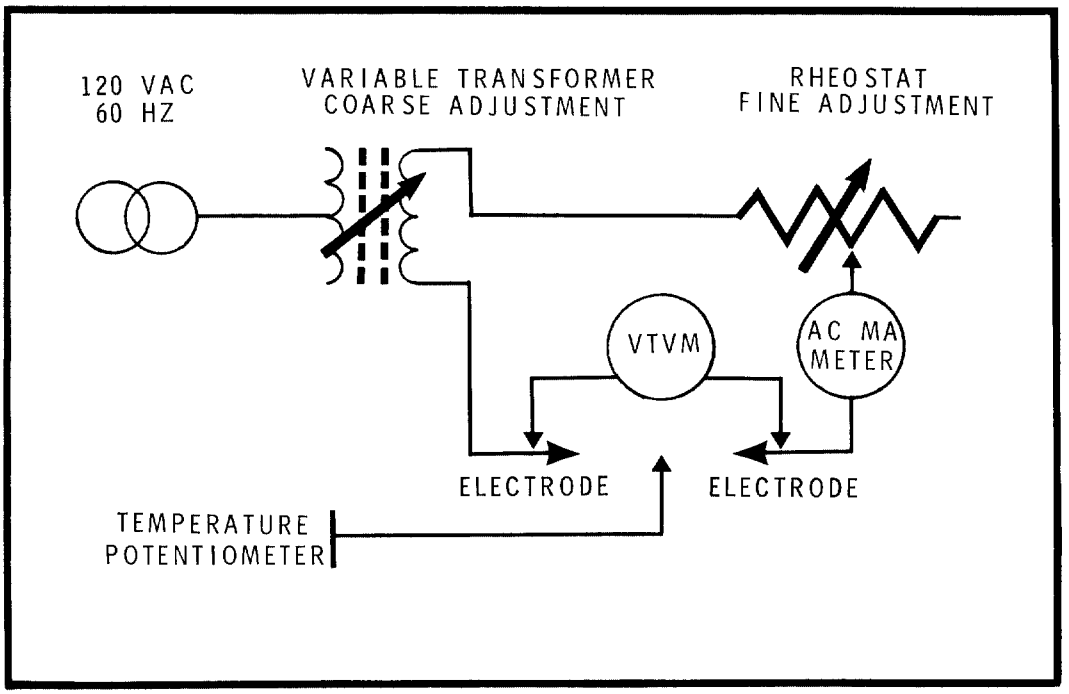

FIG. 2. Schematic diagram, ac mode.

(Table 1). The larvae were Baermann-extracted for 20 hr for the recovery of revived nematodes.

Test 12: *M. incognita acrita* egg masses were exposed to 20 vdc/mm for 2 sec and 60 vdc/mm for 2 and 60 sec. The egg masses were Baermann-extracted for the recovery of hatched larvae. Nematode infectivity was tested by collecting larvae 5 and 10 days after treatment and transferring them to young, potted cotton plants (*Gossypium hirsutum* L., 'Acala SJ-1').

RESULTS

ELECTROCUTION: In Tests 1, 2, and 3, adults and larvae survived an electric shock of 1 v/mm ac or dc. Larvae were killed by potentials 5 v/mm and above. Upon visual inspection, male and female adults appeared dead at 5 vdc/mm and 30 vac/mm and above, but eggs and larvae within the females survived and reproduced on oatmeal and yeast cultures in all treatments (Table 2). Active larvae were visible after treatment in the uterus and in eggs within the outstretched female body.

Adults in Test 4 survived at 1 vdc/mm and 1 vac/mm, and 54% survived and were recovered by Baermann extraction after exposure to 5 vac/mm. All other treatments were lethal. Larvae were recovered in Baermann funnels whether or not the female survived the treatments of Tests 4 and 5 (Table 3). Free larvae survived unharmed at 1 vdc/mm and 1 vac/mm, but only 4 and 2% survived at 5 and 10 vac/mm, respectively, as determined by Baermann extraction in Test 6.

No adults, male or female, survived the treatments in Tests 7, 8, 9, and 10. Active

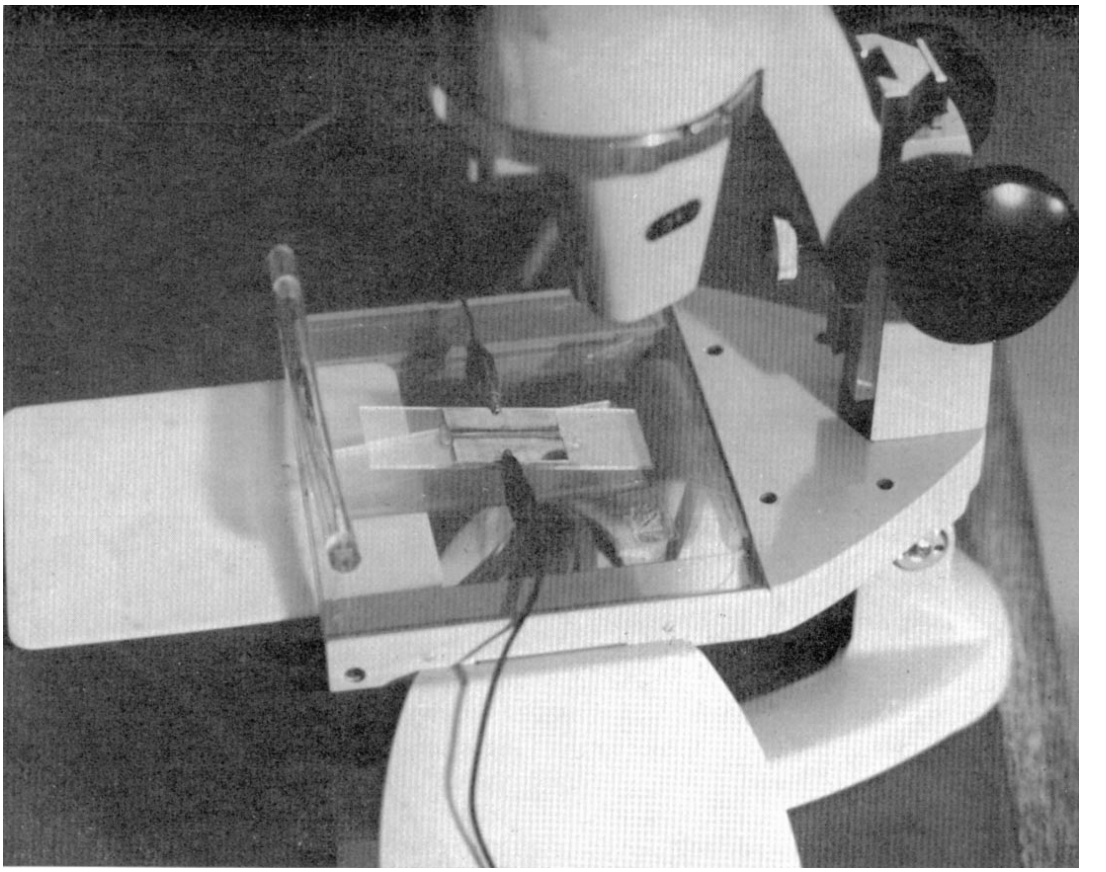

FIG. 3. Physical setup showing stainless steel electrodes on a glass slide. Probe of the temperature potentiometer is shown on left.

larvae could be seen in the uterus and eggs of dead females. Intermittent shocks of dc were as effective as a continuous exposure period (Table 1). Intermittent 30 vac/mm shocks killed at 16 sec total exposure time; sixty vac/mm at 7 sec total exposure time.

The survival of *M. incognita acrita* larvae in Test 11 was essentially as for *P. redivivus larvae* in Test 6 (Table 3).

Exposure of *M. incognita acrita* egg masses to 20 and 60 vdc/mm electric shock for 2 sec appeared to simulate hatching but retarded hatching at 60 vdc/mm for 60 sec (Table 4). The treatments did not affect larval infectivity or the ability of the mature female to produce viable eggs.

BEHAVIOR: *1 vdc/mm.*—No visible effect was noted on adults or larvae up to 5 min.

5 vdc/mm.—Some larvae and adults stopped movement immediately. The movement of others was slowed, with twitching of head or tail end. A few continued rapid movement for up to 20–30 sec of treatment, then slowed, and movement ceased within 90 sec. In some adults, rapid movement continued for up to 60–90 sec, then slowed, with cessation of movement by 3 min. At death, most adults and larvae stretched out in a more or less straight position, although a few folded back on themselves.

10 vdc/mm.—Behavior was similar to

TABLE 1. Treatment data: potentials, milliamperes, time, and temperature increase.

Treatment No.	Electric Potential[a]		Milliamperes		Duration[b]	Temperature Rise (C) Above 22 C Ambient
	vdc/mm	vac/mm	dc	ac		
1	1		0.05		5 min	0
2	5		2.5		20 sec	1
3	10		10		5 to 20 sec	3
4	15		19		3 to 5 sec	7
5	20		21		3 to 5 sec	10
6	30		51		1 to 5 sec	13
7	60		77		< 1 sec	16
8		1		0.27	5 min	0
9		5		2.1	5 min	0
10		10		4.2	5 min	2
11		15		–	5 min	4
12		20		–	3.5 to 5 min	10
13		30		– [c]	15 to 90 sec	9
14		60		–	3 to 9 sec	16

[a] Multiply by 10 for potentials in second parts of Tests 2 and 5.
[b] Treatment stopped upon cessation of movement.
[c] Not measured.

that at 5 vdc/mm, but all movement stopped by the end of 20 sec.

15 and 20 vdc/mm.—Behavior was similar to that at 5 vdc/mm, but all movement stopped by the end of 5 sec.

30 vdc/mm.—Most larvae and adults stopped movement immediately. Adults stretched out in a more or less straight position. In some, the tail curved ventrally. A few folded back on themselves. Most larvae straightened out, then folded back on themselves.

60 vdc/mm.—Larvae and adults stopped movement immediately. Adults reacted as at 30 vdc/mm. Most larvae straightened out, but a few curved or folded back on themselves.

DISCUSSION

In our studies, death by electrocution in water for adults and larvae of *P. redivivus* and larvae of *M. incognita acrita* occurred at a much lower potential than reported by Stokes and Martin (4) for *M. javanica* larvae (5 vdc/mm to 15.7 vdc/mm). Electric shocks of a higher potential reduced the time of exposure necessary for kill, with death nearly instantaneous at 60 vdc/mm.

Survival of some larvae and eggs following electric shock was demonstrated by reproduction in culture (Table 2) and by active passage of adults and larvae through a Baermann funnel (Table 3).

Hatch of 42 root-knot larvae from 50 egg masses is judged to represent escape of those occupying positions of higher electrical resistance in the mass rather than resistance to electrical effect. This can be explained by the fact that an electric current will follow the path of least resistance (2). In all three circumstances, the nematodes and/or eggs were simply bypassed.

The behavior of nematodes during electrocution was generally similar at all potentials; higher potentials merely decreased the reaction time.

From the longer ac exposure required to cause death (Tables 1, 2, 3), it seems that direct current is more lethal to nematodes than alternating current.

The killing of nematodes by electrocution (60 vdc/mm) before fixing for taxonomic

TABLE 2. Survival of *P. redivivus* after exposure to electric shock as determined by reproduction on oatmeal and yeast culture.

Nematode	Treatment	Population	Days' Incubation
Controls			
Adults dc	None	536,800[a, b]	7
Larvae dc	None	143,900	7
Adults ac	None	280,623	9
Larvae ac	None	5,870	8
Larvae	1	138,200	7
	2	0	7
	3	0	7
	4	0	7
	5	0	7
	6	0	7
	7	0	7
	8	5,804	8
	9	0	8
	10	0	8
	11	0	8
	12	0	8
	13	0	8
	14	0	8
Adults[c]	1	589,600	8
	2	38,355	8
	3	91,800	8
	4	100,650	8
	5	166,650	8
	6	39,650	8
	7	4,050	8
	8	28,637	9
	9	79,294	9
	10	66,532	9
	11	56,774	9
	12	7,140	9
	13	5,360	9
	14	4,980	9
Adults[d]	1	101,100	9
	2	122,650	9
	3	161,150	9
	4	110,550	9
	5	189,200	9
	6	107,480	9
	7	34,100	9
	8	98,430	8
	9	86,900	8
	10	109,280	8
	11	44,670	8
	12	73,330	8
	13	11,120	8
	14	16,170	8

[a] Means of five replications of ten initial nematodes each.
[b] Counted by the dilution method.
[c] Gravid females.
[d] A special effort was made to kill eggs and larvae within the female by reducing the distance between the electrodes and increasing the potential by a factor of 10.

TABLE 3. Survival of *P. redivivus* after exposure to electric shock as determined by active passage through a Scottie filter in a Baermann funnel.

		No. of Nematodes[a]		
Nematode	Treatment	Adults	Larvae	Hatched Larvae[b]
Controls				
Adults dc	None	10.0		28.4
Larvae dc	None		10.0	
Adults ac	None	9.4		20.8
Larvae ac	None		9.8	
Larvae	1		9.8	
	2		0.0	
	3		0.0	
	4		0.0	
	5		0.0	
	6		0.0	
	7		0.0	
	8		8.1	
	9		0.4	
	10		0.2	
	11		0.0	
	12		0.0	
	13		0.0	
	14		0.0	
Adults[c]	1	10.0		4.8
	2	0.0		7.4
	3	0.0		7.4
	4	0.0		1.2
	5	0.0		0.4
	6	0.0		2.6
	7	0.0		0.4
	8	8.8		8.6
	9	5.4		72.8
	10	0.0		49.8
	11	0.0		33.2
	12	0.0		24.8
	13	0.0		6.4
	14	0.0		4.4
Adults[d]	1	0.0		6.1
	2	0.0		4.2
	3	0.0		5.1
	4	0.0		11.4
	5	0.0		2.0
	6	0.0		0.8
	7	0.0		3.2
	8	0.0		15.6
	9	0.0		9.3
	10	0.0		1.2
	11	0.0		3.4
	12	0.0		5.4
	13	0.0		5.6
	14	0.0		2.0

[a] Means of five replications of ten nematodes each.
[b] Larvae that escaped from the uterus after treatment.
[c] Gravid females.
[d] A special effort was made to kill eggs and larvae within the female by reducing the distance between the electrodes and increasing the potential by a factor of 10.

TABLE 4. *M. incognita acrita* larvae recovered from egg masses exposed to electric shock and root-knot index on cotton.

Treatment	Larvae Recovered[a]			Root-knot Index[b]
	5 Days	10 Days	Total	
Control	544	580	1124	3.9
20 vdc/mm 2 sec	1196	769	1965	3.7
60 vdc/mm 2 sec	841	496	1337	3.9
60 vdc/mm 2 sec	5	37	42	0.4

[a] Means of five replications of ten egg masses each.
[b] Means of five cotton root ratings.

studies could be a useful method, because there is a slight separation or definition of certain internal organs. This should be evaluated by interested persons.

LITERATURE CITED

1. DAULTON, R. A. C., AND W. M. STOKES. 1952. The destruction or inhibition of root-knot nematodes by exposure to an electrostatic field. Empire J. Exp. Agr. 20: 271–273.
2. KNOWLTON, A. E., (ed.). 1949. Standard Handbook of Electrical Engineering, 8th ed., McGraw-Hill, p. 57.
3. LEAR, B., AND F. C. JACOB. 1955. Results of laboratory experiments with high-voltage, non-thermal electrical treatments for control of root-knot nematodes. Plant Dis. Rep. 39:397–399.
4. STOKES, W. M., AND G. C. MARTIN. 1954. Failure of an attempt to control root-knot nematodes by electrical means. Rhodesia Tobacco, 1954, 6:30–32.