Control of *Globodera rostochiensis* by Solar Heat

J. A. LaMONDIA, Graduate Research Assistant, and B. B. BRODIE, Research Plant Pathologist, USDA, ARS, Department of Plant Pathology, Cornell University, Ithaca, NY 14853

ABSTRACT

LaMondia, J. A., and Brodie, B. B. 1984. Control of *Globodera rostochiensis* by solar heat. Plant Disease 68:474-476.

The effect of clear and black plastic mulches with and without irrigation on survival of *Globodera rostochiensis* was compared with survival using no mulch. Clear plastic mulch reduced natural soil populations by 96.2–98.6% to a depth of 10 cm, totally eliminated encysted juveniles buried 5 cm deep, and significantly reduced survival of encysted juveniles buried 10 and 15 cm deep. Black plastic affected survival of *G. rostochiensis* to a depth of 5 cm. Survival of encysted juveniles in irrigated soil was significantly less than in soil without irrigation. When the experiments were repeated during the unusually cool summer of 1982, use of clear plastic significantly reduced the hatch of buried encysted juveniles, but control was less effective than in 1981.

Additional key words: solarization, temperature

A number of workers have determined the lethal time/temperature requirements for cyst nematodes in water (1,3,5,11,12, 15,17–20). Time/temperature requirements for thermal death of *Globodera rostochiensis* (Woll.) Behrens. in soil were determined in laboratory studies (10). Endo (5) determined that lethal time/temperature requirements for *Heterodera glycines* Schmidt were not significantly different for encysted juveniles in eggs, free juveniles, or free eggs, indicating that the cyst fails to protect eggs and juveniles from temperature stress. Cyst contents in dry soil appear better able to withstand high temperatures than encysted juveniles in moist soils (2,6,9). Thomason and Fife (19) concluded that the insensitivity of air-dry, encysted juveniles of *H. schachtii* to high temperatures in the Imperial Valley of California was an adaptation for survival in the upper few centimeters of soil. This appears to be a common survival mechanism for all cyst nematodes studied to date.

One means of exploiting the susceptibility of wet, encysted juveniles to temperature stress might be solar heating of wet soil with a plastic mulch. Solarization has been used to control soilborne pathogens and weeds (4,7,8,13) and to enhance the effects of biological and chemical control techniques (4). Experiments were undertaken in 1981 and 1982 to evaluate the effectiveness of solarization in reducing populations of *G. rostochiensis* under New York field conditions.

Cooperative Investigations of the U.S. Department of Agriculture, Agricultural Research Service, and the Cornell University Agricultural Experiment Station.

Accepted for publication 27 December 1983 (submitted for electronic processing).

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked *"advertisement"* in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

MATERIALS AND METHODS

A randomized block design was used to test the effects of clear plastic, black plastic, and no plastic (all with and without irrigation) on viability of encysted juveniles in clay-loam soil in Steuben County, NY. Plots were 2 × 8 m and each treatment was replicated four times. Each plot was bordered on all sides by 2 m of fallow soil. Weeds were controlled in the plots (trifluralin) and in the borders (glyphosate). Plots were sampled to determine initial numbers of viable units per cyst. From each plot, 50 cc of soil to a depth of 10 cm was taken at 1-m intervals and bulked. Cysts were extracted from a 250-cc aliquot with a USDA cyst extractor (16) and 25 cysts were crushed. In addition, uniform cysts produced on Katahdin potatoes in 1980 and standardized by size were buried in nylon bags 5, 10, and 15 cm deep in the center of each plot. In an effort to maintain the soil under the plastic at field capacity, half of the plots received supplemental trickle-irrigation each time the surfaces of uncovered plots dried out. Clear and black plastic mulches were applied on 9 July 1981 and removed on 21 September 1981.

After the mulch was removed, soil samples were taken and the final number of viable juveniles was determined as described previously. Viability of encysted juveniles previously buried in bags was determined by hatching in potato-root diffusate (PRD) and by visual observation (4). Viable second-stage juveniles were distinguished by a clear esophageal region with a distinct border to the darker intestinal region and by limited and organized vacuoles in the intestines. Nonviable juveniles had no such border or difference between the esophagus and intestine and a larger number of large, irregular vacuoles in the intestinal region.

Based on 1981 results, solarization experiments were repeated in 1982 using only clear plastic mulch with and without irrigation. Natural field populations were again monitored, and uniform cysts produced on Katahdin potatoes in 1981 and standardized by size were buried in nylon bags 5, 10, and 15 cm deep in all treatments receiving supplemental water. Clear plastic mulch was applied on 25 June 1982 and removed on 24 August 1982.

Soil thermometers buried 5, 10, and 15 cm deep in all treatments of one replicate were checked several times each day to monitor soil temperatures in 1981. In 1982, recording soil thermographs were used to monitor temperatures at 5, 10, and 15 cm under clear and no plastic.

RESULTS

Percent reduction in viable encysted juveniles of *G. rostochiensis* in naturally infested soil is shown in Table 1. The 96.2 and 98.6% reduction values achieved under clear plastic in 1981 are higher ($P = 0.01$) than those obtained with black or no plastic (control). Percent reduction of encysted juveniles from naturally infested soil in 1982 under clear plastic was higher than that achieved under no plastic (77 and 66% compared with 30 and 1% reduction, respectively), but statistical analysis indicated that differences were not significant in 1982.

Buried cysts subjected to solarization in 1981 were hatched for 7 wk in PRD. Hatch from cysts under clear plastic was less ($P = 0.01$) than the control at all three depths and under black plastic at the 5- and 10-cm depths ($P = 0.01$ and 0.05, respectively) (Table 2). Hatch of juveniles was totally inhibited from cysts buried 5 cm deep under clear plastic. Hatch from cysts buried under black plastic was less ($P = 0.05$) than the controls at 5 cm but not at 10 or 15 cm. Also, hatch of encysted juveniles from irrigated soil was less than from that in nonirrigated soil at 10 and 15 cm ($P = 0.05$ and 0.01, respectively). Hatch from buried cysts under clear plastic in 1982 was different from hatch of encysted juveniles in soil with no plastic ($P = 0.05$). Solarization with clear plastic in 1981 resulted in complete elimination of viable encysted juveniles of *G. rostochiensis* at 5 cm (Table 3). No significant differences between treatments were apparent at the 10- and 15-cm depths in 1981 or for any depths in 1982.

Air temperatures for the summers of 1981 and 1982 recorded 10 mi. from the site of the experiments at Gannett Hill Meteorological Station were below normal for both years. Temperatures for June, July, and August 1981 were 0.6, 1.7, and 1.8 degrees (C) below normal, respectively. Temperatures for June, July, and August 1982 were 2.6, 0.9, and 2.9 degrees below normal. Soil temperatures 5 cm deep under bare ground at the Geneva Experiment Station (30 mi. away) peaked at higher than 38 C for six consecutive days and higher than 32 C for 12 consecutive days during the experiment in 1981. Corresponding soil temperatures between 25 June and 24 August 1982 peaked at higher than 38 C for 4 days and higher than 32 C for only eight consecutive days (U.S. climatological data).

In 1981, soil temperatures at 5 cm under clear plastic reached a maximum of 47 C for 1 hr. Soil 10 and 15 cm deep did not reach potentially lethal temperatures. During the summer of 1982, recording thermographs indicated that clear plastic raised the soil temperature an average of 10 degrees higher than no plastic at the 5-cm depth, but no potential lethal time/temperature combinations were achieved at any depth measured. The highest temperature and time was 45 C for 1 hr at 5 cm (Table 4).

Table 1. Percent reduction of viable encysted juveniles of *Globodera rostochiensis* in naturally infested soil subjected to solarization

Treatment	Percent reduction ($\bar{x}$ of 4 reps.) 1981	1982
Clear plastic, water	96.2[a]	77.0
Clear plastic, no water	98.6	66.0
Black plastic, water	67.3	···
Black plastic, no water	49.2	···
No plastic, water	27.4	30.0
No plastic, no water	51.8	1.0
Linear contrasts		
Clear plastic vs. no plastic	0.01[b]	–
Clear plastic vs. black plastic	0.01	–
Water vs. no water	–	–
Black plastic vs. no plastic	–	–
Clear plastic, water vs. clear plastic, no water	–	–

[a]Data analyzed after $\sqrt{x+1}$ transformation (analysis of variance).
[b]Significance level. – = No significant difference.

DISCUSSION

Our results indicate that clear plastic is more effective than black plastic in reducing *G. rostochiensis* populations. Clear plastic successfully eliminated encysted juveniles buried 5 cm deep. Also, hatch of juveniles from cysts buried 10 and 15 cm deep was reduced by more than 50% in both cases. Natural populations and buried encysted juveniles reacted similarly.

Black plastic, though not as effective as clear plastic, reduced survival in cysts buried 5 cm deep. It appears that moisture plays an important role in the sensitivity of eggs to temperature stress, because a difference between survival with and without irrigation was apparent at 10- and 15-cm depths. Significance at 5 cm was obscured by the complete elimination of encysted juveniles under clear plastic at this depth. In 1982, solar heating with clear plastic caused some reduction in *G. rostochiensis*, but unusually cool temperatures resulted in less effective control. Differences between clear and no plastic were significant for inoculated, encysted juveniles but not significant for naturally infested, encysted juveniles. Although the percentage of cysts with viable contents under clear plastic was not different from the control at 10 and 15 cm in 1981 and for all depths in 1982, the number of viable juveniles per cyst was reduced. All juveniles within a particular cyst were similarly affected in laboratory studies (9). This all-or-none effect was not evident in encysted juveniles subjected to solar heating in the field, perhaps because of the effects of soil fungi, bacteria, or environmental conditions (4).

Periodic measurements demonstrated that clear plastic was more effective in raising soil temperatures than black plastic. Also, soil temperatures would probably be higher in large-area applications than in plots 2 m wide. The thermal death curve generated for encysted juveniles of *G. rostochiensis* in wet soil (9) showed a sharp increase in slope below 45 C, with 2 hr at 45 C and more than 160 hr at 40 C required for elimination at these temperatures. Because soil temperatures peak for only a few hours each day, temperatures must reach or approach 45 C to effectively reduce survival of *G. rostochiensis* in wet soil. The reduced hatch of encysted juveniles buried at 10 and 15 cm in 1981 and at all depths in 1982 may not be attributable to high temperatures alone. Factors such as the effect of long-term exposure to sublethal temperatures, the effect of fluctuating temperatures (10), and the enhancement of biological and environmental antagonism may be responsible for this phenomenon.

These results demonstrate that solarization can be used effectively to reduce *G. rostochiensis* populations in soil of

Table 2. Hatch of encysted juveniles of *Globodera rostochiensis* subjected to solarization

Treatment	No. of juveniles emerged per cyst ($\bar{x}$ of 4 reps.) 1981 5 cm	1981 10 cm	1981 15 cm	1982 5 cm	1982 10 cm	1982 15 cm
Clear plastic, water	0.0[a]	335.3	304.5	213.5	208.5	179.4
Clear plastic, no water	0.3	657.0	651.8	···	···	···
Black plastic, water	881.5	605.3	346.3	···	···	···
Black plastic, no water	1,103.5	1,084.8	1,062.8	···	···	···
No plastic, water	1,222.5	1,032.8	753.5	303.2	307.3	288.9
No plastic, no water	1,199.5	1,210.5	1,484.5	···	···	···
Linear contrasts						
Clear plastic vs. no plastic	0.01	0.01	0.01	–[b]	–	–
Black plastic vs. no plastic	0.05	–	–	–	–	–
Clear plastic vs. black plastic	0.01	0.05	–	–	–	–
Water vs. no water	–[c]	0.05	0.01	–	–	–
Clear plastic, water vs. clear plastic, no water	–	–	–	–	–	–

[a]Data analyzed after $\sqrt{x+1}$ transformation (analysis of variance).
[b]Significance level. – = No significant difference. Analysis of variance significant at 0.05.
[c]Significant obscured by control with clear plastic.

Table 3. Survival of encysted juveniles of *Globodera rostochiensis* in soil subjected to solarization (1981)

Treatment	Percent cysts with viable contents ($\bar{x}$ of 3 reps.) 5 cm	10 cm	15 cm
Clear plastic, water	0.0[y]a[z]	76.7 b	76.7 b
Clear plastic, no water	0.0 a	90.0 b	96.7 b
Black plastic, water	93.3 b	83.3 b	83.3 b
Black plastic, no water	93.3 b	86.7 b	93.3 b
No plastic, water	93.3 b	83.3 b	80.0 b
No plastic, no water	80.0 b	86.7 b	93.3 b

[y]Data analyzed after arc sine transformation (analysis of variance).
[z]Numbers followed by the same letter not significantly different ($P = 0.05$).

Table 4. Monthly maximum soil temperatures recorded with and without plastic mulch (1982)

		Depth (cm)					
		5		10		15	
Month	Treatment	Max. (C)	Duration (hr)	Max. (C)	Duration (hr)	Max. (C)	Duration (hr)
June[a]	Clear plastic	34	0.5	30	1.0	24	1.0
	None	23	1.0	23	3.0	22	1.5
July	Clear plastic	45	1.0	40	2.0	33	2.5
	None	36	2.0	31	3.0	28	3.0
August	Clear plastic	42	2.0	34	0.5	30	2.0
	None	33	1.0	29	2.0	25	4.0

[a] 28–30 June.

temperate growing regions. Although the control achieved is probably not sufficient to replace chemical control, solarization with a clear plastic mulch may have some use in small plots or in combination with chemical control. Because fumigation alone is least effective in the upper few centimeters of soil (14), fields found infested with *G. rostochiensis* are fumigated, plowed, and fumigated again (2). Solarization may prove useful as a complement to fumigation, especially in spot treatments, because a clear plastic mulch would increase the efficiency of a single fumigation and act as an additional control by eliminating encysted juveniles in the upper few centimeters of soil.

LITERATURE CITED

1. Brodie, B. B. 1976. Effects of birds ingesting *Heterodera rostochiensis* cysts on viability of eggs and larvae. J. Nematol. 8:318-322.
2. Chitwood, B. G. 1951. The Golden Nematode of Potatoes. U.S. Dep. Agric. Circ. 875. 48 pp.
3. Doliwa, U. 1956. Experimentelle untersuchungen an kartofelnematoden (*Heterodera rostochiensis* Wollenweber). Wiss. Z. Univ. Rostock 5:133-149.
4. Elad, Y., Katan, J., and Chet, I. 1980. Physical, biological and chemical control integrated for soilborne diseases in potatoes. Phytopathology 70:418-422.
5. Endo, B. Y. 1962. Lethal time-temperature relationships for *Heterodera glycines*. Phytopathology 52:992-997.
6. Fuchs, O. 1911. Beiträge zur biologie der rubennematoden *Heterodera schachtii*. Z. Landwirtsch. Versuchswes. Oesterr. XIV:923-949.
7. Grinstein, A., Orion, D., Greenberger, A., and Katan, J. 1979. Solar heating of the soil for the control of *Verticillium dahliae* and *Pratylenchus thornei*. Pages 431-438 in: Soil-Borne Plant Pathogens. B. Schippers and W. Gams, eds. Academic Press, London.
8. Katan, J., Greenberger, A., Alon, H., and Grinstein, A. 1976. Solar heating by polyethylene mulching for the control of diseases caused by soilborne pathogens. Phytopathology 66:683-688.
9. LaMondia, J. A. 1982. Studies on the potential of fungi and high temperature as means of controlling *Globodera rostocheinsis*. M.S. thesis, Cornell University, Ithaca, NY. 50 pp.
10. LaMondia, J. A., and Brodie, B. B. 1982. The effect of heat and moisture on survival of cysts of the golden nematode, *Globodera rostochiensis*, in soil. (Abstr.) Phytopathology 72:263.
11. Lewis, F. J., and Mai, W. F. 1960. Survival of encysted and free larvae of the golden nematode in relation to temperature and relative humidity. Proc. Helminthol. Soc. Wash. 27:80-85.
12. Miller, P. M. 1969. Injury to *Heterodera tabacum* by high soil temperature. Plant Dis. Rep. 53:191-193.
13. Porter, I. J., and Merriman, P. R. 1983. Effects of solarization of soil on nematode and fungal pathogens at two sites in Victoria. Soil Biol. Biochem. 15:39-44.
14. Seinhorst, J. W. 1973. The combined effects of dichloropropane-dichloropropene mixture injected into the soil and of dazomet applied to the soil surface. Neth. J. Plant Pathol. 79:194-206.
15. Slack, D. A., Riggs, R. D., and Hamblen, J. L. 1972. Effect of temperature and moisture on the survival of *Heterodera glycines* in the absence of a host. J. Nematol. 4:263-266.
16. Spears, J. M. 1968. The Golden Nematode Handbook. U.S. Dep. Agric. Handb. 353. 81 pp.
17. Steele, A. E. 1973. The effects of hot water treatments on survival of *Heterodera schachtii*. J. Nematol. 5:81-84.
18. Stone, L. E. W., and Webley, D. P. 1975. The effect of heat on the hatch of potato cyst eelworms. Plant Pathol. 24:74-76.
19. Thomason, I. J., and Fife, D. 1962. The effect of temperature on development and survival of *Heterodera schachtii*. Nematologica 7:139-145.
20. Triffit, M. J., and Hurst, R. H. 1935. On the thermal death point of *Heterodera schachtii*. J. Helminthol. 13:219-222.