MULCHING SOIL TO INCREASE YIELD AND MANAGE PLANT PARASITIC NEMATODES IN CUCUMBER (*CUCUMIS SATIVUS* L.) FIELDS: INFLUENCE OF SEASON AND PLASTIC THICKNESS

Phyllis L. Coates-Beckford, Jane E. Cohen, Laura R. Ogle, Christopher H. Prendergast, and Deta May Riley

Department of Life Sciences, University of the West Indies, Mona Campus, Kingston 7, Jamaica.

ABSTRACT

Coates-Beckford, P. L., J. E. Cohen, L. R. Ogle, C. H. Prendergast, and D. M. Riley. 1998. Mulching soil to increase yield and manage plant parasitic nematodes in cucumber (*Cucumis sativus* L.) fields: influence of season and plastic thickness. Nematropica 28:81-93.

Experiments were conducted to evaluate the effects of mulching soil with clear plastic at different periods of the year, and also of mulching with two thicknesses of plastic on cucumber growth, yield, foliar concentrations of total nitrogen or ammonium, phosphorus, and potassium, soil concentrations of total nitrogen or nitrate, phosphate, and potassium, and rhizosphere population densities of nematodes. Growth of plants in mulched plots often exceeded that in control plots. Yields from plots mulched with 0.4-mm-thick plastic for five weeks, commencing December 1, 1995, and for six weeks, commencing March 18, July 3, and August 2, 1996, and planted immediately after mulching, were greater than those from nonmulched plots. Yields from plots mulched for six weeks with 0.2-mm-thick plastic, commencing August 2, 1996, were not significantly different from control yields presumably because the plastic deteriorated within four weeks. *Rotylenchulus reniformis* and *Helicotylenchus erythrinae* were the most frequently-detected phytoparasitic nematodes. At the end of the mulching period, population densities of parasitic and nonparasitic nematodes in plots mulched with the thicker plastic in March and October and with both thicknesses of plastic in August were lower than those in control plots. Foliar and soil concentrations of nutrients usually were similar for mulched and nonmulched plots. Increased growth and yield of cucumber plants in mulched soil were, thus, closely associated with the reduction in soil population densities of parasitic nematodes rather than with changes in soil fertility.

Key words: Cucumber, *Helicotylenchus erythrinae*, nonparasitic nematodes, plastic mulch, *Rotylenchulus reniformis*, season, soil and leaf nutrients, soil solarization, temperature.

RESUMEN

Coates-Beckford, P. L., J. E. Cohen, L. R. Ogle, C. H. Prendergast y D. M. Riley. 1998. Cubierta del suelo para incrementar el rendimiento y el manejo de nematodos fitoparásitos en campos de pepino (*Cucumis sativus* L.): influencia del periodo estacional y grosor del plástico. Nematropica 28:81-93.

Se realizaron experimentos para evaluar los efectos de cubrir el suelo con plástico transparente en diferentes periodos del año y del uso de cubiertas de plástico de dos diferentes grosores en el crecimiento, rendimiento, concentración foliar de nitrógeno total o de amonio, fósforo y potasio en pepino, concentraciones en el suelo de nitrógeno total o nitrato, fosfato y potasio y densidades de población de nematodos en la rizosfera. El crecimiento de las plantas en las parcelas con cubierta con frecuencia excedió al de las parcelas control. El rendimiento de las parcelas con cubierta de plástico de 0.4 mm durante cinco semanas, empezando en diciembre 1, 1995, y durante seis semanas, empezando en marzo 18, julio 3 y agosto 2, 1996 y siembra inmediatamente después de cubrir el suelo, fue mayor que en las parcelas sin cubierta. Los rendimientos de parcelas con cubierta de plástico de 0.2 mm durante seis semanas, empezando en agosto 2, 1996, fueron no significativamente distintos de los rendimientos de las parcelas control presumiblemente porque el plástico se deterioró en cuatro se-

manas. *Rotylenchulus reniformis* y *Helicotylenchus erythrinae* fueron los nematodos fitoparásitos detectados con mayor frecuencia. Al final del periodo de cubierta, las densidades de población de los nematodos parásitos y no parásitos en las parcelas con cubierta de plástico más grueso en marzo y octubre y con ambos grosores de plástico en agosto, fueron menores que en los controles. Las concentraciones foliares y en el suelo de nutrientes resultaron similares en las parcelas con y sin cubierta. El aumento en crecimiento y rendimiento de las plantas de pepino en el suelo con cubierta estuvieron estrechamente asociadas con la reducción en las densidades de población de nematodos fitoparásitos más que debido a cambios en la fertilidad del suelo.

Palabras claves: Cubierta de plástico, *Helicotylenchus erythrinae,* nematodos no parásitos, nutrientes foliares y del suelo, pepino, periodo estacional, *Rotylenchulus reniformis,* solarización del suelo, temperatura.

INTRODUCTION

Mulching of soil wetted to field capacity with clear plastic to subject it to solar heating is known as soil solarization. This process has resulted in soil disinfestation, increased soil fertility, and improved growth of various crops (Katan *et al.*, 1987), including cucumbers (*Cucumis sativus* L.) grown in fields infested with nematodes in Jamaica (Coates-Beckford *et al.*, 1997), and pathogenic fungi in the USA (Keinath, 1995).

In countries with a temperate climate, solar heating of soil is possible only during the summer months. However, in Jamaica, the coolest months in areas at low elevations have mean daily temperatures exceeding 25°C. Therefore, one objective of this study was to determine, at a low elevation, the influence of the time of year of soil solarization on cucumber growth and soil nematode population densities. A second objective was to determine if solarization results in increased soil fertility, which could contribute to the improved growth of cucumber plants noted in previous work (Coates-Beckford *et al.*, 1997).

In earlier trials with cucumbers, the relatively thick plastic used to mulch the soil was believed to be cost effective (Coates-Beckford *et al.*, 1997). However, if thinner, less costly plastic were used, and similar yield increases obtained, the monetary returns would be greater. Hence, a trial was set up to compare the effectiveness of the different thicknesses of plastic.

MATERIALS AND METHODS

Effect of season: An experiment was established to compare the effects of mulching soil with clear plastic at different times of the year on growth, yield, and nutrient status of cucumber shoots, soil nematode population densities, and soil nutrient levels. The trial was conducted on Maverly sandy loam soil in the research field adjacent to the plant pathology laboratory of the University of the West Indies, Mona Campus, at an elevation of 12 m. a. s. l.

The land was plowed, then rotovated. Five rows, each with four pairs of 4.0-m-long × 4.5-m-wide plots, were measured to leave 1 m between the rows and 0.75 m between the plots. Cucumber was grown on the experimental site continuously in all plots until it was time for each treatment application at which time the plants were removed.

The study was designed as a split plot experiment. Main treatments were seasons and split plot treatments were mulch vs nonmulch. At each of four periods of the year, one randomly-selected member of a randomly-selected pair of plots in each row was mulched with clear plastic. The other

member of the pair was left fallow and served as the nontreated control. Plots to be mulched were watered thoroughly. Then 0.4-mm-thick clear plastic sheeting was laid on the surface of the tilled soil and kept in position by covering the edges with soil until the time of planting, at which time the plastic was removed. Mulching commenced December 1, 1995 and March 18, July 3, and October 1, 1996, and lasted for five, six, six, and five weeks, respectively.

For both mulched and nonmulched plots, immediately after the treatment period, the soil was irrigated and then five, parallel, 4-m-long furrows were made 1 m apart in each plot. Three cucumber cv. Poinsett seeds were sown in each of 13 spots 30 cm apart in each furrow. When the seedlings were three weeks old, the furrows were thinned to leave 13, evenly-spaced seedlings/furrow and 65 seedlings/plot. Records were made of shoot lengths of 10 randomly-selected plants within the three central rows of each plot at three weeks after planting and at the final harvesting time. Fruit yield was taken from all 33 central plants in each plot. Final harvest was at eight weeks after planting for plots mulched in December and July, but at six weeks for plots mulched in March to preclude theft. For plots mulched in October, fruits were not harvested due to the inclement weather at the time of flowering which caused loss of flowers and young fruits. The growing degree days (base 10) for plots mulched in December, March, July, and October were 600, 731, 781, and 635, respectively. Records also were made of the rhizosphere soil nematode population densities, concentrations of total nitrogen (N), phosphorus (P) as phosphate, and potassium (K) in soil at various intervals, and of total N, P, and K in leaves at flowering.

Rainfall, sunshine, and ambient temperature data for the experimental region were obtained from the Jamaica National Meteorological Service and the Physics Department of the University.

Plots were sprayed with 1% Glyphosate (41% w/w SL isopropylamine salt of glyphosate), at a rate of 300 L/ha, prior to mulching in December, 1995, to control weed growth. Thereafter, weeding was done manually. The first crop was sprayed once with 1% malathion to control insects. No other chemicals were applied to any of the crops.

Before and after mulching, approximately 200 cm^3 of soil was collected from each plot at a depth of 2-20 cm at each of six, randomly-selected spots within the plot. At final harvest, soil samples were taken randomly from the cucumber rhizosphere within the three central rows of plants, but excluding the plants at the ends of each row. On each occasion, the soil from each plot was combined, then passed through a 4-mm-aperture sieve. Half the volume of the sieved soil was used for nutrient analysis, and the remaining half for estimating nematode population densities (Coates-Beckford *et al.*, 1997).

To measure concentrations of N, P, and K, the soil was passed through a 2.4-mm-aperture sieve, air-dried, ground in a mortar with a pestle, then stored in a plastic bag. Total N was determined by the Kjeldahl method (Morries, 1983) by the Rural Physical Planning Division of the Jamaican Ministry of Agriculture (RPPD). Concentrations of P and K were determined in extracts of 10 g soil/50 ml of Morgan's universal extracting solution (Morgan, 1941) which were agitated for 30 min and filtered through Whatman No.1 paper. For P determinations, 2 ml of 1% ammonium molybdate in 6 N sulfuric acid was added to 25 ml of the filtrate followed by 3 drops of stannous chloride to produce a colored, reduced phosphomolybdate complex. Color intensity was measured at

660 nm on a Milton Roy Spectronic 20D spectrophotometer and compared with similarly-treated standards containing 0 to 40 ppm P. Determinations of K in the extracts were by comparison with standards containing 0 to 10 ppm K, using a Corning 410 flame photometer.

At the time of flowering, prior to fruit set, three mature leaves near the base of the main shoot were taken from eight randomly-selected plants in the three inner rows of each plot. The leaves from each plot were swirled for 20 sec in a 1% non-phosphate detergent solution then rinsed in tap water and two changes of distilled water. The leaves were blot-dried, placed in paper bags, and dried at 60°C for a minimum of seven days. The dried leaves were ground in a Thomas-Wiley plant mill, passed through a 0.5-mm-aperture screen, and stored in plastic containers. N, P, and K determinations were made by the RPPD.

Effect of plastic thickness: A second experiment was set up adjacent to Experiment 1 in an area which was in weed fallow for more than six months, to evaluate the effects of different thicknesses of plastic mulch on plant growth and yield, plant and soil nutrient levels, and soil nematode population densities. There were eight replicates of three treatments comprising mulching of soil with 0.4-mm- and 0.2-mm-thick clear plastic for six weeks, commencing August 2, 1996, and no treatment. The experimental design was a randomized complete block.

The land was prepared, the plots mulched, the cucumber seeds sown, leaf and soil samples taken, and soil nematode population densities estimated as described for Experiment 1. No chemicals were applied to the plants or the soil during the experimental period. Weeding was done manually. Fruit was harvested once, at six weeks after planting since, thereafter, viruses affected the plants severely. There were 804 growing degree days (base 10).

Soil samples were sieved and dried as described for Experiment 1. For each plot, nutrient analyses were conducted at the end of the mulching period and at harvest. Nitrate concentrations in extracts of 4 g soil/10 ml 0.04 M ammonium sulfate, prepared as described for Experiment 1, were determined by use of a Hach nitrate electrode on a Fisher Acumet 910 pH meter. Determinations of P were made on extracts of 5 g soil/25 ml Morgan's universal extracting solution (Morgan, 1941) as described for Experiment 1. Determinations of K were made as described for Experiment 1 on extracts of 0.5 g soil/50 ml 3% acetic acid which was filtered, then made up to 200 ml with acetic acid.

For each plot, 200 or 500 mg of the dried, ground leaves were wet-ashed as described by Jones Jr. and Case (1990). The concentration of ammonium in the extract of each sample was determined with the aid of the spectrophotometer by comparing the absorbance value, at a wavelength of 450 nm, with those of similarly-treated standards containing 0 to 50 ppm ammonium (Anonymous, 1953). The concentrations of P and K in the leaf extracts were determined by the same methods as those described for the soil extracts.

Data analysis: Analyses of variance were performed on all data. Student's paired *t*-test and the LSD test were used to compare the means in Experiments 1 and 2, respectively (Steele and Torrie, 1960). When analyzing nematode data, for each plot, one was added to the estimated mean number of nematodes and the final figure transformed to $\log_{10}$ before conducting the analyses.

RESULTS

Climatic conditions: Rainfall was high in August, October and November, 1996, being 130, 194, and 210 mm, respectively

Table 1. Total monthly rainfall, mean number of daily sunshine hours, and mean maximum, minimum and daily ambient temperatures for the Mona Campus, University of the West Indies, during the experimental period.

Year	Month	Rainfall (mm)	Sunshine (hr)	Temperature (°C)		
				Maximum	Minimum	Daily
1995	December	35	8.4	32.0	23.1	27.6
1996	January	10	8.2	31.5	22.3	26.9
"	February	39	8.5	31.4	22.3	26.9
"	March	4	9.0	31.7	22.9	27.3
"	April	3	8.7	32.2	22.6	27.4
"	May	51	7.4	30.8	24.7	27.8
"	June	42	8.0	31.2	25.3	28.3
"	July	37	8.9	31.7	25.6	28.7
"	August	130	7.9	32.3	24.9	28.6
"	September	39	7.1	33.4	25.8	29.6
"	October	194	8.3	32.5	25.0	28.8
"	November	210	6.5	31.2	23.8	27.5
"	December	0	8.4	30.8	22.0	26.4

(Table 1). There was no rain in December 1996, and values were very low in January, March and April of the same year, being 10, 4 and 3 mm, respectively. Values for the other months of the experimental period ranged from 35 to 51 mm. For each month, there were never fewer than 7 hr of sunshine/day and the highest value was 9 hr, which occurred in March, 1996. Monthly mean temperatures ranged from 26.4°C in December, 1996 to 29.6°C in September of the same year. Mean daily maximum temperature exceeded 30°C in all months and the mean minimum temperatures ranged from 22.0°C in December, 1996 to 25.6°C in July, 1996.

Effect of season: At three weeks after planting, there were no differences in the heights of shoots from mulched and non-mulched plots at any time (Table 2). At harvest, shoots from plots mulched in the third and fourth periods were longer than control shoots. The fresh shoot weights from the mulched plots were greater than control weights for the second and third periods. Yield from plots mulched in the first, second and third periods were greater than control yields.

The most frequently-detected phytoparasitic nematode was *Rotylenchulus reniformis* Linford and Oliveira. *Helicotylenchus erythrinae* (Zimmerman) Golden occurred less frequently, whereas *Pratylenchus coffeae* (Zimmerman) Filip. & Stek. and *Tylenchorhynchus* sp. occurred only occasionally. No differences occurred in nematode population densities between control plots and those mulched in the first and third periods (Table 3). Population densities of *R. reniformis*, total parasites, and nonparasites were significantly lower in treated than in control plots at the end of mulching for the second period and those of *R. reniformis* and nonparasites were reduced following the fourth period.

Table 2. Mean shoot lengths at two intervals after planting, fresh shoot weights at harvest, and fruit yield of cucumbers grown in soil mulched with plastic or not mulched, during four periods of the year.

Treatment	Shoot length (cm)[x]		Fresh shoot weight (g/10 plants)[x]	Fruit yield (kg/plot)[x]
	3 weeks	At harvest[y]		
		First period		
No mulch	—	136	640	9.60
Plastic mulch[z]	—	146	710	14.20
t		1.06	2.50	5.68**
		Second period		
No mulch	24	89	385	0.10
Plastic mulch	33	120	1 125	1.16
t	2.03	2.08	3.85*	3.35*
		Third period		
No mulch	15	103	760	6.85
Plastic mulch	16	122	1 163	9.86
t	0.51	3.56*	7.75**	2.78*
		Fourth period		
No mulch	9	25	148	—
Plastic mulch	11	32	186	—
t	2.68	3.08*	0.93	—

[x]Each value is the mean of five replicates. For each plot (4 m × 4.5 m), mean shoot lengths and weights were estimated from 10 of the central 33 plants and yield from all 33 plants.
[y]Final times of harvest were 8, 6, 8, and 8 weeks after planting for crops grown during the first, second, third and fourth periods, respectively.
[z]Soil mulched for 5, 6, 6, and 5 weeks before planting, commencing December 1, 1995, March 18, 1996, July 3, 1996, and October 1, 1996, for the first, second, third, and fourth periods, respectively.
*, ** = Significantly different from the nonmulched at $P = 0.05$ and 0.01, respectively, by Student's paired *t*-test.

Concentrations of N and P in soil did not differ between treated and control plots at any period (Table 4). Soil K concentrations were significantly lower and higher in mulched than in control plots at the end of treatment for the second and fourth periods, respectively (Table 4). Leaf nutrient concentrations did not differ between control and treated plots for any period.

Effect of plastic thickness: The thinner plastic disintegrated within four weeks after the start of mulching. The wind lifted the plastic at the damaged areas and caused further tearing of the mulch. By the end of the treatment period, no plot mulched with the thinner plastic had intact plastic sheeting.

Shoots from plots mulched with either the thinner or the thicker plastic were significantly longer than those from non-

Table 3. Nematode population densities in the cucumber rhizosphere soil before and after plastic mulching of soil, and at harvest, for crops grown during four periods of the year.

		Number of nematodes/100 cm^3 soil[x]											
		First period			Second period			Third period			Fourth period		
Nematode	Time of sampling	No mulch	Plastic mulch[y]	*t*	No mulch	Plastic mulch	*t*	No mulch	Plastic mulch	*t*	No mulch	Plastic mulch	*t*
Helicotylenchus erythrinae	Before	0	0	—	66	68	0.04	0	0	—	1	4	1.31
	After	130	55	0.38	90	50	1.28	0	0	—	111	11	2.30
	At harvest[z]	0	0	—	0	0	—	1	11	1.63	0	0	—
Rotylenchulus reniformis	Before	204	204	0.20	204	166	0.34	20	44	0.73	9	5	1.63
	After	51	28	1.32	64	30	3.68*	13	15	0.11	46	1	5.10**
	At harvest	204	166	0.34	63	25	1.03	101	4	1.63	66	31	0.29
Total parasites	Before	646	480	0.25	380	257	0.80	20	209	0.72	178	60	1.56
	After	206	114	0.79	166	80	3.55*	45	21	0.11	316	126	2.64
	At harvest	380	257	0.80	69	37	0.59	305	70	1.56	71	31	0.31
Non-parasites	Before	240	251	0.20	380	245	1.94	407	708	1.80	282	87	0.99
	After	267	230	0.75	199	78	5.89**	812	550	0.65	676	401	2.86*
	At harvest	240	245	1.94	490	550	0.32	315	295	0.99	571	281	2.62

[x]Each value is the mean of five replicates.

[y]Soil mulched for 5, 6, 6, and 5 weeks before planting, commencing December 1, 1995, March 18, 1996, July 3, 1996, and October 1, 1996, for the first, second, third, and fourth periods, respectively.

[z]Final times of harvest were 8, 6, 8, and 8 weeks after planting for crops grown during the first, second, third and fourth periods, respectively.

*, ** = Significantly different from the nonmulched at $P = 0.05$ and 0.01, respectively, by Student's paired *t*-test.

Table 4. Mean concentrations of various nutrients in cucumber rhizosphere soil before and after mulching soil with plastic, during four periods of the year, and in leaves at the time of flowering.

	Soil nutrients[x]									Leaf nutrients (%)[x]		
	N (%)			P (ppm)			K (ppm)					
Treatment	Before	After	At Harvest[y]	Before	After	At Harvest	Before	After	At Harvest	N	P	K
						First period						
No mulch	0.1	0.2	0.2	3.5	4.0	3.8	92	78	72	4.1	1.3	3.3
Plastic mulch[z]	0.2	0.2	0.2	3.2	3.9	3.9	92	57	57	4.5	1.4	3.6
t	1.80	2.14	0.93	1.50	0.75	0.22	0.36	2.03	1.63	0.96	1.18	1.26
						Second period						
No mulch	—	0.2	—	—	16.9	—	—	82	—	3.7	1.2	3.6
Plastic mulch	—	0.2	—	—	14.0	—	—	68	—	4.6	1.1	3.5
t	—	2.06	—	—	0.90	—	—	4.30**	—	1.02	1.48	0.37
						Third period						
No mulch	—	0.2	0.2	—	16.5	29.2	—	128	508	—	—	—
Plastic mulch	—	0.2	0.2	—	18.5	17.3	—	152	579	—	—	—
t	—	2.06	1.12	—	1.83	1.90	—	1.63	0.82	—	—	—
						Fourth period						
No mulch	—	0.2	0.2	—	21.7	21.3	—	110	107	4.6	1.4	3.0
Plastic mulch	—	0.2	0.2	—	23.1	23.7	—	133	124	4.8	1.7	3.6
t	—	0	0	—	0.16	0.26	—	4.14**	0.66	1.22	2.48	2.55

[x]Each figure is the mean of five replicates. N = total nitrogen, P = phosphates in soil and phosphorus in leaves, K = potassium.
[y]Final times of harvest were 8, 6, 8, and 8 weeks after planting for crops grown during the first, second, third and fourth periods, respectively.
[z]Soil mulched for 5, 6, 6, and 5 weeks before planting, commencing December 1, 1995, March 18, 1996, July 3, 1996, and October 1, 1996, for the first, second, third, and fourth periods, respectively.
*, ** = Significantly different from the nonmulched at $P = 0.05$ and 0.01, respectively, by Student's paired *t*-test.

Table 5. Mean shoot lengths at various intervals after planting, and yield of cucumber plants grown in soil mulched with two thicknesses of plastic or not mulched.

Treatment[y]	Thickness of mulch (mm)	Shoot length (cm)[x]			Fruit yield (kg/plot)[x]
		3 weeks	4 weeks	At harvest[z]	
No mulch		14[z]	45	105	1.2
Plastic mulch	0.2	22**	66**	124	3.6
Plastic mulch	0.4	23**	72**	130**	5.0*
LSD ($P = 0.05$)		5.1	14.4	23.4	3.8
LSD ($P = 0.01$)		7.1	19.7	32.5	5.3

[x]Each value is the mean of eight replicates. For each plot (4 m × 4.5 m), mean shoot lengths were estimated from 10 of the central 33 plants and yield from all 33 plants.
[y]Soil mulched for six weeks before planting, commencing August 2, 1996.
[z]Time of harvest was six weeks after planting.
*, ** = Significantly different from the nonmulched at $P = 0.05$ and 0.01, respectively, by the LSD test.

mulched plots at three and four weeks after planting (Table 5). At harvest, only those plants from plots mulched with the thicker plastic had shoots significantly longer and yields greater than those of the controls.

Those nematode species present at the site of Experiment 1 also occurred at the site of Experiment 2. *H. erythrinae* was detected only at harvest and population densities were similar for all treatments. Population densities of *R. reniformis* and nonparasites in soil mulched with either the thinner or the thicker plastic were lower after treatment than those in nonmulched soil (Table 6). Only those plots mulched with the thicker plastic had population densities of total parasites lower than in control plots at the end of the mulching period and at harvest. At harvest, population densities of nonparasites were similar in treated and nontreated plots. Those of *R. reniformis* remained lower in plots mulched with both types of plastic.

There were no differences between treated and nontreated plots in N, P and K concentrations at any sampling time for soil and leaf samples (Table 7).

DISCUSSION

Plastic mulching of soil often was associated with greater growth and yield of cucumbers and lower levels of phytopathogenic soil nematode population densities than those in nonmulched soil, as noted in previous studies on cucumbers (Coates-Beckford *et al.*, 1997) and other crops (Katan, 1981; Katan *et al.*, 1987).

Mulching was associated with changes in soil concentrations of neither N nor P, in contrast to results of other workers who noted increased levels of nitrate (Chen and Katan, 1980), ammonium (Stapleton, 1991), and P (Meron *et al.*, 1989; Stapleton and DeVay, 1982; Stapleton *et al.*, 1991) in mulched soil. On a single occasion, mulching was associated with higher concentrations of K than in nonmulched soil, as noted also by several workers (Chen and Katan, 1980, Gamliel and Katan, 1991; Meron *et al.*, 1989, Stapleton *et al.*, 1991). Cucumber leaf nutrient concentrations did not differ between plants from mulched and nonmulched plots, in con-

Table 6. Nematode population densities in cucumber rhizosphere soil before and after mulching of soil with two thicknesses of plastic or not mulching, and at harvest.

		Number of nematodes/100 cm^3 soil[x]		
			Plastic mulch[y]	
Nematode	Time of sampling	No mulch	0.2 mm-thick	0.4 mm-thick
Helicotylenchus erythrinae	Before	0	0	0
	After	0	0	0
	At harvest[z]	26	23	10
Rotylenchulus reniformis	Before	280	278	263
	After	283	76*	38*
	At harvest	276	23*	23*
Total parasites	Before	320	338	326
	After	338	96	51**
	At harvest	348	54	48*
Nonparasites	Before	950	976	960
	After	910	292**	278**
	At harvest	926	560	770

[x]Each value is the mean of eight replicates.
[y]Soil mulched for six weeks before planting, commencing August 2, 1996.
[z]Time of harvest was six weeks after planting.
*, ** = Significantly different from the nonmulched at $P = 0.05$ and 0.01, respectively, by the LSD test.

trast to other reports of higher levels of nitrate, P, and K in leaves of tomato (Wein and Minotti, 1988) and higher concentrations of nutrients in leaves of bean (Meron *et al.*, 1989) from mulched soil than in those from control plots. Perhaps the superior growth and yield of cucumbers resulted from weed control (Coates-Beckford *et al.*, 1997) and from the decline in soil population density of *R. reniformis*, the most frequently-occurring plant pathogenic nematode. Weed control would have reduced competition for available nutrients. Nematode control may have permitted the growth of healthy root systems and the consequent efficient use of the available soil nutrients, as proposed by Heffes *et al.* (1992) for *R. reniformis* and the root-knot nematode (Heffes *et al.*, 1991 and 1992).

During the first and third periods of Experiment 1, which were the coldest and hottest periods, respectively, plant growth and yield were greater in the treated than in the nontreated plots although population densities of phytoparasitic nematodes were not reduced significantly by mulching. Plastic mulching, in addition to controlling weeds, may have stimulated additional growth-pro-

Table 7. Mean concentrations of various nutrients in cucumber rhizosphere soil after mulching with two thicknesses of plastic or not mulching, and at harvest, and in leaves at the time of flowering.

Treatment[y]	Thickness of mulch (mm)	Soil nutrients (ppm × 10^2)[x]						Leaf nutrients (%)[x]		
		N		P		K				
		After	At Harvest[z]	After	At Harvest	After	At Harvest	N	P	K
No mulch		0.3	0.4	0.9	0.4	3.8	1.2	2.9	0.5	2.4
Plastic mulch	0.2	0.7	1.6	1.3	0.3	5.1	1.1	2.5	0.6	2.4
Plastic mulch	0.4	0.8	0.5	1.3	0.3	6.6	2.9	2.6	0.6	2.2

[x]Each value is the mean of eight replicates. N = nitrates for soil and ammonium for leaves, P = phosphates for soil and phosphorus for leaves, K = potassium.
[y]Soil mulched for six weeks before planting, commencing August 2, 1996.
[z]Time of harvest was six weeks after planting.

moting activities in the soil such as microbial activities (Brady, 1974). Mulching has been shown to reduce the densities of some populations of phytonematodes during the coldest season in Jamaica (Coates-Beckford *et al.*, 1997). For Experiment 2, nematode population densities were reduced when soil was mulched in August during the hottest season, as also noted in previous studies (Coates-Beckford *et al.*, 1997). Perhaps the occurrence of much higher rainfall in August than in July led to greater effectiveness of the hydrothermal process of solarization (Katan, 1976) in the former month, thus enabling control of nematodes in Experiment 2, unlike in the third period of Experiment 1.

The thinner plastic apparently did not permit the soil to be solarized for the required length of time during the mulching period in the hottest season since several areas disintegrated within four weeks. The initial good growth of plants in plots mulched with the thinner plastic did not result in yields greater than those from nonmulched plots. Disintegration of the mulch and tearing caused by the wind most likely allowed the escape of heat and volatile chemicals produced during solarization, interrupting disinfestation or permitting reinfestation of the soil.

Thus, at low elevations in Jamaica where the mean monthly temperature and hours of sunshine exceed 26°C and seven hours, respectively, mulching soil with plastic of a suitable thickness may lead to increased yields of cucumbers throughout the year and may suppress nematode population densities during plant growth. These results are in contrast to those from regions where some months of the year may have temperatures too low for mulching with plastic to be an effective and beneficial practice (Hankin *et al.*, 1982).

ACKNOWLEDGEMENTS

We thank the Environmental Foundation of Jamaica for funding this research and Dr. P. S. Raju for advice during the initial stages of this work.

LITERATURE CITED

ANONYMOUS. 1953. A Handbook of Colorimetric Chemical Analytical Methods. The Tintometer Ltd., Salisbury, England.

BRADY, N. C. 1974. The Nature and Properties of Soils. MacMillan Publishing Co. Inc., New York, NY, U.S.A.

CHEN, Y., and J. KATAN. 1980. Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil Science 230:271-277.

COATES-BECKFORD, P. L., J. E. COHEN, L. R. OGLE, C. H. PRENDERGAST, and D. M. RILEY. 1997. Effect of plastic mulches on growth and yield of cucumber (*Cucumis sativus* L.) and soil nematode and microbial population densities. Nematropica 27:193-209.

GAMLIEL, A., and J. KATAN. 1991. Involvement of fluorescent pseudomonads and other microorganisms in increased growth response of plants in solarized soils. Phytopathology 81:494-502.

GRIFFIN, G., W. JOKELA, and D. ROSS. 1995. Recommended soil nitrate-N tests. Pp. 1-8 *in* Recommended Soil Testing Procedures for the Northeastern United States. Northeastern Publication No. 493. Agricultural Experiment Stations, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia, U.S.A.

HANKIN, L., D. E. HILL, and G. R. STEPHENS. 1982. Effect of mulches on bacterial populations and enzyme activity in soil and vegetable yields. Plant and Soil 64:193-201.

HEFFES, T. P., P. L. COATES-BECKFORD, and H. ROBOTHAM. 1991. Effects of *Meloidogyne incognita* on growth and nutrient content of *Amaranthus viridis* and two cultivars of *Hibiscus sabdariffa*. Nematropica 21:7-18.

HEFFES, T. P., P. L. COATES-BECKFORD, and H. ROBOTHAM. 1992. Effects of *Meloidogyne incognita* and *Rotylenchulus reniformis* on growth and nutrient content of *Vigna unguiculata* and *Zea mays*. Nematropica 22:139-148.

JONES, JR., J. B., and V. W. CASE. 1990. Sampling, handling, and analyzing plant tissue samples. Pp. 389-427 *in* R. L. Westerman, ed. Soil Testing

and Plant Analysis. Soil Science Society of America, Inc., Madison, WI, U.S.A.

KATAN, J. 1981. Solar heating (solarization) of soil for control of soil-borne pests. Annual Review of Phytopathology 73:1215-1219.

KATAN, J., A. GREENBERGER, H. ALON, and A. GRINSTEIN. 1976. Solar heating by polyethylene mulching for the control of diseases caused by soilborne pathogens. Phytopathology 66:683-688.

KATAN, J., A. GRINSTEIN, A. GREENBERGER, O. YARDEN, and J. E. DeVAY. 1987. The first decade (1976-1986) of soil solarization (solar heating): a chronological bibliography. Phytoparasitica 15:229-255.

MERON, M., Y. FILLER, Y. COHEN, M. GALILEE, A. GRINSTEIN, A. GAMLIEL, Y. CHEN, and J. KATAN. 1989. Solarization and fumigation for reclamation of organic soils. Acta Horticulturae 255:117-124.

MORGAN, M. F. 1941. Chemical soil diagnosis by the universal testing system. Connecticut Agricultural Experiment Station Bulletin 450:579-634.

MORRIES, P. 1983. A century of Kjeldahl (1883-1983). Journal of the Association of Public Analysts 21:53-58.

STAPLETON, J. J. 1991. Thermal inactivation of crop pests and pathogens and other soil changes caused by solarization. Pp. 37-47 *in* J. E. DeVay, J. J. Stapleton, and C. L. Elmore, eds. Soil Solarization. Plant Production and Protection Paper 109. Food and Agriculture Organization, Rome, Italy.

STAPLETON, J. J., and J. E. DeVAY. 1982. Effect of soil solarization on populations of selected soilborne microorganisms and growth of deciduous fruit tree seedlings. Phytopathology 72:323-326.

STAPLETON, J. J., J. E. DeVAY, and B. LEAR. 1991. Simulated and field effects of ammonia-based fertilizers and soil solarization on pathogen survival, soil fertility and crop growth. Pp. 331-342 *in* J. E. DeVay, J. J. Stapleton, and C. L. Elmore, eds. Soil Solarization. Plant Production and Protection Paper 109. Food and Agriculture Organization, Rome, Italy.

WEIN, H. C., and P. L. MINOTTI. 1988. Increasing yield of tomatoes with plastic mulch and apex removal. Journal of the American Society of Horticultural Science 113:342-347.

Received: *4.III.98*

Recibido:

Accepted for publication: *18.VII.98*

Acceptado para publicación: