Effects of Management Practices on Nematode and Fungus Populations and Cucumber Yield[1]

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Abstract: Three crops of cucumber were grown in succession in beds by use of trickle irrigation, plastic film mulch, and soil chemical treatments over a 17-month period, including a fallow winter season. Total yield for the three crops was highest (1208 quintals/ha) in film-mulched plots treated with MBR-CP, and next-highest in film-mulched plots treated with DD-MENCS (1094 quintals/ha); total yield was only 456 quintals/ha in film-mulched control (untreated) plots. Yield in untreated film-mulched plots was 256% of that in untreated unmulched plots (178 quintals/ha). Plant growth and yields were greatest when populations of nematodes and soil-borne fungi were suppressed to very low levels. The residual control by soil treatments lasted longest on *Meloidogyne incognita* and *Fusarium solani*. *Key Words:* multiple cropping, multiple pest control.

Use of trickle irrigation for high-value vegetable crops has increased greatly in the southeastern USA in the past 3 years (9). This practice, especially in conjunction with soil fumigation and plastic-film mulching has resulted in remarkable yield increases for cucumber, pepper, tomato, squash, okra, pole bean, and cantaloup (3, 5, 6, 8, 9, 14, 15). Because of the high costs of soil fumigation, trickle irrigation, and film mulching, considerable interest has developed in the possibility of multiple cropping, growing a second and third crop immediately after the first. Although double cropping has been successful with film mulching and overhead irrigation (2), the practice has been little explored with trickle irrigation (9). This study was conducted to determine the potential of multiple cropping with soil fumigation, film mulching, and trickle irrigation, and to ascertain possible production problems.

MATERIALS AND METHODS

The experiments were conducted in 1974 and 1975 on Tifton loamy sand (ca 85% sand, 10% silt, and 5% clay) in a field infested with *Meloidogyne incognita* (Kofoid & White) Chitwood, *Criconemoides ornatus* Raski, *Trichodorus christiei* Allen, *Pratylenchus* spp., and several potentially pathogenic fungi including *Fusarium oxysporum* Schlecht, *F. solani* (Mart) Appel & Wor., *F. roseum* (LK) em. Snyd. & Hans., *Pythium* spp., and *Rhizoctonia solani* Kuhn. In 1973 the test area was planted with southern peas, *Vigna unguiculata* (L.) Walp., as a summer cover crop, and with hairy vetch, *Vicia villosa* Roth, as a winter cover crop.

Each experimental plot contained a single raised bed, 1.68 × 12.2 m, with one row. The experimental design was a randomized complete block. Treatments were replicated four times. The following pesticides and rates (kg ai/ha) were used: a nematicide, ethoprop, 8.96; soil fungicides, chloroneb, 26.9; and sodium azide, 33.6; broad-spectrum soil fumigants, DD-MENCS (20% methyl isothiocyanate + 80% chlorinated C_3 hydrocarbons), 376; and MBR-CP (67% methyl bromide + 33% chloropicrin), 376; and a herbicide, bensulide, 6.7. Fertilizer application and placement were as follows: 1) Film-mulched plots were given 0-8.6-0 N-P-K and 7-6-5.8 N-P-K, each at 560 kg/ha, broadcast and incorporated preplant into the upper 15 cm of soil with a tractor-driven rototiller. Also, 13-0-36.5 N-P-K at 1120 kg/ha was applied before planting in double bands 46 cm apart, with each band 23 cm from the plant row. 2) Unmulched plots were given fertilizer at similar rates and in similar preplanting applications, except that the 13-0-36.5 N-P-K at 1120 kg/ha was applied as a sidedressing after the final cultivation. All plots were given a supplement of 4.48 kg N-K/ha/day as soluble $CaNO_3$ applied twice a week in irrigation water. All chemical treatments were applied on the same day. Fumigants were injected 25 cm deep

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into the soil through 9 chisels 20 cm apart, and the soil surface was sealed by compaction with a bed-shaper attachment. Granules of sodium azide and ethoprop and a water suspension of chloroneb were spread on the soil surface and incorporated into the top 15 cm of soil as described for the fertilizer. Bensulide was sprayed on the soil surface and incorporated into the top 15 cm of soil.

Soil moisture was 85% of field capacity when the chemicals were applied, and the soil temperature 15 cm deep was 11 C. Bi-wall (Anjac Plastics, Inc., El Monte, California 91731) trickle-irrigation tubing was laid on the soil surface in all plots; mulched plots were immediately covered with biodegradable plastic film mulch as described previously (6) and were not disturbed for 14 days. Then holes (6-cm diam) were cut 30 cm apart in the film mulch (a single row/bed) to allow aeration. One week later (March 18, 1974), 'Gemini 7' cucumbers (*Cucumis sativus* L.) were planted (three seeds/hill) 2 to 4 cm deep through the holes in the film mulch and similarly on unmulched plots. Soil temperature 5 cm deep at planting was 20 C.

After final harvest of the first crop of cucumber, the vines were cut near the soil surface and removed from the field. All plots were replanted with 'Poinsett' cucumbers on August 27, 1974, as described for the first crop. Soil temperature 5 cm deep at planting was 35 C.

The film mulch and irrigation tubing were removed from the plots after final harvest of the second crop. From September until April the minimum and maximum soil temperatures 5 cm deep averaged 13 C and 22 C (range 4–37 C).

Before the third crop was planted, additional fertilizer (5-4.3-12.5, N-P-K) was broadcast at 1120 kg/ha over all beds and incorporated. In addition, bensulide was sprayed on the soil surface at 6.7 kg (ai)/ha and incorporated 5 to 8 cm deep. Trickle irrigation tubing was laid on the surface of the plots, but they remained uncovered for the duration of the test. All plots were planted to 'Gemini 353' cucumbers on April 21, 1975, as described above. Soil temperature 5 cm deep at planting was 23 C. Paraquat was sprayed at 0.56 kg ai/ha on all plots immediately after planting for control of weeds and grasses.

All plants were sprayed with chlorothalonil (1.12 kg ai/ha) for control of fungi and carbaryl (1.68 kg ai/ha), azinphosmethyl (0.56 kg ai/ha), or methomyl (0.56 kg ai/ha) for control of insects as needed.

Soil was assayed for plant-parasitic nematodes 8 and 110 days after the first crop was planted, 8 days before and 80 days after the second crop was planted and when the third crop was planted and 80 days later. Ten cores of soil, 2.5 × 15 cm deep, were collected from the center 6 m of each plot and mixed thoroughly. A 150-cm^3 sample was processed by the centrifugal-flotation method (7).

Fungi were assayed from 2–5 g of moist soil taken 8 days after the first and second crops were planted, when the third crop was planted, and after it was harvested (respectively about 1, 6, 14, and 17 months after the plots were treated). The selective media used for assay were modified peptone-PCNB for *Fusarium* spp. (10), gallic acid medium for *Pythium* spp. (4), and gallic acid medium modified by the addition of pyroxychlor [2-chloro-6-methoxy-4-(trichloromethyl)pyridine] at 0.1 ml/liter for *Rhizoctonia solani*. Populations of fungi were expressed as propagules/g of oven-dried soil.

When seedlings were 20–30 days old, 10 plants were selected at random from areas outside the center 6 m of each plot and evaluated for root and hypocotyl discoloration and decay. Root and hypocotyl tissues were washed for 30–45 min in running tap water at 10–25 C, blotted dry on sterile filter paper, and transferred to water agar. Fungi growing from the tissues after 2–5 days at 25–30 C were transferred to potato-dextrose agar (PDA) and identified. Ten plants were collected at random from areas outside the center 6 m of each plot and indexed for galls caused by root-knot nematodes 50 days after planting. After the final harvest, 20 plants were selected at random from each plot and indexed for galls. Galling on individual plants was rated on a scale of 1–5: (1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of the roots galled). Growth and yield were recorded from plants in the center 6 m of each plot. Harvests were made at 3-to-4-day intervals as follows: Crop 1, May 22 to July 5; Crop 2, October 2 to November 8, 1974; and Crop 3, June 6 to July 14, 1975. Marketable yield for processing was determined according to USDA standards (16).

Data were subjected to analysis of variance, and significant differences were identified with Duncan's multiple-range test. Various combinations of data were also subjected to correlation and regression analysis.

RESULTS

Nematodes: The most prevalent and uniformly distributed nematodes found in the soil before planting were *Meloidogyne incognita* and *Criconemoides ornatus.* Because *Trichodorus christiei* and *Pratylenchus* spp., also present in the soil, were scarce and unevenly distributed, no data are given on their population densities.

M. incognita was reduced to near or below detectable levels throughout the study by DD-MENCS (unmulched or film mulched) and by MBR-CP under film mulch (Table 1); the sole exception was the large number of larvae found 80 days after the third crop was planted in unmulched plots treated with DD-MENCS (Table 1). Populations of *M. incognita* larvae under film mulch were not reduced by sodium azide, sodium azide + ethoprop, or ethoprop (except in ethoprop-treated plots 80 days after the second crop was planted). The populations of *M. incognita* larvae exceeded 200/150 cm^3 of soil 110 days after the first crop was planted in film-mulched plots treated with sodium azide, chloroneb, sodium azide + ethoprop, and ethoprop. Populations of *C. ornatus* were not reduced 8 days after the first crop was planted in film-mulched plots treated with soil chemicals, but were lower in all treated plots 110 days after the first crop was planted than in untreated plots (range 0 to 10 in film-mulched treated plots vs 73 in untreated mulched plots). Populations of *C. ornatus* later in the study were not affected by soil chemical treatments.

Populations of *M. incognita* larvae in the soil 110 days after the first crop was planted were correlated with root-gall indices 50 days after planting (r = +0.46) and 100 days after planting (r = +0.50). Number of pairs of observations N = 36 for all correlations. Root-gall indices 50 and 125 days after the first crop was planted were reduced in unmulched and film-mulched plots by DD-MENCS, and in film-mulched plots by sodium azide + ethoprop, ethoprop, and MBR-CP (Table 2). Root-gall indices 50 and 100 days after the second crop was planted were lower in unmulched and film-mulched plots treated with DD-MENCS and in film-mulched plots treated with MBR-CP than in the respective control plots. Treatment of film-mulched plots with sodium azide, chloroneb, sodium azide + ethoprop, and ethoprop did not affect root-gall indices in the second and third crops. Populations of *M. incognita* larvae in the soil at planting of the third crop were correlated with root-gall indices 80 days after planting (r = +0.52). Fifty and 80 days after planting the third crop, root-gall indices in unmulched and film-mulched plots treated with DD-MENCS, and in film-mulched plots treated with MBR-CP were lower than in the respective control plots. Ethoprop (film-mulched) reduced root-gall indices only in the first crop. Root-gall indices of plants from film-mulched plots treated with sodium azide + ethoprop were similar to those of plants from ethoprop-treated plots.

Soil fungi: Populations of *Fusarium oxysporum, F. roseum* and *Pythium* spp. were reduced 8 days after the first crop was planted in unmulched and film-mulched plots (30 days after applying the chemicals) by DD-MENCS and by MBR-CP in film-mulched plots (Table 3). Populations of fungi increased in most plots, but 8 days after the second crop was planted, populations of *F. solani* were lower in film-mulched plots treated with DD-MENCS, sodium azide + ethoprop, and MBR-CP than in film-mulched control plots. There were few differences in populations of soil fungi among treatments after the second crop was planted. However, DD-MENCS in unmulched plots reduced *F. oxysporum* more than *F. solani.* When the third crop was planted, 14 months after soil treatment, populations of *Pythium* spp. and *F. oxysporum* were still significantly lower in unmulched and film-mulched plots treated with DD-MENCS and film-mulched plots treated with MBR-CP than in the respective

TABLE 1. Soil population of *Meloidogyne incognita* as influenced by film mulch and soil chemical treatment.

Treatment	Rate (kg ai/ha)	No. larvae/150 cm³ soil[z] Crop 1: 8 days after planting	Crop 1: 110 days after planting	Crop 2: 8 days before planting	Crop 2: 80 days after planting	Crop 3: At planting	Crop 3: 80 days after planting
Unmulched							
Bensulide (B), control	6.70	50	93 cd	293 ab	85 cd	23 c	1235 a
DD-MENCS + B	376.0 + 6.70	8	3 d	8 c	3 d	0 c	1015 a
Film mulch							
Bensulide (B), control	6.70	23	118 bcd	238 ab	860 a	85 ac	440 a
DD-MENCS	376.0	0	0 d	0 c	0 d	0 c	3 b
Sodium azide (SA)	33.6	28	683 a	300 ab	1020 a	48 bc	238 a
Chloroneb + B	26.9 6.70	15	280 b	450 a	313 bc	153 a	520 a
SA + ethoprop	33.6 + 8.96	10	248 bc	300 ab	763 ab	83 ac	95 a
Ethoprop	8.96	70	275 b	188 b	120 cd	128 ab	433 a
MBR-CP	336.0	0	5 d	0 c	13 cd	0 c	3 b

[z]Data are means for four replicate plots. Within each column, values followed by a letter in common are not significantly different (P = <0.05) according to Duncan's multiple-range test. Absence of letters indicates that no values in the column are significantly different.

TABLE 2. Root-gall of cucumber as influenced by film mulch and soil chemical treatment.

Treatment	Rate (kg ai/ha)	Root-gall index[a] Crop 1 50 days after planting	Crop 1 125 days after planting	Crop 2 50 days after planting	Crop 2 100 days after planting	Crop 3 50 days after planting	Crop 3 80 days after planting
Unmulched							
Bensulide (B), control	6.70	3.00 b	3.90 ab	2.68 a	4.00 ab	1.83 a	5.00 a
DD-MENCS + B	376.0 + 6.70	1.00 c	1.00 c	1.25 b	1.10 c	1.40 b	2.53 b
Film mulch							
Bensulide (B), control	6.70	4.19 a	4.86 a	2.35 a	3.40 b	2.56 a	5.00 a
DD-MENCS	376.0	1.00 c	1.03 c	1.13 b	1.00 c	1.00 c	1.48 c
Sodium azide (SA)	33.6	3.00 b	4.81 a	2.50 a	4.53 a	3.61 a	4.98 a
Chloroneb + B	26.9 + 6.70	3.19 b	4.38 a	2.55 a	3.83 ab	2.03 a	5.00 a
SA + ethoprop	33.6 + 8.96	1.38 c	3.26 b	2.78 a	4.33 a	3.49 a	5.00 a
Ethoprop	8.96	1.88 c	3.27 b	2.63 a	3.83 ab	3.67 a	4.85 a
MBR-CP	336.0	1.00 c	1.00 c	1.00 b	1.13 c	1.04 c	1.00 c

[a]Index on a scale of 1–5, in which 1 = galls and 5 = 76–100% roots galled. Data are means for four replicate plots. Within each column, values followed by a letter in common are not significantly different (P = <0.05) according to Duncan's multiple-range test.

TABLE 3. Populations of soilborne fungi as influenced by film mulch and soil chemical treatments.

Treatment	Rate (kg ai/ha)	No. fungal propagules/g oven-dried soil[a]										
		Crop 1 (8 days after planting)			Crop 2 (8 days after planting)			Crop 3				
								At planting			After harvest	
		Fusarium oxysporum	*Fusarium solani*	*Pythium* spp.	*Fusarium oxysporum*	*Fusarium solani*	*Pythium* spp.	*Fusarium oxysporum*	*Fusarium solani*	*Pythium* spp.	*Fusarium* spp.	*Pythium* spp.
Unmulched												
Bensulide (B), control	6.70	2581 ab	806 bc	126 ab	2748 a	2516 b	36 ab	2474 a	1397 abc	91 a	10,940 a	109 a
DD-MENCS + B	376.0 + 6.70	221 c	109 d	0 c	636 c	872 b	7 b	1237 bc	1154 abc	16 bcd	4,550 bc	100 ab
Film mulch												
Bensulide (B), control	6.70	3284 a	1557 a	79 abc	939 c	7005 a	13 b	1898 ab	2290 a	39 ab	8,460 ab	33 abc
DD-MENCS	376.0	32 c	0 d	0 c	1140 bc	1509 b	25 b	356 d	274 bc	5 d	2,550 d	10 c
Sodium azide (SA)	33.6	736 bc	398 cd	40 bc	1607 abc	4189 ab	30 b	635 cd	857 abc	47 abc	9,080 abc	58 abc
Chloroneb + B	26.9 + 6.70	2546 ab	1040 b	150 a	2444 ab	3784 ab	79 a	1866 ab	1690 ab	30 abc	15,130 a	158 a
SA + ethoprop	33.6 + 8.96	1802 abc	562 c	111 ab	1274 bc	1406 b	20 b	1187 bc	1449 abc	77 a	6,420 abc	44 abc
Ethoprop	8.96	2824 a	1096 b	101 ab	1274 bc	4190 ab	10 b	1840 ab	2157 a	47 ab	8,340 ab	88 ab
MBR-CP	336.0	161 c	16 d	1 c	703 c	1174 b	11 b	358 d	166 c	10 cd	4,780 cd	20 bc

[a]Data are means for four replicate plots. Within each column, values followed by a letter in common are not significantly different ($P = <0.05$) according to Duncan's multiple-range test.

control plots. Populations of *F. solani* were reduced by use of the fumigants under film mulch, but DD-MENCS had no effect on populations in unmulched plots. The suppression of soil fungi was still evident after harvest of the third crop, 17 months after the soil was fumigated. Treatment with sodium azide and ethoprop did not influence populations of soil fungi, but treatment with chloroneb increased populations of *F. oxysporum* and *Pythium* spp. at the planting of the second crop.

Soils were assayed from *Rhizoctonia solani* only when the third crop was planted. Populations ranged from 0 to 0.8 propagules/10 g of oven-dried soil, and there were no significant differences among treatments.

Root discoloration and isolation of fungi from seedlings: There was very little root discoloration in 3-to-4-wk-old seedlings in the first and second crop, and there were no differences among treatments. In the third crop, however, the percentages of seedlings infected with *F. oxysporum* were significantly lower in film-mulched plots treated with DD-MENCS (3%), sodium azide (3%), or MBR-CP (3%) than in control plots (20%). The percentages of seedlings infected with *F. solani* were lower in all treated plots under film mulch (range, 3–13%) than in the control plots (28%), but the root-disease indices of seedlings were not affected by the treatments. No attempt was made to assess the severity of root disease in mature plants.

Growth and yield: The cucumbers produced their best growth and highest yields when populations of nematodes and soilborne fungi were very low. No indication of phytotoxicity was observed. Growth of plants in unmulched plots in the first crop was greater in DD-MENCS-treated plots than in the control (Table 4). In film-mulched plots, plant growth was greater in plots treated with DD-MENCS, sodium azide, sodium azide + ethoprop, and MBR-CP than in untreated plots. Growth of plants 4 weeks after planting the first crop was inversely related to the soil populations of *Pythium* spp. (r = –0.46), *F. oxysporum* (r = –0.50), and *F. solani* (r = –0.52). Also, plant growth was inversely related to the soil population of *F. solani* 142 days after planting (r = –0.43).

Fumigation with DD-MENCS in unmulched plots increased total marketable yield in the first crop over that of the control (Table 4). All chemicals, except ethoprop and chloroneb in film-mulched plots increased yields of marketable fruit during harvests in May, but only DD-MENCS and MBR-CP increased yield over that of controls during harvests in June and July. The total marketable yields were correlated with plant growth (r = +0.72) and inversely correlated with populations of *Pythium* spp. (r = –0.48), *F. oxysporum* (r = –0.53), *F. solani* (r = –0.60), and root-knot nematodes (r = –0.46) early in the growing season.

Total marketable yields from the second crop were very low (Table 4). Even so, yields of marketable fruit were greater from all treated plots under film mulch than from control plots from Oct. 2 to Oct. 25. Also, yields from film-mulched plots treated with sodium azide, ethoprop, and MBR-CP were greater than yields from control plots from Nov. 1 to Nov. 8. The total marketable yield from the second crop was not correlated with populations of soilborne fungi or nematodes. Marketable yields near the end of the growing season, however, were inversely correlated with root-gall indices (r = –0.40) 50 days after planting.

Height of 4-week-old seedlings in the third crop was not affected by soil chemical treatments (Table 4), but was inversely related to the soil population of root-knot nematodes at planting (r = –0.33) and the root-gall indices 50 days after planting (r = –0.33).

Total marketable yields of the third crop were greater from unmulched and film-mulched plots with DD-MENCS and from film-mulched plots treated with MBR-CP than from the respective control plots (Table 4). The total marketable yield was inversely related to the soil population of *C. ornatus* 80 days after planting (r = –0.90) and the soil populations of *Pythium* spp. (r = –0.43), *F. solani* (r = –0.48), and *F. oxysporum* (r = –0.61) at planting.

Total marketable yield across all crops ranged from 178 to 1208 quintals/ha. Without film mulch, yield of marketable fruit from plots treated with DD-MENCS was 343% of that from control plots. With film mulch, marketable yields from plots treated

TABLE 4. Growth and total marketable yield of cucumber as influenced by film mulch and soil chemical treatments.[y]

Treatment	Rate (kg ai/ha)	Growth index[z]	Crop 1		Crop 2		Plant height (cm)	Crop 3		Total	
			Quintals/ha	%	Quintals/ha	%		Quintals/ha	%	Quintals/ha	%
Unmulched											
Bensulide (B), control	6.70	1.75 d	58 d	41 d	0 d	0 c	16	120 c	73	178 d	58 e
DD-MENCS + B	376.0 + 6.70	3.50 bc	332 b	67 c	6 d	29 b	15	273 b	78	611 b	71 cd
Film mulch											
Bensulide (B), control	6.70	2.75 c	187 c	77 ab	89 ab	78 a	13	180 c	72	456 c	75 bc
DD-MENCS	376.0	4.25 ab	646 a	82 a	77 bc	75 a	15	371 a	73	1094 a	79 ab
Sodium azide (SA)	33.6	4.50 a	263 a	68 bc	51 c	77 a	13	174 c	73	488 bc	71 cd
Chloroneb + B	26.9 + 6.70	2.75 c	250 bc	72 bc	62 bc	68 a	12	138 c	69	450 c	71 cd
SA + ethoprop	33.6 + 8.96	4.50 a	330 b	65 c	55 c	82 a	11	128 c	74	513 bc	68 d
Ethoprop	8.96	3.50 bc	238 bc	65 c	52 c	74 a	12	160 c	77	450 c	70 cd
MBR-CP	336.0	5.00 a	703 a	85 a	118 a	80 a	16	387 a	76	1208 a	81 a

[y]Data are means for four replicate plots. Within each column, values followed by the same letter are not significantly different ($P = <0.05$) according to Duncan's multiple-range test. Absence of letters indicates that values in the column are not significantly different.

[z]1–5 scale: 1 = plants small, chlorotic, nonvigorous; and 5 = plants large, dark-green, vigorous. Growth indices and measurements were 4 weeks after planting.

with DD-MENCS and MBR-CP were respectively 240% and 265% of that from control plots. In control plots, the total marketable yield from film-mulched plots was 256% of that from unmulched plots. The marketable yield of film-mulched plots treated with DD-MENCS was respectively 179% and 615% of yields of plots treated with DD-MENCS and of unmulched control plots.

The percentage of total fruits marketable in the three crops was increased by the use of film mulch, but only MBR-CP increased the percentage of marketable fruits in mulched plots. In unmulched plots, treatment with DD-MENCS increased yield and improved the quality of the fruits (Table 4).

Interactions among nematodes and soilborne fungi: Multiple linear-regression analysis on plant growth and yield indicated that populations of nematodes and soilborne fungi increased the coefficient of determination, R^2 (the proportion of the variability in the dependent variable that is attributable to regression). The variation in growth of plants in the first crop was caused mostly by soil fungi; the numbers of *F. solani* propagules in the soil at planting accounted for 34% of the variation in plant growth 4 weeks after planting. Most of the variation in early yield was caused by root-knot nematodes; root-gall indices contributed respectively 40, 30, and 43% of the variation in yield of marketable fruit during March, from June 1 to June 20, and from June 21 to July 5. However, the only significant contribution to variations in the total yield of the crop for the full season was made by the population of *F. solani* + *F. roseum* ($R^2 = +0.69$).

In the second crop, only 19% of the variation in marketable yield was attributable to the chemical treatment. The root-gall indices, populations of nematodes and soil fungi, and percentage of fungal infection in seedlings did not significantly increase R^2.

In the third crop, 81% of the variation in marketable yield was attributable to root-gall indices 50 days after planting.

DISCUSSION

The results indicate that biodegradable plastic film mulch increases the yield of cucumbers, and that nematodes and pathogenic soilborne fungi reduce yield. Our data also indicated that three consecutive crops of cucumbers can be grown after one application of soil chemicals; no additional soil treatments are needed for control of nematodes and soilborne fungi. However, in areas with greater disease and nematode intensity, effective control for three consecutive crops may not be possible.

The unexpectedly low yields from the second crop cannot be fully explained. Molecrickets severely damaged young seedlings, reducing the stands and contributing to the very low yields. Also, the 'Poinsett' cucumber used in the second crop is not a hybrid and does not have the production potential of the 'Gemini' hybrids used in the first and third crops.

Film mulches offer several advantages in crop production; they increase the efficiency of soil fumigants by serving as a sealant, decrease reinfestation of the treated soil, prevent leaching of nutrients, prevent soil compaction, provide weed control, conserve moisture and at times maintain the soil at temperatures favorable for plant growth.

Nematodes and soilborne fungi decrease growth and yield more in stressed than in unstressed plants (15). In our test, water and nutrients were assumed to be adequate, and should not have been stress factors. Even so, total yields in plots under the influence of soil fumigation were more than double the total yield in film-mulched untreated plots.

Control of nematodes and soilborne fungi with sodium azide and sodium azide + ethoprop under film mulch increased yields in the first crop, but only soil fumigation with DD-MENCS and MBR-CP extended the protection of roots to allow high yields in subsequent crops. Apparently, sodium azide and sodium azide + ethoprop may control nematodes and soilborne fungi in a single crop, but multiple crops require more or longer protection from nematodes and other pathogenic organisms than was provided by these chemicals. Other researchers have found that azide salts give good pest control (11, 12, 13), but our studies indicate that an additional nematicide must be used in combination with sodium azide in soils heavily infested with root-knot nematodes.

Root distribution under film mulch and with trickle irrigation differs from that in conventional crop production without mulch and with sprinkler irrigation (1, 3). Many vegetables, including cucumbers, have shallow root systems, only 30–90 cm deep; under film mulch and with trickle irrigation the roots tend to be even more confined, only 15–20 cm deep, and with many fine roots in the top 3 cm. Thus, control of pathogens in topsoil is even more critical under film mulch and with trickle irrigation than in conventional crop production.

In the third crop of cucumbers, the degree of nematode control, as judged from root-gall indices, and the reduction in populations of soil fungi in film-mulched plots treated with DD-MENCS and MBR-CP, was above our expectations. The duration of pest control was especially noteworthy because the film mulch was removed from all plots after the second crop of cucumbers, and the plots were exposed to natural rainfall (71 cm) and wind from November 15, 1974, until the end of the study, on June 17, 1975; one would expect that splashing rain and movement of soil by water would provide ample opportunity for reinfestation of treated plots.

Our data indicate that it is possible to control root-knot nematodes, suppress populations of soil fungi, and increase yields of cucumber with one application of a soil fumigant such as DD-MENCS or MBR-CP before film mulching. The residual control lasted longest for nematodes and *F. solani*. We discontinued our research after producing three crops, but since populations of nematodes and fungi were still reduced at the last harvest, a fourth crop could probably have been grown successfully in fumigated soil.

LITERATURE CITED

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