# Root Diseases of Cucumber in Irrigated Multiple-Cropping System with Pest Management

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## ABSTRACT

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Cucumber for pickles was planted each of 6 yr in a 2-yr multiple-cropping sequence of turnip-peanut-cucumber-turnip-cucumber-soybean with four types of soil pest management. Treatments were: 1) soil fumigation with 98% methyl bromide + 2% chloropicrin (MBR-CP) each winter; 2) soil fumigation with 20% methyl isothiocyanate + 80% chlorinated $C_3$ hydrocarbons (DD-MENCS) each winter + maximum pest control with herbicides and a nematicide; 3) no soil fumigation, but herbicides and a nematicide used for an intermediate level of pest control; and 4) no soil fumigation or nematicide, but one herbicide and cultivation used as needed on each crop for a minimum level of weed control. Root diseases and postemergence damping-off were caused primarily by *Pythium aphanidermatum*, *P. irregulare*, and *Rhizoctonia solani* AG-4. The highest yields of cucumber and the lowest incidence of root disease severity and postemergence damping-off were in the MBR-CP treatment. Chloramben caused swollen, fan- to club-shaped root enlargements and apparently increased root disease severity in cucumber in the maximum and intermediate treatments. Root enlargements were no longer observed when ethalfluralin was substituted for chloramben. Turnip preceding cucumber reduced root disease severity and postemergence damping-off compared with peanut, but the difference in yield of marketable cucumbers was not significant.

Additional key words: *Meloidogyne incognita*

Cucumbers are grown frequently in the southern United States in irrigated multiple-cropping systems to extend the cropping season. To obtain economically efficient yields of marketable fruit, pest control must be coordinated with other production practices. In a film mulch system with trickle irrigation, yields of cucumber for fresh market were greatest when soilborne pathogenic fungi and nematodes were controlled (5,6,21). Herbicides also must be used for weed control to produce cucumber in non-mulched multiple-cropping systems (3,20). Root disease severity was slight, but root-knot nematodes and weeds reduced yields of cucumbers harvested for pickles in a previous study (20).

This research was initiated to determine the influence of different types of pest management utilizing herbicides, nematicides, and soil fumigants on soilborne pathogenic fungi and nematodes in cucumber grown for single harvesting for pickles in a multiple-cropping system.

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## MATERIALS AND METHODS

Blended cucumber (*Cucumis sativus* L.) seed consisting of 85% Explorer Calypso or Carolina, gynoecious cultivars, and 15% Chipper, the pollinator cultivar, was planted each year from 1975 to 1980 in a 2-yr multiple-cropping sequence of turnip-peanut-cucumber-turnip-cucumber-soybean. Thus, cucumber was planted in September following peanut in odd years and in April following turnip in even years.

**Cultural practices.** After harvest of the previous crop the soil was plowed 15–20 cm deep and shaped into beds 1.8 m wide and 10–15 cm high, and nematicide or herbicide treatments, or both, were applied (Table 1). Cucumber was planted within 2 days following the harvest of peanut for pods and 5–10 days following harvest of turnip greens. The experiment was part of a larger split-plot design in strips. Cropping sequences were whole plots replicated twice, and subplots (three 1.8-m beds 7.7 m long) were six replicates of four types of pest management for soil pests. The four types were:

1. MBR-CP. Between 14 November and 8 February each year soil was treated with 358.7 kg/ha MBR-CP (98% methyl bromide + 2% chloropicrin) injected to 25 cm deep with chisels 20 cm apart. The

soil surface was shaped and sealed with a bed-shaper attachment, and the plots were covered with black polyethylene (152 μm thick) for 48 hr. No other soil pesticides were applied, and weeds were removed by hand in each crop when plants began to form vines.

2. Maximum. Soil was fumigated between 14 November and 17 December with 376.6 kg/ha DD-MENCS (20% methyl isothiocyanate + 80% chlorinated $C_3$ hydrocarbons) using the methods described for MBR-CP, except the plots were not covered with plastic. Ethoprop granules, 8.96 kg a.i./ha, were applied on the soil surface and incorporated 15 cm deep with a tractor-driven rotary cultivator before planting each crop in 1975 and 1976. A maximum pest control program with herbicides and insecticides was used on each crop.

3. Intermediate. Pesticide usage was based on crop history, monitoring, and scouting reports. Ethoprop (8.96 kg/ha) was applied before planting each crop from 1975 to 1978. Phenamiphos 15G (8.96 kg/ha) was used in 1979 and 1980. Herbicides and cultivation were used as needed.

4. Minimum. Pesticide usage was limited. One herbicide and cultivation were used on each crop, and insecticide applications were based on scouting reports. Nematicides were not used.

Foliar fungicides and insecticides were used as needed on each crop at all management levels. Additional insecticide applications were sometimes used at the maximum level for complete insect control. Cropping sequence and pest management levels were maintained on the same land unit for the duration of the experiment. Ammonium forms of nitrogen in 10-34-0 or a 32% solution of $NH_4NO_3$ urea were used to supply nitrogen for turnips and cucumber; nitrogen was not applied to soybean and peanut. Soil was maintained at or above pH 6.0. Fruits were graded for size and the number of rotted fruits determined as previously described (22). Fruits with sunken, brown cankers or water-soaked lesions >1 cm in diameter were considered rotted. Subplots were separated by 3.3-m buffer zones, and plant and soil samples were collected from the middle 15 $m^2$ of each subplot to avoid contaminated soil mixed into the edges of the subplots by tillage practices. Yield was taken on 7.7 m of the center bed.

**Root and hypocotyl disease severity.** All cucumber plants in 1.8 m of a row were collected 10–20 days after planting and rated for root and hypocotyl disease severity on a scale of 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% root and hypocotyl discoloration and decay and 5 = dead plants. Root growth was based on a scale where 1 = poor growth and 5 = excellent growth. Root abnormalities similar to those caused by herbicides (18) were recorded using a scale where 1 = no abnormalities and 5 = severely deformed roots. Stand counts were recorded three times at weekly intervals beginning 7–10 days after planting, and postemergence damping-off was determined. During the growing season wilting or dying plants were removed and evaluated for root and hypocotyl disease severity. To isolate fungi from roots and hypocotyls, 5- to 10-mm tissue sections were removed and rinsed 30–60 min under running tap water (15–25 C) or surface-disinfected 10–15 sec in 0.5% NaOCl, blotted dry on sterile filter paper, and incubated 2–4 days on water agar at 20–30 C. Hyphal tips were transferred to potato-dextrose agar (PDA) and identified.

**Rhizosphere assays.** Rhizosphere soil on cucumber seedlings following peanut was assayed for fungi in 1975 and 1977. Plants (3–41) from 1.8 m of a row were shaken to remove loose soil. Hypocotyls and roots were placed into 300–600 ml of water in flasks. Flasks were shaken 5 min on a Burrill wrist-action shaker (setting 2 or 3). Samples (1-ml) of stirred soil suspension were placed into petri dishes of gallic acid medium (2) and modified pentachloronitrobenzene (PCNB) medium (13). Soil suspensions diluted 1:10, 1:100, or 1:200 with sterile 0.2 or 0.375% water agar were plated on modified PCNB medium or OAES medium (15), respectively. In 1977, rhizosphere soil suspensions diluted 1:15 with sterile water agar were assayed for actinomycetes by diluting with starch-casein agar (7). Fungi were isolated from roots and hypocotyls removed from the flasks, as described above. Populations of fungi in nonrhizosphere soil dilutions were assayed on gallic acid, modified PCNB, and OAES media 2 wk after fumigation in 1977, 1–3 wk after turnip was planted in 1975 and 1976, and in July, 2 mo after peanut was planted, in 1975 and 1977.

**Pathogenicity tests.** Fungi isolated from lesions on roots or hypocotyls of cucumber, from the rhizosphere of cucumber roots, or from soil assays were tested for pathogenicity on cucumber seedlings in a greenhouse. Cultures were grown on 3% cornmeal-sand (w/w) and used to infest heat-treated (65–75 C for 30 min) Dothan loamy sand, 1:300–1:500 (v/v). Seedlings were rated for root disease severity 10–20 days after planting.

**Nematodes.** Soil was assayed for plant-parasitic nematodes each month (except January) for 6 yr. Ten 2.5 × 15 cm cores of soil were collected from each subplot, composited, and thoroughly mixed. A 150-$cm^3$ sample was processed by the centrifugal-flotation method (4). Plant roots were indexed for galls induced by root-knot nematodes (*Meloidogyne* spp.) 17 and 12 days after planting in 1977 and 1979 and after harvest each year. Twenty plants selected at random were rated for galls on a scale of 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of the roots galled.

Data were analyzed with least squares analysis of variance, correlation, linear regression, and stepwise multiple-regression statistical programs.

**Table 1.** Pesticides applied to cucumbers in different pest management levels in a multiple-cropping system, 1975–1980[a]

| Pest management level | Chemicals (years) | Rate (kg/ha) |
|---|---|---|
| MBR-CP[b] | Methyl bromide (98%) + chloropicrin (2%) (1975–1980) | 358.70 |
| Maximum[c] | Methyl isothiocyanate (20%) + chlorinated $C_3$ hydrocarbons (80%) (1975–1980) | 376.60 |
| | Ethoprop (1975,1976) | 8.96 |
| | Nitralin (1975,1976) | 0.84 |
| | Chloramben (1975–1978) | 2.24 |
| | Ethalfluralin (1978–1980) | 1.12 |
| Intermediate[d] | Ethoprop (1975–1978) | 8.96 |
| | Phenamiphos (1979,1980) | 8.96 |
| | Nitralin (1975,1976) | 0.84 |
| | Chloramben (1975–1977) | 2.24 |
| | Ethalfluralin (1978–1980) | 1.12 |
| Minimum[e] | Nitralin (1975,1976) | 0.84 |
| | Chloramben (1977) | 2.24 |
| | Ethalfluralin (1978–1980) | 1.12 |

[a] Cucumber followed peanut in September of odd-numbered years and turnip in April of even-numbered years.

[b] Soil fumigated with MBR-CP between 14 November and 8 February before planting turnips. Plots maintained free from weeds by hand cultivation.

[c] Soil fumigated with DD-MENCS between 14 November and 17 December. Herbicides and nematicides used on each crop. Plots maintained free from weeds by hand cultivation.

[d] Soil not fumigated. Herbicides and nematicides used only when weed and nematode populations estimated at above threshold levels.

[e] Soil not fumigated and nematicides not used. One herbicide used on each crop.

## RESULTS

**Root and hypocotyl disease severity.** Root and hypocotyl disease of cucumber was greater following peanut than following turnip and was generally less in fumigated than in nonfumigated soil (Tables 2 and 3). Fungi isolated most frequently from diseased cucumber seedlings following turnip were *Pythium* *aphanidermatum* (Edson) Fitzp., *P. irregulare* Buis., and *Pythium* spp. (14% of the seedlings); *Fusarium oxysporum* Schlecht. (13%); *F. solani* (Mart.) Appel & Wor. (5%); and *Rhizoctonia solani* Kühn (AG-4) (3%). Following peanut, *P. aphanidermatum* + *P. irregulare* (32%) and *R. solani* (14%) were isolated most frequently and *F. oxysporum* (6%) and *F. solani* (3%) less frequently. The frequency of isolation varied each year. In the first crop following peanut, *R. solani* was isolated from 30% of the seedlings and *Pythium* spp. from 8%, but in the second crop, *R. solani* isolations decreased to 12% of the seedlings and *Pythium* spp. increased to 19%. In the third crop, only *P. aphanidermatum* was isolated from 1-wk-old wilted seedlings. Following turnip, *F. oxysporum* and *F. solani* were predominant the first year and *Pythium* spp. the second, but only 9% of the seedlings yielded cultures of fungi in the third year. Mature wilted or stunted plants following both crops in the 2 yr yielded primarily cultures of *R. solani*, but few fungi were isolated from wilted plants in the fourth year. Wilted plants usually had reddish brown lesions or no lesions, and vascular discoloration typical of Fusarium wilt was not observed.

**Rhizosphere assays.** Populations of *Pythium* spp. in the rhizosphere of 13- to 16-day-old seedlings following peanut in September 1975 were significantly greater in the intermediate than in the other types of pest management (516 vs. 116–256 propagules/g oven dry soil). *Penicillium* spp. + *Paecilomyces* spp. in the rhizosphere of seedlings were greater from the minimum than from the maximum or intermediate level but not from the MBR-CP level. Populations of *R. solani, F. solani*, other *Fusarium* spp., *Aspergillus* spp., *Trichoderma* spp., *Mucor* spp., *Rhizopus* spp., and *Neocosmospora vasinfecta* E. F. Smith did not differ among management levels. Multiple-regression analysis indicated that a highly significant 28% of the variation in the number of seedlings with no root and hypocotyl discoloration was related to populations of *Pythium* spp. in the rhizosphere and that 41% of the variation was related to populations of *Pythium* spp. + *Fusarium* spp. in the rhizosphere. In 1977, there were no differences among treatments in fungi identified in rhizosphere assays. The fungi isolated most frequently from seedlings used for rhizosphere assays were *R. solani, P. irregulare*, and *Fusarium* spp.

Populations of *Pythium* spp. were 0 and 6 propagules per gram in the MBR-CP and maximum treatments, compared with 178 and 155 propagules per gram in the intermediate and minimum treatments, respectively, 2 wk after fumigation in 1977. In contrast, populations were 9–61 propagules per gram in fumigated soils collected in turnip and peanut, 1975–1977, compared with 20–264 propagules per gram in nonfumigated soil. *R. solani* AG-4 was not detected in fumigated soil and 5–10 propagules/100 g were present in nonfumigated soil in November 1977. In turnip and peanut, populations of *R. solani* AG-4 were quite variable and ranged from 0 to 19 propagules/100 g among treatments at different samplings.

**Pathogenicity tests.** *R. solani* AG-4, *P. aphanidermatum*, and *P. irregulare* were highly virulent to cucumber and caused severe root and hypocotyl necrosis and >50% damping-off. A binucleate *Rhizoctonia*-like fungus and a sterile, white basidiomycete caused slight to moderate hypocotyl necrosis but no damping-off. Isolates of *F. solani, F. oxysporum*, and *Macrophomina phaseolina* (Tassi) Goid. did not cause root or hypocotyl decay or damping-off.

**Nematodes.** Populations of nematodes were reduced by soil fumigation in the MBR-CP and maximum treatments, but numbers of nematodes were low and variable in most samplings. Nematodes found in the study were *Meloidogyne incognita* (Kofoid & White) Chitwood, *M. hapla* Chitwood, *Paratrichodorus minor* (Colbran) Siddiqi, *Macroposthonia ornata* (Raski) de Grisse & Loof, and *Pratylenchus* spp. Root gall indices were more indicative of root-knot nematode control than were numbers of nematodes. Little or no root galling was found in the MBR-CP and maximum treatments following turnip, but root galling was considerable in two crops of cucumber following peanut (Table 4). Treating soil with ethoprop in the intermediate level gave little or no reduction in root galling, but phenamiphos gave complete control. In the minimum level where no nematicide was used, root galling was moderate in the second crop of cucumber following turnip but low in other years.

**Yields of marketable fruits.** Yields varied greatly from year to year and were usually better with the MBR-CP treatment than with the other treatments (Table 5). When the 6 yr were combined, the MBR-CP treatment yielded significantly more than the other treatments, but there were no differences among the maximum, intermediate, and minimum pest management levels. Average yield of cucumber following the two crops was

**Table 2.** Root and hypocotyl disease severity in cucumber seedlings grown in a 2-yr multiple-cropping system of turnip-peanut-cucumber-turnip-cucumber-soybean for 6 yr with different soil pesticide treatments

| | Root and hypocotyl disease index[y] | | | | | |
|---|---|---|---|---|---|---|
| **Pest management level** | **1975** | **1976** | **1977** | **1978** | **1979** | **1980** |
| MBR-CP | 1.9 b[z] | 1.4 b | 2.2 | 1.2 b | 2.6 | 1.0 b |
| Maximum | 3.1 a | 1.6 ab | 2.7 | 1.2 b | 2.6 | 1.1 b |
| Intermediate | 2.9 a | 1.7 a | 2.7 | 2.1 a | 3.3 | 1.2 ab |
| Minimum | 2.2 b | 1.7 a | 2.9 | 2.1 a | 2.7 | 1.3 a |
| | | | NS | | NS | |

[y] 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay and 5 = dead plants. Plants were evaluated 10–20 days after planting when the first true leaf was emerging.
[z] Numbers in columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). NS = no significant differences.

**Table 3.** Postemergence damping-off in 1- to 3-wk-old cucumber seedlings grown in a 2-yr multiple-cropping system of turnip-peanut-cucumber-turnip-cucumber-soybean for 6 yr with different soil pesticide treatments

| | Postemergence damping-off (%) | | | | |
|---|---|---|---|---|---|
| **Pest management level** | **1975** | **1977** | **1978** | **1979** | **1980** |
| MBR-CP | 23 b[z] | 16 c | 4 b | 38 b | 8 |
| Maximum | 60 a | 26 b | 2 b | 37 b | 14 |
| Intermediate | 65 a | 47 a | 22 a | 57 a | 19 |
| Minimum | 49 a | 28 b | 20 a | 30 c | 15 |
| | | | | | NS |

[z] Numbers in columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). NS = no significant differences.

**Table 4.** Root gall indices[y] in cucumber grown in a 2-yr multiple-cropping system of turnip-peanut-cucumber-turnip-cucumber-soybean for 6 yr with different soil pesticide treatments

| | Following peanut | | | Following turnip | | |
|---|---|---|---|---|---|---|
| **Pest management level** | **1975** | **1977** | **1979** | **1976** | **1978** | **1980** |
| MBR-CP | 2.3 a[z] | 2.3 | 1.4 a | 1.0 b | 1.1 b | 1.0 |
| Maximum | 1.4 b | 2.2 | 1.1 b | 1.0 b | 1.0 b | 1.0 |
| Intermediate | 2.0 a | 2.8 | 1.0 b | 1.7 a | 3.2 a | 1.0 |
| Minimum | 1.7 b | 2.3 | 1.4 a | 1.6 a | 3.4 a | 1.5 |
| | | NS | | | | NS |

[y] 1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of roots galled.
[z] Numbers in columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$). NS = no significant differences.

**Table 5.** Yield of cucumber grown in a 2-yr multiple-cropping system of turnip-peanut-cucumber-turnip-cucumber-soybean for 6 yr with different soil pesticide treatments

| | Yield (t/ha) | | | | | |
|---|---|---|---|---|---|---|
| | Following peanut | | | Following turnip | | |
| Pest management level | 1975 | 1977 | 1979 | 1976 | 1978 | 1980 |
| MBR-CP | 23.8 a[z] | 10.8 a | 6.0 b | 10.5 a | 18.1 a | 24.4 a |
| Maximum | 9.9 c | 6.0 b | 4.5 b | 7.4 a | 3.9 b | 20.3 ab |
| Intermediate | 5.1 d | 4.5 b | 10.4 a | 1.4 b | 1.3 b | 20.2 ab |
| Minimum | 15.8 b | 4.7 b | 4.2 b | 1.8 b | 1.7 b | 16.3 b |

[z] Numbers in columns followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

not different, but following peanut the yield from the maximum treatment was greater than those from the intermediate and minimum treatments; there were no differences in yield among the maximum, intermediate, and minimum treatments following turnip.

There was very little fruit rot (<5%) in most subplots during the study because fruit rot control sprays were applied to the soil when the plants began to vine. Fruit rot was caused primarily by *R. solani* AG-4 and *Pythium* spp.

**Interactions of pest management levels, root diseases, and nematodes.** A stepwise multiple regression with root and hypocotyl disease severity and populations of nematodes in soil during the month of harvest was run with yield as the dependent variable. Fixed effects of management levels, season, and management level × season interactions explained 20%, disease severity differences explained 13%, and populations of stubby root and ring nematodes explained 7% of the variations in total yields of marketable fruits for the 6 yr ($P = 0.01$).

## DISCUSSION

This study emphasizes the importance of controlling root diseases and establishing an adequate stand of plants to produce high yields of cucumbers for pickles. In a multiple-cropping system where several methods of pest management are integrated, a procedure used to control one pest may have an unexpected effect on another. In our study, several interactions increased root injury in cucumber and decreased yield. Residues from preceding crops were buried with a moldboard plow before planting cucumber, a cultural practice that buries propagules of *R. solani* and *Pythium* spp. (10,19) and reduces *Rhizoctonia* fruit rot of cucumber (10,22). When beds were formed and nematicides were incorporated with a tractor-driven rotary cultivator, however, debris from the previous crop was brought to the surface and incorporated into the root zone. This was particularly noticeable following peanuts, and the incorporation of the peanut debris apparently contributed to increased postemergence damping-off caused by *P. aphanidermatum* and *R. solani* AG-4. Phytotoxins from decomposing tissues and high soil temperatures also may have contributed to increased root disease.

Soil temperatures following peanut in September are more conducive to pathogenesis of *P. aphanidermatum* than soil temperatures following turnip in April. Isolates of *P. aphanidermatum* and *R. solani* AG-4 causing severe preemergence damping-off and root disease in cucumber are also virulent on peanut (D. R. Sumner and D. K. Bell, *unpublished*), so it is not surprising that root diseases were a limiting factor in cucumber following peanut (11). *P. irregulare* and *R. solani* AG-4 are also pathogens on turnip seedlings (17), but crucifer residues have been used effectively to reduce diseases induced by *R. solani* and *Aphanomyces euteiches* (Drechs.) in greenhouse experiments (9,12). Sulfur-containing compounds thought to be detrimental to soilborne pathogens are produced by decomposing cruciferous tissues (8), but the importance of these compounds in reducing root disease in fields is not known.

Our research suggests some benefit in reduction of root disease from a preceding turnip crop, but differences in yield between cucumber following turnip and cucumber following peanut were not as great as the year-to-year variability. When cucumber followed peanut, more than 9 mo had elapsed since the soil was fumigated, compared with only 4 mo when cucumber followed turnip, allowing more time for soil to be recontaminated. High soil temperatures and peanut residues may have increased the inoculum potential of *R. solani* and *Pythium* spp. Also, the efficacy of ethoprop in controlling nematodes may have been influenced by cropping sequences and soil temperature (14).

Another unexpected side effect was the swollen, fan- to club-shaped root enlargements caused by chloramben. Experiments in a greenhouse, begun when root injury was first observed in the field tests, showed that chloramben increased root diseases of cucumber in soil naturally or artificially infested with *R. solani* AG-4, a binucleate *Rhizoctonia*-like fungus, *P. aphanidermatum, P. irregulare,* and *F. oxysporum* (18). Root disease was also increased by nitralin in the greenhouse in soil infested with *P. aphanidermatum* and *F. oxysporum*, compared with cucumber grown in infested soils without herbicides. In contrast, ethoprop reduced root disease caused by *R. solani* AG-4 but did not influence root disease in soil infested with other pathogens (18). When chloramben and nitralin were replaced with ethalfluralin for weed control in this study, root abnormalities were no longer observed.

The least injury by soilborne pathogenic fungi and root-knot nematodes and the highest yields of marketable fruits were in the MBR-CP treatment, where only a soil fumigant was used. However, yield averaged less than the 20 t/ha that previous research has shown can be produced in the Georgia Coastal Plain (16). The maximum treatment was also fumigated, except DD-MENCS was used instead of MBR-CP and the plots were not covered with plastic. Differences in populations of soil fungi were not observed between the two treatments, and both treatments were hand-weeded. Thus, the additional pesticides applied in the maximum treatment appeared to counteract the beneficial effect of soil fumigation by increasing root disease and root injury. Yields in the maximum treatment exceeded the intermediate and minimum treatments in only 2 of the 6 yr. Previous work with soil fumigation indicated that DD-MENCS was as effective as MBR-CP in controlling soilborne pathogenic fungi and nematodes (6,21).

Other factors that may have influenced year-to-year fluctuations in plant stands and yield were occasional hard rains of 3–5 cm immediately after planting and variabilities in depth and rate of seeding. These and other unknown factors may have caused inconsistencies in differences among management levels.

Soil fumigation greatly increases the costs of production, and large yield increases are necessary to justify soil fumigation economically (1). In a film mulch system of production with trickle irrigation, and in some nonmulched systems of continuous vegetable production, soil pest control may justify soil fumigation (6,20). In a multiple cropping system of agronomic and vegetable crops, however, maximum soil pest control may not be feasible economically unless high-value vegetable crops are planted immediately following fumigation and precautions are taken not to reinfest the topsoil. If soils suppressive to pathogens could be established in a multiple cropping system, use of soil chemicals might be reduced or eliminated.

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