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Tomato Production and Soil Pest Control in Relation to Width of Fumigated and Mulched Bed and Soil Fumigation Rate[1]

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Abstract. **Polyethylene mulched bed widths (28, 56, 84 and 112 cm) with methyl bromide-chloropicrin gas mixture (67–33%, 280 kg/ha) soil fumigation were evaluated in 2 tests for soil pest control and production of tomato (*Lycopersicon esculentum* Mill.). In 2 other tests, methyl bromide-chloropicrin rates of 0, 70, 140, 210 and 280 kg/ha applied under a 112-cm wide mulched bed were evaluated. Populations of root-knot nematodes, parasitic soil fungi, and root-gall indices decreased with increases in mulched bed width. All fumigation rates resulted in decreased populations of root-knot larvae, *Fusarium* spp., *Pythium* spp., *Rhizoctonia solani* and root-gall indices compared with nonfumigated plots. In greenhouse tests, tomato seedlings emerged and survived best in potted soil from mulched plots with the widest bed and those treated with the highest rate of fumigant. Marketable tomato yields increased linearly with increased bed width in 1 test whereas yields were similar among treatments in the other tests.**

Intensive cultural practices involving polyethylene mulch, broadspectrum soil fumigation, drip irrigation, and frequent application of N and K in drip irrigation has increased yields of many high value vegetable crops (1–5, 7–12, 14, 16). The high yield increases from the use of polyethylene mulch, especially with soil fumigation, appear to be due to a number of factors. Geraldson (2) found that tomato and cucumber yield increases of about 20–30% with plastic mulch were due to factors other than prevention of ground rot. Chalfant et al. (1) reported large yield increases of summer squash with polyethylene mulch even without soil chemical treatment. Jones et al. (10) reported polyethylene mulch without soil fumigants reduced disease severity in several tomato tests. However, the best soil pest control and largest vegetable yields were usually obtained when mulch and soil fumigation were utilized (3, 4, 7–9, 11, 12, 14, 16). Overman and Jones (14) found 'Walter' tomato yielded as well with a single injection chisel application of ⅓ of the soil fumigant under a 75-cm wide mulched bed as with 3 injection chisels of the fumigant spaced 27 cm apart. The purpose of this study was to determine the influence of the mulched bed width fumigated and rate of fumigant on soil pest control and yield of tomato.

Studies were conducted in 1978 and 1979 on a Dothan loamy sand near Tifton, Georgia. Mulched bed widths of 28, 56, 84, and 112 cm on 183-cm row spacing were evaluated in spring and fall tests. A methyl bromide-chloropicrin (67–33%, MB-C, bromomethane-trichloronitromethane) gas mixture was applied using 1, 2, 3 and 4 chisels (spaced 23 cm apart), respectively, with increasing bed widths at 15 cm deep and at the rate of 280 kg/ha for the treated area. Prior to soil treatment 40 N, 83 P, and 34 K kg/ha (calculations based on a 112-cm wide bed) were broadcast in the bed area and rototilled to a 15 cm depth. A single Viaflo drip tube placed 3 cm deep and 15 cm from the plant row was used for irrigation and to apply the equivalent of 4.5 N and 3.7 K kg/ha/day twice weekly. In the spring study fumigant and mulch were applied on March 24 at which time soil temperatures at 15 cm averaged 22°C. Plant holes were cut 30 cm apart in the mulch 10 days after fumigation. 'Walter' tomato plants were transplanted 7 days later. In the fall test, treatments were applied on July 20 at which time soil temperatures at 15 cm averaged 29°C. Plant holes were cut in the mulch 2 days later and 'Big Set' plants were transplanted 3 days later.

In 1979 spring and fall tests, different rates of the MB-C (67–33% gas mixture were evaluated using a constant 112-cm wide bed covered with mulch. MB-C gas mixture at rates of 0, 70, 140, 210 and 280 kg/ha were injected with 1 to 4 chisels with increasing rates, respectively. Fertilization and drip irrigation practices were the same as for 1978 except T-tape drip tube with a 30-cm emitter spacing was used in the spring test. Treatments were applied March 27 at which time soil temperatures at 15 cm averaged 17°C. 'Walter' plants were transplanted 16 days later. Treatments in the fall test were applied on July 2, soil temperatures at 15 cm averaged 32°C. 'Monte Carlo' plants were transplanted 11 days later. In all tests, treatments were arranged in a randomized complete block design with 4 replications. Plots were 9 m long in 1978 and 6 m in 1979.

Soil samples for nematode assays were collected before fumigation, before transplanting, and after last fruit harvest, except in spring of 1979; the last samples were collected before fruit harvest. Nematode populations were determined by a modified centrifugal-flotation method (6). Soil samples for fungal assays were collected after last fruit harvest in 1978 and just before the first harvest in 1979. Populations of *Pythium* spp. were determined by plating on Tsao's $P_{10}VP$ medium (17) modified by adding 0.01 g/liter of rose bengal to make colonies more visible, *Fusarium* spp. on Nash and Snyder's medium (13) and *Rhizoctonia solani* using tablebeet seed as bait (15). Greenhouse bioassay tests in which nontreated tomato seeds were planted in the soil from the various treatments complemented the laboratory platings. Four pots (10 cm diameter) were filled with soil from each plot and seeded with 75 tomato seed/pot. Surviving plants were counted 21 days after seeding, and organisms present were determined by isolation from representative damping-off seedlings.

Pink to mature green fruit were harvested, graded, counted and weighed to determine yield. After the last harvest, the plants were rated for root galls [*Meloidogyne incognita* (Kofoid & White) Chitwood] on a 1 to 5 scale: 1 = no galling; 2 = 1–25; 3 = 26–50; 4 = 51–75; and 5 = 76–100% roots galled.

Populations of root-knot nematodes in the 1978 plots were low and uniform before fumigation and averaged 13 larvae/150 cc soil. Nematode populations were high and significantly greater in the 28-cm mulched beds than in the wider mulched beds by the end of the season in the spring test (Table 1). Nematode populations were not different in samples collected at harvest in the fall test. Root-gall indices were greater on plants grown in the narrowest mulched beds in both the spring and fall test. Populations of *Fusarium*, *Pythium*, and *Rhizoctonia* spp. were also higher at harvest in soil taken from the 28-cm wide fumigated beds than in wider beds (Table 1). There was an inverse relationship between the populations of root-knot nematodes, *Fusarium* and *Pythium* spp., and the width of fumigated bed. The recontamination in the narrow mulched bed plots was very rapid in comparison to the wider mulched and fumigated plots. In the greenhouse bioassay tests, tomato seedling survival was lower in soil from the 2 narrow mulched bed treatments (28 and 56 cm) than in soil from the wider mulched bed treatments (Table 1). The nematode and fungal pathogens apparently did cause enough damage to reduce fruit yield in 1 test since yields increased linearly with increasing width of fumigated and mulched beds in the spring test but not in the fall (Table 1). In the spring test, fruit weight was in-

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Table 1. Populations of root knot nematodes, soil fungi, survival of tomato seedlings in soil and tomato yield as influenced by bed width fumigated.

Fumigated bed width (cm)[z]	Root-knot larvae (No./150 cc soil)	Root-gall indices[x]	Genera of soil fungi[y] *Fusarium*[w] (ppg × 10^{-4})	*Pythium*[w] (ppg)	*Rhizoctonia*[w] (%)	Soil bioassay (% tomato survival)	Fruit yield (No. in 1,000s/ha)	Fruit yield (MT/ha)
			Spring 1978					
28	1,391a[u]	4.7a	3.5a	3.0a	14a	5b	164b	34.8c
56	244b	2.1b	1.7b	0.6b	6b	18b	193ab	39.3bc
84	1b	1.6bc	0.7c	0.1b	3b	51a	203a	42.1ab
112	2b	1.1c	0.6c	0.0b	2b	59a	213a	45.1a
			Fall 1978					
28	244	1.4a	0.7a	16.9a	25a	--[v]	397	52.3
56	160	1.2ab	0.3b	13.7ab	8b	--	389	52.2
84	99	1.1b	0.2bc	8.7b	6b	--	424	55.0
112	12	1.0b	0.1c	3.1c	2b	--	442	55.7

[z]Methyl bromide (67%)–chloropicrin (33%) gas mixture was applied at 280 kg/ha for treated area.
[y]Soil samples for fungi, bioassay and the last sampling for root-knot larvae were collected after last fruit harvest.
[x]Rated on 1 to 5 scale: 1 = no galls, 2 = 1–25, 3 = 26–50, 4 = 51–75 and 5 = 76–100% roots galled.
[w]ppg stands for propagules per g of dry soil. *Rhizoctonia* expressed as percentage of beet seed yielding organisms.
[v]Soil bioassay data were not collected.
[u]Mean separation in columns by Duncan's multiple range test, 5% level. No significant differences between treatment means in columns without letters.

Table 2. Population of root knot nematodes, soil fungi, tomato seedling survival, and tomato yields as influenced by methyl bromide-chloropicrin fumigation rates.

Fumigation Rate[z] (kg/ha)	Root-knot larvae[y] (No./150 cc soil)	Root-gall indices[x]	Genera of soil fungi[y] *Fusarium*[w] (ppg × 10^{3})	*Pythium*[w] (ppg)	Soil bioassay[y] (% tomato survival)	Fruit yield (No. in 1,000s/ha)	Fruit yield (MT/ha)
			Spring 1979				
0	2,608a[v]	--[u]	4.2a	12.6a	30c	243	43.1
70	1,200ab	--	1.8b	2.0b	62b	231	39.5
140	0b	--	0.1c	0.0b	78a	269	45.5
210	3b	--	0.1c	0.0b	80a	240	41.1
280	0b	--	0.1c	0.0b	77a	220	33.9
			Fall 1979				
0	1,660a	4.2a	4.1a	33.2a	8c	337	52.3
70	750b	2.5b	1.7b	15.6b	32b	398	62.8
140	420b	1.6c	1.6b	12.9b	26b	377	55.5
210	351b	1.3c	2.1b	11.8b	34b	415	61.6
280	166b	1.1c	0.7b	13.0b	67a	381	57.3

[z]Width of bed was 112 cm.
[y]Soil samples for soil fungi, bioassay and the last sampling for root-knot larvae were collected before first fruit harvest.
[x]Rated on 1 to 5 scale: 1 = no galls, 2 = 1–25, 3 = 36–50, 4 = 51–75 and 5 = 76–100% roots galled.
[w]ppg stands for propagules per g of dry soil.
[v]Mean separation in columns by Duncan's multiple range test, 5% level. No significant differences between treatment means in columns without letters.
[u]Data were not collected.

versely related to root-knot larvae in last soil samplings (r = —0.50*), root knot indices (r = —0.60*), *Pythium* (r = —0.63*), *Fusarium* (r = —0.60*) and *Rhizoctonia* (r = —0.55*) and a positive relationship with tomato seedling survival in greenhouse (r = 0.52*).

In the 1979 spring and fall tests, fumigation treatments generally resulted in lower populations of root-knot nematodes, *Fusarium* spp., *Pythium* spp., and *Rhizoctonia solani* (Table 2). Root-knot indices at harvest in the fall test were higher in nonfumigated plots than in fumigated plots. Fumigation also resulted in higher tomato survival in greenhouse bioassay tests. The 70 kg/ha rate was less effective than the highest fumigation rate. Fruit yield in number and weight of medium size and larger did not differ among fumigation rates (Table 2).

Isolations made from damped off tomato seedlings in the greenhouse bioassay tests yielded primarily *Pythium* spp. (mainly *P. irregulare*); *Fusarium* spp. and *Rhizoctonia solani* were isolated less frequently.

The absence of more damaging soil-borne diseases such as southern blight (*Sclerotium rolfsii* Sacc.) and bacterial wilt (*Pseudomonas solanacearum* E. F. Sm.) may explain the failure to obtain a greater yield response to wider mulched and fumigated beds and to high fumigation rates.

Our research results confirm and extend previous findings that polyethylene mulch, drip irrigation, and fertilization with irrigation water can result in acceptable vegetable yields even with suboptimum control of some soil pests (1). Although root-knot nematodes and pathogenic soil fungi were present in relatively large numbers in narrow mulched and fumigated beds and in wide mulched beds without MB-C fumigation, their deleterious effects may have been masked by the improved soil moisture and nutrition with this intensive system. An abundant root system was concentrated near the soil surface on the side of the plant row near the drip tube and was apparently sufficient to overcome any stress induced by soil pathogens so long as adequate moisture and nutrients were applied in the drip system.

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Cotyledon Shading and Seedling Growth of Pumpkin[1]

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Abstract. **Pumpkin (*Cucurbita moschata* Poir, cv. Dickinson Field) seedlings were grown in the light, in the dark, or in the light with the cotyledons covered. Cotyledons kept in the dark or covered, lost a fourth of their dry weight to support axis tissue growth and were dead 25 days after planting. Dry weight of light-grown cotyledons decreased initially but by 25 days after planting equaled their initial dry weight. Dry weight of dark-grown axis tissue increased for 9 days and then remained constant. The weight of axis tissue of plants grown in the light at 25 days was 4-fold greater than axis tissue from plants whose cotyledons were covered. The data show that shading of the cotyledons dramatically affect the growth of the axis tissue of the young pumpkin seedling.**

Ungerminated pumpkin cotyledons contain 30% of their dry weight as lipid, 26% as protein and most of the remainder as starch (2). After planting, the cotyledons emerge, synthesize chlorophyll in the presence of light, and function as leaves (3). The cells in the cotyledons expand (5) and the stored material is transferred to the axis tissue (2,7). The dry weight of the cotyledon is so large that only a portion of this reserve is used by the time the axis has emerged from the soil (7,8). Thus, the remaining reserve material is available to increase axis growth after the seedling has emerged. The carbon material synthesized from photosynthesis by the cotyledons may also be transported to the axis tissue (7). This report shows the contribution the stored material and the effect of shading the cotyledon have upon growth of the axis tissue of a young pumpkin seedling.

Seeds of 'Dickinson Field' were sown in a glasshouse on June 1 of 1978 and 1979. Temperatures fluxuated between 27° and 32°C and normal sunlight received (16 hr photoperiod). The experimental design was a randomized complete block of 3 treatments with 3 replications of 10 plants in each treatment. Seedlings emerged in 5 days and one group of plants was covered and kept in the dark. The contribution that the stored material in the cotyledons make toward axis growth was determined with this group. The cotyledons of a second group of plants were covered with aluminum foil 2 days after emergence (7 days after planting) while the axis was exposed to light. The contribution that the stored material from the cotyledons and phytosynthesis of the axis tissue make toward axis growth was estimated with this group. A third group of plants was allowed to grow normally in the light. The cotyledons of these plants could contribute both stored material and photosynthate toward axis growth.

At various times after planting, the plants were removed from the soil, separated into axis (shoots, roots, and leaves) and cotyledons and dried at 60°C for 24 hr after which the parts were weighed.

When plants were kept in the dark, the cotyledon dry weight decreased for 15 days and then remained constant (Table 1). Concurrently, the axis dry weight increased for 13 days. After 13 days, no additional growth of the axis occurred. The plants were dead 25 days after planting. At this time, the total dry weight (axis plus cotyledons) had decreased 25% from the initial seed weight of 1.2g (excluding the seed coat). The material lost was utilized to support growth and development of the seedling (1,2,4,7).

The loss of dry weight from cotyledons which were covered with aluminum foil (Table 2) followed a pattern similar to cotyledons kept in the dark. The cotyledons lost weight for 9 days, the weight remained constant for an additional 9 days and then decreased and were dead at 27 days. Both cotyledons which were covered and those grown in the dark decreased to a final dry weight of 0.3 g. This decrease in dry weight is similar to results obtained with peas (1,4), where the storage reserve remains below ground and does not function as leaves or produce photosynthate.

The axis of plants whose cotyledons were covered grew at a linear rate for 15 days and then increased rapidly (Table 2). Axis tissue grown in the dark increased to a maximum of 0.6 g dry weight and this value was attained 11 days after planting by axis tissue whose cotyledons were covered. The remaining increase in axis dry weight can be assumed to be due to photosynthesis by the axis tissue.

When the plants were allowed to grow normally, the plants emerged in 5 days and by 9 days the cotyledons had stopped decreasing in dry weight (Table 3). The cotyledon weight remained constant for the next 9 days and then increased in dry weight. By 27 days after

Table 1. The changes in dry weight of cotyledons and axis tissue of seedlings grown in the dark.[z].

Days after planting	g dry wt	
	Cotyledons	Axis
1	1.1	---
3	1.0	0.1
5	0.8	0.2
7	0.6	0.3
9	0.5	0.4
11	0.5	0.5
13	0.4	0.6
15	0.3	0.6
18	0.3	0.6
21	0.3	0.6
24	0.3	0.6
25	Dead	Dead

[z]Seedlings emerged after 5 days.

Table 2. The changes in dry weight of cotyledons covered with aluminum foil and axis tissue which was exposed to light.[z].

Days after planting	g dry wt	
	Cotyledons	Axis
1	1.1	---
3	1.0	0.1
5	0.8	0.2
7	0.6	0.3
9	0.5	0.4
11	0.5	0.6
13	0.5	0.7
15	0.6	0.8
18	0.5	1.2
21	0.4	3.0
24	0.3	4.0
27	Dead	6.0

[z]Seedlings emerged 5 days after planting, and cotyledons were covered after 7 days.

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