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SOIL FUMIGATION INCREASES CALADIUM TUBER PRODUCTION ON SANDY SOIL[1]

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Abstract. **Soil fumigation improved tuber production of** Caladium x hortulanum **Birdsey cv. Candidum on Myakka fine sand by increasing tuber number and size (grade). However, there was no residual benefit from year to year in soil where fumigation alternated or was repeated each year. In a second test, gross tuber yields, by weight, were increased 227% and 331% by methyl bromide 67%/chloropicrin 33% (MBC) (350 and 435 lb./acre), 105% and 98% by 1,3-dichloropropene (1,3-D) (15 or 30 gal/acre), and 298% by 1,3-D/chloropicrin 17% (35 gal/acre). Supplemental applications of granular formulations of nonvolatile nematicides ethoprop (20 lb./acre), carbofuran (16 lb./acre), or fenamiphos (8 lb./acre) to soil fumigated with MBC (350 lb./acre) did not improve tuber production.**

The muck soil of Highlands County, Florida is the center of the nation's caladium tuber industry. Because muck soil is limited and subsides approximately 1 inch annually under cultivation, a program for producing tubers on sandy spodosols is being developed. When the best available horticultural practices are followed, tuber production on sandy soil can equal or exceed that obtained with present commercial methods on muck (1, 2).

Root-knot nematodes, *Meloidogyne* spp., are major pests of caladiums grown on sand and muck. Christie (1) maintained that some of the most severe root-knot damage in Florida occurs on muck and that nematodes thrived best in fairly loose, well aerated, moderately dry soils. But, probably because of the difference in biological activity and moisture management of the 2 soil types, infestations in sandy soil can be particularly devastating.

The experiments reported here were designed to answer the following questions pertinent to refining the best management practices now evolving through research for tuber production on sands: 1.) Is annual soil fumigation in the best interest of optimum soil productivity and tuber yield increases, 2.) Does the use of certain fumigants over others result in greater tuber production, and 3.) Are supplemental nonvolatile nematicides effective in improving tuber quality and production in fumigated soil?

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Materials and Methods

Cultural practices for managing field preparation, irrigation, bed construction, soil fumigant, fertilizer placement, use of full-bed mulch, and planting stock management were similar in all tests to those published previously (3) for sandy soil. Fumigant rates presented are based on a net acre treated under the plastic mulch; each gross acre of beds on 4.5 ft centers using 3 fumigant streams 12 inches apart, requires 2/3 the rate of the net acre. All yield data were calculated to a base of 1000 ft of a single row planting in which chips were set 4 or 5 inches apart in the row. A production index (PI) to estimate crop value was calculated for each fumigation treatment (3): PI = n #3's + 1.5 n #2's + 6 n Jumbos + 9 n Mammoths + 12 N Super Mammoths, where n = number of tubers in each grade.

Test 1. A crop management system was initiated in 1977 in a field of subsurface irrigated Myakka fine sand to determine the effect of soil fumigation scheduling on caladium tuber production. Treatments in the 1977 and 1978 caladium crops included a preplant application of methyl bromide 67%/chloropicrin 33% (MBC) (Terr-O-Gas 67®) at 350 lb./acre compared with a nonfumigated control plot. In 1979, these treatments were split to establish the following combinations: 1.) Fumigated 1977, 1978, and 1979; 2.) Nonfumigated 1977, 1978, and 1979; 3.) Fumigated 1977, and 1978 but nonfumigated 1979; and 4.) Nonfumigated 1977 and 1978 but fumigated 1979.

Two weeks after 5 replicates of 40-ft long plots were prepared in a randomized block and fumigated, Candidum stock grown commercially the previous year on muck soil were hot water treated (4), hand chipped, and dusted with captan (Captan® 50WP). Eight chips of 'Candidum' were planted through the plastic mulch 4 inches apart in a randomly selected 3-ft section of each 40-ft main plot. Cultivars with other histories occupied the rest of each main plot; these data are not presented herein.

Plots were fumigated April 16, 1979, planted April 30, and harvested January 3, 1980. Plant roots were indexed for severity of root-knot nematode galls immediately after digging, using a scale of 0 to 5 where 0 = no galls and 5 = severe galling. Tubers were air cured for 2 wk and graded (5) by hand. Plant survival, number of tubers in each grade, and total weight of harvest were recorded.

Test 2. Three fumigants at 1 or more rates per acre were evaluated for effects on caladium tuber production on Myakka fine sand in the spring of 1981: 1,3-D (Telone II®) at 15 or 30 gal/acre, 1,3-D/chloropicrin 17% (1,3-D/C) (Telone C-17®) at 35 gal/acre, and MBC at 350 or 435 lb./acre. Treatments were applied in 50 ft plots replicated 4 times in randomized blocks. Fumigants were applied with full-bed mulch on April 8, 1981. 'Candidum' tubers harvested from sandy soil the previous year were hot water treated, hand chipped, and dusted with Captan 50WP prior to planting on 5-inch spacing in the row April 22. Tubers were harvested January 6, 1982 and roots were assayed for presence of root-knot nematode galls. Tubers were cured for 1 wk, cleaned, counted, and weighed.

Test 3. This test was designed to evaluate the benefits of a residual nematicide used in addition to a soil fumigant. Prior to fumigating the beds of the entire test area with MBC at the rate of 350 lb./acre and mulching the bed, granular nonvolatile materials were broadcast incorporated in 4.5 x 28-ft plots. Three residual nematicides were compared with a no-residual-nematicide control in a randomized block with 4 replications: ethoprop (Mocap® 10G, 20 lb. a.i./acre), carbofuran (Furadan® 10G, 16 lb. a.i./acre), and fenamiphos (Nemacur® 15G, 8 lb. a.i./acre). Chips of grower's stock of 'Candidum' were planted through the mulch 2 wk following application of the fumigation on April 13, 1978. Tubers were harvested January 3, 1979, cured for 2 wk, counted, weighed, and graded.

Results and Discussion

Test 1. Soil fumigation with MBC in the current crop year (Table 1) improved gross weight of tubers and the PI. No benefit accrued to the yield of the current crop from previous fumigation practices. The level of root-knot nematode galling on tuber roots at harvest was related to the fumigation practice and yield. Plots treated in 3 consecutive years evinced less root-knot galling than any tubers produced when nonfumigated production was part of the history. The degree of galling on roots dug from plots not treated in 1977 and 1978, but treated in 1979, was significantly higher than the 3-year continuous fumigation regime, but equal to the severity of galling in soil not treated in 1979, but treated in 1977 and 1978.

Fumigation in the crop year increased plant survival. In addition to an increase in gross weight of tubers related to plant survival, there was an increase in weight due to an upward shifting of tuber size to larger grades, i.e. greater number of Jumbo size tubers at the expense of the smaller tubers. No Jumbos were dug from the 3-yr controls. Regardless of the previous year's fumigation practice, crops not fumigated the current year are exposed to similar nematode pressure, and yields are reduced dramatically (50-60%). No record of disease was made, but observation indicated little incidence of prolonged problems. However, these results suggest some complication increasing with time which affected the quality of production because not all of the chips planted produced a tuber during the growing season when grown in soil not fumigated the current crop year (Table 1).

Test 2. All treatments with 1,3-D, 1,3-D/C and MBC improved tuber yields (Table 2), and highest yields were obtained with MBC (435 lb./acre) or 1,3-D/C (35 gal/acre). Because cost of the most expensive fumigant tested can be recovered several times over, a crop management program designed to attain the highest yield is practical. Although the incidence of root-knot nematodes was suppressed by all treatments, 52% of the tubers in the best treatment (MBC) were infested at time of harvest.

Preplant soil treatment with labeled rates of soil fumigants is not designed to sterilize the field but to only reduce pest infestations to a level which permits optimum crop production. Individual pests which escape a lethal dose of the fumigant because of location in the soil profile or stage of development when encountered by the fumigant survive to re-establish the population as the host provides a food supply. In fields heavily infested with the root-knot nematode, an 8- or 9-month crop such as caladium offers ample opportunity for significant recovery of soil-borne pathogens.

Test 3. Ethoprop, carbofuran, and fenamiphos reduced

Table 1. Effect of soil fumigation management on plant survival, gross weight, crop value and root-knot nematode (*Meloidogyne* sp.) infestation of 'Candidum' caladium tubers produced per 1000 ft of a single row planting on sandy soil.

Fumigated 1977 & 1978[z]	Fumigated 1979	Plant survival	Gross wt (lb.)	Production index[y]		Root-knot index[x]
				All grades	Jumbo	
−	−	1933 b[w]	223 b[w]	5,736 b[w]	0 c[w]	3.27 c[v]
	+	2400 a	647 a	14,140 a	600 ab	2.51 b
+	−	1867 b	259 b	6,270 b	267 bc	2.94 bc
	+	2400 a	627 a	12,139 a	867 a	1.78 a

[z]Fumigation in all years = methyl bromide 67%/chloropicrin 33% (350 lb./acre).
[y]PI = n No. 3 + 1.5 n No. 2 + 3 n No. 1 + 6 n Jumbos + 9 n Mammoths + 12 n Super Mammoths, where n = number of tubers in each grade.
[x]Index: 0 = none, 5 = severe root galling.
[w]Mean separation within columns by Tukey's HSD Test, 5% level.
[v]Mean separation within columns by Tukey's HSD Test, 10% level.

Table 2. Percent of root-knot nematode (*Meloidogyne* sp.) infested tubers at harvest, tuber weight, and increase in crop value following preplant applications of various soil fumigants in 1980.

Treatment[z]	Rate/gross acre	Tubers		Yield increase (%)	Estimated[y]	
		% infested	Weight (lb.)[y]		Chemical cost ($)	% yield increase required to pay for fumigant
Control	—	84 c[x]	254 d	—	—	—
1,3-D	15 gal	57 ab	647 c	105	3.10	.8
1,3-D	30 gal	65 b	504 c	98	6.20	2.4
MBC	350 lb.	54 a	832 b	227	8.71	1.5
1,3-D/C	35 gal	58 ab	1012 a	298	10.25	1.4
MBC	435 lb.	52 a	1095 a	331	11.07	1.3

[z]1,3-D = 1,3-dichloropropene; MBC = 67% methyl bromide, 33% chloropicrin; 1,3-D/C = 1,3-D + 17% chloropicrin.
[y]Per 1000 ft of a single row planting.
[x]Mean separation within columns by Tukey's HSD Test, 5% level.

Table 3. Effect of non-volatile nematicides on production and root-knot nematode (*Meloidogyne* sp.) infestation of caladium tubers planted in soil also fumigated with methyl bromide 67%/chloropicrin 33% (350 lb./acre).

Nematicide	Formulation	Rate (lb. a.i./acre)	Gross wt (lb.)[z]	No. tubers[z]	Production index[y]	Tubers infested (%)
Control	—	—	644 a[x]	3125 a	16,272 a	94 c
Ethoprop	10G	20	606 ab	3125 a	16,432 a	61 b
Carbofuran	10G	16	590 b	2834 b	14,768 b	40 ab
Fenamiphos	15G	8	534 c	3250 a	15,434 b	26 a

[z]Per 1000 ft single row planting.
[y]PI = n No. 1's + 1.5 n No. 2's + 3 n No. 3's + 6 n Jumbos + 9 n Mammoths + 12 n Super Mammoths, where n = number of tubers in each grade.
[x]Mean separation within columns by Tukey's HSD Test, 5% level.

the percent of tubers infested with root-knot nematodes (Table 3); however, at best, 26% of the tubers were rated positive for presence of the nematode in fenamiphos treated soil. In addition to failing to eliminate nematode infections, fenamiphos and carbofuran reduced gross weight and the value of the tubers produced. Carbofuran reduced the number of tubers that were produced; fenamiphos reduced the size of tubers produced. Although ethoprop did not reduce yields by any of the measurements taken, 61% of the tubers harvested from the soil tested with this compound were infested with root-knot nematodes. Thus, the supplemental use of residual, nonvolatile nematicides on fumigated soil in an attempt to prolong protection of the tubers from root-knot nematode invasion was not successful. Protection was prolonged, but not to the point where nematode-free tubers could be harvested. Also, the additional protection attained did not result in increased yields.

Soil fumigation with MBC in the current season on sandy soil increased tuber production of caladiums. Yields with all fumigants evaluated were directly related to the cost of the fumigant. The higher the cost, the greater the yield. MBC at 435 lb./acre resulted in highest yield, and this yield increase was 15 times greater than the yield necessary to pay for the fumigant. There is no economic benefit to be derived from using nonvolatile nematicides to improve nematode control by soil fumigation. Root-knot nematodes were not eliminated and yield was not increased by the supplemental use of these compounds on fumigated soil.

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EVALUATION OF FERTILIZER TYPES AND RATES ON CALADIUM X HORTULANUM BIRDSEY 'CANDIDUM' TUBER PRODUCTION IN MUCK AND SANDY SOIL MANAGEMENT SYSTEMS[1]

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Abstract. **Standard commercial soluble fertilizer practices used in muck or sandy soils and rates of soluble or a resin-coated controlled release fertilizer were evaluated for production of caladium tubers in 2 soil management systems. When fertilizers were surface banded under a full-bed plastic mulch on a sandy soil, the production index (crop value) with 100 lb. N/row acre as Osmocote® 18-6-12 (8-9 month controlled release formulation) was equivalent to 200 lb. N/row acre as soluble 18-0-25. The production index was 23 or 29% greater with 200 or 300 lb. N, respectively, than with 100 lb. N as Osmocote 18-6-12. In a muck soil system, 4 monthly broadcast applications totaling 200 lb. N/row acre as soluble 10-10-10 produced yields equivalent to a single preplant banded application of Osmocote 18-6-12 at 200 or 300 lb. N/row acre. Carry-over effects on production of potted plants were observed, but were not considered of commercial significance.**

Caladium tuber production represents an estimated 7-8 million dollar industry in Florida, yet very little information is reported on field production techniques (7). Guidelines for hot water treatment of tubers for nematode control (6); soil fumigation for control of weeds, nematodes, and soil-borne diseases (5, 6); and postharvest handling (4) are available. We reported, in a companion paper (5), the effect of fumigation and stock on tuber production in muck or sandy soils. We demonstrated that soil fumigation increased

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