J. Amer. Soc. Hort. Sci. 103(3):385–388. 1978.

Response of Onions Grown for Transplants to Soil Fumigation[1]

C. A. Jaworski, S. M. McCarter, A. W. Johnson, and R. E. Williamson[2]
Agricultural Research Service, U. S. Department of Agriculture, Coastal Plain Station, Tifton, GA 31794

Additional index words. Allium cepa, nematodes, fungi, soil-borne pathogens

Abstract. **Six general-purpose fumigants applied by different methods were evaluated for control of the fungal-nematode complex on onion (*Allium cepa* L.) for transplant production. Most soil treatments improved plant vigor, size, uniformity, and yield, and these positive responses were correlated with reduced populations of soil-borne fungi and nematodes. Growth response and control of pathogens varied with the fumigant used and the method of application. Populations of *Pythium* spp. and *Fusarium* spp. were reduced with methyl bromide, methyl bromide-chloropicrin mixture, chloropicrin, DD-MENCS (Vorlex), metham (748 liters/ha, drenched) and Bunema (drenched). Metham (748 liters/ha, drenched or drenched and incorporated) controlled *Rhizoctonia solani* Kuehn. Complete control of root-knot nematodes was obtained with methyl bromide and methyl bromide-chloropicrin mixture and nearly complete control with chloropicrin and DD-MENCS.**

Southern Georgia is a major production area for field-grown vegetable transplants intended for shipment to other vegetable production areas (4). The scarcity of newly cleared land suitable for vegetable transplant production and the need to increase yield and improve transplant uniformity to facilitate mechanical harvest has forced growers to establish permanent production sites on previously cultivated land. The use of permanent production sites has increased the incidence of soil-borne diseases caused by fungi, bacteria, and nematodes.

The Georgia Department of Agriculture estimates that about 200 million onion transplants are produced annually on about 60 ha in southern Georgia. Onions for transplants are seeded from late July until the following March. Poor plant stands and poor growth due to high levels of soil-borne pathogens occur most frequently during the high temperature periods of late summer and early fall. Plant parasitic nematodes can cause severe damage of onions (11). Growers using land continuously for vegetable transplant production must maintain soil relatively free of pathogenic fungi, nematodes, and weeds. Six general-purpose fumigants applied by different methods were evaluated for effectiveness in controlling the fungal-nematode complex in onion seedbeds and in stimulating onion growth.

Materials and Methods

Tests were conducted on Tifton loamy sand at the Coastal Plain Experiment Station, Tifton, Georgia, in 1975 and 1976. After land preparation in late July, different soil fumigants were applied to 1.8 × 12.2 m beds. Treatments included: 1) methyl bromide (MBR, 490 kg/ha, applied under a 102 μm black polyethylene film); 2) chloropicrin (CP, 137 and 327 liters/ha), injected; 3) MBR-CP gel (containing 67% MBR and 31% CP, 280 kg/ha), injected; 4) metham (sodium methyl dithiocarbamate, 374 or 748 liters/ha), applied as a drench in 6,500 liters of water, as a drench in 6,500 liters of water and incorporated into the top 15-cm of soil and with a tractor-drawn rototiller, or injected; 5) DD-MENCS (20% methyl isothiocyanate + 80% 1,2 dichloropropane, 1,3-dichloropropene and related chlorinated hydrocarbons, 327 liters/ha), injected; 6) Bunema (40% potassium N-hydroxymethyl-N-methyldithiocarbamate, 374 liters/ha), applied as a drench in 6,500 liters of water, as a drench in 6,500 liters of water and incorporated into the top 15-cm of soil with a rototiller, or injected; and 7) control (no chemical treatment). All chemical injections were made 20 cm deep with a tractor-mounted fumigator with injection chisels 20 cm apart. The beds were reshaped, and simultaneously with chemical injection, the surface was pressed firmly. All chemicals except MBR were applied 22 days before seeding. MBR was applied 9–10 days before seeding, and the polyethylene cover was removed 5–6 days before seeding. All chemicals except MBR were sealed immediately after application with 1.3 cm of water applied with a solid-set sprinkler irrigation system. All plots were aerated with a tractor-mounted rotary tiller 5–6 days before seeding. Treatments were arranged in a randomized complete block design with four replications.

On August 13, 1975, beds were seeded with 'Texas Early Grano' onion, in 8 rows, 0.18 m apart, with 79 seed/m placed in seed tapes. On August 19, 1976, 'Granex' onions were seeded with a Stanhay seeder placing 295 seed/m row in 4 rows, 0.36 m apart. Before seeding, 67, 58, and 56 kg/ha of N, P, and K, respectively, and 1,120 kg/ha of dolomitic limestone were rototilled into the top 15-cm of each bed. Plants were side-dressed with 35 kg/ha of N in 1975 and 17 kg/ha in 1976. Dimethyl tetrachloroterephthalate (DCPA) was applied at 11.2 kg/ha for weed control immediately after seeding. Sprinkler irrigation was used as needed to incorporate herbicide and to promote rapid seed germination and growth.

Soil samples (1.5 liters/plot) were collected at harvest in 1975. In 1976, soil samples were collected before seeding, and also at harvest. The soil sample was thoroughly mixed and 2–5 g of moist soil assayed for selected plant pathogenic fungi. Populations of *Pythium* spp. were determined on modified Kerr's medium (3); *Fusarium* spp. on Nash and Snyder's medium (10); and *Rhizoctonia solani* with Ko and Hora's selective medium (6). In 1975 and 1976, soil samples were collected and assayed for plant parasitic nematodes prior to treatment and after harvest. Twenty cores (2.5 × 15 cm) were collected from each plot, thoroughly mixed and assayed for nematodes by the modified centrifugal flotation method (5). Populations of root-knot (*Meloidogyne incognita* (Kofoid & White) Chitwood), stubby root (*Trichodorus christiei* Allen), ring (*Cricomoides*

[1]Received for publication December 2, 1977. Financial support was provided through United States Department of Agriculture Cooperative Agreement No. 12-14-7001-518. This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA or the University of Georgia nor does it imply registration under FIFRA. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval of the exclusion of other products that may also be suitable.

[2]Soil Scientist, Agricultural Research Service; Associate Professor, University of Georgia, Athens, GA 30602; Nematologist, Agricultural Research Service; and Agricultural Engineer, University of Georgia. We thank William C. Wright, H. Joe Davis, and Thomas L. Hilton for technical assistance.

ornatum Raski), and spiral (*Helicotylenchus dihystera* Cobb (Sher) nematodes were uniformly distributed in the experimental areas before chemical treatment. Plants were also indexed for root-knot galls at harvest, and rated on a scale of 1 (no galls) to 5 (many galls).

One month after seeding, plants were rated for growth on a scale of 1 (poor) to 5 (excellent). All onion transplants from 3 m of row were harvested, graded into marketable and culls, counted, and weighed Oct. 23, 1975 and Oct. 27, 1976.

Results

Soil treatment of onion seedbeds with selected general-purpose fumigants improved plant vigor, size uniformity, marketable and total yields, and plant size (Tables 1 and 2). Plant vigor in all treatments in 1975 was significantly greater than that of plants in the nontreated plots. In 1976, all treatments except metham (drenched) and Bunema (drenched or rototilled) were significantly greater than those in nontreated plots. Yields of marketable and total (marketable plus culls) transplants were increased by all chemical treatments in 1975 (Table 1). In 1976, all treatments except Bunema drenched and rototilled increased yields of marketable transplants. Metham drenched and Bunema did not increase yields of total transplants (Table 2). In 1975, the most uniform transplants as indicated by % marketable, occurred in plots treated with MBR, CP, metham drenched at 748 liters/ha, and DD-MENCS. In 1976, the highest percentage of marketable transplants occurred in plots treated with MBR, MBR-CP, CP, metham rototilled, metham injected and DD-MENCS. Treatments with MBR-CP and DD-MENCS in 1976 and MBR and CP in 1975 and 1976 increased fresh wt of roots and shoots of marketable transplants. Fresh wt per marketable transplants was 3.4 and 13.1 g in 1975 and 4.1 and 10.4 g in 1976 for transplants from nontreated and CP-treated plots, respectively. Bunema and metham were less effective than the other fumigants in increasing fresh plant wt.

The soil fumigants were generally effective in reducing populations of soil-borne pathogens below damaging levels (Table 3). In 1975, when soils were assayed at the time of harvest, populations of *Pythium* spp. and *Fusarium* spp. were significantly lower in all treated than nontreated plots. Populations of *Rhizoctonia solani* were variable and were not significantly different except they were lower in plots treated with the high rate of metham. In 1976, when soils were assayed soon after treatment, all chemical treatments except injected Bunema significantly reduced populations of *Pythium, Fusarium* and *R. solani* (Table 3). Soil samples taken at harvest during 1976 (data not presented) showed that some increase

Table 1. Yield and growth of onion transplants as influenced by soil fumigants at Tifton, Georgia during 1975.

Chemical, rate per ha, and application[z]	Plant vigor[y]	Yield/3 m row: Number		Yield/3 m row: Weight (kg)		% mkt.	Wt/mkt. plant (g)
		Mkt.	Total	Mkt.	Total		
Methyl bromide, 490 kg, UT	3.5c	97a[x]	106a	.96ab	.97ab	92	9.9ab
Chloropicrin, 137 liters, I	5.0a	81a	88a	1.06a	1.07a	92	13.1a
Metham, 374 liters, D	3.8bc	62a	80a	.32cd	.33cd	78	5.2bc
Metham, 748 liters, D	4.5ab	93a	101a	.68abc	.68abc	92	7.3bc
Metham, 748 liters, R	4.0bc	59a	80a	.31cd	.33cd	74	5.3bc
Metham, 748 liters, I	3.8bc	69a	84a	.48cd	.49cd	82	7.0bc
DD-MENCS, 327 liters, I	5.0a	69a	81a	.53bc	.54bc	85	7.7b
Control (no chemical)	2.3d	8b	12b	.03d	.03d	67	3.4c

[z]UT, I, D and R = applied under polyethylene; injected 20-cm deep with chisels 20-cm apart; sprayed on soil surface and drenched with 1.3-cm water via sprinkler irrigation system; sprayed on soil surface and incorporated into the top 15-cm soil layer with a tractor-drawn rototiller, respectively.

[y]Plant vigor ratings were made 1 month after seeding based on a 1 to 5 scale where 1 = poor and 5 = excellent growth.

[x]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Yield and growth of onion transplants as influenced by soil fumigants at Tifton, Georgia during 1976.

Chemical, rate per ha, and application[z]	Plant vigor[y]	Yield/3 m row: Number		Yield/3 m row: Weight (kg)		% mkt.	Wt/mkt. plant (g)
		Mkt.	Total	Mkt.	Total		
Methyl bromide, 490 kg, UT	3.0a	255a[x]	340abc	1.97abc	2.10abc	75	7.7ab
MBR-CP, 280 kg, I	3.8a	278a	359ab	2.84a	2.99a	77	10.2a
Chloropicrin, 327 liters, I	3.5a	257a	329abcd	2.67ab	2.80a	78	10.4a
Metham, 748 liters, D	2.3ab	141b	262bcde	.95cde	1.08cde	54	6.7b
Metham, 748 liters, R	3.3a	256a	348abc	1.65bcd	1.75bcd	74	6.4b
Metham, 748 liters, I	3.3a	242a	314abcd	1.09cde	1.21cde	77	4.5b
Bunema, 374 liters, D	2.8ab	95bc	236de	.47e	.67e	40	5.0b
Bunema, 374 liters, R	2.3ab	86bc	166e	.39e	.47e	52	4.5b
Bunema, 374 liters, I	3.3a	149b	246cde	.81de	.90de	61	5.4b
DD-MENCS, 327 liters, I	3.3a	322a	414a	2.31ab	2.46ab	78	7.2b
Control (no chemical)	1.5b	51c	167e	.21e	.35e	31	4.1b

[z]UT, I, D and R = applied under polyethylene; injected 20-cm deep with chisels 20-cm apart; sprayed on soil surface and drenched with 1.3-cm water via sprinkler irrigation system; sprayed on soil surface and incorporated into the top 15-cm soil layer with a tractor-drawn rototiller, respectively.

[y]Plant vigor ratings were made 1 month after seeding based on a 1 to 5 scale where 1 = poor and 5 = excellent growth.

[x]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Influence of various soil fumigants and methods of application on populations of selected genera of plant pathogenic fungi in soils used for onion transplant production at Tifton, Georgia during 1975 and 1976.

Chemical, rate per ha, and application[z]	1975[y]			1976[y]		
	Pythium (ppg)	*Fusarium* (ppg)	*Rhizoctonia* (%)	*Pythium* (ppg)	*Fusarium* (ppg)	*Rhizoctonia* (%)
Methyl bromide, 490 kg, UT	4b[x]	863d	7ab	0b	131b	0b
MBR-CP, 280 kg, I	–[w]	–	–	<1b	113b	2b
Chloropicrin, 137 liters, I	<1b	1,444d	8ab	–	–	–
Chloropicrin, 327 liters, I	–	–	–	<1b	294b	0b
Metham, 374 liters, D	6b	3,394bc	2ab	–	–	–
Metham, 748 liters, D	<1b	1,425d	<1b	0b	56b	0b
Metham, 748 liters, R	<1b	2,513cd	<1b	0b	356b	0b
Metham, 748 liters, I	8b	2,031cd	10a	1b	750b	2b
Bunema, 374 liters, D	–	–	–	0b	338b	<1b
Bunema, 374 liters, R	–	–	–	<1b	1,050b	2b
Bunema, 374 liters, I	–	–	–	7a	2,719a	6b
DD-MENCS, 327 liters, I	<1b	1,281d	3ab	0b	225b	<1b
Control (no chemical)	75a	5,750a	10a	11a	2,719a	15a

[z]UT, I, D and R = applied under polyethylene; injected 20-cm deep with chisels 20-cm apart; sprayed on soil surface and drenched with 1.3-cm water via sprinkler irrigation system; sprayed on soil surface and incorporated into the top 15-cm soil layer with a tractor-drawn rototiller, respectively.

[y]The abbreviation ppg denotes propagules per g of oven dry soil, and *Rhizoctonia* is expressed as percentage of soil plugs yielding the organism. Soil samples were taken at harvest in 1975 and after treatment, but before seeding in 1976. Each value is a means of four replications.

[x]Mean separation in columns by Duncan's multiple range test, 5% level.

[w]Treatment was not included in test.

in population or reinfestation by soil-borne pathogens occurred during the growing season. Species of *Pythium* in the soil included *P. irrigulare, P. ultimum,* and *P. aphanidermatum.* The predominant species of *Fusarium* were *F. solani, F. roseum* and *F. oxysporum.*

After soil treatment, nematode populations were very low in all plots and did not differ significantly from numbers of nematodes in the nontreated plots. However, based on root-gall indices, 100% control of root-knot nematodes was obtained with MBR and MBR-CP and nearly complete control with CP and DD-MENCS.

The greatest yield and plant growth resulted when nematodes and fungi were suppressed by soil fumigation. There was an inverse relationship between populations of *Pythium* spp. and no. of marketable transplants (r = –.69**), weight of marketable transplants (r = –.55**), no. of total transplants (r = –.72**) in 1975, and the no. of marketable transplants (r = –.56*), and weight of marketable transplants (r = –.48*) in 1976. There was an inverse relationship between no. of *Fusarium* spp. propagules in the soil and no. of marketable transplants (r = –.61**), weight of marketable transplants (r = –.58**), no. of total transplants (r = –.59**) in 1975, and no. of marketable transplants (r = –.54*) and weight of marketable transplants (r = –.55*) in 1976. There was a negative relationship between no. of *T. christiei* and no. of marketable transplants (r = –.48**), weight of marketable transplants (r = –.37**), and no of total transplants (r = –.49**).

Discussion

During late summer and early fall in the Coastal Plain of Georgia, daily max soil temp at 1–2 cm depth are commonly 30–39° C. Damage to onion and other vegetable transplants caused by soil-borne pathogens is most severe at high temp. Abawi and Lorbeer (1) found that the severity of damping-off of onion seedlings caused by *Fusarium oxysporum* f. sp. *cepae* increased with temp from 10–32° C and was directly correlated with inoculum density in the soil. High temp *Pythium* spp. (8), *Sclerotium rolfsii,* and other soil-borne organisms, cause damping off, root rot, and stem rot on numerous crops in the Coastal Plain area of Georgia, and they may cause damage to onion.

General purpose fumigants are needed to control fungi and nematodes that occur on vegetable transplants. Our studies show that results vary depending on the fumigant used as well as the method of application. Metham and Bunema were more effective in control of fungi when applied as a drench with a water seal than when injected or rototilled. Similar results were reported with metham for control of *Sclerotium rolfsii* on tomato transplants (9). Drench application was more effective than injection or rototill application because a drench application results in a greater concn of fumigant in the top 6 cm of soil where fungi are most active (12). The breakdown of metham to its toxic degradation product methylisothiocyanate (MIT) is very rapid, and MIT adsorption in coarse textured soils is low enough that most of the MIT will remain in the soil solution where it can be effective against the target organism (2). Large increases in dry wt of onion seedlings resulting from metham and dazomet treatments have been reported (7).

In our tests, the fumigants MBR, MBR-CP, CP and DD-MENCS generally resulted in the best growth and yield of onion transplants and reduced soil-borne pathogens below damaging levels. It is doubtful that transplant growers in southern Georgia will use MBR because of the high cost of the chemical and polyethylene. The fumigants MBR-CP, CP, and DD-MENCS appear most promising for controlling the fungal-nematode complex since a water seal instead of a polyethylene cover can be used after fumigant application.

Literature Cited

1. Abawi, G. S. and J. W. Lorbeer. 1972. Several aspects of the ecology of pathology of *Fusarium oxysporum* f. sp. *cepae. Phytopathology* 62:870-876.
2. Gerstl, Z., U. Mingelgrin, and B. Yoron. 1977. Behavior of vapam and methylisothiocyanate in soils. *Soil Sci. Soc. Amer. Proc.* 41:545-548.
3. Hendrix, F. F., Jr. and E. G. Kuhlman. 1965. Factors affecting direct recovery of *Phytophthora cinnamomi* from soil. *Phytopathology* 55:1183-1187.

4. Jaworski, C. A., B. B. Brodie, N. C. Glaze, S. M. McCarter, J. M. Good and R. E. Webb. 1973. Research studies on field production of tomato transplants in southern Georgia. U. S. Dept. Agric. Prod. Res. Rpt. 148.
5. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. *Plant Dis. Rptr.* 48:692.
6. Ko, W. and F. K. Hora. 1971. A selective medium for the quantitative determination of *Rhizoctonia solani* in soil. *Phytopathology* 61:707-710.
7. Lopez, C. R. and U. L. Gonzalez. 1973. The effects of fungicides and fumigants applied to soil of onion seedbeds. *Proc. Tropical Region, Amer. Soc. Hort. Sci.* 17:277-284.
8. McCarter, S. M. and R. H. Littrell. 1970. Comparative pathogenicity of *Pythium aphanidermatum* and *Pythium myriotylum* to twelve plant species and intraspecific variation in virulence. *Photopathology* 60:264-268.
9. ——————, C. A. Jaworski, A. W. Johnson and R. E. Williamson. 1976. Efficacy of soil fumigants and methods of application for controlling southern blight of tomatoes grown for transplants. *Phytopathology* 66:910-913.
10. Nash, S. M. and W. C. Snyder. 1962. Quantitative estimations by plant counts of propagules of the bean root rot *Fusarium* in field soils. *Phytopathology* 52:567-572.
11. Rhoades, H. L. 1969. Nematicide efficacy in controlling sting and stubby-root nematodes attacking onions in central Florida. *Plant Dis. Rptr.* 53:728-730.
12. Sumner, D. R. 1974. Ecology and control of seedling diseases of crucifers. *Phytopathology* 64:692-698.

J. Amer. Soc. Hort. Sci. 103(3):388–392. 1978.

Effects of Harvest Date and Ethylene Concentration in Controlled Atmosphere Storage on the Quality of 'McIntosh' Apples[1]

F. W. Liu
Department of Pomology, Cornell University, Ithaca, N.Y. 14853

Additional index words. Malus domestica, maturity, storage disorders

Abstract. **'McIntosh' apples (*Malus domestica* Borkh.) were harvested on 3 different dates and stored in controlled atmosphere (CA) storage with less than 1, 10 or 500 ppm ethylene. After 5 and 8 months of storage the fruits which had been harvested 5 to 6 days before the onset of the climacteric were less ripe and had less breakdown than fruits harvested after the onset of the climacteric. The fruits harvested at the preclimacteric stage had either comparable or slightly better eating quality but less red color than fruits harvested later. High levels of ethylene had slight but statistically significant negative effects on firmness and acidity of early harvested fruits judged by sensory evaluation after 5-month storage plus 7-day holding and by objective evaluation after 8-month storage plus 1- or 7-day holding at 21°C. An attempt was made to find a method to estimate the physiological age of preclimacteric apples. The minimum treatment time required for 10 ppm ethylene to trigger the onset of the climacteric at 21°C is judged to be promising.**

Recent studies have indicated that ethylene promotes the ripening and senescence of apples under CA and low pressure conditions (1, 3). 'McIntosh' apples harvested at the preclimacteric stage remained firmer and less ripe in CA with low ethylene levels than those in CA with high ethylene levels (4, 5, 6). Little information about the effects of harvest date and ethylene levels in CA on the eating quality of the fruits was reported by these authors. The main purpose of this study was to study these factors.

Since harvesting at the preclimacteric stage is reported to be a necessary condition for 'McIntosh' apples to be benefited by ethylene removal in CA (5), a way to predict the time of the onset of the climacteric is desirable. Methods to verify whether or not an apple is preclimacteric are available. They include measuring CO_2 production (9), measuring ethylene production (7, 9), and measuring internal ethylene concn of the harvested fruits.[2] However, methods for estimating the physiological age of preclimacteric apples in terms of how near they are to the natural onset of the climacteric are still lacking.

Materials and Methods

The effect of 3 harvest dates (Sept. 11, 17 and 22) and 3 levels of ethylene (<1, 10, and 500 ppm) in CA storage on the condition and quality of 'McIntosh' apples were tested with a factorial design. Each of the 9 treatments had duplicate samples for 5-month and 8-month assessments. Each sample contained 50 fruits harvested from 3 adjacent mature trees (16–17 fruits from each tree). The fruits were stored in 19-liter (5 gal.) jars (50 fruits/jar) in a continuous flow CA system at 2.2–3.3°C as previously reported (5). The atmospheres were maintained at 3% O_2 – 3% CO_2 and the appropriate concn of ethylene within ± 10% error. At the end of 5-month and 8-month storage the fruits were transferred from each jar to paper bags and placed in 21°C air. Evaluations of the condition and quality of the fruits were made 1 and 7 days after the transfer.

A 25-fruit sub-sample from each 50-fruit sample was used for each evaluation. The 25 fruits were displayed as a group for sensory evaluations by 6 or 7 experienced apple taste panelists. Each panelist visually evaluated the composite sample for surface color, ground color, gloss, and overall appearance. Then each panelist tasted 3 apples for firmness, sweetness, acidity, astringency, aroma, overall flavor and aroma, overall ripeness, and overall eating quality without considering the color and appearance factors. A 5-point scale was used for each item of the evaluation. For sweetness, acidity, and astringency evaluations a score of 3 represented adequacy; scores of less than 3 represented excess; and scores of more then 3 represented deficiency. For other items a lower score meant redder surface color, greener ground color, better appearance, firmer texture, less ripeness, or better flavor, aroma, and overall eating quality. After the sensory evaluation the fruits were

[1]Received for publication August 8, 1977.

[2]Dilley, D. R. undated. Warehouse procedure for determining ethylene in apple fruits – a fruit maturity indicator. Michigan State University Mimeograph.