Efficacy of Soil Fumigants and Methods of Application for Controlling Southern Blight of Tomatoes Grown for Transplants

S. M. McCarter, C. A. Jaworski, A. W. Johnson, and R. E. Williamson

Associate Professor, Department of Plant Pathology and Plant Genetics, University of Georgia, Athens 30602; Soil Scientist and Nematologist, respectively, Agricultural Research Service, United States Department of Agriculture; and Assistant Professor, Department of Agricultural Engineering, Coastal Plain Experiment Station, Tifton, Georgia 31794.

Financial support was provided through United States Department of Agriculture Cooperative Agreement No. 12-14-7001-518.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the United States Department of Agriculture, and does not imply its approval to the exclusion of other products that also may be suitable.

We thank the Georgia Plant Growers Association for providing plot land for the test and T. J. Ratcliffe for his assistance with disease evaluation.

Accepted for publication 13 January 1976.

ABSTRACT

MC CARTER, S. M., 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

Thirteen treatments involving six general purpose fumigants applied by different methods were evaluated for control of southern blight of field-grown tomato transplants caused by *Sclerotium rolfsii*. All chemicals significantly reduced disease incidence, but they varied greatly in effectiveness. Vapam was the most effective and gave better control when applied as a drench than when injected or incorporated into the soil. Chloropicrin (Picfume, injected), methyl bromide (MC-2), and Terr-O-Gel (injected under polyethylene) were moderately effective in reducing disease incidence. Vorlex (water-soluble formulation) significantly reduced southern blight incidence but gave poorer control than most of the other chemicals regardless of the method of application. Terr-O-Gel and Terr-O-Cide injected into the soil also were less effective than most other treatments.

Additional key words: soil-borne pathogens, *Lycopersicon esculentum*.

In earlier years, growers in southern Georgia who produced tomato transplants for shipment to the northern United States and Canada avoided southern blight caused by *Sclerotium rolfsii* Sacc., and some other soil-borne fungal and nematode pathogens by growing plants on recently-cleared land and by moving to new sites before major disease problems developed (7). Recently, the scarcity of noncropped land suitable for transplant production coupled with the need to increase yield and improve plant-size uniformity forced growers to establish permanent production sites on previously cultivated land. Some of the areas selected for this purpose have been planted previously to peanut, soybean, and other crops that are highly susceptible to *S. rolfsii*. Consequently, southern blight has become a major problem on some permanent production sites and is expected to increase in severity as tomato plants are produced repeatedly on the same land. The only control measures presently used by transplant growers are deep turning of organic debris to remove the food base that contributes to development of *S. rolfsii*, summer fallow, and crop rotation, where these measures are possible (3). Heavy losses sometimes occur despite the use of these cultural practices. We feel that soil treatment with a general purpose fumigant is the most promising method for controlling *S. rolfsii* and other soil-borne organisms that attack tomato transplants. However, little information is available on the use of these fumigants for production of field-grown vegetable transplants in the southern United States. The purpose of this work was to determine whether southern blight of tomato transplants could be controlled effectively with general purpose fumigants and to determine the most effective method of application where alternatives are possible.

MATERIALS AND METHODS

The test was conducted during the spring of 1975 near Tifton, Georgia, in a grower's field where *S. rolfsii* had caused heavy losses of tomato transplants during 1974. After land preparation in early March, soil beds (1.8 m × 13.7 m) were prepared and six soil fumigants were applied by various methods. Treatments were (i) Dowfume MC-2 [98% methyl bromide + 2% chloropicrin, 490 kg/hectare (ha)], released with hand applicators under 102-μm (4-mil) black polyethylene film; (ii) Picfume (chloropicrin, 196 liters/ha), injected into the soil; (iii) Terr-O-Gel 67 (67% methyl bromide + 31.75% chloropicrin), injected at the rate 168 kg/ha and covered with a 102-μm polyethylene film or at 280 kg/ha and left uncovered; (iv) Terr-O-Cide (30% chloropicrin + 70% 1,3-dichloropropene, 1,2-dichloropropane and related chlorinated hydrocarbons, 187 liters/ha), injected; (v) Vorlex (20% methyl isothiocyanate + 80% 1,2-dichloropropane, 1,3-dichloropropene and related chlorinated hydrocarbons mixed with an emulsifier to render the mixture water-miscible, 280 liters/ha), either applied as a drench in 6,500 liters of water, sprayed onto the soil surface and incorporated into the top 15-cm with a tractor-mounted rotary tiller, or injected into the soil; (vi) Vapam (sodium methyl dithiocarbamate), either applied at the rate of 374 and 748 liters/ha as a drench in 6,500 liters of water, as a drench at 748 liters/ha in 6,500 liters of water and incorporated into the top 15-cm of soil with a rotary tiller, or at 748 liters/ha injected into the soil; and (vii) check (no chemical treatment). All chemical injections were made 15-20 cm deep with a tractor-mounted fumigator with injection chisels placed 20 cm apart. Beds were reshaped and the soil surface pressed firm simultaneously with chemical injection. Additionally, all chemicals except those applied under polyethylene (MC-2 and Terr-O-Gel) were sealed in with approximately 1.3 cm of water applied immediately after chemical application with a solid-set sprinkler irrigation system. All chemicals except Dowfume MC-2 were applied 4-5 weeks before seeding. Fumigant MC-2 was applied 15 days before seeding and the polyethylene cover was removed 3 days after chemical application. The 13 treatment combinations described above were arranged in a randomized complete block design with four replications, each consisting of three beds. All plots were aerated with a tractor-mounted rotary tiller 1 day before seeding.

Tomato (*Lycopersicon esculentum* Mill. 'Campbell 28') seeds (98/m) were planted 23 April with a Stanhay seeder in four rows 0.36 m apart on each bed. The seedbed was fertilized with 54, 48, and 45 kg/ha of N, P, and K, respectively, applied as complete fertilizer placed 2.5 cm under the seed in an 8-cm band at planting. Plants were side-dressed with a total of 35 kg/ha of N applied as calcium nitrate, 2 and 4 weeks after seeding. Diphenamid (*N,N*-dimethyl-2-2-diphenyl acetamide, Enide, 6.7 kg/ha) was applied for weed control at seeding. Sprinkler irrigation was used as needed to promote rapid seed germination and normal growth. Plant height was regulated by scheduled clipping with a tractor-mounted rotary mower as plants reached marketable size (8). Carbaryl (1-napthyl methylcarbamate, Sevin 80%, 0.7 kg/ha on young seedlings and 1.6 kg/ha on older seedlings) was used for routine insect control. Maneb (manganese ethylene bisdithiocarbamate, Manzate D, 0.9 kg/ha on young seedlings and 1.7 kg/ha on older plants), or chlorothalonil (Bravo 6F, 1.2 liters/ha on young plants and 2.3 liters/ha on older plants) was applied at 5- to 7-day intervals for control of foliar pathogens. Methomyl [S-methyl-*N* ((methylcarbamoyl) oxy) thioacetamidate, Lannate 90%, 0.56 kg/ha] was used as needed for lepidopterous insect control.

Incidence of southern blight was recorded as plants reached marketable size. Final disease severity was determined by counting disease loci that occurred in the center bed of each three-bed plot 55 days after seeding or 10 days after the normal harvest period. A disease locus consisted of an area where one or more plants were killed by *S. rolfsii*. Where extended row lengths were killed, each 15-cm section, with approximately 12 plants, was considered to be one infection locus.

RESULTS

Plants in all plots remained relatively free of southern blight as well as other major diseases until they reached marketable size in early June. Plants apparently were resistant to attack by *S. rolfsii* while they were growing vigorously. However, as they were placed under stress by depletion of soil nutrients and as temperature increased, an unusually and uniformly high incidence of southern blight occurred in nontreated plots. More than 70 percent of the approximately 4,000 plants in some of the 1.8 × 13.7-m nontreated plots either were killed by *S. rolfsii* or had stem lesions near the soil line. In the more severe cases, a mat of mycelium with developing sclerotia developed at the soil line on each plant throughout a given row.

All of the chemical treatments significantly reduced disease severity (Table 1). However, the effectiveness of

TABLE 1. Effect of several soil fumigants on the incidence of southern blight (caused by *Sclerotium rolfsii*) on tomato transplants

Fumigant	Rate (liters or kg per hectare)	Application method[a]	Infection loci[b] (mean no.)
Vapam	748 liters	Drench	3.8 z[c]
Vapam	748 liters	Drench and incorporated	19.5 y
Vapam	374 liters	Drench	21.5 xy
Chloropicrin (Picfume)	196 liters	Injected	26.8 w-y
Methyl bromide (MC-2)	490 kg	Under polyethylene	37.0 wx
Terr-O-Gel	168 kg	Injected, covered with polyethylene	37.0 wx
Vapam	748 liters	Injected	41.3 w
Terr-O-Gel	280 kg	Injected	62.3 v
Vorlex	280 liters	Sprayed and incorporated	72.8 uv
Vorlex	280 liters	Injected	81.8 u
Terr-O-Cide	187 liters	Injected	89.0 u
Vorlex	280 liters	Drench	119.5 t
Check (no chemical)	. . .	. . .	153.4 s

[a]Drench treatments were applied in 6,500 liters of water per hectare. Injections were made 15- to 20-cm deep with a tractor-mounted fumigator with shanks 20 cm apart. Chemicals were incorporated 15-cm deep with a tractor-mounted rotary tiller.

[b]Each value is the mean of four replications. Data were taken on the center bed of three-bed plots. A disease locus consisted of an area in which one or more plants had died or each 15-cm length of row where extended areas were killed.

[c]Values followed by the same letter are not significantly different as determined by Duncan's new multiple range test ($P = 0.05$).

different chemicals in controlling southern blight ranged from poor to excellent, and the rate and method of application affected the performance of individual chemicals. Vapam was the most effective chemical evaluated, especially when applied to the soil as a drench at the rate of 748 liters/ha in 6,500 liters of water followed by application of 1.3 cm of water by sprinkler irrigation. Treatments of Vapam applied as a drench (748 liters/ha) incorporated by rototilling, and Vapam applied at the rate of 374 liters/ha as a drench were less effective than the 748-liter drench, but were more effective than the 748-liter Vapam injection treatment. Chloropicrin (Picfume, injected), methyl bromide (MC-2), and Terr-O-Gel (168 kg/ha injected and covered with polyethylene) were moderately effective in controlling southern blight. Terr-O-Gel at 168 kg/ha injected and covered was more effective than the same chemical at 280 kg/ha injected but left uncovered. The three Vorlex treatments and Terr-O-Cide were generally less effective than the other chemicals. Vorlex was more effective when sprayed onto the soil surface and incorporated or when injected than when applied as a drench.

DISCUSSION

Sclerotium rolfsii has a wide host range, and many biological, cultural, and chemical control measures have been evaluated on various crops (3, 6, 18). Work on chemical control has involved the use of fungicides, nematicides, and general purpose fumigants (3, 6, 9). We were particularly interested in the effectiveness of general-purpose fumigants rather than specific fungicides for controlling southern blight on tomato transplants as other soil-borne fungi and nematodes must be controlled in some permanent production sites. Our results indicate that certain general purpose fumigants may be feasible for controlling southern blight on tomato transplants and that performance will be affected by the rate and method of application.

Vapam was most effective when applied at 748 liters/ha as a drench with a water seal. We believe that the Vapam drench was more effective than the soil incorporation and injection applications because the drench provided a high concentration of chemical in the top 6-cm of soil where *S. rolfsii* is most active (3). Vapam was more effective in our test than has generally been reported by others (2, 16, 17). Our favorable results may have been due to the shorter growing season for tomato transplants compared with other crops, or to different methods of application. Young (16) found that Vapam sprayed onto the soil and covered delayed appearance and decreased incidence of southern blight on tomatoes grown for fruit production; however, 31 percent of plants in treated plots died by 87 days after transplanting. In another test (17), Vapam provided good control of southern blight on tomatoes until the end of the market season. Aycock (2) reduced *S. rolfsii* damage on Dutch iris with Vapam applied at 234 and 468 liters/ha but yield was not increased. Rates of 936 and 1,404 liters/ha were phytotoxic in his tests. In our tests Vapam at 748 liters/ha caused some stunting of tomato seedlings early in the growing season. However, rapid recovery occurred and, at harvest, plants from Vapam-treated plots were more vigorous than plants from nontreated plots or plots treated with other chemicals.

In our tests methyl bromide (Dowfume MC-2), chloropicrin (Picfume), and a methyl bromide-chloropicrin combination (Terr-O-Gel) were only moderately effective in controlling southern blight and gave a poorer response than would be suggested by other reports (1, 4, 5, 10, 12, 13, 15). However, our results must be considered in relative terms because some recontamination of treated areas probably occurred through water and soil movement from adjacent nontreated plots. Heavy spring rains (14.5 cm during last 2 weeks of March and 24.4 cm in April) occurred after the treatments were applied in 1975. Both methyl bromide and chloropicrin are highly effective against *S. rolfsii* and most other soil-borne fungi (1, 4, 5, 10, 12, 13, 15). Schmitt (15) reported chloropicrin to be the most effective of 12 volatile fumigants that he evaluated against *S. rolfsii* and seven other fungi. Chloropicrin killed all mycelium of *S. rolfsii* in soil at 71 liters/ha when the soil was covered and at 398 liters/ha when sealed with water. This chemical is also highly effective against sclerotia of *S. rolfsii*, especially when the gas is confined in the soil (1, 4, 10). Chloropicrin also gave good control of *S. rolfsii* on annual larkspur in the field (10) and on sugarbeet seedlings in the greenhouse (1).

In Florida tests (9), Vorlex and several other fumigant mixtures provided control of southern blight of tomatoes when treated soil was covered with plastic, but no significant control when soil was left uncovered. Vorlex generally reduced incidence of southern blight in our tests but not enough to be considered economically important on transplants. Soil fumigation with D-D (1,3-dichloropropene and 1,2-dichloropropane) increased the incidence of southern blight in tomatoes grown for fruit production in Georgia (14).

Additional work is in progress to determine the best general purpose fumigant or combination of chemical treatments and a practical method of application for controlling several soil-borne disease fungi and nematodes on vegetable transplants. Tomato transplants are seeded in early spring. Since several of the fumigants under consideration have a waiting period of 3-4 weeks, soil treatment in the fall or early winter may be necessary to allow early seeding and to avoid phytotoxicity (11). Recontamination of treated soil by surface movement of water and soil is expected to be one of the major problems that must be overcome.

LITERATURE CITED

1. ABEYGUNAWARDENA, D. V. W., and R. K. S. WOOD. 1957. Effect of certain fungicides on Sclerotium rolfsii in the soil. Phytopathology 47:607-609.
2. AYCOCK, R. 1959. Soil treatments for control of Sclerotium rolfsii in Dutch iris. Plant Dis. Rep. 43:283-286.
3. AYCOCK, R. 1966. Stem rot and other diseases caused by Sclerotium rolfsii. N. C. Agric. Exp. Stn. Tech. Bull. 174. 202 p.
4. DAVEY, A. E., and L. D. LEACH. 1941. Experiments with fungicides for use against Sclerotium rolfsii in soils. Hilgardia 13:523-547.
5. GODFREY, G. H., and P. A. YOUNG. 1943. Soil fumigation for plant disease control. Tex. Agric. Exp. Stn. Bull. 628. 40 p.

6. HARRISON, A. L. 1961. Symposium on Sclerotium rolfsii: control of Sclerotium rolfsii with chemicals. Phytopathology 51:124-128.
7. JAWORSKI, C. A., B. B. BRODIE, N. C. GLAZE, S. M. MC CARTER, J. M. GOOD, and R. E. WEBB. 1973. Research studies on field production of tomato transplants in southern Georgia. U.S. Dep. Agric. Prod. Res. Rep. 148. 58 p.
8. JAWORSKI, C. A., R. E. WEBB, G. E. WILCOX, and S. A. GARRISON. 1969. Performance of tomato cultivars after various types of transplant clipping. J. Am. Soc. Hortic. Sci. 94:614-616.
9. JONES, J. P., A. J. OVERMAN, and C. M. GERALDSON. 1966. Effect of fumigants and plastic film on the control of several soil-borne pathogens of tomato. Phytopathology 56:929-932.
10. MC CLELLAN, W. D. 1947. Efficacy of certain soil fumigants and fertilizers against crown rot of annual larkspur caused by Sclerotium rolfsii. Phytopathology 37:198-200.
11. MC CLELLAN, W. D., J. R. CHRISTIE, and N. L. HORN. 1949. Efficacy of soil fumigants as affected by soil temperature and moisture. Phytopathology 39:272-283.
12. MUNNECKE, D. E., and J. FERGUSON. 1953. Methyl bromide for nursery soil fumigation. Phytopathology 43:375-377.
13. MUNNECKE, D. E., and D. L. LINDGREN. 1954. Chemical measurements of methyl bromide concentration in relation to kill of fungi and nematodes in nursery soil. Phytopathology 44:605-606.
14. RANKIN, H. W., and J. M. GOOD. 1959. Effect of soil fumigation on the prevalence of southern blight of tomatoes. Plant Dis. Rep. 43:444-445.
15. SCHMITT, C. G. 1949. Comparison of volatile soil fungicides. Phytopathology 39:21 (Abstr.).
16. YOUNG, P. A. 1956. Chemical tests to control southern blight of tomato. Tex. Agric. Exp. Stn. Prog. Rep. 1893. 3 p.
17. YOUNG, P. A. 1960. Controlling southern blight of tomato with chemicals and crop rotation. Phytopathology 50:578 (Abstr.).
18. WELLS, H. D., D. K. BELL, and C. A. JAWORSKI. 1972. Efficacy of Trichoderma harzianum as a biocontrol of Sclerotium rolfsii. Phytopathology 62:442-447.