Factors Affecting Efficacy of Metham Applied Through Sprinkler Irrigation for Control of Allium White Rot

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ABSTRACT

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In the laboratory, metham applied to soil columns as a drench killed 50% of the sclerotia of *Sclerotium cepivorum* at 16–17 μg/ml and 95% of the sclerotia at 50 μg/ml. Maximum kill of sclerotia by metham was obtained from 12 to 24 hr after application. Soil pH had little effect on the efficacy of metham, but at low soil temperature (5 C), more time was required to kill sclerotia. In soil columns, only 55% of the sclerotia were killed in the top 2 cm of soil, whereas at greater depths, nearly 100% of the sclerotia were killed. High concentrations of metham applied to soil columns were made ineffective by a subsequent drench of water. Metham applied through sprinkler irrigation at 234 L/ha with 2.5 cm of water provided 94% control of white rot on bunching onions and 30% control on leeks in field tests. The poor level of control on leeks may have been due to rain (31 mm) that fell on the field after metham application.

Metham (Vapam) applied to soil decomposes to methyl isothiocyanate (MIT), which is highly toxic to fungi (9,13). Metham is usually applied to fields by soil injection 15–20 cm deep with shanks spaced 20–25 cm apart. With this method, metham must be applied at uneconomically high rates of 700–935 L/ha (75–100 gal/acre) at a cost of $1,148–1,533/ha ($465–620/acre). At these rates, metham has not consistently provided satisfactory control of soilborne diseases.

Recent work in Israel (4,5) has shown that metham can be applied through sprinkler-irrigation systems with water at rates as low as 234–500 L/ha (25–53 gal/acre). At this rate, excellent disease control is obtained (4,7,8). More recently, Sumner (11) reported complete kill of propagules of *Rhizoctonia solani* and *Pythium* species in the field by applying metham through sprinkler irrigation at 468 L/ha (50 gal/acre). Adams et al (3) reported 90% control of Sclerotinia lettuce drop with metham at 234 L/ha (25 gal/acre) applied in a similar manner. Metham applied through sprinkler irrigation at rates as low as 234 L/ha (25 gal/acre) may provide economical control of a number of soilborne diseases and weeds and probably soil insects and nematodes.

The purpose of this investigation was to study factors that would affect the practical application of metham for control of Allium white rot caused by *Sclerotium cepivorum* Berk.

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MATERIALS AND METHODS

Laboratory experiments. The *S. cepivorum* strain used was isolated from bunching onions grown in New Jersey. The fungus was grown on sand-cornmeal (5% cornmeal) at 20 C for 6 wk. The sand-cornmeal medium was mixed into natural soil (Rumford loamy sand [RLS], pH 6.4) and stored at 5 C until needed. For each test, infested soil was diluted to 10% with fresh uninfested RLS.

Soil infested with *S. cepivorum* was placed in plastic soil columns 3 cm in diameter and 20 cm long. The bottoms of the columns were plugged with a rubber stopper that had a small hole for drainage. Each column contained about 150 g of soil. The amount of metham solution applied to each column was sufficient to allow an excess to drain from the bottom of each tube. Except where indicated, the soil was removed from the columns after 4 days and mixed, then sclerotia of *S. cepivorum* were retrieved from the soil (1). The sclerotia were surface-sterilized in 0.5% NaClO for 5 min and 20 sclerotia (10 sclerotia per 9-cm petri dish) were placed on acidified potato-dextrose agar containing rose bengal (33 μg/ml). After 2 wk at 20 C, the number of viable sclerotia was determined as evidenced by development of *S. cepivorum* colonies.

In other experiments, the 3-cm-diameter columns were cut into rings 2 cm long. Ten of these rings were taped together to form a segmented column 20 cm long and the column was attached to the top of the columns used before. The lower portion of this column was filled with uninfested RLS, the upper segmented portion of the column was filled with *S. cepivorum*-infested RLS, and the top 2-cm ring in each column contained no soil. In these experiments, sclerotia were recovered from each 2-cm ring of the segmented portion of the column and plated out on the medium. The treatments and the experiments were performed at least twice with four replicates.

Field tests. In the summer of 1981, production fields in three farms in Vineland, NJ, were treated with metham for control of white rot. The three fields varied from 25 × 100 to 27 × 200 m. Soil texture in these fields was sandy loam or gravelly sandy loam and the pH ranged from 6.2–6.8. On each of these farms, the farmers placed irrigation lines in the field in their usual manner. Four sheets of clear plastic (8 × 8 m) were placed in each field to serve as untreated control plots and were removed from the field immediately after treatment application. The fields were treated with metham at 234 L/ha (25 gal/acre) with about 25 mm (1 in.) of water between 25 June and 22 July 1981. An injection pump (model L-905, John Blue Co., Huntsville, AL 35807) was used to inject metham into the irrigation line during the 2- to 3-hr irrigation period. Before irrigation, 12 cans were placed on the field to collect irrigation water to determine the amount and uniformity of the irrigation treatment. Soil samples were taken 1–2 days after the metham application from each of the four untreated areas and from four adjacent treated areas. Each soil sample was a composit of 10 core samples (2 cm diam.) 15 cm deep. The soil samples were assayed later for the number and viability of sclerotia of *S. cepivorum*. In each field, there were four untreated control plots and four adjacent treated plots in a randomized complete block design.

On 24 July 1981, 4 wk after metham application, the field on the Nurge farm was disked and planted with leek seedlings. The field was harvested on 26 April 1982. From each plot, three rows 6.1 m long were harvested and each leek plant was rated healthy or diseased and according to whether it was a marketable plant. On 11 September 1981, 7 wk after metham application, the field on the Flaim farm was disked, 1.6-m beds formed, and Beltsville bunching onions planted. The field was harvested on 19 May 1982. In each plot, two rows 4.6 m long were harvested and each plant was rated either healthy or diseased. To estimate yield in the treated area on this farm, the farmer harvested four rows 12.2 m long and bunched, washed, and packed the bunching onions in his usual manner. The field on the Russo farm was not planted with bunching onions as originally planned, and thus only data from the soil samples could be obtained.

RESULTS

Laboratory experiments. In the column tests, an LD_{50} was obtained at 16–17 μg/ml of metham and an LD_{95} at about 50 μg/ml (Fig. 1). In other tests (Fig. 2) with metham at 100 μg/ml, only 95% of the sclerotia were killed. It was found that 12–24 hr were required to obtain maximum kill of the sclerotia when metham was applied to the soil columns at 100 μg/ml (Fig. 2). Within 7 hr, 50% of the sclerotia were killed.

Temperature had a pronounced effect on the efficacy of metham. At 20 C, 86% of the sclerotia were killed within 1 day. At 10 and 15 C, it took 2 days to kill about 100% of the sclerotia, whereas it took 3 days at 5 C. Soil pH had little effect on the efficacy of metham in soils ranging from 4.4–10.2.

The degree of kill of the sclerotia in segmented columns depended on soil depth. When 20 ml of metham was applied to these columns at 100 μg/ml and the soil at various depths was assayed 3 days later, about 100% of the sclerotia were killed at depths of 2–10 cm. At depths of 0–2 cm, only 45% of the sclerotia were killed, whereas 40% were killed at depths of 12–14 cm. At depths greater than 14 cm, few sclerotia were killed (Table 1).

When 5 ml of metham at 1,000 μg/ml was applied to the segmented columns followed by 50 ml of water, there was no significant kill of the sclerotia to a depth of 14 cm. At depths of 14–18 cm, however, significant ($P = 0.01$) kill of sclerotia was obtained (Table 2).

Metham was applied at various concentrations to the soil in the middle segments of the columns (8–10 cm deep) to determine movement of metham or MIT in soil. Four days after the metham treatment, sclerotia from each segment of the column were isolated and their viability determined. Results indicated that at 800 μg/ml or less, there was very little effective movement of metham or MIT. At rates of 1,200 μg/ml or higher, metham or MIT moved 4 cm or more both up and down in the columns at levels high enough to kill a high percentage (>80%) of the sclerotia.

Field experiments. Metham was applied to the three fields with 25–30 mm of water through the sprinkler-irrigation systems. The concentration of metham in the irrigation water was calculated to be 300–355 μg a.i./ml. Uniformity of the irrigation treatment on each field was rather poor, especially on the Nurge farm (Table 3). A significant amount of rain fell on two of the fields the night metham was applied (Table 3). In these two fields, metham was less effective in killing sclerotia of *S. cepivorum* than in the field where no rain fell (Table 3).

At harvest, the four untreated plots in each field were readily discernible. In the leek field, it was obvious that there was a very high incidence of white rot caused by *S. cepivorum*, whereas in the bunching onion field, there was a very poor plant stand and many plants were obviously diseased. In the treated areas of both fields, the plant stand was good and nearly all plants appeared healthy.

In the leek field, there were slightly fewer plants in the control plots than in the metham-treated plots (Table 4). Incidence of white rot in the control plots was 100%, whereas that in the treated plots was 70%. About 50% of the plants in the treated portion of the field were marketable, whereas only 8% of the plants in the untreated area were suitable for harvest (Table 4). In the bunching onion field, there were significantly fewer plants in the control plots than in the treated plots (Table 4). In the control plots, incidence of white rot was about 49%, whereas that in the treated plots was only 3% (Table 4). In both fields, the yield in the metham-treated plots was about eight times that in the control plots.

DISCUSSION

The time required for conversion of metham to MIT in soil varies with temperature, moisture, soil type, and pH (4,6,9,10,12,13), but the conversion usually is nearly complete within 10 hr. The time required for complete kill of the sclerotia of *S. cepivorum* in our soil experiments (12–24 hr) could represent the time required for the production of MIT. Soil pH has been reported to affect the production of MIT in soil treated with metham (12,13) but our results did not confirm this. Low soil temperature, however, had an adverse effect on the conversion of metham to MIT as detected by recovery of viable sclerotia of *S. cepivorum*. Even at temperatures as low as 5 C, metham was effective in killing sclerotia.

Metham applied to the segmented columns at a concentration high enough to kill 95% or more of the sclerotia killed nearly all the sclerotia at depths of 2–10 cm. Only 45% of the sclerotia in the soil at depths of 0–2 cm were killed, which may have been due to the loss of MIT to the atmosphere. Loss of MIT could have a significant effect on control of some

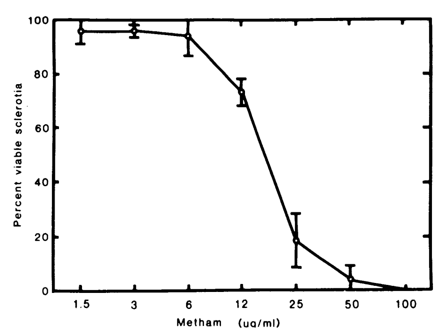

Fig. 1. Effect of metham concentrations on viability of *Sclerotium cepivorum* sclerotia in soil. Vertical bars indicate the standard deviation ($n = 4$). There was 95 ± 7% viable sclerotia in the water-treated control.

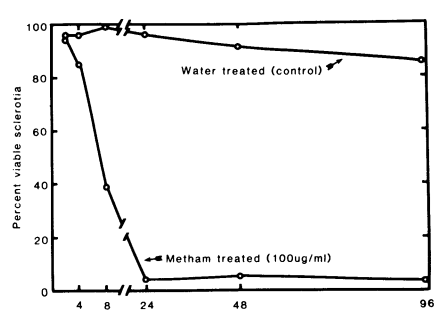

Fig. 2. Effect of time on the toxicity of metham to sclerotia of *Sclerotium cepivorum* in soil.

Table 1. Effect of soil depth on the efficacy of metham on sclerotia of *Sclerotium cepivorum* in soil columns 3 days after treatment[y]

Depth in column (cm)	Viable sclerotia (%)
0–2	55 b[z]
2–4	0 a
4–6	0 a
6–8	1 a
8–10	0 a
10–12	22 a
12–14	59 b
14–16	80 bc
16–18	78 bc
Control	95 c

[y] Twenty milliliters of metham at 100 μg/ml was applied to the soil columns.

[z] Values followed by the same letter are not significantly different ($P = 0.01$) according to Duncan's multiple range test.

Table 2. Effect of high concentration of metham applied to soil columns followed by a drench of water on the survival of sclerotia of *Sclerotium cepivorum* 4 days after treatment[x]

Depth in column (cm)	Viable sclerotia (%)
0–2	94 a[y]
2–4	92 a
4–6	90 a
6–8	85 a
8–10	88 a
10–12	89 a
12–14	81 a
14–16	20 b
16–18	4 c
Metham control[z]	20 b
Water control	95 a

[x] Five milliliters of metham at 1,000 μg/ml was applied to the soil columns followed by 50 ml of water.

[y] Values followed by the same letter are not significantly different ($P = 0.01$) according to Duncan's multiple range test.

[z] Fifty milliliters of metham at 100 μg/ml was applied to these soil columns.

Table 3. Amount of irrigation and rain, inoculum density of *Sclerotium cepivorum*, and percentage of sclerotia killed by metham applied through sprinkler irrigation at 234 L/ha

Farm (crop)	Irrigation treatment Average (mm)	Irrigation treatment Range (mm)	Rainfall after treatment (mm)	Viable sclerotia in untreated plots (sclerotia/100 g of soil)	Sclerotia killed by metham treatment (%)
Nurge (leeks)	25	6–56	31	3.2	86
Flaim (bunching onions)	30	16–42	18	1.5	83
Russo (not planted)	29	15–46	0	1.1	100

Table 4. The effect of metham applied through sprinkler irrigation at 234 L/ha on incidence of white rot, crop yield, and value of yield

Crop	Treatment	Total no. plants/plot	Marketable plants/plot (%)	White rot (%)	Estimated no. crates/ha	Value of yield[a] ($/ha)	Increased profit[b] ($/ha)
Leeks	Control	120	8	100	153	981	...
	Metham	147	51	70	1,082	6,936	5,572
Bunching onions	Control	203	60	49	897	4,449	...
	Metham	877	97	3	7,598	37,686	32,854

[a] Values are based on the average price of $6.41 for leeks and $4.96 for bunching onions per crate received by farmers in southern New Jersey in 1981.
[b] Profit values were determined on the value of the metham-treated yield minus the value of the yield from the control minus the cost of the metham ($383/ha).

diseases if the treated field were not disked between application of metham and planting of the crop. By disking, the inoculum density of the pathogen in the top 2 cm of soil would be diluted with treated soil containing fewer viable propagules.

When metham was applied to soil columns at a concentration 10 times that needed to kill sclerotia and carried to a depth of 14–18 cm with the addition of water (Table 2), the sclerotia above this depth (0–14 cm) were unaffected by metham. Farmers may want to apply a concentrated solution of metham to their fields through an irrigation system and water it into the soil, but such an application method is much less effective in killing plant pathogens than metering metham into the irrigation system over a period of 1–3 hr.

In the field tests, metham at 234 L/ha (25 gal/acre) killed 100% of the sclerotia of *S. cepivorum* on the Russo farm, 86% on the Nurge farm, and 83% on the Flaim farm, as indicated by the analysis of soil samples collected 2 days after the metham treatments were applied. Disease control on leeks at the Nurge farm was only 30% compared with 94% on bunching onions at the Flaim farm. Leeks are more resistant than bunching onions to white rot (2). We suspect the poor level of disease control on leeks was due to the severe rain storm (31 mm) at the Nurge farm the night metham was applied to the field because laboratory studies (Table 2) showed that metham can be leached into the soil, reducing its effectiveness. Another possible explanation for the poor disease control on this farm is the nonuniformity of the irrigation treatment. The field received an average of 25 mm of irrigation water containing metham; however, some areas received as little as 6 mm and other areas received as much as 56 mm (Table 3).

The cost of metham at 234 L/ha (25 gal/acre) is about $383/ha ($155/acre). This cost represents about 60 crates of leeks or 77 crates of bunching onions. The application cost of this soil fumigant is much less than the conventional soil-injection method in terms of dollars, labor, energy, and time. In addition, one field test has shown that this method and rate of application provides significantly better disease control and increased crop yield at less cost to the farmer (3) than another soil fumigant applied by the conventional soil-injection method.

When applying metham to fields through sprinkler-irrigation systems, it is important to include the amount of water to be applied with the metham. For example, 234 L of metham (32.7%) applied with 2.5 cm of water provides a concentration of metham in the soil at about 350 μg/ml. If the same amount of metham is applied with twice as much water, the concentration of metham would be only 175 μg/ml. Under field conditions, this may not be sufficient to provide a high percentage of kill of the target organism. Thus, it is important to make recommendations of metham when applied through irrigation in terms of liters per hectare per centimeter of water. The amount of water applied with the metham should vary depending on the soil type and the depth of soil to be treated. Muck soils will require more water than sandy soils. If one doubles the amount of water to be applied because of soil type or because the target pest survives at greater than normal depths (20–25 cm) one should also double the amount of metham applied.

Because of results reported here and previously (3), many farmers in southern New Jersey are now using sprinkler irrigation to apply metham to control Allium white rot, lettuce drop, and many other soilborne pests.

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