Soil Fumigation with Dazomet and Methyl Bromide for Control of Corky Root of Iceberg Lettuce

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ABSTRACT

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In microplots (1.5 × 2 m) at Davis, CA, soil fumigation with dazomet (450 kg/ha) and methyl bromide + chloropicrin (500 kg/ha) controlled corky root of iceberg (crisphead) lettuce (*Lactuca sativa*) caused by *Rhizomonas suberifaciens*. At harvest, the plant disease scores were 25–50% lower and shoot and root dry weights were 40 and 33% higher, respectively, in fumigated plots than in nonfumigated controls. Similar results were obtained in a larger field experiment at Salinas, CA, in which dazomet (200 or 400 kg/ha) and methyl bromide + chloropicrin (400 kg/ha) were compared with a nonfumigated control. One month before harvest, plants from control plots had disease severities 3.6 times greater than plants from plots treated with dazomet at 400 kg/ha or methyl bromide + chloropicrin at 400 kg/ha. Head weights (untrimmed) from plants grown in plots treated with dazomet at 400 kg/ha and methyl bromide + chloropicrin at 400 kg/ha were 39 and 52% higher, respectively, than those from control plots. Application of dazomet at 200 kg/ha resulted in insignificant control of corky root.

Corky root, caused by *Rhizomonas suberifaciens* (15), is an important disease of iceberg (crisphead) lettuce (*Lactuca sativa* L.) in the coastal valleys of California and in Florida, Wisconsin, and New York (12). Resistant cultivars are available for the northern (10) and southeastern (4) production areas in the United States. However, all commercial cultivars adapted to California are very susceptible to the disease (2).

Cultural practices such as use of cover crops, increased bed height, and minimal irrigations have been recommended (8) but are only partially effective. Better control can be obtained by preplant soil fumigation with a liquid mixture of methyl bromide + chloropicrin under pressure (8). However, this practice has severe limitations, such as the need to seal the gases in the soil with polyethylene sheets (tarps), the toxicity of the gases to the applicator, and the perceived hazards associated with bromide residues in tissue and soil (9). Use of products that yield methyl isothiocyanite (MIT) in soil such as metham sodium and dazomet are not associated with these drawbacks. Use of tarps is not required, and toxic residues are not known to remain in soils (6). Both products are less toxic to the applicator (6). Dazomet is a granular product that may be applied with a simple lime spreader and incorporated with a rotovator.

The efficacy of metham sodium (8) and 1,3 DP plus MIT (Vorlex), but not 1,3 DP (Telone) alone, for control of the disease was reported even before the causal agent of corky root had been identified (3). Although dazomet has not been reported to control corky root of lettuce, this product does control crown gall (1) caused by *Agrobacterium tumefaciens*, which probably belongs to the same super family as *R. suberifaciens* (15).

The purpose of this study was to find a safer and less expensive alternative to methyl bromide + chloropicrin for controlling corky root of lettuce and to compare the effects of dazomet and methyl bromide + chloropicrin treatments on the severity of the disease and the growth of the plant.

MATERIALS AND METHODS

Microplot experiments. Eight microplots (1.5 × 2 m) were constructed with fiberglass rings (14) at Davis, CA, where corky root of lettuce has not been reported. Soil was not fumigated before the first experiment (spring 1988), but, 8 wk before planting the fall crop, all plots were treated with 500 kg/ha methyl bromide + chloropicrin (53%:47% v/v ratio, liquid mixture under pressure) to reduce populations of *R. suberifaciens* remaining from the spring infestation.

Roots for microplot infestation were collected from a severely diseased field in Salinas, CA, known to contain *R. suberifaciens*. Each plot was sprinkled with 0.9 kg and 0.3 kg (spring and fall, respectively) of blended roots diluted in 10 L water. The slurry was allowed to partially dry for 2 hr, was mixed into the soil with a rake, and then was incorporated to a depth of 20 cm with a rotovator. The soil was shaped into beds, moistened for fumigation, and covered with 0.15 mm thick clear plastic. Three or four weeks after soil infestation, fall or spring, respectively, three plots were sprinkled with 450 kg/ha dazomet (Basamid Granular, Hopkins Agricultural Chemical Co., Madison, WI). The granules were incorporated to a depth of 20 cm with a rotovator and the plots were recovered with clear plastic. One or four days later in the fall or spring, respectively, three plots were injected with 500 kg/ha methyl bromide + chloropicrin (3:1 v/v ratio) through the plastic. Control plots were also covered with plastic. Plots were arranged in a randomized, unbalanced, incomplete block design with three dazomet plots, three methyl bromide + chloropicrin plots, and two untreated control plots.

Two or three weeks after fumigation, in the fall or spring, respectively, Salinas lettuce was seeded in rows 0.5 m apart on each bed. One month later, the plants were thinned to a distance of 30 cm between plants. Standard fertilization, irrigation, and pest control practices were used (13). The incidence of corky root on seedlings thinned from the rows was recorded. At harvest, the roots were scored for disease severity with a 0–6 scale (11,14), and untrimmed head fresh weight and head and root dry weights were recorded. For dry weights, tissue was dried in a forced air oven at 80 C for 96 hr before weighing.

Large scale field experiment. A field experiment was conducted at the USDA experiment station in Salinas in Chualar loam soil naturally infested with *R. suberifaciens*. The field had been planted to lettuce in each of the previous 2 yr, and *R. suberifaciens* had been isolated from diseased roots (13).

Triticale, grown as a winter cover crop before the fumigation experiment, was removed from the field. The field was tilled with an offset disk to a depth of 15–20 cm, 2 mo before planting, and fertilized with 80 kg of triple super phosphate per hectare. Wireworms (*Limonius* sp.) were controlled with ethoprop (Mocap G, Rhone-Poulenc Inc., Mt. Pleasant, TN) at 22.4 kg/ha.

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Four treatments (nonfumigated, methyl bromide + chloropicrin and two levels of dazomet) were arranged in a randomized complete block design with four replications. Each plot was composed of four 1- × 24-m beds. The plots were separated by 1-m-wide paths. Methyl bromide + chloropicrin (57:43% v/v liquid mixture under pressure) was injected under the tarp and 20 cm into the soil at a rate of 400 kg/ha by a commercial applicator 22 days before the projected planting date. Dazomet was sprinkled on the soil at 200 and 400 kg/ha, rotovated to 15 cm, rolled, and sprinkler irrigated to seal the soil surface 16 days before planting. Tarps were removed (from methyl bromide + chloropicrin plots) and the entire field was rotovated to allow fumigants to escape 10 days before planting.

Iceberg lettuce cv. Salinas was planted in two rows (50 cm apart) on each bed, thinned 43 days later to a spacing of 30 cm between plants, and harvested 74 days after planting. Immediately after planting, the herbicide pronamide (Kerb, Rohm and Haas, Philadelphia, PA) was applied at 4.5 kg f.p./ha. The crop was sprinkler irrigated with approximately 1–2 cm of water weekly, and side dressed with 250 kg of ammonium nitrate per hectare 27 days before harvest. Lepidopteran insects were controlled with applications of *Bacillus thuringiensis* var. *kurstaki* (Javelin, Sandoz, Des Plaines, IL) at 0.5 L f.p./ha.

At thinning, shoot fresh weights and disease severity of five plants per plot were recorded. Disease severity was measured using a 1–12 Horsfall-Barratt scale based on percentage area of taproot corked (1 = 0%, 2 = 0–3%, 3 = 3–6%, 4 = 6–12%, 5 = 12–25%, 6 = 25–50%, 7 = 50–75%, 8 = 75–87%, 9 = 87–94%, 10 = 94–97%, 11 = 97–100%, 12 = 100%).

At harvest, 20 plants in each replicate plot were collected from one of the two center beds starting 2 m into each plot to avoid edge effects. Fresh and dry untrimmed head weights, fresh and dry root weights, and disease severity scores (0–6 scale) were determined. Dry weights were obtained after tissue was dried for 96 hours at 80 C.

Statistical analysis. Statistical computations were made using software from Statistical Analysis Systems (release 6.03 SAS institute Inc., Cary, NC) and Minitab (Statistics Department, The Pennsylvania State University, University Park, PA). The SAS general linear models procedure was used to perform analysis of variance. Linear contrasts and contrast estimates were obtained with the estimate statement. Chi-square analysis of nonparametric disease severity data was performed with Minitab.

RESULTS

Microplots. In both the spring and fall experiments, disease incidence and severity were significantly lower in the fumigated than in the control plots, both at thinning and harvest (Table 1). No significant differences were found between the two different fumigants in their effect on corky root incidence or severity at thinning or harvest, respectively. In both experiments, root dry weights and head fresh and dry weights were significantly higher for plants from fumigated plots than for those from untreated plots (Table 2). Fumigation with methyl bromide + chloropicrin resulted in higher head and root weights compared to dazomet in the spring, but root and head dry weights were higher after dazomet in the fall.

Large-scale field plots. One month before harvest, the percentage of each taproot showing corkiness was reduced from 15% in control plots to 4% in dazomet (400 kg/ha) and methyl bromide + chloropicrin plots (Table 3). Plants from plots treated with dazomet at 400 kg/ha or methyl bromide + chloropicrin had lower disease severities than dazomet at 200 kg/ha. Shoot and root fresh weights were not affected by the treatments.

At harvest time, again no difference was found in disease severity between dazomet at 200 kg/ha and the control plots (Table 4). Methyl bromide + chloropicrin and dazomet at 400 kg/ha reduced severity of corky root significantly ($P = 0.01$), but methyl bromide

Table 1. Effect of preplant fumigation of microplots infested with *Rhizomonas suberifaciens* on incidence and severity of corky root of lettuce cv. Salinas for spring and fall crops

Season	Treatment	Incidence at thinning[a] (%)	Number of plants in each severity class at harvest[b] 1	2	3	4	5–6	Linear contrast	Contrast estimates incidence (%)	Chi-squares for number of plants in severity classes
Spring	Control	47.7	0	9	6	3	0	Control vs. fumigated	−35.9**[c]	17.8**, df = 2
	Methyl bromide							MC vs. dazomet	4.1	5.8, df = 2
	+ chloropicrin (MC)	9.7	14	3	1	0	0			
	Dazomet	13.8	8	7	5	0	0			
Fall	Control	59.5	11	2	5	3	7	Control vs. fumigated	−54.1**	33.5**, df = 4
	MC	7.9	24	3	1	0	0	MC vs. dazomet	−5.0	2.0, df = 1
	Dazomet	2.9	27	1	0	0	0			

[a] Means of three replications evaluated 1 mo after seeds were planted.
[b] Scored on a 0-6 scale.
[c] Significance levels: ** = 0.01.

Table 2. Effect of preplant fumigation of microplots infested with *Rhizomonas suberifaciens* on roots (dry weight) and heads (fresh and dry weight) of lettuce cv. Salinas in spring and fall crops

Season	Treatment	Root (g)	Head Fresh (g)	Head Dry (g)	Linear contrast	Contrast estimate Root (g)	Contrast estimate Head Fresh (g)	Contrast estimate Head Dry (g)
Spring	Control	2.7[a]	275[a]	24.0[a]	Control vs. fumigated	1.07**[b]	224**	14.8**
	Methyl bromide				MC vs. dazomet	−0.61**	−121**	−7.8*
	+ chloropicrin							
	(MC)	4.0	559	42.7				
	Dazomet	3.4	437	34.9				
Fall	Control	1.1	470	18.8	Control vs. fumigated	0.70*	206*	13.1**
	MC	1.6	617	28.7	MC vs. dazomet	0.40*	117	6.3*
	Dazomet	2.0	734	35.0				

[a] Means of three replications.
[b] Significance levels: * = 0.05, ** = 0.01.

Table 3. Effect of preplant fumigation of a field naturally infested with *Rhizomonas suberifaciens* on severity of corky root and shoot and root fresh weight of lettuce Salinas, 31 days before harvest

Treatment	Rate (kg/ha)	Disease severity[a]	Shoot (g)	Root (g)	Linear contrast	Contrast estimates: Disease severity[a]	Shoot (g)	Root (g)
Control		14.5[b]	12.3[b]	1.3[b]	Control vs. fumigants	−8.4**[c]	8.07	0.72
Methyl bromide + chloropicrin (MC)	400	3.9	19.3	2.0	MC vs. dazomet	−3.4*	1.6	−0.03
Dazomet	200	10.2	22.7	2.0	MC vs. dazomet 400	−0.3	−0.2	−0.10
Dazomet	400	4.2	19.0	1.9	Dazomet 200 vs. dazomet 400	−6.0**	−3.6	−0.13

[a] Disease severity is expressed as a percent of taproot area corked.
[b] Mean of three replicates.
[c] Significance levels * = 0.05, ** = 0.01.

Table 4. Effect of preplant fumigation of a field naturally infested with *Rhizomonas suberifaciens* on severity of corky root, and heads (fresh and dry weight) and roots (dry weight) of lettuce cv. Salinas at harvest

Treatment	Rate (kg/ha)	Disease score[a] (no. of plants) 1–2	3	4–5	Head weight[b] (g)[c] Fresh	Dry	Root weight (g)[c]	Linear contrast	Chi-squares disease score	Contrast estimates: Head weight[b] (g)[c] Fresh	Dry	Root weight (g)[c]
Control		0	0	80	400	28.8	3.83	Control vs. fumigants	27.2**[d]	266**	16.6**	1.9**
Methyl bromide + chloropicrin (MC)	400	7	34	39	835	50.9	5.11	MC vs. dazomet	36.9**	−259**	−8.3	0.9
Dazomet	200	0	1	79	500	38.5	5.34	MC vs. dazomet 400	9.9*	181	−4.3	1.6*
Dazomet	400	7	16	57	654	46.7	6.74	Dazomet 200 vs. dazomet 400	23.8**	158	8.1	1.4

[a] Scored on a 0–6 scale.
[b] Untrimmed.
[c] Mean of four replicates composed of five plants/replicate.
[d] Significance levels: * = 0.05, ** = 0.01, two degrees of freedom.

+ chloropicrin reduced disease severities significantly ($P = 0.05$) more than dazomet at 400 kg/ha. However, root dry weight was significantly higher in this treatment than the methyl bromide + chloropicrin treatment ($P = 0.05$) (Table 4). Control plots had lighter heads and roots than all fumigated plots.

Plants from methyl bromide + chloropicrin and dazomet (400 kg/ha) treated plots were not significantly different with respect to head weights. However, plants from both dazomet treated plots taken together produced lower head fresh weights than plants from methyl bromide + chloropicrin treated plots.

DISCUSSION

Disease severity and yield loss associated with corky root of lettuce was effectively reduced by soil fumigation with methyl bromide + chloropicrin or dazomet. Although populations of the causal bacterium, *R. suberifaciens*, were not measured, disease control was probably achieved by the bactericidal activity of these fumigants. The high rates of dazomet (400 or 450 kg/ha) gave a level of disease control similar to methyl bromide + chloropicrin. However, neither methyl bromide + chloropicrin nor dazomet controlled the disease completely in microplots or in the field experiment at Salinas. This may be due to rapid horizontal or vertical recontamination from the surrounding microplots, soil, or irrigation water. On a commercial scale, encompassing many hectares, horizontal recontamination may be less likely to occur.

Dazomet has some important advantages over methyl bromide + chloropicrin. Neither tarps nor heavy machinery are required, resulting in lower cost (5). The granular formulation is convenient and has less hazard to applicators (6). Most importantly, concerns over bromide residues in soil, groundwater, and on produce (9) are greater than for dazomet.

The most significant disadvantage with products that yield MIT compared to methyl bromide is the slow diffusion of MIT through cool and fine-textured soils. Dazomet was not directly compared with metham sodium for control of corky root, but the latter was effective for control of the disease in previous work (3,8). Based on ease of use (5) and the efficacy presented here, we believe that dazomet may have wider utility than metham sodium.

In the large field experiment (Table 4), the fresh weight of heads from lettuce grown in nonfumigated plots was 52 or 39% less than that of heads from plots treated with methyl bromide + chloropicrin or dazomet (400 kg/ha), respectively, and about 20% less than that of heads from a corky root resistant breeding line of Salinas × Green Lake (440-8, obtained from E. Ryder, USDA, Salinas) grown nearby. This breeding line yields the same as Salinas in the absence of *R. suberifaciens* (7). Thus, 19–32% of the increase in head size seen in fumigated plots resulted from growth promoting effects and/or control of other pathogens besides *R. suberifaciens*. Such nonspecific effects by fumigants confirm previous reports (6).

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