Soil Moisture Effects on Control of Pythium ultimum or Rhizoctonia solani with Methyl Bromide

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ABSTRACT

Peat moss:fine sand mixture (U.C. mix) infested with *Pythium ultimum* or *Rhizoctonia solani* was fumigated continuously for 1, 2, 5, or 8 days with approx 600, 1,200, or 2,300 parts per million of methyl bromide gas in air to measure the effects of varying soil moisture on the efficacy of the fumigant in controlling damping-off of peas. The effect of soil moisture on control of damping-off was pronounced in soil infested with *P. ultimum,* but not so pronounced in soil infested with *R. solani.* Most effective control of *P. ultimum* was obtained in moderately moist soil (12% water), next in very wet soil (37% water), and least in very dry soil (2% water). With *R. solani,* best control of damping-off was obtained in moderately moist soil (10% water). In contrast to results with *P. ultimum,* control of damping-off due to *R. solani* in very wet soil (37% water) and in very dry soil (2% water) was similar and only slightly poorer than that obtained in moderately moist soil. Phytopathology 61:194-197.

Additional key words: Damping-off, soil fumigation.

Control of fungus pathogens near the soil surface by methyl bromide fumigation is most effective when the soil is moist. Poor results are obtained when the soil is very dry or very wet. Various biological and physicochemical factors are responsible (2). Even in laboratory experiments designed to avoid complicating factors inherent in soils, differences in susceptibility of *Alternaria solani* to methyl bromide were noted, depending upon the atmospheric relative humidity existing during the treatment.

Yet, in spite of the apparent importance of soil moisture, no accurate measurements on the effect of soil moisture on plant pathogens in soil during fumigations with methyl bromide have been made. We therefore fumigated soils infested either with *Pythium ultimum* Trow. or *Rhizoctonia solani* Kuehn for varying periods under controlled conditions, and measured the effects of varying soil moisture on the efficacy of methyl bromide gas in controlling damping-off of peas.

MATERIALS AND METHODS.—*Fumigation apparatus.*—Soil was fumigated in an apparatus, a portion of which is shown in Fig. 1. Prescribed concn of methyl bromide were prepared in a large tank, and mixed with compressed air to make concn of approx 600, 1,200, or 2,300 ppm (M. J. Kolbezen & F. Abu-El-Haj, *personal communication*). Each concn of the gas was led into a manifold with eight outlets. There were three manifolds, each with a different concn of gas, making a total of 24 soil cylinders for each experiment. The rate of flow of each outlet was controlled by a calibrated restrictor to equal 20 ml/min. The mixture of methyl bromide and air was introduced at the base of a modified 1-liter graduate cylinder. The gas percolated through the soil, and escaped through an opening in a tightly fitted rubber stopper at the top into a fume hood.

The concn of gas was determined by gas chromatography at the inlet and outlet of each cylinder of soil. In all cases, equilibrium occurred within 3 hr after the start of the experiment. The concn of the effluent was determined daily during each run, and was uniform after equilibrium was attained. Treatments were continuously applied for 1, 2, 5, or 8 days. Each treatment was run in duplicate except for the 8-day exposure, which was run singly. The other position on the manifold was used as a control to determine possible methyl bromide toxicity. In this cylinder, noninfested soil was exposed to methyl bromide for 8 days. No toxic effect of methyl bromide was noted in plantings of peas in this soil in any experiment. The other control consisted of noninoculated soil in four cylinders through which air was passed, but not methyl bromide. One soil column was used for each time period, but the emergence of the peas planted in these controls was so uniform that the data of the four were bulked and used to calculate the per cent damping-off of the controls. After the treatment period, air was passed through the columns until no methyl bromide was detectable.

The contents from each cylinder were used to plant 16 pots, each containing 50 g of soil and five pea seeds. The soil was watered and the pots were held for 14 days in a growth chamber set at 21 C for *P. ultimum* and 24 C for *R. solani* with a 12-hr day under 800-1,000 ft-c fluorescent light. Incidence of damping-off for the various treatments reported was calculated as percentage obtained by dividing the number emerged in methyl bromide-treated soil by the number emerged in aerated, noninfested soil, multiplying by 100 and subtracting from 100.

Preparation of infested soil.—Uniform lots of U.C. mix consisting of 50% sphagnum peat moss and 50% fine sand (1) infested with the pathogens were used. For *Pythium* infestations, one large lot was prepared and held at −18 C until needed. *Rhizoctonia solani* will not withstand similar cold storage (4), so a different method was used to standardize it.

Pythium ultimum was grown on sterile vermiculite-Czapek's medium (5) for 3 weeks and screened through a 7-mm mesh screen. Approximately 1 kg of the moist inoculum was added to 50 kg of freshly steamed and cooled U.C. mix and thoroughly mixed. To each of 11 standard greenhouse flats (46 × 46 × 7.7 cm), 4.5 kg of steamed U.C. mix were added; the flats were planted heavily with pea seeds (*Pisum sativum* L. 'Little Marvel') and covered with 4.5 kg of infested

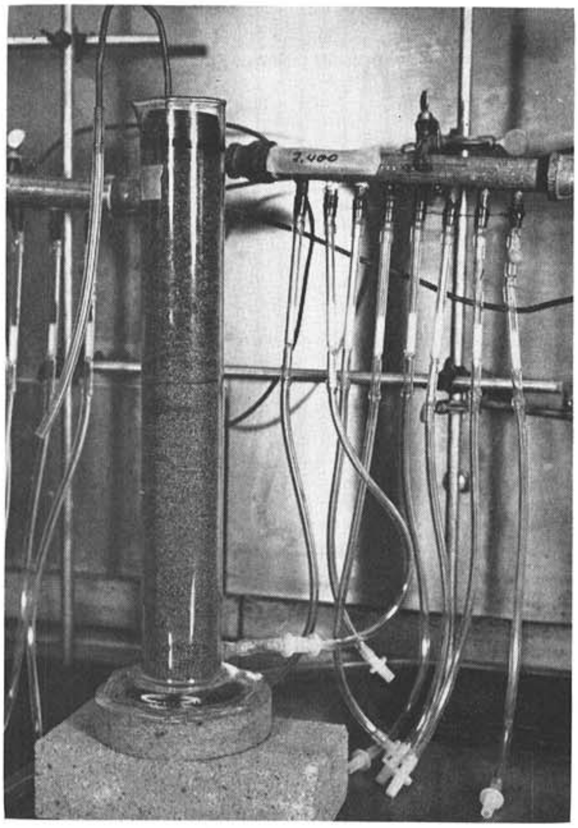

Fig. 1. Portion of the apparatus used to fumigate columns of soil with methyl bromide. Manifold (upper right) with eight outlets, one of which is connected to a soil column.

soil. Noninfested soil to be used as a control was sown with pea seeds at the same time. The soil was watered carefully to hold the moisture at a low level during the first 6 days after planting, but was not watered for the following 6 days. Pre-emergence damping-off was over 90% in all flats of infested soil. No damping-off occurred in the noninfested soil.

The soil from the flats was bulked, thoroughly mixed by hand, and screened to remove plant debris. It was divided into samples weighing 4 kg, wrapped tightly in polyethylene bags, and stored at −18 C. Noninfested soil was handled in a similar manner. The moisture content of the soil at time of storage was 17%. One-kg sample of the soil was placed in a 1-liter graduate cylinder, and the amount of additional moisture required to saturate the columns was determined for later adjustments of moisture contents. This value was approx 37% on a wt-to-wt basis. Air was passed slowly through the wet column for 8 days, and evaporation was negligible.

Rhizoctonia-infested soil was prepared fresh for each experiment by adding 4% (by wt) of 3-week-old vermiculite-Czapek cultures to freshly steamed U.C. mix. It was mixed by a machine (twin shell blender) for 20 min and used without storing or other treatment.

Three soil moisture levels, considered in farming practice to be high, opt, and low for planting were used. After adding the fungi to freshly prepared soil, as it is used routinely in greenhouse practice, the water content was 12% in the *Pythium* series and 10% in the *Rhizoctonia* series. These were considered to be the moderately moist soils. One kg of these soils was used per column. The other columns containing high and low moisture were prepared so that all columns contained approximately the same amt of soil figured on a dry wt basis. The high water content series were obtained by adding sufficient water to make a total of 37%. At this moisture level the soil was saturated, but no water drained from the bottom of the column.

The low water-content soils (2%) were obtained by spreading them in thin layers on a laboratory bench and allowing them to air dry. Soil infested with *P. ultimum* was thawed and dried in 96 hr; soil infested with *R. solani* was mixed and dried in 20 hr.

With all soil treatments, the weighed soil was carefully added to the columns and tamped so that the columns were as uniform as possible.

RESULTS.—*Pythium ultimum*.—Most effective control was obtained in soil containing 12% water, moderate control was obtained in the very wet, and very little control was obtained in the very dry soil (Fig. 2). Also, the dosage response curves (DRC) were different for each soil condition, but with the exception of the very wet soil, they were similar within each moisture level.

With the soil moisture opt for control (12%), the slopes of the DRC were parallel; however, each increase in days of exposure to methyl bromide resulted in progressively less effectiveness in controlling damping-off. Even so, *P. ultimum* was extremely susceptible to methyl bromide.

DRC from the very wet soil were different than those from the other two soils in the *P. ultimum* series. With exposure for 1 day, there was no effect of increased dose of methyl bromide on damping-off control. This lack of response carried over into the 2-day exposures for doses of 600 and 1,200 ppm, but was overcome by a dose of 2,300 ppm. Exposures for 5 or 8 days resulted in DRC showing increased response to increased dose, as was observed with the very dry and the moderately moist soils.

The control of *P. ultimum* in dry (2%) soil was very poor. The DRC were flat and, by approximation, it was determined that it would take a dose of 18,000 ppm applied for 8 days to reduce damping-off to 5%.

A test was made with *P. ultimum* (12% series) to determine whether the fungus was eradicated or merely suppressed by the presence of methyl bromide (Table 1). After the final damping-off readings were taken from the experimental material above, the remaining plant debris from the pea seedlings was removed and the soil was held at −18 C for 2-10 days. After thawing, it was replanted to peas and the per cent damping-off was compared with that obtained from the first planting. Generally, damping-off was more severe in the second planting. Perhaps most significant was the

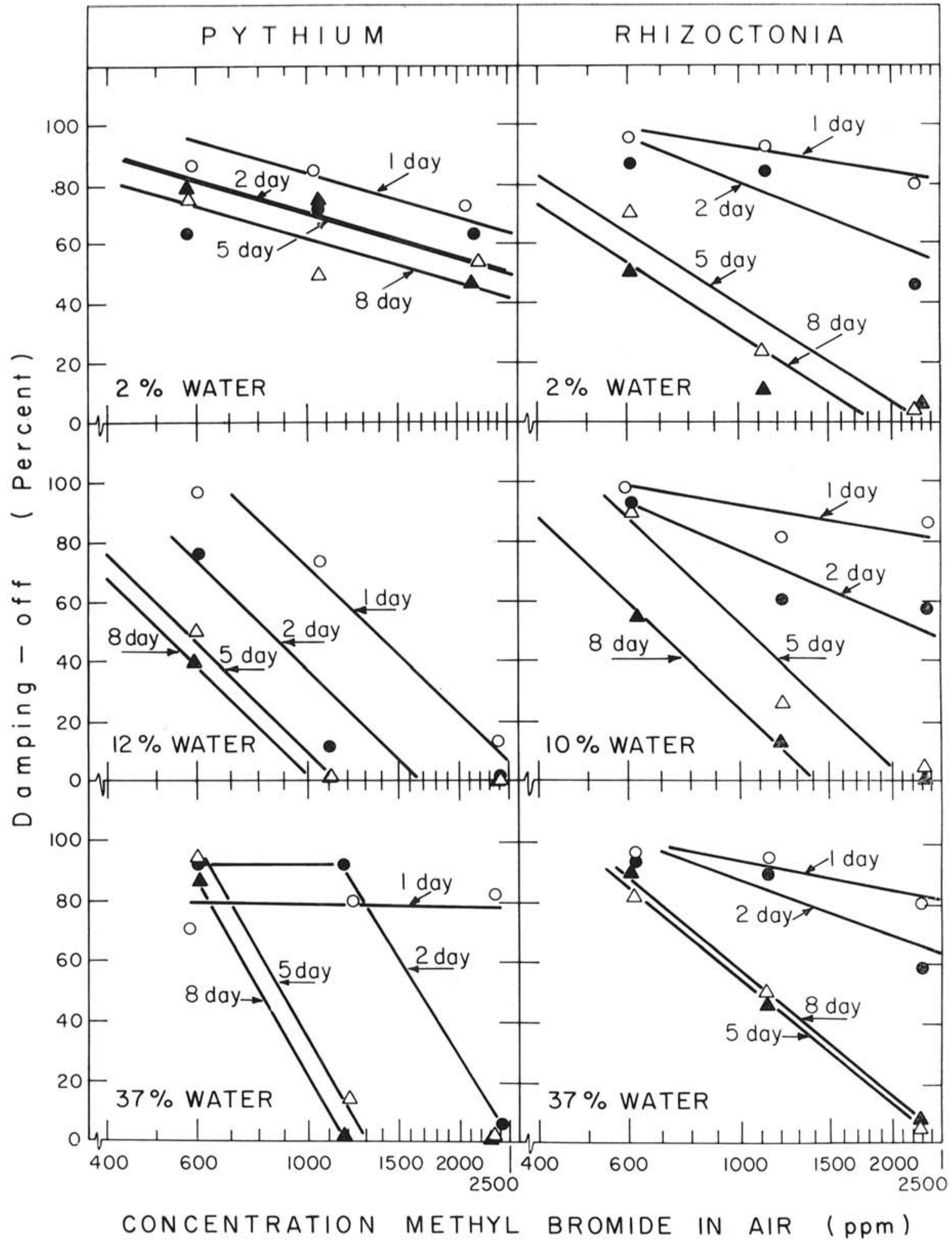

Fig. 2. Dosage response curves (DRC) showing the effect of soil moisture content, concn of methyl bromide, and duration of exposure to the gas on damping-off of peas (*Pisum sativum*) planted in soil infested either with ***Rhizoctonia solani*** or ***Pythium ultimum***.

TABLE 1. Comparison of per cent damping-off between plantings of peas made immediately after soil infested with *Pythium ultimum* was fumigated with methyl bromide, and after the remnants of the first planting were removed and the soil was frozen, thawed, then replanted approximately 2 weeks later

Methyl[a] bromide	Days	Damping-off, 1st planting	Damping-off, 2nd planting
ppm		%	%
600	1	96	95
	2	75	69
	5	51	93
	8	40	57
1,200	1	75	69
	2	11	73
	5	0	3
	8	0	8
2,300	1	12	57
	2	0	0
	5	0	0
	8	0	7

[a] Approximate mean of all treatments.

fact that in only two of five cases was the fungus apparently eradicated from the soil. In the other three cases, a small amt of inoculum survived.

Rhizoctonia solani.—The response in all three soils with different moisture contents was remarkably similar (Fig. 2). Best control of damping-off occurred in soil containing 10% moisture. The DRC were flat and practically identical for exposures of 1 day with soils at all moisture levels. DRC for exposures of 2 days diverged from the DRC for 1 day. This divergence with an increase in dose was still present in DRC for 5 days, although not so pronounced. DRC for exposures of 8 days were parallel to and nearly identical to DRC for 5 days.

DISCUSSION.—Commercial experience, as well as results of research, has demonstrated that fumigation of soil for control of fungi, weed seeds, nematodes, and insects is routinely optimum under "not-too-wet" and "not-too-dry" soil moisture conditions. It has been virtually impossible to kill some organisms with extremely high concn of methyl bromide (3) if the soil is too dry. The results with *P. ultimum* in these experiments confirm these observations. In contrast, the results obtained with *R. solani* are less clear-cut. Best control of damping-off occurred in the soil containing 10% water, but the over-all response of *R. solani* to varying dose, time, and soil moisture was similar. It is impossible to know from these experiments the reasons for the differences in response of the two species of fungi. In other respects they have differed sharply. *Pythium ultimum* withstands extended periods of storage at −18 C; *R. solani* does not. *Pythium ultimum* withstands protracted periods of drying in infested soil; *R. solani* does not (4). Thus, it is sufficient to say that the two species differ in their response to experimental conditions.

The different response of *P. ultimum* in wet and dry soils bears scrutiny. At low doses (600 ppm) of methyl bromide, percentage damping-off was not effectively reduced even when exposed for 8 days in either wet or dry soils. In wet soil, this was overcome by increasing the dose, but it was not overcome in dry soil by the same means. The fact that the slopes of the DRC for 5 and 8 days for wet soils were steeper than for those from the other two soils, combined with the lag in the 2-day curve and ineffectiveness of all doses for 1 day, may indicate that *P. ultimum* is most susceptible to methyl bromide in wet soils, but that factors such as sorption and solvation must be overcome first before the gas is able to penetrate and kill the fungus propagules. With the dry soil, these factors would not be so limiting, and other factors may be responsible for the resistance of *P. ultimum*.

These studies are part of a continuing program on fumigation of soils for control of soil-borne fungi. The results reported herein confirm the usual recommendation made in field fumigations for shallow-rooted crops; i.e., soil moisture should be sufficiently high for opt planting before successful control with methyl bromide may be expected. The case is reversed when very deep penetration of the gas into soils is desired for control of *Armillaria mellea* on roots of trees, shrubs, or vines. Here, moisture blocks the diffusion of the gas and renders methyl bromide ineffectual in controlling *A. mellea*. Thus, for very deep soil fumigation it is mandatory that the soil be as dry as possible. The objectives of fumigation must be considered when listing the opt conditions.

The difference between eradication of a soil-borne pest and effective control is sometimes not clearly distinguished. It is known that eradication of organisms in open field soils on an extensive scale is a practical impossibility. The data from Table 1 indicate that even though damping-off was not detected in the first planting of methyl bromide-treated soil, a significant amt was detected in the second planting in the same soil. Thus, a small fraction survived undetected and was able to manifest itself in subsequent plantings. Probably this happens routinely in the field.

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