Control of Fusarium wilt of Carnation by Soil Heating Processes

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Nursery and ornamental crop production accounts for 10% of the methyl bromide used in the United States. For some diseases, such as Fusarium wilt of carnation (caused by *Fusarium oxysporum* f.sp. *dianthi*), methyl bromide has been the primary means of control for decades. We are conducting experiments to determine the efficacy of heat (steam and electronic) and chemical (basamid and methyl iodide) alternatives to methyl bromide. Experiments with methyl iodide have been done in collaboration with Howard Ohr and Ole Becker (from UC Riverside), and will be reported elsewhere. This report summarizes our research with soil heating processes.

Steam was applied to ground beds by means of manifolds buried 30 cm deep in the soil. Plots were covered with steam tarps and live steam was injected into the manifolds for two hours. Tarps were removed two hours later. In raised beds, manifolds were placed in various arrangements and the entire bed structure was covered with a steaming tarp. Steam was injected for 2-3 hrs, and tarps removed 2 hr later.

Electronic (ohmic) heating was accomplished by driving 4-ft-long steel rods into the ground to depths of 60-90 cm in two linear, parallel arrays. The rods in one linear array served as anodes, while the rods in the second array served as cathodes. The arrays were 120 cm apart. Current was passed between the electrodes to cause soil heating. Treatments were applied over a 72 hr period.

In all heat treatments, soil temperatures were continuously monitored using thermocouples. In steam treatments, temperatures were recorded at 5 min intervals, while in ohmic treatments, temperatures were recorded at 60 min intervals. In ground beds, thermocouples were buried to depths of 5, 30, 60 and 90 cm at several points in each plot. In raised beds, which were only 20-25 cm deep, thermocouples were buried in horizontal arrays around the manifolds.

Treatment efficacy was assessed by two methods. Soil containing known amounts of inoculum was placed in fine mesh bags and buried in plots prior to treatment. In ground beds, bags were buried to depths of 30, 60, and 90 cm. In raised beds, bags were buried in locations adjoining thermocouples. All bags were recovered after treatment and inoculum survival assessed by dilution plating on selective media. In addition to monitoring treatment effects on known populations, we also recovered samples of bed soils before and after treatment. In ground beds, samples were collected from 0-30, 30-60, and 60-90 cm depths. In raised beds, samples were collected from soil adjacent to the thermocouples. Additionally, small (2-5 cm) clods were recovered from raised beds before and after steam treatments. Fusarium populations were estimated in all soil samples by dilution plating onto selective media.

In ground beds treated with steam, soil heated very quickly in the uppermost 5 cm of the profile, reaching temperatures of 100°C in a matter of minutes. Temperatures at the 30cm depth varied from 60-100 °C, while temperatures at 60 and 90 cm never exceeded soil ambient. As a result, there was no kill of buried inoculum at the 60 and 90 cm depths and inoculum mortality at 30 cm was inconsistent (0-3X10^3 ppg survived out of initial populations of 10^6 ppg).

In our 1995 experiment, soil heating in the ohmic treatments proceeded more slowly, and to greater depth than steam heating. Soil temperatures over 72 hours reached 60-65 °C at 5, 60 and 90 cm. In 1996, soil temperatures reached 80-90 °C at 5 cm and 55-65 °C at 60 cm. Ohmic-heated plots were distinguished from all other treatments (steam and chemical) in that there was virtually no survival of inoculum (out of initial populations of 10^6 ppg) to depths of 90 cm in the soil.

Ninety days after planting the 1995 experiment, all plants in the untreated controls were killed by *Fusarium oxysporum* f.sp. *dianthi*. Plant mortality in steam and ohmic-heated plots was not significantly different from methyl bromide-treated plots. However, over time (6-12 months) there was significant plant mortality in all treatments as disease spread laterally from infection centers to adjoining plots and beds. Because disease spread so quickly between adjoining plots, obscuring treatment effects, our 1996 experiment utilizes plots with greater spatial separation and includes no untreated controls.

In raised beds treated with steam, different locations within beds heated at different rates. However, all thermocouple locations indicated temperatures >95 °C by the end of the 2 hr treatment period. In those locations where soil was more slow to heat, some inoculum survival was recorded (<10 ppg out of initial populations of 10^6 ppg). We also detected very small amounts (<10 ppg) of viable *Fusarium oxysporum* surviving in soil clods recovered from some steamed beds.

Because very little inoculum survives steaming in raised beds, a major concern has been the prevention of soil recontamination by *F. oxysporum* f.sp. *dianthi*. We have found *F. oxysporum* f.sp. *dianthi* to be air-borne on dust particles in the greenhouse and currently are experimenting with means of preventing such air-borne inoculum from re-introducing the pathogen into steamed beds. We are testing both a physical barrier (plastic sheeting at the soil surface) as well as biological agents which may have antagonistic properties. The biological products being tested include SoilGard (Thermo Trilogy Corp.), Mycostop (AgBio Development, Inc.), and Promot Plus (J.H. Biotech, Inc.). These experiments are in progress.

Our experiments indicate that while the ohmic treatments provide relatively uniform heating of soil and eliminate inoculum to significant depths, ohmic heating probably is not practical on a large scale at this time. Steam heating of ground beds did not provide uniform soil heating and allowed foci of high inoculum survival. Steam heating of raised beds can result in near-complete inoculum kill, but recontamination of beds poses a significant threat to crop survival over time.

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