USE OF HOTWATER FOR NEMATODE CONTROL: A RESEARCH SUMMARY

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The use of hotwater is not a new concept to nematode management. Belwey (1923) found that it took two million gallons of hotwater per acre by a surface drench method to achieve nematode control. Compton (1936) devised a portable hotwater sterilizer to be used at the end of a steam line for killing soil nematodes. Since the 1930's, most research has focused on procedural development of hotwater dips for nematode disinfestation of plant materials. Only more recently, have studies been reinitiated to evaluate soil applications of hotwater for nematode control (Noling et al; 1994). This report attempts to summarize Florida research efforts on the use of hotwater for nematode control utilizing a prototype hotwater machine, developed and patented by AquaHeat Technologies Inc. of Minneapolis, Minnesota.

During the fall of 1992, the first experiment with hotwater was conducted and demonstrated that drip irrigation system delivery of hot water (104 F) could not provide effective nematode control, particularly at soil depths in excess of 8 inches. A second experiment in spring 1993, indicated that a "bottoms-up" approach, where a majority of total hotwater soil input was delivered 16-18 inches below the finished plant bed, did not uniformly heat soil or provide nematode control within the surface 6 inches of soil. Since the spring of 1993, field experiments have focused on evaluating modifications to soil incorporation and hotwater delivery systems. In some studies hotwater was applied as a surface drench or directly soil injected to a depth of 8-10 inches via 10-12 steel chisels. Rototilling and rotovation soil incorporation methods have been evaluated. Tractor speeds were varied between 0.2 and 1.2 mph so as to examine the influence of dosage, the total volume of hotwater delivery per unit length of plant row. Water temperature and flow rates were held constant at temperatures between 220-230 F and 75-90 gpm. Soil temperatures were usually monitored at 3 or 4 depths, ranging between 2 and 18 inches, and compared with equivalent measurements in an untreated control.

The overall results from hotwater experiments performed in Florida since 1994 have indicated that irrespective of soil depth, maximum soil temperature elevations above that of the untreated control increases linearly with dosage. The soil is generally heated very rapidly, and in most cases, does not return to ambient conditions for many hours following treatment. The data also suggests that threshold levels of total hotwater dosage required to elevate soil temperatures of a fine sandy soil (96% sand, <2% silt, clay, organic matter) to achieve nematode control under a plastic mulch covered plant bed is in the range of 30,000 to 70,000 gallons per treated acre. The wide range in water requirements are due to heating inefficiencies caused by differences in soil type and moisture content, as well as initial, seasonally defined, soil temperature conditions. For example, comparisons of field trials performed during the spring, summer, fall, and winter months showed that up to twice as much hotwater may be required during the winter months when soil temperatures of 60 F occur. The method of soil incorporation also appears to be very important in determining volumetric requirements of hotwater treatments for nematode control. For example, rototiller mixing of soil in a vertical plane tends to increase heat losses by allowing cool air to intrude the soil and allowing heated water vapor to escape with each revolution of the rototiller blade. Whereas, rotovator incorporation, mixing of hotwater into soil in a horizontal plane, minimizes these losses by embedding the heated soil layer at the depth in which hotwater is injected into soil. Other studies have also confirmed that irrigation water (79 F) introduced as simulated rainfall immediately after a hotwater soil treatment reduces maximum temperature development and increases the rate of heat loss, thereby reducing cumulative exposures of nematodes to elevated soil temperatures.

The depth to which lethal temperature have been achieved (8-10 inches) also appears to be dependent upon soil incorporation depth. For example, in sandy soils, it is not possible to escape significant heat losses occurring via downward percolation of hotwater into deeper, cooler nontarget soil profiles. In contrast, due to the slow downward percolation of water within heavier textured soils, water tends to pond at the depth of soil incorporation, and heat losses to deeper soil layers appears to be significantly reduced. Soil temperature gradients are immediate and transition zones between hot and cold soil narrow. To date the most promising use of hotwater soil treatments appears to occur in heavier textured soils or in soils where a compacted or impermeable layer restricts and delays downward, gravitational movement of hot water. The fear exits however, that regardless of soil type, lack of pest control in soil horizons below the incorporation depth will allow subsequent pest recolonization and only delay pest impacts to crop growth.

New technological advances in hotwater generation, delivery, distribution, and soil incorporation must still be developed to adapt hotwater methods for broad scale, commercial field use. Further research is also needed to determine, in real time, hotwater volume requirements for efficacious field soil treatment regimes. It also appears that commercial development and expanded use of hotwater soil treatments for nematode control will also depend on overcoming other technical, environmental, and economic constraints. Because hotwater alone is unlikely to substitute directly for methyl bromide soil fumigation, an integrated system, with hotwater in combination with other approaches must also be considered. These integrated approaches have not been intensively studied and additional research will be required to maximize pest-specific efficacy, consistency, and geographical adaptability.

Seasonal Influences on the Relationship Between Maximum Temperature Development at Any Depth and HotWater Volumetric Inputs