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Greenhouse Nematode Management, Florida Greenhouse Vegetable Production Handbook - Vol 3 [1]

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Many different greenhouse types and designs are used for normal ornamental, vegetable and floricultural productions in Florida. Nematode problems affecting greenhouse crops and commodities are generally quite rare, and can usually be avoided if appropriate pests management practices are considered. When they do occur, the most economically important genera of greenhouse production include root-knot (*Meloidogyne*) (Figure 1), lesion (*Pratylenchus*), Burrowing (*Radapholus*) and leaf stem, or foliar nematodes (*Aphelenchoides* or *Ditylenchus*). In most cases, problems with these nematodes arise from planting of infected seed or planting-stocks, in systems utilizing bare ground (Figure 2) or raised ground beds (Figure 3), or where contaminated soil is used as a component of the growing medium. Subsequent spread of nematodes within the greenhouse usually occurs via movement of infested soil or plant material by workers, water, or greenhouse equipment. In some greenhouse systems, nematodes can be introduced into and recirculated quickly via drainage and irrigation water to inoculate most other healthy plants within the greenhouse. The latter scenario clearly defines how nematodes problems can be amplified quickly once introduced. For greenhouse production, nematode management must therefore be viewed first as one of exclusion or avoidance. Once nematodes are introduced and damage becomes visible, it is currently not possible to chemically or non-chemically resolve the problem to avoid potentially significant yields losses thereafter. Some of the most important sources of contamination and hence major factors to consider include: 1) seed and planting stocks, 2) irrigation water, 3) soil and potting media, and 4) general cleanliness.

Greenhouse Production Systems

Soilless Culture/Substrates

Cultivation of greenhouse crops and commodities on raised beds, benches, and in artificial (inert) or soilless substrates (sometimes hydroponic

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Figure 1. Typical symptoms of root galling induced by root-knot nematodes (Meliodogyne spp.) on vegetable crops of (A) yellow squash, (B) tomato, (C) pepper, and (D) cucumber.

Figure 2. Trellised greenhouse production system utilizing netting as roof cover and bare ground for a plant rooting medium.

culture) has been widely used for many years in Florida (Figure 4). Soilless culture of these crops and commodities is accomplished by using artificial substrates such as rock wool, rock, clay, granules, perllite, and flexible polyurethane foam-blocks to allow plant roots to absorb nutrients and water. In some areas of the world, other locally available substrate materials have been used such as peat moss, rice hulls, coconut fiber, and composted tree bark.

Figure 3. Trellised greenhouse production system utilizing plastic sheeting as roof cover and mulch covered raised beds of a native soil as a plant rooting media. Note root-knot nematode and Fusarium wilt on tomato plants.

More information including comprehensive description of soilless culture can be obtained from other sections of this production guide ("http://edis.ifas.ufl.edu/ TOPIC_BOOK_Florida_Greenhouse_Vegetable_Production_Handbook).

Figure 4. Trellised greenhouse production system utilizing linear bag culture using a soilless substrate.

Although soilless media are usually pathogen free, infestations of these media by plant pathogenic nematodes and disease microorganisms may occur in the greenhouse if proper sanitation procedures are not followed from point of manufacture to end use in the greenhouse structure. In some instances, steam (90°C for 1/2 hour) (Figure 5) has been used to sterilize any or all of these for subsequent reuse (not recommended).

Figure 5. Small-scale system for introducing steam via a manifold of perforated pipe into a soil bin for nematode control in a greenhouse production system.

Soil/Ground Culture

Some greenhouse production systems rely upon growing crops directly in the natural soil under the roof cover (Figure 6). In ground or raised bed soil culture, nematodes can be major production problem practically in presence of other disease organisms such as Fusarium (Figure 3). In these systems, other types of management practices must be relied upon to resolve nematode problems. These practices include not only those used in soilless systems but also typically preplant treatments with steam, rather than chemicals, to effectively eliminate nematodes from soil. Other practices that can be equally important in the overall nematode management plan include general measures of IPM, such as site selection, sanitation, host plant resistance, and use of nematode free planting materials.

Figure 6. Greenhouse system relying on a raised-bed plasticulture system for crop production.

Nematode Management Practices and Considerations

Exclusion

Site Selection

Many different factors should be considered in selecting a suitable site for greenhouse placement, such as proximity to water, labor, road systems, and agricultural markets. There are also important pest management considerations. Whenever practical, the site should be removed from major open field areas of commercial fruit and vegetable production. This will serve to minimize opportunity for pest introduction into greenhouse facilities. If ground based production systems will be used, then soils free of economically important plant parasitic nematodes should only be selected for greenhouse placement. Once nematodes are introduced, it is currently not possible to eliminate or eradicate the problem. Greenhouses structures should also be situated to avoid introduction of nematodes and other soilborne pests via downstream movement of drainage or runoff water and soil.

Irrigation

Another primary source of plant-parasitic nematode spread and introduction into greenhouse structures has been demonstrated via irrigation water from streams, ditches and ponds. Nematodes have even been found in irrigation waters from shallow wells also indicating that they can be from those sources as well. Since nematodes can be carried through irrigation water that has drained from an infested field, growers should avoid use of ditch or pond waters for greenhouse irrigation or for spray mixtures. Recycling of greenhouse irrigation water should also be avoided since nematodes can be recirculated quickly via the reused irrigation water to inoculate most other healthy plants within the greenhouse. If greenhouse water must be reused it should be decontaminated by heating to 90°C or greater. Given the small, microscopic size of nematodes, irrigation screens and filters should not be relied upon as means of nematode exclusion or control.

Sanitation

Nematode-Free Planting Materials

In most cases, greenhouse problems with both soilborne and foliar nematodes arise from planting of infected seed or planting stocks. At present there are no chemical or nonchemical management tactics available which can resolve nematode problems within the greenhouse once introduced into the crop. As a result nematode-free transplants or plug plants which rely upon soilless substrates from production are increasingly used to exclude foliar and soilborne species of nematodes, but also to expedite plant establishment and crop production. In addition hot water dips have been developed as a control strategy to eliminate plant-parasitic nematodes form both roots and foliar tissues of infested plant materials to be used as transplants (e.g., strawberry). The dip treatment consists of submerging plants in hot water for a specified time and then immediately transferring the treated plants into cold water for an additional time period. The temperature at which different species of nematode are killed is variable and depends upon temperature and time of exposure (a dosage concept of concentration x time). Plants which have been treated with hot water generally require additional care and water after planting than nontreated plants, but the hot water treatment has been used to successfully eliminate nematodes from planting stock. Rouging infected plants when early symptoms are first recognized may also help minimize any plant introduced-nematode problem within the greenhouse.

Other Sanitation Practices

Other cultural measures which reduce nematode problems in the greenhouses include rapid destruction of infested crop root systems following harvest. Discarding infected potted plants will help prevent spread of nematode. Entry points for greenhouse structures should also contain sanitizing stations for hands, shoes, boots, tools, and other equipment.

Physical Approaches

Because of the relatively low thermal sensitivities of nematodes and other soilborne pests, physical approaches which utilize heat have generally proved to be the most effective and widely used management strategies within greenhouses. In general terms, the thermal sensitivities of a wide range of soilborne plant pests that can be encountered are relatively broad (Figure 7). On a relative temperature scale, nematodes and water molds would be considered relatively intolerant of high temperature, being effectively killed by 30 minute exposure at temperatures as low as 120°F. Within the range of 120-140°F, most plant pathogenic fungi and bacteria are killed. Certain weeds and viral pathogens compose the most tolerant group, requiring 30-minute exposures at temperatures of 160°F or greater for pest elimination. A 30-minute exposure of 180°F or greater is generally recognized as the recommended soil pasteurization temperature and the period of exposure to provide a broad spectrum measure of soilborne pest and disease control. The following section defines specific pest control systems which rely on heat to control nematodes in greenhouse production.

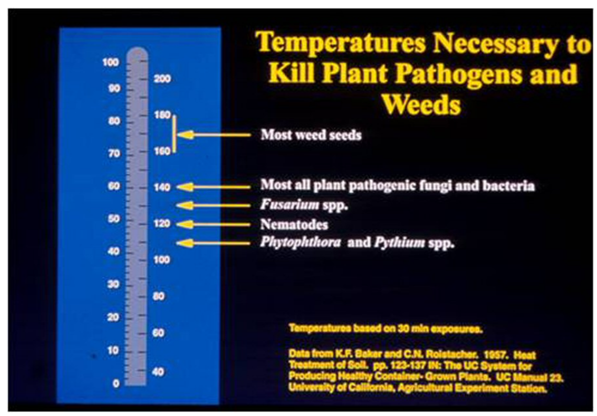

Figure 7. Generalized relationship of soil temperatures for 30 minute exposures to kill various soilborne pests and pathogens (after Baker *et al.*, 1957).

Steam

Steam is a well established and effective technique for soilborne pest and disease control and is extensively used for bulk soil, substrate, or even small scale field treatments within greenhouses and nursery plant operations. Steaming, as defined here, is the introduction of vapor water (>212°F: 100°C) into soil to elevate soil temperatures to levels lethal (160-180°F) to soilborne pests. Soil temperature and treatment duration determine whether complete elimination (sterilization) or only partial removal of soil microflora (pasteurization) occurs.

Since its inception in 1888, various methods have been developed to deliver and apply steam for soilborne pest and disease control. The most common methods include systems in which soil is brought to the boiler where steam was introduced into bins or chambers for bulk soil treatment (Figure 5). For other systems, a small portable steam boiler (Figure 8) is brought to the treatment site where the steam is introduced directly, via a conduit, into buried perforated pipe or tile, winch drawn plows or directly under an inverted pan (Figure 9), tray, or tarpaulin cover. For the latter systems, the soil needs to be covered with pan, tray or canvas sheet to conserve energy and minimize heat loss from soil. As a general rule, it is recommended that steam treatment is maintained so that the coldest spot in the ground bed or substrate is held at 180°F for 30 minutes. A negative pressure steaming system has also been developed in which steam is blown under a tarpaulin cover. The steam is pulled into the soil by negative pressure created by an exhaust fan which pulls air out of the soil through buried perforated pipes. This process has not only proved to be effective in greenhouses but has expedited the steaming treatment process. Self propelled soil steaming systems are also commercially available for small-scale field treatments.

Figure 8. Small portable steam boiler and diesel fuel supply tank.

Due to the high costs, heating inefficiencies, pest control inconsistencies, and other treatment impracticalities, steam is not currently used for large scale, open-field greenhouse uses. In most cases, where comparisons have been made, greenhouse uses of steam have proven to be as effective as chemical soil sterilant approaches (e.g., methyl bromide).

Figure 9. Mobile, winch drawn steam system to introduce steam directly under inverted pan to control nematodes and other soilborne pests in a greenhouse production system.

Problems have developed, however, when soils have been sterilized; practically when the complete elimination of all soil microorganisms occurs after prolong exposures to temperatures in excess of 200 °F. These problems include increased soil aggregation and destruction of soil structure and release of phototoxic substances from soil and organic matter including soluble salts, ammonia, and heavy metals such as manganese. Fortunately some of these adverse side effects can be remedied when the soil is only partially sterilized, generously irrigated afterwards, or pasteurized with steam at reduced temperatures of 160-180°F.

Other disadvantages of steam include: (1) the large capital investments in steam equipment, (2) permanently installed duct/drain systems and (3) time-consuming treatment involving moving, burial or repositioning of pans or tarpaulin covers each time the system needs to be relocated to a new steaming site. Steam also cannot be effectively used in heavier soils with slow vapor and water percolation, soils with high organic matter content, or those with high water soil-water table. Steam also does not uniformly heat the soil in open field uses nor always heat ground beds (Figure10) deeply enough to control major wilt diseases such as Verticillium or Fusarium. Steam has proven effective when a limited amount of substrate is treated but not ground soil. This is due to the depth at which harmful organisms can be found in the soil, which too often is either out of the reach of steam or can be reached only at extremely high costs. Heating the soil to depths of more than 12 inches requires much longer use of the boiler, more hand labor, and fuel quantities.

Figure 10. Use of steam applied under tarpaulin cover via buried perforated pipe for nematode control in a raised bed, greenhouse production system.

Soil Solarization

Soil solarization is a nonchemical technique in which a transparent polyethylene plastic mulch is laid over moist soil for a 6 to 12 week period to heat noncropped, greenhouse soils to temperatures lethal to nematodes and other soilborne pathogens. Soil temperatures are magnified due to the trapping of incoming solar radiation under the clear polyethylene plastic. To be effective, soils must be maintained at a high soil moisture content to increase the susceptibility (thermal sensitivity) of soil borne pests and thermal conductivity of soil. Moist plastic mulched soils increase soil temperatures due primarily to the elimination of heat loss by evaporation and upper heat convection, in addition to a greenhouse effect by prohibiting dissipation of radiation from soil.

On a global scale, the most successful use of soil solarization has been reported in ground beds of greenhouses within sunny Mediterranean countries with heavier (loamy to clay soils) rather than sandy soils, as well as in closed plastic houses in cooler climates. Solarization of bags of nursery potting mixes was also recently certified in California as an alternative to steam or fumigation with methyl bromide. This technique has not been extensively tested in Florida. It is known that soils with poor water holding capacity and rapid drainage can significantly inhibit heat transfer to deeper soil horizons. As a result, loss of pest control is often times directly correlated to soil depth. The depth to which lethal temperature can be achieved (6 to 8 inches) is also dependent on the intensity and duration of sunlight and ambient temperature. At present, the only time to consider soil solarization for pest control in Florida is during our hot summer months.

Other Management Practices

Host Plant Resistance

Use of nematode-resistant crop varieties is often viewed as the foundation of a successful integrated nematode management program. In a resistant variety, nematodes fail to develop and reproduce normally within root tissues. Commercially available nematode-resistant vegetable varieties are currently available for tomato, pepper, southern pea, and sweet potato. However, new nematode resistant crop varieties are increasingly becoming available as emphasis increases on nonchemical forms of nematode management. In many European and Mediterranean countries, grafting of susceptible plants onto to nematode resistant rootstocks is being used in protected culture systems for a number of annual greenhouse crops including tomato, eggplant, and various cucurbits, This technology has yet to be fully developed for field or greenhouse production systems of the U.S. Greenhouse growers should consult their local county cooperative extension service agent for new nematode resistant crop varieties suitable for greenhouse production which may have become available.

Chemical Nematicides

At present, there are no conventional fumigant or nonfumigant nematicides registered for greenhouse use in Florida. Thus, greenhouse growers must rely on other IPM practices such as exclusion, sanitation, nematode resistant plant varieties when available, and other cultural and physical means of nematode management.

Biological Control

At present there are no effective commercially available biological control agents which can be successfully used to control nematode problems within greenhouses.

Table 1. Examples of Greenhouse Nematode Management Tactics

	Management Tactic Description
EXCLUSION	Tactics which prevent the introduction and spread of nematodes into the greenhouse. Nematode-Free Planting Materials – Use plug transplants produced from soilless culture devoid of nematodes.
SANITATION	Removal and disposal of nematode infrect plant materials.
PROTECTION	Chemical Control - no fumigant or nonfumigant nematicides currently registered for greenhouse use. Solarization - trapping of solar energy under clear plastic panels to heat soil to lethal levels to nematodes. Biocontrol - non available. Soilless Subtrates - Use of pathogen free artificial subtrates for crop production (e.g., perlite, rockwool). Host Plant Resistance - Crop varieties which reduce nematodes reproduction, typically with reduced crop damage.
ERADICATION	Elimination of nematodes from soil or plant materials within greenhouse structure. Gernally not feasible from natural soil based greenhouse systems. Steam Pasteurization - 60oC FOR 30 MIN Steam Sertilization - 100oC (not recommended) Hot Water Dips - Plants emerged in hot water to kill internal nematode parasites of roots or foliar tissue.