

Plant-parasitic nematodes in soil-less culture systems

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Summary – The development from growing plants in field soil to soil-less culture systems has not resulted in the elimination of problems caused by plant-parasitic nematodes. Species of *Meloidogyne* and *Radopholus* have been reported to occur in soil-less culture systems, such as flower crops. The reasons for initial nematode infestation are numerous but the primary reason is likely to be infested plant material. Since nematodes are not expected in soil-less systems, they are often overlooked. However, extension specialists report an increasing occurrence of plant-parasitic nematodes in soil-less culture systems and nematodes seem to be more prevalent than is often thought likely. In an attempt to increase the awareness of the prevalence of plant-parasitic nematodes in soil-less culture systems, this short paper summarises incidences of nematode detections and reviews methods for their detection and strategies for their control.

Keywords – control, detection, *Meloidogyne hapla*, recirculation water, roses.

Fruit, vegetables and flower crops are grown more and more frequently in soil-less culture systems in glass-houses, mainly to avoid the severe problems with soil-borne pests and diseases that occur in crops grown in the field. The presence of plant-parasitic nematodes, such as root-lesion nematodes (*Pratylenchus* spp.) and root-knot nematodes (*Meloidogyne* spp.), often influences decisions by growers to move to soil-less culture systems. In this way growers generally expect to avoid nematode problems. However, in practice this is not necessarily the case. *Radopholus similis* has been reported to occur on *Anthurium andreanum* and Maranthaceae in soil-less culture (Amsing & Runia, 1995). More recently, *Meloidogyne incognita* and *M. arenaria* were found on roses grown in soil-less culture in Sicily (D'Errico & Ingenito, 2003) and *M. hapla* was found in rockwool and coconut-peat cultures of roses in Germany (Hallmann *et al.*, 2004). Overall, there is still very little published documentation on nematode problems in soil-less culture systems, although the problem is not new to growers and extension specialists in several countries. In one particular case, a grower lost over 30% of his roses within the first year due to *M. hapla* (Braunsmann & Hallmann, unpubl.). All commonly used substrates, such as rockwool, coconut-peat and perlite, are suitable for nematode infestation (Stapel & Amsing, 2004). Do plant-

parasitic nematodes represent an increasing threat for crops grown in soil-less culture systems? The objective of this review is to summarise the current knowledge on plant-parasitic nematodes in soil-less culture systems.

Sources of nematode infestation

The most common source of nematode infestation is most likely infested planting material. Infestation can occur through infested soil adhering to seedlings and cuttings, growth of rootstocks in infested field soil or the use of infested irrigation water. However, infested soil can also be carried into soil-less systems by wind, equipment, animals and humans. A second source of nematode infestation could be contaminated water because water from wells, reservoirs and streams can contain plant-parasitic nematodes. Therefore, planting material as well as irrigation water should be routinely checked for plant-parasitic nematodes; it should be possible to treat water to eliminate any possible contamination by nematodes.

Detection methods

Detection of nematode infestation is of key importance and should be done as early as possible. If plant symptoms

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become visible, the nematodes have most likely contaminated the entire production unit by dissemination with the recirculation water. Therefore, routine monitoring for the occurrence of plant-parasitic nematodes in plant roots, growth substrate and recirculation water is recommended. The following methods are those recommended for such monitoring and the determination of infestation levels.

DIRECT EXAMINATION

Samples (5-10 g) of root tissue plus growth substrate collected from plants grown in the trays are transferred to water in a Petri dish and teased apart with strong mounted needles. Most nematode stages, including eggs, are released from the root tissue and growth substrate within a few minutes and can be examined on the bottom of the dish with a stereoscopic microscope at magnifications from 15-50 \times using transmitted or incidental light. This is particularly relevant for migratory endoparasites (e.g., *Radopholus*, *Pratylenchus*) as well as males and infective second-stage juveniles of *Meloidogyne*. Sedentary stages of *Meloidogyne* are best seen by dissecting the root galls formed by this species. Nematode specimens can be collected with a handling needle or fine pipette for species identification under a light microscope at 100 \times magnification. PCR-based methods may aid species identification and perhaps speed up the inspection of imported plant material (Hooper *et al.*, 2005).

INCUBATION METHOD

Incubation of roots plus growth substrate for periods from 24 h up to 5 days improves nematode recovery and enables the detection of low nematode infestation levels. Samples of 10-50 g of roots plus growth substrate are placed on a modified Baermann funnel (Shurtleff & Averre III, 2000). Nematodes emerge from the sample and sink to the bottom of the funnel stem, from where they can be collected for further examination. Combination of the Baermann funnel with a mistifier improves oxygenation and thus nematode activity, which results in greater nematode numbers being found.

FILTER DEVICE

If destructive sampling of plant roots must be avoided, nematodes can also be detected in the recirculation water. The greatest numbers of nematodes can be expected in the excess recirculation water drained from the trays.

The drainage water collected from all trays of a production unit is passed through a fine sieve of 20-25 μm aperture. The sieve should be held in the water stream for 15-20 min and nematodes collected on the sieve are examined under the microscope. This technique is simple but laborious and therefore less suitable for routine monitoring. Further improvement of this approach was achieved by a custom-made filter device designed by the authors (GEFA Prozesstechnik GmbH, Dortmund, Germany). The filter consisted of a stainless steel cylinder of 15 cm height and 12 cm diam., with a folded mesh of 25 μm aperture forming the wall of the cylinder. Total filter area was 700 cm^2 . The filter was fitted into an iron filter holder and tightly capped. All recirculation water had to pass the sieve and was then pumped into the reservoir tank. Depending on water quality, operation times up to 3 days are possible without clogging of the filter. The filter can easily be removed and nematodes transferred into a bottle for further examination.

Control measures

Control of plant-parasitic nematodes in soil-less culture systems is extremely difficult. Nematicides should never be a solution in hydroponics and in most cases are not available. Common procedures such as crop rotation or resistant cultivars are often not suitable. In general, a nematode infestation can only be eradicated by replacing all parts in contact with the contaminated water, *i.e.*, trays, pipes, drippers, *etc.* Therefore, the primary goal has to be avoidance of nematode infestation. In addition to routine checking of planting material and recirculation water, the use of certified plant material is recommended. If plant-parasitic nematodes are found, the infestation source needs to be quickly identified and eliminated. In addition, further measurements need to be employed to reduce nematode damage by means of water treatment and management practices.

HEAT TREATMENT

Heat treatment is a very effective measure to reduce plant pathogens in the recirculation water. A temperature of 53 $^{\circ}\text{C}$ for 15 s is lethal for *Radopholus similis* (Runia & Amsing, 2001a, b). For simultaneous control of plant-pathogenic fungi, bacteria and nematodes, disinfection of the recirculation water for 2 min at 60 $^{\circ}\text{C}$ is recommended (Runia & Amsing, 2001b). Those conditions will also be lethal for plant-parasitic nematodes other than *R. si-*

milis (Evans, 1991). As indicated by Runia and Amsing (2001b), the energy input for 2 min at 60°C is 42% less than for 30 s at 95°C; however, overall costs are still high.

ULTRA-VIOLET RADIATION

Ultra-violet (UV) radiation is effective against fungi, bacteria, viruses and nematodes. Moens and Hendrickx (1989) examined the sensitivity of *M. incognita* to UV-rays under laboratory conditions. Fifty percent of the *M. incognita* juveniles were immobilised at an irradiation dose of 142 mJ/cm². However, a dose of 14 mJ/cm² was sufficient to inhibit completely nematode infection of tomatoes. Similar results are reported for *R. similis*, where a dose of 10 mJ/cm² was sufficient to inhibit nematode multiplication (Amsing & Runia, 1995). Therefore, the UV doses of 100 mJ/cm² recommended for the control of fungi and bacteria will also control plant-parasitic nematodes. Exposures of 100 mJ/cm² are achieved when drain water with a minimum transmission rate of 50% passes the UV unit at a flow rate of 2.5 m³/h (Amsing & Runia, 1995).

FILTRATION

The size of plant-parasitic nematodes (350-800 µm length and 18-40 µm diam.) allows their separation by filtration. Various filtration techniques have been tested in the past. Moens and Hendrickx (1992) used a series of four filters comprising a gauze cartridge (150 µm) and three polyester felt filter bags (80, 10 and 1 µm) through which the recirculation water was pumped. All plant-parasitic nematodes were retained. Membrane filtration seems less suitable due to potential clogging of the pores and unreliability (Runia, 1995). Commonly used slow sand filtration can help to reduce nematode numbers in the water, but will not provide complete control of plant-parasitic nematodes as they will pass through the sand filter after some time (Runia & Amsing, 1995).

SEDIMENTATION

Another simple way of reducing nematode numbers in the recirculation water is by means of sedimentation. This can be achieved in the reservoir tank if the water for irrigation is taken from the top of the water level opposite to the water inlet. Nematodes entering the reservoir tank will sediment before reaching the water outlet.

RESISTANCE

Resistance is the most economically and ecologically sound measure to control plant-parasitic nematodes. Unfortunately, only a few resistant cultivars of the crops grown are commercially available. For roses, resistance towards *M. hapla* has been reported in *Rosa noisettiana* cv. Manetti, a popular rose rootstock used in cut flower production in warmer climates (Ohkawa & Saigusa, 1981; Voisin *et al.*, 1995). However, this rootstock is not always the preferred choice in more temperate regions of Europe, where susceptible *R. canina* cv. Inermis is commonly used as a rootstock. Resistant cultivars are also available for tomato towards *M. incognita*, *M. arenaria* and *M. javanica*. Hopefully, continuing breeding efforts will lead to a broader selection of resistant cultivars and rootstocks in the near future.

PLANT GROWTH MANAGEMENT

Under optimal growth conditions plants can better withstand damage caused by plant-parasitic nematodes. Therefore, all conditions that influence plant growth, such as pH, nutrient concentration, nutrient balance, temperature and illumination, should be optimised. Pruning techniques such as the bending of weaker shoots to support growth of the remaining shoots, a common practice on roses, has also been shown to support strong and healthy plants.

Conclusions

If the presence of plant-parasitic nematodes is suspected in soil-less culture systems, plant material and recirculation water should be routinely monitored. Following the discovery of nematode infestation, the source of infestation needs to be quickly identified and eliminated. Nematode dissemination with recirculation water into non-infested areas can be best avoided by treating the recirculation water by means of heat or UV radiation. Control of nematodes on infested plants is difficult as chemicals in most cases are not available and alternatives do not exist. Severe nematode infestation can only be eliminated by a thorough clean-up of the whole system and avoidance of reinfestation.

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