PLANT-PARASITIC NEMATODES AND THEIR SIGNIFICANCE IN FOREST NURSERY PRODUCTION

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The forest nursery industry is particularly vulnerable to plant disease problems, including those caused by nematodes, because the objective of the industry is to obtain maximum seedling production with the minimum of time and space. Continuous cultivation of the same or similar plants within the same area is usually conducive to a rapid build up of nematode populations as well as other soil-borne pathogens. Irrigation also maintains suitable soil moisture levels for optimum plant growth so that the soil is kept ideally moist for nematode feeding and reproduction. High fertility levels cause lush root development that provides nematodes with an overabundant source of food.

Nematodes belong to a widely diverse group of invertebrates. There are many types of nematodes, including free-living, marine, and terrestrial forms, animal parasites, and plant parasites. Plant nematodes occur chiefly in the soil, are colorless, and have an elongated cylindrical shape. They are classified according to their parasitic habits. Those which live and complete at least part of their life cycle in the host tissue are termed endoparasites. Those that feed on plant roots without actually entering the plant tissue are called ectoparasites, and most plant pathogens fall in this group.

Plant nematodes usually have six developmental stages: egg, four larval or juvenile stages, and adult. There are four moults, allowing for increase in size and completion of maturity; the first moult usually occurs in the egg. The endoparasites usually lay their eggs in the host tissue either singly or en masse in a gelatinous matrix. The females in certain groups of nematodes retain the eggs within their bodies, which in turn become cysts. The ectoparasites deposit their eggs singly in the soil. When a nematode moults, the cuticle is shed. Some nematodes do not feed during this part of their life cycle, but pass through all four moults before obtaining food from the root tissue. With other nematodes, it has been shown that feeding is an essential prerequisite to moulting.

Most species of plant nematodes are bisexual, with males and females present. In a few cases, adult males are lacking or rarely occur.

The reaction of plants to attack by plant-parasitic nematodes varies considerably with different nematode and plant species. Nematode diseases ordinarily can not be diagnosed by symptoms alone. Poor growth, stunting, and discolored foliage resulting from nematode damage may also be produced by organisms other than nematodes or by certain environmental factors.

The parasitic life of the root knot nematode is typical of the sedentary endoparasite. The second stage larvae emerge from the egg, migrate through the soil, and become attacted to the young feeder roots of the host seedlings. The larvae enter near root tips and force their way into the central cylinder of the root. There they remain in a fixed position and enlarge as they mature, finally becoming pear-shaped. At maturity, the females deposit eggs in a protective gelatinous mass with as many as 300 to 500 eggs in some masses. These egg masses may be found just beneath the surface, or on the surface, of the roots. Nurse cells produced by the plant host in response to nematode feeding provide the sedentary females with a food source while they complete their life cycle. The feeding by these nematodes also cause galls to develop on the roots of most plants. As these galls decay, the eggs are released into the soil and the life cycle starts over again.

The lance nematode is a good example of a vagrant endoparasite of tree seedlings. This nematode is particularly damaging to pine seedlings. All stages, both larval and adult, are capable of penetrating the feeder roots and as they migrate through the cortical tissue they cause extensive internal destruction. This cortical breakdown allows other pathogens to enter and contribute to the general decay of the root system. Eggs may be laid in the root tissue or be deposited in the soil. The lance females, which remain worm-like at maturity, lay their eggs singly and produce no gelatinous mass.

The vagrant ectoparasites, such as the stunt nematode, do not enter the roots and the life cycle is completed entirely in the soil. They feed on the tender, young seedling roots by penetrating the epidermal cells with their stylet. Following a short period of feeding, they move to a new spot on the root surface and feed again. After the female larvae feed, moult, mature, and become fertilized, they lay eggs singly in the soil.

Sedentary endoparasites, such as the root-knot nematode, may cause galling of roots and in some cases there is a proliferation of root development near the galls. Others may cause little, if any, root galling and are revealed only as the swollen females erupt through the root epidermis. In contrast, lesions, necrotic cortex, and general decay of feeder roots are common when a vagrant endoparasite is causing disease. With vagrant ectoparasites, such as the stunt nematodes, the effect is less drastic. In some instances they cause discoloration and stunting of roots, surface lesions, galls on root tips in a few cases, but more often the effect of their feeding is just a general over-all reduction in lateral root development without any noticable decay.

The above-ground symptoms of all types of nematode diseases are generally similar. These symptoms are usually the same as those on any plant which has been deprived of an ample and properly functioning root system. Seedlings are stunted, leaves are reduced in size, and they become pale or chlorotic. Diseased seedlings have an increased tendency to show symptoms of mineral deficiency, even when high levels of fertility are maintained. Affected plants lack vigor and usually can not withstand long dry spells.

Low population levels of certain nematode species can be very damaging and are capable of causing obvious stunting. However, the majority of parasitic nematodes found in southern nurseries cause no observable field symptoms when population levels are low. In fact, at low levels it is difficult to measure any reduction in plant growth caused by their parasitism. Plant damage can only be seen if there is a continuous increase in the nematode population to a point where very high numbers are encountered. Exceptions to this are the fungus-nematode root rot complexes. Another exception occurs when the aggregate of several parasitic species, each few in number, constitute a high mixed population level.

Some of the more common plant-parasitic nematodes reported in forest nurseries are listed in table 1.

There are two general approaches in any nursery nematode control program. The first involves exclusion. The idea is simply not to permit the nematode to get into the nursery, assuming that the pest is not already there. Untreated top soil should not be hauled in to build seedbeds. In an effort to achieve sanitation, cultivation tools should be cleaned before use. The source of irrigation water is important. Water obtained from a river, pond, or drainage ditch may contain parasitic nematodes. However, because of the microscopic size of these parasites, and because they are soil inhabiting or live in plant tissues, the problems of detecting and preventing their spread is difficult and may be impossible for the nurseryman. The second approach is to learn to live with nematodes. Once the nursery is infested, it is virtually impossible to eradicate them. So the problem becomes one of population dynamics and we must employ means of lowering population levels to a point where seedlings can be grown profitably.

Since most forest nurseries are now reducing their annual production, crop rotation is possible. This is a very important cultural practice used in agriculture for nematode control when the species involved has a narrow host range. Parasitic nematodes live and reproduce only when they can feed on suitable host plants. In the absence of such plants, the nematodes starve. By growing non-host plants in alternate years, we can significantly reduce nematode populations. Fallow periods also lower nematode population levels. Harrowing or discing periodically is necessary to keep the land relatively free of weeds. This is important because certain weeds are satisfactory secondary hosts for many parasitic nematodes.

There are many chemicals recommended for the control of soil-borne nematodes; halogenated hydrocarbons are the most widely used. This group includes such familiar formulations as methyl bromide, ethylene dibromide,

Table 1.--Some common a natodes in forest nurseries

Feeding class	Genus	Common name	Comments
ENDOPARASITE			
vagrant	Hoplolaimus	lance	Very devastating pathogen on pine seedlings
	Pratylenchus	root-lesion	Effect unknown in southern nurseries
sedentary	Meloidodera	pine cystoid	Damaging to pine seedlings; however, not too widespread
	Meloidogyne	root-knot	Not yet reported to cause disease in southern forest nurseries
ECTOPARASITE	Belonolaimus	sting	Very danaging pathogen on pine seedlings in sandy soils
	Tylenchorhynchus	stunt	Causes disease when high populations present
	Hemicycliophora	sheath	Associated with problem spots in a few nurseries
	Xiphinema	dagger	Associated with problem spots; still need additional information
	Trichodorus	stubby-root)	
	Criconemoides	ring)	
	Hemicriconemoides	sheathoid)	Effect unknown in southern nurseries
	Helicotylenchus	)	
	Rotylenchus	spiral)	
	Schutellonema	)	

dichloropropane, dichloropropene, and dibromochloropropane. Much of the information concerning fumigation is of a local nature and it is rather difficult to draw general conclusions on the best chemical and manner of application for a given locality or given problem. Various nematodes react differently to the same nematocide, and the same species may react differently to different nematocides. This probably explains why there are so many divergent soil fumigation programs in forest nurseries in the southern states.

There is yet much to be learned about this phase of nursery management. With the advent of new multiple—use soil fumigants now coming on the market, small plot evaluation trials need to be started in several nurseries throughout the South. If satisfactory control of weeds, soil fungi, and nematodes can be achieved with the application of one multiple purpose soil fumigant, the high cost per acre of a broadcast treatment will be acceptable, and this particular management practice should prove to be economically feasible.

Nurserymen frequently ask us at the Athens Laboratory to analyze soil samples from diseased areas in their nurseries. They want us to offer suggestions as to whether or not they should fumigate. Unfortunately, we can not predict whether a particular population level or combination of parasitic species will cause a disease during a specific growing season, or even if they will be a source of trouble the following year. There is no doubt that a large part of the growth response and increased yield in nurseries following the use of nematocides is caused by nematode control. However, the emperical approach which has been taken in soil fumigation of nurseries has left us with insufficient information concerning the development of field symptoms. Correlations between symptoms and population levels of the various nematodes involved in nursery problems have not been studied extensively and some basic work in this area will broaden the possibilities of control. We want to learn more about nematode—tree associations. We would like to discover just how nematodes damage roots and reduce growth of forest tree seedlings. Once we discover which nematodes are causing root damage, and just how many in a given environment will cause a particular disease, we will be better able to conduct an advisory service to aid in the successful control of nematode diseases in forest tree nurseries.

DISCUSSION TO: A. A. Foster and J. L. Ruehle

Q. Is there any attempt being made to use trap crops as cover crops in the southeast?

A. (Ruehle) This has been tried some in Florida and several other places, I believe, but you have a different situation here because your idea is to go in, when the interest crop is starting to be produced, and plow that crop up at the right time to be most susceptible to being perished. If you let this crop go too long, then you are building yourself up a nice population of these pests. It's not as though they get in the roots and then die. Some of the trap crop is lost too. Another idea is the use of African marigold or other plants of this nature. These produce something in the roots which is supposed to control and be toxic to nematodes; thus lowering the population in the soil. It has been tried and used successfully on some of the Islands in the Pacific which produce tea. It has been used in Holland, too. So far as I know, no one has tried these to any benefit in the United States. Some day we may be growing marigolds out in our forest ranges, but I don't know whether its worth the trouble.

Q. What is the relative susceptability of different cover crops for nematodes--such as how would you compare soybeans to corn and oats?

A. (Ruehle) Well, this is tough because something like soybeans, if you got the right nematode, the soybean cyst nematode increases very well but from what I know of this nematode, it doesn't bother pines. Cowpeas--they are quite susceptible to some varieties of root knot. If you're growing pines, you may not have a problem but if you're growing some broadleaf seedlings you may have to change cover crops. It's just like I mentioned in my talk, we know very little about what nematodes are doing in many of these species you raise in the nurseries. It's just going to be a matter of getting down and digging a little bit before we find out; but, it's a good. point to keep in mind when you are working with cover crops and you get into a problem. Where you don't fumigate for this, just keep nematodes in mind and you may have created yourself problems of this kind.

Q. We had a problem defined as a nematode root rot complex. How often does that happen and what do you do, call a pathologist or nematologist?

A. (Ruehle) I think a lot of that work was speculation. I don't want to downgrade any of that business because I don't know enough about it nor what role the nematodes play in the production of pine seedlings. I seriously doubt that the sclerotium fusarium complex would cause the typical black root rot. Root rot is going to be dependent on preliminary type nematodes. It may be aggravated to some extent, but I just believe these complexes are going to do well without preliminary nematodes. Now when you are getting into this other shady area to what Jimmy Rowan calls brown root rot, he says he can tell the difference, what role nematodes play here now I just don't know. I would even be afraid to guess. But, it's still a good idea to call in a pathologist.

Q. Have there been any other reported cases, other than those of the State Plant Board of Florida, to where the nematode was eliminated and the root rot problem reduced?

A. (Ruehle) Yes, down in Louisiana. I don't know about recent work, but it was reported in Louisiana. They used DD at pretty high rates. They said they got control of root rot and this is what started putting people on the idea that this was a nematode—fungus complex. Only nobody's been able to duplicate it.

COIDENTS by Mr. Heltzel:

It happened to us too. We had response from DD and some other nematocides. However, we had equally as good, or better, response from straight methyl bromide.

A. (Ruehle) Yes, pure methyl bromide has the action to stop these things. You're not only controlling a nematode population, you're controlling a fungus population. This would really be the recommendation and you got the added advantage of throwing in a weed killer along with the methyl bromide.

MINTS by Mr. Davey:

There has been some other reports on this. There is a book currently underway at North Carolina State on soybean nematodes and the fusarium root rot. The soybean that has been found there, apparently, if the nematode is controlled, the fusarium doesn't get involved. In fact, in pure culture studies, fusarium has been found stimulating to the growth of the soybean, but put a few nematodes in there, punch a few holes in the root, and apparently the fusarium gets in.

A. (Ruehle) Oh, yes, well this is absolutely true with nematodes, root knot, and cotton root knot nematode. Many of these we know about in agricultural situations, but this same thing in forest nurseries- this I don't know.