CITRUS NEMATODE

Tylenchulus semipenetrans Cobb

1 PATHOLOGICAL PROFILE

2.1 Distribution and status

The citrus nematode is a soil-borne pest causing slow decline in all citrus producing regions of the world. It occurs in all the citrus growing areas of southern Africa where it forms part of the citrus root rot complex. It is particularly common in older orchards and in replant situations.

In South Africa the host range of the citrus nematode is limited to citrus, citrus hybrids and grapes. It is the only nematode species that causes losses of economic importance on citrus in southern Africa.

1.2 Description

The citrus nematode life cycle comprises the egg, four juvenile stages and the adult. The first stage juveniles develop within the eggs and moult to form second stage juveniles which hatch from the eggs, and infect the feeder roots. These juveniles are slim, worm-like creatures of microscopic size.

Only the females attack and penetrate deep into the feeder root cortical tissue where they become immobile, establish permanent feeding sites and swell posteriorly (Figure 7.3). The mature female lays 75 to 100 eggs in a gelatinous matrix. Eggs hatch under suitable conditions, i.e. following irrigation or rain, when the soil temperature is above 20°C. The eggs are able to survive for up to nine years in the soil.

The above description of *Tylenchulus* is by no means complete. Growers wishing to obtain more details should consult the publication "Plant Parasitic Nematodes in Subtropical and Tropical Agriculture" by L.W. Duncan and E. Cohn available from C A B International, Oxon, UK.

1.3 Symptoms

Unlike gall-forming nematodes, the symptoms of citrus nematode are often nondescript and difficult to diagnose. This nematode causes a gradual deterioration of older trees, which leads to loss of vigour and yield. Leaves of severely infested trees are dull green and smaller than normal. Small twigs die back, resulting in a sparse canopy. Nutrient deficiency symptoms are also common.

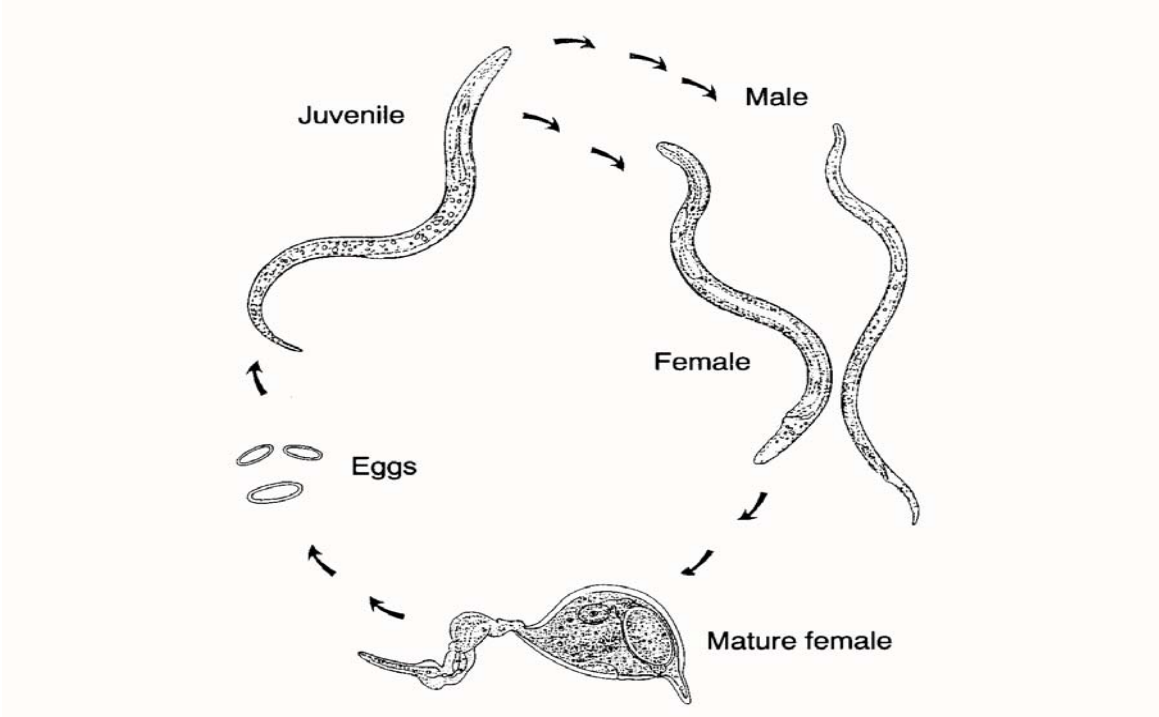

Figure 7.3. Simplified life cycle of the citrus nematode (Courtesy J. Heyns)

Nematode injury leads to an impairment of the root's ability to take up nutrients selectively. As a result of this there is, under saline conditions, an increase in sodium uptake, and a corresponding decrease in potassium uptake, which can result in sodium toxicity. The main symptom is a yellowing of the leaves. In extreme cases leaf drop may occur.

Since the increase in sodium uptake is associated with a decrease in potassium uptake, infested orchards tend to produce smaller fruit. Additional factors such as water stress and depletion of carbohydrates also contribute to the production of smaller fruit and eventual tree decline.

On examination of heavily infested feeder roots, the presence of feeding females can sometimes be observed. These roots are encrusted with clay and sand particles which adhere to the gelatinous material that surrounds the eggs. This results in infested feeder roots having a dirty appearance compared to the yellowish appearance of healthy roots. Heavily infested roots may be slightly thicker than healthy roots.

Secondary infection by fungi such as *Phytophthora* and *Fusarium* which gain entrance to the roots at nematode feeding sites, results in cortical sloughing and death of feeder roots.

1.4 Transmission

The citrus nematode moves very slowly through the soil. Dissemination in the past was mostly due to infested nursery stock from infested open-ground nurseries where the nematode was spread from tree to tree by flood irrigation.

The second most important means of dissemination is through the use of infested irrigation water. However, current research indicates that, though rivers such as the Crocodile and Letaba are infested, it may take several years before plantings on virgin soils irrigated from these rivers become infested. This is due to extreme temperatures which occur in the root zones of newly established plantings and the slow natural migration of the citrus nematode through the soil. Irrigation water can be decontaminated by the use of settling ponds or filtration systems.

Separate equipment for use in infested and non infested orchards may be feasible in some cases. To prevent the spread of nematodes to non-infested orchards it may be feasible to continually disinfest equipment prior to use in non-infested orchards by removing soil particles with high pressure water hoses.

1.5 Seasonal occurrence

The seasonal fluctuation of citrus nematode populations differs between the summer and winter rainfall areas of southern Africa.

In the summer rainfall areas the juvenile populations in the soil and roots tend to peak after each root flush. These peaks occur during spring (September to October). Hatching of the juveniles is thus correlated with the occurrence of root flushes

In the winter rainfall areas seasonal changes in the soil environment appear to be more important than the timing of root flushes. The juvenile populations start to increase with the commencement of the rainy season during autumn (March to April) and reach a peak in late winter (August).

Unlike the females, whose heads are embedded in the roots, the juveniles are sensitive to extreme moisture conditions. The female populations in the roots therefore fluctuate less than the juvenile population in the soil.

2 MANAGEMENT ASPECTS

2.1 Disease assessment

2.1.1 Non-bearing trees

All trees approved by the Citrus Improvement Programme (CIP) are free of nematodes. On virgin soil nematode populations will normally not become established before trees reach bearing age. This is due to the lack of shade and resultant extreme temperatures which occur in the root zones of newly established plantings, and the slow natural migration of the citrus nematode through the soil. (Soil temperatures of up to 43°C have been measured at a depth of 10 cm below the soil surface in Limpopo Province Lowveld during the month of January.).

Even if the trees are irrigated with nematode infested water, the development of nematode populations on young trees is slow.

The same applies to citrus planted on replant soils infested with citrus nematode eggs. As long as the canopies are too small to provide sufficient shade, the juveniles that hatch are killed before the roots can be infested.

Organic mulches or persistent weed growth can lower soil temperatures and result in the re-establishment of citrus nematode populations on replant soils within two years after planting. Sampling of trees on replant soils on an annual basis is therefore necessary. Trees planted on virgin soils need to be monitored for nematodes only every third year.

2.1.2 Bearing trees

The effect of nematodes on yield differs from orchard to orchard, depending on the overall orchard condition. General thresholds, based on adult female counts taken from root samples, have been developed to determine when nematicide applications are necessary. Samples for such assessment should be sent to the Diagnostic Centre. For sampling procedure consult the part on the Diagnostic Centre in Chapter 5.

Samples can be taken at any time of the year as nematode female counts are used as criteria (Tables 7.3 and 7.4). The samples must be taken from trees which are rated between 0 and 4, where 0 represents a healthy tree and 10 a dead tree.

Research has shown that only trees with ratings ranging from 1 to 4 respond to nematicide treatment. The descriptions of the ratings 1 to 5 are as follows:

Rating 1-2: Healthy tree canopy, dark green, vigorous, large leaves and fruit.

Rating 3: Healthy tree. No obvious decline symptoms. Canopy a slightly lighter green.

Rating 4: Slight terminal branch die-back. Canopy beginning to become sparse. Smaller terminal leaves and fruit.

Rating 5: Canopy sparse. Terminal branch die-back, leaf chlorosis. Small leaves and fruit. Yield reduction obvious.

The **host-pathogen relationship** is illustrated in Figure 7.4 and can be explained as follows:

CIP approved trees are initially nematode free. When these trees are planted on virgin or well prepared replant soil with undetectable low nematode population levels, they will initially be healthy (Stage A, Figure 7.4). The survival of nematode juveniles which hatch from eggs in replant soil, will in time result in a nematode population becoming established (Stage 2, Figure 7.4).

In replant soils, hatching juveniles survive in the shaded areas created by the increasing tree canopy size. While these trees are young, vigorous and well maintained, no obvious decline in plant health occurs. Feeder roots are replaced as soon as they become ineffective. (Stage B, Figure 7.4). However, as the population increases, roots are eventually destroyed at a faster rate than they can be replaced. As the tree is in production by this stage and needs to support a crop of fruit as well, it starts to decline in vigour and growth (Stage C, Figure 7.4).

The nematode population continues to increase (Stage 3, Figure 7.4), until a stage is reached where the roots are destroyed by secondary pathogens such as *Fusarium.* By this stage there are few roots left for the nematodes to infest and the population starts to decline (Stage 4, Figure 7.4). The tree declines until it eventually reaches an equilibrium with the population (Stage 5, Figure 7.4). The tree survives (Stage D, Figure 7.4), but does not produce a profitable crop.

Sampling at stage D can lead to a false impression being created by the low nematode counts leading the grower to believe that nematodes played no role in the decline of the trees. To prevent this, **growers are advised to sample their trees regularly between stages A and C for analysis by the DC to detect potential nematode problems before fruit size or yield are affected.**

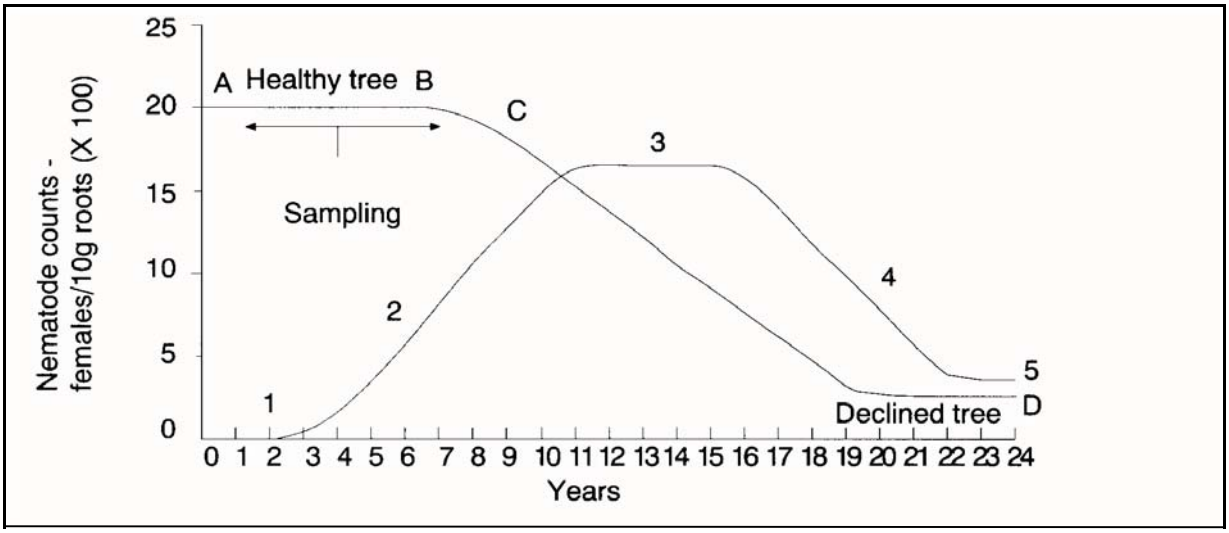

Figure 7.4. The host-pathogen relationship that exists between the citrus tree and the citrus nematode population.

2.2 Control options

2.2.1 Cultural

Certified nursery trees

The most important control option for new orchards is to exclude nematodes by only planting trees approved by the CIP.

Orchard management

The response to nematode control treatments can be limited in orchards where tree condition is affected by other problems. Correcting problems such as poor drainage, inadequate soil depth for root development, drought stress, excessive salinity or irrigation schedules that favour *Phytophthora* root rot could be more important than trying to control nematode populations and should be corrected before investing in nematicides.

Tolerant rootstocks

Tolerant rootstocks should be used where possible. Selection must also be based on soil type and horticultural considerations. Table 7.2 illustrates the relative susceptibility of different rootstocks to the citrus nematode. (Consult the chapter on ROOTSTOCK CHOICE in Volume 1 of these guidelines).

Table 7.2. Relative tolerance of the most commonly used rootstocks in southern Africa to citrus nematode

Rootstock	Tolerance to *Tylenchulus semipenetrans*
Rough lemon	Highly susceptible
Volckameriana	Highly susceptible
Empress mandarin	Highly susceptible
Cleopatra mandarin	Highly susceptible
Carrizo citrange	Susceptible
Troyer citrange	Susceptible
Yuma citrange	Susceptible
X639 hybrid	Susceptible
Minneola x trifoliate	Susceptible
Swingle citrumelo	Tolerant*
Trifoliate	Resistant

*With the exception of a few replant orchards where the citrus nematode succeeded to break this resistance.

Soil solarisation

Control by means of hydrothermal heating of the soil is ineffective due to the survival of nematode eggs and is therefore not recommended.

Soil preparation

When replanting on old citrus, soils all the old roots must ideally be removed and the soils must be planted with a cover crop such as *Eragrostis* grass for at least one, but preferably three years, before replanting. Though there is no guarantee that this will destroy the citrus nematode egg population completely, it will be reduced to almost undetectable levels.

Alternatively, the soil should be allowed to dry out completely after soil preparation by deep ploughing or ripping. This will totally eliminate the juvenile stages but not the eggs. As the tree canopies increase in size, the shading effect creates a micro-climate favourable for the citrus nematode. Eggs which hatch under these conditions will re-establish the nematode population and chemical treatment will again become necessary.

2.2.2 Biological control

Microbial agents which attack citrus nematodes do exist. These include bacteria and fungi such as *Arthrobotrys, Monacrosporium* and *Dactylella. Paecillomyces lilanicus* has been registered for commercial use on citrus. Results are erratic and growers using biological control products should realise that it takes great effort to keep the environmental conditions in the soil favourable for the biological agents to survive.

Growers should avoid the use of unregistered biological control agents as these products are often contaminated with other soil borne diseases, e.g. *Phytophthora.*

All biocontrol products should state the registration (L) number, the genus, species, batch number, propagules/g and expiry date.

2.2.3 Plant protection products

Pre-plant treatments

The most effective way to eliminate the citrus nematode, and other pathogenic fungi after removal of an old infested orchard, is by methyl bromide (MBr) hot gas fumigation. Fumigation should be done by a pest control specialist because of the danger to humans and the specialist knowledge required to apply this chemical effectively. The registered treatment is as follows:

MBr 100 g/m^2

A safety period of 30 days between treatment and planting should be observed to avoid phytotoxicity.

Soil solarisation with clear polyethylene for 8 weeks was ineffective.

Post-plant treatments

In the summer rainfall areas, applications should commence at the completion of each of the spring (late September), summer (December) and autumn foliar flushes. Alternatively, three treatments should be applied starting at the end of September and thereafter every two months.

In the winter rainfall areas the first treatment should be applied with the commencement of the rainy season, in March/April, followed by a second treatment two months later in May/June and the final treatment two months later (July/August).

To ensure that the life cycle of the citrus nematode is effectively broken, it is essential that all three treatments are applied. Rather treat fewer orchards correctly, than all the orchards partially.

The registered post-plant treatments are as follows:

	Per m^2
Counter GR	20 g
Nemacur EC	4-10 ml
Nemacur GR	18-40 g
Rugby GR	15-25 g
Temik GR	12,5 g
Mocap EC	7,5 ml

Temik moves both basipetally and acropetally in the tree and is used as a broad spectrum insecticide/nematicide. On some farms it is not used because of disruption of biological control in the canopy of the tree. If used as a broad spectrum systemic insecticide, it should be

alternated with other crop protection products to prevent the likelihood of accelerated microbial degradation (AMD) developing.
Nemacur is registered for use only once per season on the same soils. It will therefore have to be alternated with other nematicides.

Counter is an effective nematicide, but gives off an odour if it is not properly incorporated into the soil, which affects the natural enemies attacking red scale. Red scale repercussions can occur as a result of the use of this product. Counter should therefore not be applied during the period of peak natural enemy activity in orchards in which red scale is not under commercial control. The time of the year will differ from one area to another but will be from approximately December to April.

Rugby has been used very successfully in breaking the citrus nematode's life cycle. However, three applications per season are necessary.

The following general comments apply to the use of nematicides :

- The nematicides registered in South Africa for application after planting are either carbamates or organophosphates. Both chemical groups are acetyl cholinesterase inhibitors.

- AMD of Temik (carbamate) and Nemacur (organophosphate) has been found to occur in South Africa after repeated applications of these chemicals. The same nematicide should therefore not be used in successive seasons on the same soil. The use of organophosphate nematicides may, in certain cases, also predispose soils to AMD of carbamate nematicides. The different organophosphates should therefore also be alternated. If a grower suspects (as a result of poor reduction in nematode counts following treatment) that AMD is occurring in a particular orchard, he should contact the Diagnostic Centre in Nelspruit (ph. 013 759 8000).

- Applications should be made on moist, weed-free soil surfaces. Nematicides are highly toxic and should therefore be incorporated into the soil as soon as possible after application by means of irrigation with 40-50 mm water.

- The nematicide, whether systemic or contact, must be applied over the entire feeder root area.

- Orchards which are visually in good condition, but which produce small fruit or low yields and where the nematode counts are higher than the threshold levels, should be treated first. These are the trees which will probably give the highest returns on money spent on nematicides.

Table 7.3. Sampling and nematicide application calendar for citrus nematode in bearing orchards in the summer rainfall areas.

	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Sampling*												
Spring treatment **												
Summer treatment ***												
Autumn treatment ****												

* Sampling: Sampling can be done at any time of the year. However, July to August is preferred as this allows several months for dead females to disintegrate if a treatment was applied during the previous autumn, but leaves enough time to obtain sampling results before the first applications in October.

** Spring treatment: Counter, Nemacur, Rugby, Mocap or Temik can be used.

*** Summer treatment: Counter can be applied if red scale is under commercial control. Nemacur can be applied if it was not applied as a spring application. Make sure that picking will commence only after the 150 day withholding period. Temik can be used on late maturing cultivars. Do not harvest within the 150 day withholding period or, in the case of lemons, 100 days. Rugby and Mocap can be used.

**** Autumn treatment: Counter can be applied if red scale is under commercial control. **If not, do not use!** Nemacur and Temik should not be used because of withholding periods. Rugby and Mocap can be used since they have no withholding period

Table 7.4. Sampling and nematicide application calendar for citrus nematode in bearing orchards in the winter rainfall areas.

	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
Sampling *												
First treatment**												
Second treatment***												
Third treatment ******												

* Sampling: Nematode female counts can be done at any time of the year. Sampling from January to March allows several months for the disintegration of females if a treatment was applied in August the previous year. This also allows enough time to receive results before treatments commence at the beginning of the rainy season.

** Withholding periods: These must always be considered when choosing a nematicide. Refer to Table 10.7.