Potatoes Aartappels SA

Eelworm pests

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EELWORMS (NEMATODES)

Few people are aware of the importance of eelworms (nematodes) because they are microscopically small. However, nematodes are one of the most abundant organisms on earth with more than 14 000 species. Experts have estimated that in an area of 1 m² about one million nematodes of hundreds of different species can occur.

The latter nematodes occupy many different ecological niches. They occur in every conceivable habitat and some are parasites in plants and animals and also in other organisms. Nematodes can be herbivores, omnivores or carnivores. Some of them are very specific about what they feed on while other species are common feeders, e.g. root-knot nematodes and lesion nematodes that have a wide host range.

The nematode species composition in South Africa differs from that of other countries. The species composition of nematodes in South Africa may vary in different regions and on different farms because climate and crops cultivated affect the species composition.

More than 450 plant-parasitic nematode species have been recorded in South Africa, of which 95 are from potatoes or soil in which potatoes were produced.

Role of eelworms in soil health

Most free-living eelworms feed on bacteria, fungi and parasitic eelworms. Eelworms play a special role in the decomposition of organic matter in soil ecosystems. They partially break down plant material so it can be further broken down by bacterial composters. The population levels of free-living (non-parasitic) eelworm in soil are used worldwide as an indicator of soil health.

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DAMAGE

A recent survey by the Agricultural Research Council (ARC) indicates that potato farmers in eight production regions believe that eelworm are always a serious problem, whereas eelworms in five regions are sometimes a serious problem. Farmers in only three regions rarely experience eelworm problems.

Nematode infestation causes direct and indirect damage. Direct root damage results in inability to absorb water and nutrients and this can lead to yield reductions. Indirect damage may include:

- Impairment of root function leads to weakened plants that are susceptible to leaf diseases such as brown spot;
- Some species may be the vector of other diseases such as TRV *(Tobacco rattle virus)*;
- Wounds on roots and tubers caused by eelworms serve as a pathway for pathogens such as *Verticillium dahliae*, *Fusarium spp* and soft rot pathogens that are part of the early dying disease of potatoes; and
- Symptoms of especially root-knot nematode lead to a decrease in the quality and the downgrading of of table and seed potatoes.

Juvenile eelworms feed on tissue by pushing a stylet, which is a microscopic hollow tube, into the tissue. Enzymes to digest plant cells are released into the root and plant sap is absorbed through the feeding tube of the eelworm.

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MANAGE THE RISK OF EELWORMS

FIELD CHOICE

RISK	MANAGEMENT
Eelworm status unknown	The population level and eelworm species can be determined by sending a soil sample and the roots of any actively growing volunteer potatoes or roots of weeds to a laboratory for analysis. Make sure the sample is taken correctly.
Soil with a history of nematode	Apply chemical control before planting.
Short rotation cycle	• Plant crops that are not hosts of nematodes between potato plantings. • Cover crops such as *Eragrostis* are good crop rotation crops.
Waterlogged soil	Avoid waterlogged soil as it weakens root function.
Sandy soil	The structure of sandy soil is ideal for nematodes to move in. Ensure that nematode control measures are applied accurately.
Plant residue in the soil	A large amount of non-composted plant residues complicates chemical treatment. Remove it or leave the soil fallow.
Clay soil	Fumigation is not effective in heavy clay soils.

CULTIVAR CHOICE

RISK	MANAGEMENT
Susceptible potato cultivars	• No tolerant or resistant potato cultivars are available. Therefore, make sure that all other measures to reduce nematode are applied. • Consider planting short growers to limit the life cycles of eelworm, effectively reducing potential damage.

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MANAGE THE RISK OF EELWORMS

PLANTING TIME

RISK	MANAGEMENT
Cold soil	• Fumigation is not effective in cold soil. If planting time cannot be moved, fumigate soil by the end of the previous season and then leave the soil fallow in winter. • Make sure that animals that have eaten contaminated potatoes do not graze on the land. • Apply nematicides after fumigation and before or during planting time as prescribeed in the the instructions.
Warm soil	• Eelworms multiply rapidly at high temperatures. • If planting in warm soil, ensure that control measures are applied thoroughly. • If a field has a history of eelworm, avoid planting in warm soil.

SOIL TREATMENT

RISK	MANAGEMENT
Cloddy soil	Fumigation and nematicides are not effective in cloddy soil. Ensure good soil preparation.
Label instructions are not followed	Treatment is ineffective. Follow the recommendations on the label of each product.
Clay soil	Fumigation is not effective in heavy clay soils.

SEED

RISK	MANAGEMENT
Contaminated seed potatoes	• Infected seed would establish eelworms in the soil, even if the soil was treated against nematodes. • Only plant certified seed and consult the inspection report to assess the risk involved.

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MANAGE THE RISK OF EELWORMS

CROP MAINTENANCE

RISK	MANAGEMENT
Contaminated water	• Rapidly flowing rivers are often infected with eelworms. • Pump water from a dam or a slowly flowing river near the surface.
Weakened plants	• When weakened plants become infected by nematodes, the plant is unable to grow optimally and this can result in crop failure or tubers severely infected with eelworms. • Ensure that fertilisation and irrigation are optimal. • Control leaf diseases and insect pests.
High rainfall during the season	• High rainfall during the season can cause the water level to rise to the root zone. • Eelworms found in deeper soil layers end up in the root zone.

HARVEST

RISK	MANAGEMENT
Infected tubers are stored in the soil	• When infected tubers are stored in the soil, eelworm continues to multiply. • Early kill-off followed by harvesting as soon as the skin has set can be applied to limit damage.
Infected tubers are fed to farm animals	If cull potatoes are heavily infected, the ideal option is to burn it rather than feeding to cattle.

WASH

RISK	MANAGEMENT
Galls on tubers	When tubers with galls are washed and brushed the outer layers of tissue are easily removed. This causes open lesions that may lead to soft rot. Apply a sanitiser correctly.

Nematodes have been in existance for a very long time

Eelworms are one of the oldest forms of life. Although the oldest fossil record is 400 million years old, an expert on the prehistoric history of eelworms believes that the group probably originated (in geological terms) shortly after bacteria, fungi and protozoa. This means that they probably originated one billion years ago.

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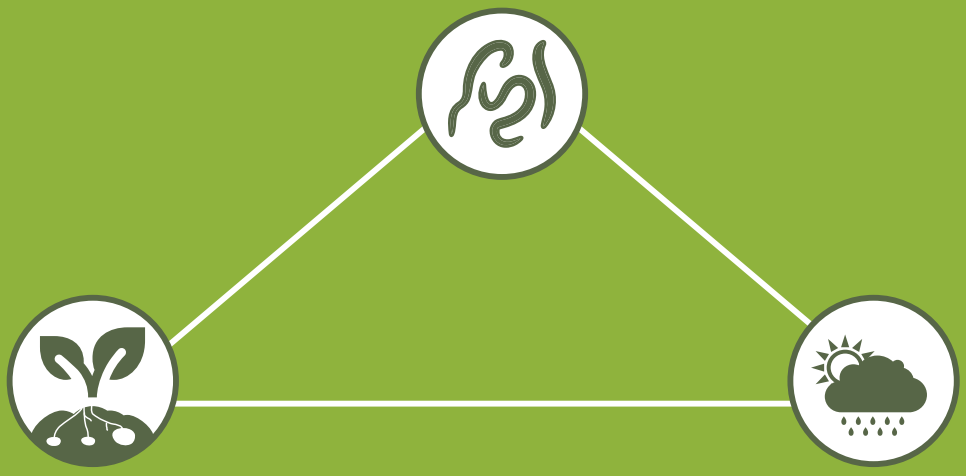
DISEASE DEVELOPMENT

Nematodes

- Root-knot and lesion nematodes cause the biggest problems in South Africa.
- Eelworms are killed by nematicides during the J2 stage.
- Eelworms depend on water to move in soil.
- Eelworm eggs survive for long periods in soil.



PLANT

- All potato cultivars are susceptible to eelworms.
- Weakened plants are more susceptible to infestation.
- Plants with strong, healthy root systems are more tolerant to damage caused by nematodes.

ENVIRONMENTAL CONDITIONS

- Waterlogged conditions promote eelworm infestation.
- Eelworms multiply rapidly at high temperatures.

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NEMATODE SPECIES IN SOUTH AFRICA

According to the SAPPNS and NCN databases, six species of rootknot nematode *(Meloidognye spp)* were recorded in 15 regions, while 12 species of lesion nematode *(Pratylenchus spp)* were recorded in 15 regions. *Nanidorus minor*, which is the vector of TRV *(Tobacco rattle virus)*, was recorded in 13 regions. Please note: TRV has not yet been recorded in South Africa.

Root-knot nematode

Root-knot nematode is a pest that occurs on most crops and is known to be a problem in tropical and subtropical areas of the world. Six root-knot nematode species have been recorded in South Africa, viz. *Meloidogyne acronea, M. arenaria, M. chitwoodi, M. enterolobii, M. hapla, M. incognita* and *M. javanica*. Of all the species, *M. incognita* and *M. javanica* are most common.

The life cycle of the root-knot nematode includes an egg and four juvenile stages. They develop in the egg until the second larva stage (J2). The J2 juvenile stages respond to stimuli of root secretion and favourable soil and environmental conditions by hatching from the egg and invading the roots and tubers.

Development continues in the plant. Adult female larvae lay between 200 and 1 000 eggs in a jelly-like mass on or under the surface of an infested root or tuber. The life cycle of rootknot

Nematode varies between three and six weeks and under favourable conditions, five to six generations can be completed in one season. Most species develop optimally at temperatures >20°C, but *M. hapla* and *M. chitwoodi* can develop at lower temperatures. M. chitwoodi is capable of developing at about 8°C. This means that these species can multiply in cold storage.

M. hapla has been reported in KwaZulu-Natal, Eastern Cape and Northern Cape.
M. chitwoodi has been reported in KwaZulu-Natal, North-Eastern Cape and Eastern Cape.

Lesion nematode

The presence and damage that this group of nematodes cause, are often underestimated because above-ground symptoms are often confused with symptoms of soil-borne diseases such as Verticilium and Fusarium wilt. However, lesion nematode is common in South Africa and can cause significant damage.

Of the 12 species reported, *Pratylenchus zeae* was found in nine production regions. In principle, lesion nematodes are endoparasites, but about 20% to 50% of the population can be found in soil and feed as ectoparasites on roots. All stages of lesion nematode can over-winter and certain species such as *P. penetrans* can survive at temperatures below freezing. The optimum temperatures are between 10°C and 30°C, depending on the species. Lesions caused by ectoparasitic individuals give access to root tissue to spores of *Fusarium* and *Verticillium* species.

Golden cyst nematode (quarantine organism)

Two parasitic cyst nematode species exist, viz. *Globodera pallida*, not found in South Africa, but is a problem in Europe and *G. rostochiensis* (golden cyst nematode), which is very restricted on identified farms in the Eastern Cape, Gauteng and Western Cape. Farms where the golden cyst nematode was found, were quarantined by the Department to limit the spread to other farms and regions. Furthermore, all registered seed plantings in South Africa are being investigated by the Potato Certification Service for the presence of golden cyst nematodes.

The risk of golden cyst nematodes being spread by seed potatoes in South Africa is very low.

Every effort should be made to limit the spread of *Globodera rostochiensis* and keep *G. pallida* out of the country. It is estimated that a loss of 2 t/ha can be expected when 20 eggs per gram of soil occur. Eggs in cysts can survive in the soil for 20 – 30 years. Although cysts do not appear in tubers, they can occur unnoticed on the surface of tubers. This is one of the reasons why Potatoes South Africa is strongly opposed to the importation of seed potatoes.

EELWORMS IN SOIL

Distribution of eelworm in soil

Eelworms are aquatic organisms and move (swim) between soil particles with undulating movements from head to tail in the thin layer of water adsorbed on the surface of soil particles. The soil particle serves as the basis for the larva to move forward.

When soil is dry, the layer of water is too thin to swim in and surface tension prevents the larva from moving.

Also, if the layer around soil particles is too thick, they cannot move forward because the soil particles cannot serve as a base for moving forward. It happens when the soil is very wet. This non-directional movement of larvae under wet conditions causes them to move downwards in soil, often below the root zone.

When the soil dries out again, the nematodes move upwards in the water film.

Under favourable conditions, eelworms can move up to one metre in the soil to suitable roots. If eelworms end up in groundwater with a low concentration of oxygen, they will not be able to swim to the top and will eventually die. Eggs are not washed to the lower soil layers and will hatch to infect roots for as long as soil moisture and oxygen concentration are favourable.

When the spaces between soil particles are smaller than the diameter of eelworm individuals, larvae movement is limited.

Eelworms, therefore, do not spread as quickly in clay soils (clay percentage higher than 20%) as in sandy soils. Therefore, sandy soil poses a high risk of eelworm damage.

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EELWORMS IN SOIL

Survival in soil

Eelworms have developed different strategies to ensure survival in soil, namely:

- Immature eelworms are protected by the thick wall of eggs;
- Gelatinous envelope containing root-knot nematode eggs;
- Resistant cyst walls in which cyst nematode eggs are present;
- Ability to temporarily halt their life cycle until conditions are favourable for development; and
- Physiological processes to survive extreme adverse environmental conditions. Under local conditions, *anhydrobiosis* is of great importance as it enables rootknot nematodes to survive under arid conditions. In this form, they are metabolically inactive, but once moisture is available, nematodes become active again. Physiological processes exist to withstand cold, heat and oxygen deficiency in various nematodes.

PRINCIPLES OF EELWORM CONTROL IN SOUTH AFRICA

An eelworm control programme is successful if the number of nematodes in soil is kept as low as possible between potato plantings and in the potato growing season. There is no control method that can be successful in isolation to control nematodes. As many measures as possible should be applied to limit population levels of nematodes in the soil.

Eelworms occur in almost all potato soils and it is challenging, often impossible, to rid the soil of nematodes once it has become infected. Factors contributing to this include:

- High population levels in soil due to short life cycle (3 – 4 weeks) and large numbers of eggs laid every 20 – 30 days. The higher the temperature the shorter the life cycle;
- Ability to survive for long periods in the soil;
- Eggs that hatch over time and not all at once;
- Wide host range that includes many weeds; and
- Uncomposted plant remains that ensure survival over short periods.

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Know the status of eelworms in the soil

The population levels of eelworms in the soil are indicative of the risk of damage in the next season. It is becoming increasingly important to know which nematode species are present in the soil so that resistant crops and cover crops can be planted.

There are several laboratories in South Africa that identify eelworms and can estimate the level of infestation. Soil samples should be taken during the season preceding potatoes when the roots of the plants are still alive so that the specialists can identify the eelworms. It is not possible to determine the species to which eggs belong, but the number of eggs in a soil sample indicates the population level. Soil and root samples should be taken to be representative of the entire field. Samples should be taken about 15 cm deep in a zig-zag pattern all over the field.

All the individual samples should be well mixed with about 2 kg of soil, then placed in a clean plastic bag, marked clearly with a card that is securely attached to the bag. Keep the sample cool (definitely out of the sun) and send it to the laboratory as soon as possible. Make arrangements to prevent delay.

Limit further spread

Nematodes only move in the water on their own under specific conditions. Their spread is due to contaminated plant material, ignorance and uninformed agricultural practices. It can also spread through wind or contaminated irrigation - and runoff water. The infected cull potatoes fed to animals also serve as a spreading mechanism as nematodes are not killed in the digestive system of animals.

Potato cultivar choice

No potato cultivars currently available are resistant to root-knot or lesion nematodes. By planting and harvesting cultivars with a short growing season and harvesting as soon as tubers are ready, the number of life cycles of eelworms can be limited to minimise damage.

In Europe, cultivars are resistant to cyst and lesion nematodes, but not to root-knot nematodes. Planting such cultivars will be of value only if root-knot nematodes are not present in the soil.

Avoid other eelworm hosts

If the right crops are planted and the rotation cycle is long enough, crop rotation is one of the most effective ways to reduce the occurrence of plant-parasitic eelworms in the soil. Lesion nematode control by crop rotation is difficult because almost all crops, including grasses, are hosts to lesion nematodes. Although root-knot nematodes have a wide range of hosts, some grasses can be used. Crops that should not be used in rotation with potatoes if eelworms are a problem, include beans, maize, tomatoes, peppers, tobacco, alfalfa and peas. There are cultivars of cotton and oats that can be planted because of their resistance to root-knot nematodes.

Grasses that can be used in rotation with potatoes are Blue Buffalo grass, Bristle grass, Crotalaria species (Sunn Hemp), Vetiver grass, millet cultivars such as *Panicum miliaceum*, Weeping Love grass (Ermelo type), Rhodes grass, Ryegrass and Smutsfinger grass. The various grass crops and different cultivars of a specific grass can differ in respect of there resistance to root-knot nematode species. In order to successfully use rotational crops to reduce eelworm populations, it will become increasingly necessary to determine the resistance or tolerance of different crops to specific nematode species.

Many weeds are also hosts of eelworms and together with volunteer potatoes they can maintain or even increase the eelworm population in the soil - even if resistant rotational crops are planted. Weed should be controlled as soon as potatoes are harvested.

Crop rotation of at least four years is recommended, but the longer the period between potato plantings, the greater the chance that the nematode population will decrease in the soil.

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Do not store potatoes in soil

Root-knot nematodes do not cease to invade and multiply in tubers after foliage die-off. Juvenile stages within a tuber immediately continue to multiply and for as long as the soil temperature is favourable (20 – 30°C), damage will increase. If tubers are stored in cold soil, damage will occur more slowly than in the case of high soil temperatures. Tubers with galls at the end of the season (even if only a few) should be harvested as soon as possible to minimise damage.

Chemical control

If nematicides are used correctly, it is a very effective way to reduce the number of nematodes in the soil so that potatoes can be successfully produced. Currently, ten active ingredients sold as 28 different products are registered for use on potatoes. To ensure that these costly remedies effectively control eelworms, follow the instructions on the label carefully. For example, instructions of most nematicides require soil to be fumigated before nematicide is applied. Fumigation is not effective in cold soils because the active ingredient goes from liquid to gas form at a specific temperature, depending on the product. If potatoes are planted in late winter / early spring, soil in summer rainfall areas can be treated at the end of the previous season and then left to lie fallow during the winter.

For successful application of fumigants, soil texture, moisture status and temperature are crucial. Follow directions on the label carefully or discuss with an expert in the field.

Contact nematicides kill only the stages of eelworm that occur in the soil and have no effect on eggs or individuals in plant tissue. Before treating soil, juvenile stages of eelworm should be stimulated to leave the eggs by irrigating when the temperature is high enough for juvenile stages to be active.

No nematicides are effective for the whole season and kill juvenile stages only in the upper soil layer - in addition, eelworm hatches over some time. If soil is infested with juveniles, the population will increase again during the season as larvae move from the deeper soil layers to the upper layer. The longer the season, the higher the population in the root and tuber zone.

The higher the nematode population before planting, the earlier in the season the population in the upper soil layers will increase, especially if irrigation practices are not optimal.

A strong root system

Proper soil preparation is the basis for a strong root system. The soil must be cultivated deep enough to ensure oxygen supply.

Some biological agents stimulate root growth and tolerance to root parasites, namely plant growth-stimulating rhizobacteria (PGPRs), plant growth hormones (auxin and cytokinin), micorrhiza's, endophytes (such as *Trichoderma*) and remedies containing salicin and harpin protein. Good quality compost and compost tea promote optimal nutrition and thereby promote a healthy root system.

Certified seed

Seed potatoes are not necessarily free from nematodes. Seed production, however, is subject to good practices, including proper rotation which reduces the risk of nematode infectation. The maximum percentage of seed with nematode lesions on potato seed is as follows:

	G0	G1-3			G4-6			G7-8		
		Elite	Class 1	Standard	Elite	Class 1	Standard	Elite	Class 1	Standard
Root-knot nematode	0	0.1	0.2	1.0	0.1	0.5	1.0	0.2	0.5	1.0
Lesion nematode	0	0.1	0.5	5.0	0.5	1.0	0.5	1.0	2.0	5.0
Maximum joint % allowable	0	0.1	0.5	5.0	0.5	1.0	0.5	1.0	2.0	5.0

The future of eelworm control

Nematicides are currently the best option for potato producers to reduce the population in a field and are successful if applied correctly. However, chemicals are increasingly being withdrawn from the market. Remember the effect when aldicarp was withdrawn at short notice. Nematologists warn that alternative strategies should already be developed and consider cover crops and green manure in an integrated management programme as the future for controlling eelworms on potatoes.

Alternative approaches to eelworm management

As far as biological agents are concerned, research and development is being done by various companies and organisations, but there is currently nothing specifically registered for nematode control on potatoes. Numerous biological remedies are successfully used to effect a strong root system and thereby tolerance to eelworm.

Bio-fumigation with crops of the Brassica family shows potential. The principle of bio-fumigation is that the biologically active compounds are released into the soil to reduce population levels of soil-borne pathogens and eelworms. Crops include certain cultivars of white mustard, canola, rocket and fodder radish. Plants of the latter crops are shredded when still green, worked into the soil and left for six weeks so that bio-fumigation can take place. The plant material also serves as a green manure.

Soil solarisation involves raising the temperature of the upper 30 cm of soil to kill nematodes, weed seeds, bacteria, fungal spores and certain soil-borne pathogens. In dry seasons, soil is covered with translucent plastic (30 microns), the sides sealed and left for eight weeks for the soil temperature to reach 50°C.

Ensure there is a plan in place for responsible disposal of plastic as plastics exposed to sunlight for a few weeks become brittle and cannot be reused.

Cover crops will play an important role in controlling eelworm in future. Information regarding the resistance of different cover crops to specific plant-parasitic nematodes and soil-borne pathogens does not exist at present, but research has recently begun.

Cover crop mixtures for cool and warm seasons are available and the benefits of cover crops include increased soil organic component, reducing compaction, increase of the N content (if a legume is included in the mix), reducing erosion (by run-off water and wind) and better water penetration. These effects eventually contribute to a strong root system.

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ROOT-KNOT NEMATODE AND POWDERY SCAB SYMPTOMS CAN BE CONFUSED

Powdery scab lesions are generally dark in colour (1) while rootknot galls do not discolour. Root galls caused by *Spongospora suberranea* have the appearance of a bunch of grapes (2) while it is not the case of galls with root-knot nematode. When powdery scab scars are brushed off during the washing process, the tissue has a rust-brown colour (3) whereas this is not the case when root-knot nematode galls are brushed off.

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SYMPTOMS OF GOLDEN CYST NEMATODE

Photo: USDA ARS Picture gallery

SYMPTOMS OF LESION NEMATODE

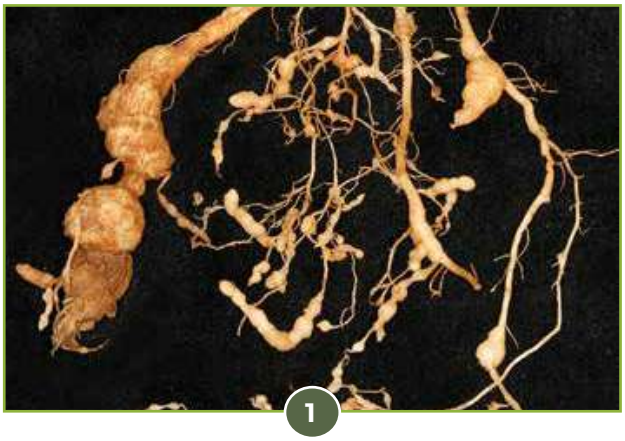
Roots infected with lesion nematodes usually change colour from dark brown to red, whereas symptoms on tubers are sunken purple-brown lesions which are mainly visible on the underside side of tubers by the end of the season.

The sunken lesions are rarely deeper than 0.5 mm and the underlying tissue is usually unaffected. The quality of the tubers usually deteriorates after it has been stored for some time.

SYMPTOMS OF ROOT-KNOT NEMATODE

Infected roots (1) and tubers (2) form characteristic galls which reduce the quality of tubers and result in the rejection of seed potatoes. If plants are infected shortly after planting and if the soil populations are very high, tubers can be deformed (3).

Adult females in tubers can be found up to 2 cm deep, but usually occur just underneath the skin (4). Tuber with galls that has been brushed (5).



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